Indexation, Inflation, and Monetary Policy

Fernando Lefort
Klaus Schmidt-Hebbel
editors

Central Bank of Chile / Banco Central de Chile

INDEXATION, INFLATION, AND MONETARY POLICY: AN OVERVIEW

Fernando Lefort
Pontificia Universidad Católica de Chile

Klaus Schmidt-Hebbel
Central Bank of Chile

Indexation policies and practices are common in many markets and economies. In most cases, price adjustment mechanisms arise in private contracts as a consequence of high and pervasive inflation. Sometimes governments also play an important role in promoting the use of indexation in their issues of public debt, taxation systems, public tariff settings, and other institutional arrangements.

Although practices that can generally be classified as indexation are widespread in most modern economies, this topic remains highly controversial. On the one hand, from a microeconomic point of view, it is clear that indexation facilitates economic arrangements and contracts between private agents under high and even under moderate inflation. In particular, indexation allows the system of relative prices to survive large inflation shocks. Wage and financial indexation are clear examples of arrangements that accomplish this purpose. Wage indexation substitutes for the need for frequent renegotiation of wages and may reduce labor market transactions costs in economies where inflation is at least moderate. And the experience of several emerging economies shows that indexing financial instruments may be key to success in developing liquid long-term fixed-income markets.

On the other hand, indexation also has macroeconomic implications. In particular, indexation has played a critical role in many stabilization programs. The academic literature regarding this point is not without controversy. Supporters of indexation claim that automatic price adjustments facilitate the reduction of inflation and the stabilization of output in the presence of monetary shocks. But indexation has its detractors as well. The standard case against indexation is built on the premise that indexation to past inflation increases inflationary inertia, tending to perpetuate inflation and making rapid, low-cost stabilization less likely. It has also been argued that exchange rate–based stabilization programs in countries suffering from stubbornly persistent inflation—to which indexation may contribute—are doomed to fail by causing a real overvaluation of the domestic currency (Goldfajn and Valdés, 1999; Fischer, 2001).

The recent history of the Chilean economy provides fertile ground for assessing the extent and impact of indexation, from both the macroeconomic and the microeconomic viewpoint. Chile has had it all: indexation of private contracts including wages, house rentals, tuition, and health insurance; indexation of financial instruments such as consumer loans, mortgages, corporate bonds, and indeed almost all fixed-income securities with a maturity beyond one quarter; and indexation of policy instruments such as exchange rates, interest rates on public debt, income tax brackets, and public sector wages.

The development of these indexation mechanisms beginning in the 1960s was undoubtedly a rational response to high inflation. However, in the wake of this generalized indexation, inflation was reduced massively during the 1990s. The policy implemented by the newly independent central bank attained a reduction in annual consumer price inflation from 27 percent in 1990 to 3 percent in 2001.

At the beginning of the 1990s, policymakers saw it as important to reduce the widespread prevalence of indexation based on past inflation, and especially its role in determining the prices of nontradable goods, wages, the nominal exchange rate, and interest rates. Consequently, in September 1990 the Central Bank of Chile adopted a monetary framework based on public announcement of an explicit, forward-looking annual inflation target. Today there is wide agreement that this significant change in monetary regime has contributed to a gradual decline in inflation to levels consistent with a permanent target range of 2 to 4 percent per year (Loayza and Soto, 2002). This was attained only recently, however, when inflation targeting was perfected by the adoption of a flexible exchange rate system and significant improvements in the transparency and accountability of monetary policy.

The Central Bank of Chile recently introduced two further changes that contribute to deindexation in financial markets:

nominalization of interest rates on short-term central bank debt, and nominalization of the monetary policy interest rate. The central bank started issuing nonindexed short-term domestic debt of forty-two days' and of ninety days' maturity in July 1997. Placement of these issues at fixed nominal interest rates has been very successful on four counts. First, financial markets have received them well, as reflected in low inflation risk premiums. Second, these issues help in completing Chile's financial markets, adding nominal debt instruments to the existing ninety-day indexed debt. Third, this placement provides the public and the monetary authority with direct information about inflation expectations (including the inflation risk premium). Last but not least, the placement of nominal debt represents an important step toward the nominalization of short-term financial instruments issued by the private sector.

By 2001, inflation expectations in Chile had stabilized at levels consistent with the official target range of 2 to 4 percent. In August of that year the central bank took an additional step toward nominalization, setting its main monetary policy instrument, the overnight interbank loan rate, in nominal terms. The bank also started to issue 30, 60, and 90-day nominal debt and stopped issuing 90-day indexed debt, replacing it with 360-day indexed debt. Hence the market for short-term indexed financial instruments has been partially replaced by the market for nonindexed debt, and this development is supported by much less volatile nominal interest rates.

Despite these policy changes, however, the Chilean economy remains highly indexed, especially in the medium-term fixed-income financial market and in the markets for nontraded goods and services and for labor. In the absence of strong reasons or incentives to abandon indexation, even under conditions of low and stable inflation, agents in these markets tend to stick to their decades-long habits of indexation based on past inflation. Hysteresis in indexation thus mimics hysteresis in currency and asset dollarization, the alternative response to high inflation observed in many countries.

This volume contributes to the literature on indexation and inflation by publishing nine new papers that are at the research frontier on these issues. Their scope ranges from analyses of specific topics, such as the optimal management of indexed public debt and the consequences of wage indexation, to presentations of recent empirical evidence regarding indexation and inflation persistence.

The papers are revised versions of papers presented at the First Annual Conference of the Central Bank of Chile, on “Indexation, Inflation, and Monetary Policy,” held in Santiago in August 1997.

This introduction reviews the issues addressed by the various papers, in the context of the related academic and policy literature. First, we look at specific indexation practices adopted in different markets in response to inflation and their consequences for those markets. Here we discuss the creation of artificial indexed units of account as well as the indexation of wages, financial instruments, and public debt. Second, we discuss the relationship between indexation practices, inflation persistence, and the outcome of stabilization programs. In this context we also reconsider the question of the appropriate choice of monetary policy regime in a deindexed, low-inflation economy.

The first paper, written by Oscar Landerretche, Fernando Lefort, and Rodrigo Valdés, can be seen as a direct extension of this introduction. The authors provide a comprehensive review of the theoretical literature on indexation that, unlike other surveys on this subject, analyzes the effects of indexation in specific markets on aggregate inflation. It thus updates and complements previous surveys, including those of Van Gompel (1994), who emphasizes labor market indexation; Campbell and Shiller (1996), who focus on financial indexation; and Dornbusch and Simonsen (1983), who look at the relationship between indexation and inflation in general. The paper examines the theoretical literature and policy dimensions of the three main categories of indexation: wage indexation, financial indexation, and exchange rate indexation. The authors identify the causes of each type of indexation and its consequences both for the corresponding market and for the broader economy. They then analyze the effects of each type of indexation on the inflation process as well as on the costs of stabilization and the authorities' willingness to adopt a stabilization program.

1. Indexation Practices and Their Effects

Price indexation of policy instruments, labor, and financial contracts can be considered a rational response, observed in many countries, to persistent inflation. Market participants and policymakers have devised various indexation mechanisms as means of protection, to reduce the costs of high and variable inflation. We begin by reviewing the main indexation practices and their implications for policy instruments and market behavior.

1.1 Choosing an Indexed Unit of Account

Many economies have faced high inflation at one point or another in their history. When inflation rises to two- or three-digit levels, market transactions and contracts become disrupted. As inflation erodes real values and misaligns relative prices, agents are required to reset prices and renegotiate contracts with increasing frequency. At some point, to reduce the need for constant readjustments, prices and contracts begin to be quoted in a unit of account that is not affected by domestic inflation. Selecting an indexed unit of account involves separation of the first two functions of money—as a medium of exchange and as a store of value—from its third function, that of a unit of account. Of course, this can be done in many different ways. Several countries experiencing high inflation have chosen a foreign currency as their unit of account (and often as a store of value as well) while retaining local money as the medium of exchange. Substitution of the U.S. dollar for local currencies and in the denomination of asset prices is observed in several Latin American countries, including many that have achieved low inflation. Hysteresis of de facto dollarization is widespread, making it very difficult to reintroduce the domestic currency after currency and asset substitution have taken place (Calvo and Végh, 1992).

The paper by Robert J. Shiller in this volume analyzes the experience of the Chilean Unidad de Fomento (UF), an artificial unit of account that provides an alternative to adopting a foreign currency. Adopted in 1967, the UF was the world's first successful inflation-indexed unit of account. It was later adopted by Colombia, Ecuador, and Mexico. Shiller, following the pioneering work of Irving Fisher (1911, 1928, 1934), analyses the factors that led to the creation of the Chilean UF.

There are several lessons to be learned from the Chilean experience. For example, the UF is linked to a price index, the official consumer price index (CPI), that attempts to measure the true cost of living in Chile. Therefore, when debts and other obligations are denominated in UF, they are held constant in terms of purchasing power. Using the dollar as an alternative unit of account would not provide the same protection, for the same reasons that preclude international purchasing power parity from holding. At the same time, the government's adoption of an indexed unit of account solves a coordination problem that otherwise could inhibit indexation or trigger the use of the dollar. The UF has additional features that may appear secondary but in fact have contributed to its success. For instance, the daily proportion of the lagged monthly CPI change is reflected in the daily value of the UF, contributing to its widespread use in daily transactions.

In sum, Shiller is enthusiastic about the Chilean UF. He argues that using this indexed accounting unit solves important practical problems that arise when financial indexation is not introduced despite conditions of moderate to high inflation. However, one important caveat in adopting an indexed unit of account is that it may contribute to more sticky inflation expectations and greater inflation inertia. Despite the latter danger, Shiller recommends its use in other countries, including the United States. However, in countries that have achieved relatively low inflation, one might also consider using units of account indexed to nominal income, to attain a superior sharing of risks across different generations. Shiller argues that an alternative unit, indexed to wages, as was considered in Chile and is currently being used in Uruguay, may also provide a suitable instrument of indexation. This leads us to consider the more general issue of wage indexation next.

1.2 Wage Indexation

Under moderate to high inflation, wage contracts tend to include arrangements between workers and employers that remove the need for continuous renegotiation and recalculation of wages in response to inflation shocks. High costs of wage renegotiation favor lengthening the duration of labor contracts. As shown by Gray (1978) and Aizenman (1984), wage indexation allows a reduction in the frequency of wage renegotiation by keeping real wages relatively constant. Wage indexation is also justified as a risk-sharing mechanism. Here the idea, as formalized by Baily (1974) and Azariadis (1975), is that more risk-averse workers are willing to accept real wages paid by their less risk-averse employers that are lower than those observed in the spot job market, as long as the workers are offered a mechanism that keeps real wages unchanged when unexpected inflation shocks occur. Of course, wage indexation mechanisms also generate the potential for redistribution between employers and employees. The paper by Landerretche, Lefort, and Valdés in this volume provides a more detailed discussion of this topic.

Views on wage indexation largely depend on the form of wage indexation being considered. The literature (for example, Aizenman, 1987) has emphasized that wage indexation must entail mechanisms that allow wages to adjust automatically to new information without having to renegotiate the terms of the contract. Therefore it is not sufficient simply to take inflation into account when setting wages. The paper by Esteban Jadresic in this volume focuses on the implications of wage indexation for macroeconomic stabilization programs, a topic discussed further below. Jadresic also discusses in detail the different categories of wage indexation mechanisms. He makes a crucial distinction between wages that are indexed to current inflation, as in Gray's (1976) original analysis, and wages indexed to lagged inflation, as frequently observed in actual wage contracts.

1.3 Financial Indexation

The Unidad de Fomento was introduced in January 1967 by the Chilean Superintendency of Banks and Financial Institutions, the government agency in charge of the regulation and supervision of banks and other financial institutions. The intent was to provide an indexed unit of account in which long-term financial instruments could be denominated. It is clear that indexing financial instruments provides protection against inflation risk and therefore helps to complete financial markets. As pointed out by Campbell and Shiller (1996), there are other ways to protect financial investments from inflation risk. A standard procedure consists in rolling over short-term securities, since their nominal rates quickly adjust to inflation shocks. However, a series of rolled-over short-term securities is not equivalent to a single long-term indexed instrument, because the latter also provides insurance against changes in the real interest rate. Such insurance is of particular value for investments of long duration, including pension savings and mortgages.

Financial indexation has other benefits as well. One is that the coexistence of nominal and indexed bonds that are otherwise identical (including identical maturities) provides a measure of market expectations of inflation (strictly speaking, the sum of inflation expectations and the inflation risk premium). Another benefit is that the existence of indexed long-term securities provides an incentive to increase financial savings. The recent experience of Chile, the United Kingdom, and the United States, starting from very different initial conditions, reflects these benefits. In Chile, where all medium- to long-term debt was indexed, the central bank has started issuing one-year nominal bonds that complement existing indexed bonds. In the United Kingdom and the United States, where long-term indexed government paper was nonexistent, both governments started issuing long-term indexed bonds in the 1990s (Breedon, 1995).

The paper by Eduardo Walker in this volume reviews the Chilean experience with financial indexation. He shows that indexation of financial markets has contributed to the development of Chile's capital markets. Of course, indexation alone is not enough. Walker argues that three specific reforms are required to complement the adoption of an indexed unit of account: lifting financial repression and liberalizing interest rates, reforming the tax code to achieve inflation neutrality, and creating effective supervisory institutions. Walker and Lefort (1999) add to this list the adoption of a sound macroeconomic environment, privatization of public enterprises, and privatization of the pension system.

Walker's paper provides empirical evidence that creation of an indexed fixed-income market has also contributed to the development of Chile's stock market. Moreover, he shows that short- and long-term indexed bonds provide unique and relevant yield patterns that cannot be replicated by international markets. Therefore they constitute an effective way of completing financial markets. Walker argues that in the absence of a government-backed UF, Chilean capital markets would have relied on foreign currency to protect against inflation, and the maturities of peso-denominated securities would have been much shorter. The paper also provides empirical evidence regarding the optimal portfolio composition needed to hedge specific sector risks in the Chilean economy. Walker concludes by suggesting that, given the existence of indexed financial instruments in Chile, central bank asset holdings should include long-term U.S. public debt and equities from other emerging economies, and investment in fixed-income foreign securities by local investors is not advisable.

1.4 Indexed Public Debt

An indexed unit of account opens the door to the issuance of indexed public debt. Since Calvo (1988), it is well understood that the inflation bias of a central bank, reflected by its incentive to erode the real value of public debt, declines with the level of indexed public debt. Hence issuing such debt is a signal of the central bank's commitment to achieve low inflation.

On the other hand, the possibility of issuing indexed debt in addition to nominal and foreign-currency debt raises issues for the optimal management of public debt. In addition to deciding the maturity structure or contingent payments of such debt, policymakers must now make decisions about its denomination. Two papers in this volume contribute to the literature on this topic. The paper by Robert J. Barro analyzes public debt management from the point of view of public finance theory. The author focuses on the structure of public debt under the assumption that the government aims at tax smoothing when facing a stochastic sequence of exogenous government expenditure. This work is related to earlier work by Barro (1979), Lucas and Stokey (1983), and Persson and Svensson (1984), but unlike the last two contributions, it assumes that the government can effectively commit itself to future fiscal actions, and thus the resulting composition of the debt is not necessarily time consistent.

Barro analyzes optimal public debt management at three levels. First, the optimal level of public debt cannot be determined for the extreme case where taxes are not distortionary and other conditions of Ricardian equivalence hold. Second, if taxes are distortionary, then tax rates should be smoothened over time; hence the optimal level of public debt is determinate, but its composition by maturity or by category (indexed versus nonindexed) is not. Third, the optimal composition of debt can only be determined under conditions of uncertainty regarding fiscal or macroeconomic variables. Under the latter condition, Barro's paper derives some interesting conclusions. On the one hand, if the government can issue debt contingent on the level of outlays, all noncontingent debt should be issued as an indexed consol. The idea is to achieve a maturity structure of the noncontingent debt without any gaps. Then the author looks at the optimal debt structure when contingent debt is not available. Under such conditions the optimal structure can be attained by issuing indexed bonds with longer maturities than a standard consol. Consistent with the idea that the optimal debt structure will take the form of long-term indexed bonds, some developed countries such as the United States and the United Kingdom started issuing indexed long-term public debt instruments in the 1990s, as noted above.

Related literature on this topic, such as Bohn (1990) and Calvo and Guidotti (1990), argues that since inflation and current government outlays are positively correlated, nominal public debt may be desirable in order to exploit the negative covariance between inflation and the real value of debt. In his paper, however, Barro disputes this argument. If there are no moral hazard problems regarding public sector behavior, and therefore nominal debt can be issued at no extra cost, it seems much more convenient to issue only explicit contingent debt and indexed debt.

The paper by Ilan Goldfajn in this volume complements the preceding discussion with an analysis of the Brazilian case. His paper examines a model for optimum management of debt by the public sector, considering three types of debt: nominal, CPI-indexed, and foreign currency–denominated debt. Like Bohn (1990) and Calvo and Guidotti (1990), who consider the nonfeasibility of issuing explicit contingent debt, Goldfajn's model predicts that the main factors determining debt composition are the inflation variance, total outstanding debt, the nominal exchange rate variance, and the correlations between inflation and public revenue and expenditure. The empirical findings reported by Goldfajn for the case of Brazil tend to confirm these hypotheses. The intuition for these results is that the main benefit of indexed debt is in stabilizing the real value of debt and eliminating the temptation to inflate it away. On the other hand, and for the same underlying reason, nominal debt serves as implicit contingent debt, and its importance should increase with the correlation between inflation and public net expenditure. Finally, foreign currency–denominated debt should be issued when real exchange rates are not excessively volatile and the correlation between real exchange shocks and government outlays is negative. The application of this model to Brazil's experience is relatively successful in explaining the relative composition of that country's public debt during the past decade.

2. Indexation and Macroeconomic Stabilization

Indexation of wages, prices, and policy instruments also involves costs. In particular, it contributes to inflation inertia, making it slower and harder to reduce inflation and amplifying the inflationary impact of adverse price shocks. The cost-benefit ratio of indexation becomes unfavorable when a formerly high-inflation country achieves moderate to low inflation, as the benefits of indexation are diluted while its costs rise.

In recent years several developing countries (including Brazil, Chile, Mexico, and Israel) have implemented successful macroeconomic stabilization programs, including as part of their reform package the deindexation of wages, the use of the exchange rate as the economy's nominal anchor, or both.

2.1 Indexation and the Persistence of Inflation

We noted at the outset the claim by critics of indexation that indexation, especially to past inflation, increases the persistence of inflation and makes it much harder to achieve macroeconomic stabilization. Bruno (1993) and Edwards (1993) argue that the persistence of inflation, partly caused by indexation practices, may have jeopardized the success of exchange rate–based stabilization programs, because such practices are bound to generate a real overvaluation of the currency and may contribute to balance of payments crises.

The paper by Sebastian Edwards and Fernando Lefort in this volume seeks to increase our understanding of the empirical relationship between indexation practices and inflation and its persistence. The authors analyze and estimate inflation persistence over time in sixteen developing and industrial countries. Their empirical evidence suggests that persistence varies greatly across countries and, for a given country, over time. This finding is in contrast with a standard assumption in the literature, notably by Fuhrer and Moore (1995), that measurement of the effect of wage indexation on inflation persistence requires that such persistence be time invariant.

Edwards and Lefort also provide conclusive evidence on the relationship between the degree of inflationary persistence and the level of inflation. They show that the higher a country's inflation, the more inflationary inertia is present. More important for the question of the effect of indexation on the success of stabilization, they also present evidence indicating that inflationary persistence rises with the degree of indexation. Finally, the paper provides a detailed study of inflationary inertia in repeated exchange rate–based stabilizations in Chile, Israel, and Mexico. The authors show that inflationary persistence tends to decline with the adoption of a stabilization program, but to rise again as time passes. They ascribe this result to indexation practices based on past inflation, which persist after stabilization has been implemented, and to the lack of credibility of the exchange rate–based stabilization program.

2.2 Macroeconomic Consequences of Wage and Price Indexation

The empirical evidence just discussed indicates that the adoption of indexation practices tends to increase the persistence of inflation, making stabilization more difficult. This is in contrast to the claims of economists during the 1970s, when it was asserted that indexation actually favored output stabilization and inflation reduction. Friedman (1974), Gray (1976), and Fischer (1977) reached the conclusion that indexation helps in stabilizing output when monetary shocks dominate real shocks. Consistent with this line of argument, Ball (1994) showed that greater wage flexibility—measured by an indicator that averages contract duration, degree of indexation, and degree of synchronization—reduced the sacrifice ratio during stabilization programs. To make this empirical result consistent with the findings of Edwards and Lefort in this volume, one must consider that Ball focused exclusively on periods of time and economies where stabilization programs were being implemented, whereas Edwards and Lefort look at the general relationship between indexation practices and inflation persistence, independent of whether a stabilization program was under way. In addition, Ball's measure of wage flexibility is affected not only by the degree of indexation, but also by other features of wage contracts.

In any case, Simonsen (1983) and others after him have criticized the argument by Friedman and others on the grounds that actual indexation practices have amounted to lagged and uncoordinated indexation rather than the instantaneous and synchronized type that the latter authors assumed. This distinction is important, since it implies that wages indexed to lagged inflation imply nominal rather than real wage rigidity. Accordingly, Fischer developed a line of research (Fischer, 1977, 1985, 1988) that analyzes the precise consequences of wage indexation for output stabilization.

Two of the papers in this volume contribute to this literature. The study by Esteban Jadresic reexamines the macroeconomic consequences of wage indexation, taking into explicit account specific lag structures used in actual wage contracts indexed to past inflation. He analyzes the effects of these lags on aggregate wage formation, the cost of deflation, output variability, and inflation, under different shocks and policy regimes. He addresses specifically the interaction between wage indexation practices and exchange rate regimes at different levels of inflation. The paper shows that, unlike the (unrealistic) case in which wage increases are based on contemporary inflation, wage indexation based on past inflation can increase the cost of disinflation, destabilize output, and, when the central bank is not firmly committed to keeping inflation low, increase inflation. This paper also compares the effects of wage indexation based on past inflation with those of other rules for adjusting wages. Jadresic's main conclusion is that when actual wage indexation rules are modeled, their consequences for output and price stabilization tend to be as most policymakers believe: wage indexation increases the costs of disinflation. A contribution of Jadresic's paper, compared with similar work by Bonomo and Garcia (1994), is that the latter consider only the case of gradual and credible policies that contribute to output expansion. Jadresic's work extends the analysis to different classes of stabilization programs under various conditions.

The paper by Luis Oscar Herrera in this volume offers a complementary perspective, analyzing the relationship between automatic indexation of prices and wages and the cost of inflation reduction. Herrera derives an extended aggregate supply model by including automatic cost-of-living adjustment clauses in prices (or wages) based on past inflation, which he uses to examine stabilization costs. He assesses a number of stabilization plans that vary according to how gradual or credible they were, and he derives the impact of the frequency of indexation on these costs. The paper's main results suggest that the inertia introduced by indexation raises the cost of stabilizing inflation. That cost is much attenuated, however, when price stabilization is implemented gradually and credibly. In the various stabilization cases analyzed in the paper, the relationship between the frequency of indexation and the cost of stabilization follows an inverted U curve. Hence costs are lower when wage indexation is absent or infrequent and when it is very frequent, and highest at intermediate frequencies ranging from three to six months. The implication is that less frequent indexation does not necessarily lower sacrifice ratios, because whether or not it does so depends on the starting point. Another interesting application of these results is their contribution to explaining the persistence of moderate inflation processes. As inflation becomes chronic, the price and wage indexation that normally accompanies inflation tends to raise the cost of price stabilization. This increase reduces the political willingness to deal with inflation, thus contributing to its persistence.

2.3 Indexation and Monetary Policy

As already mentioned, Chilean policymakers have deindexed several of their monetary policy instruments in the recent past. When inflation fell to 3 percent a year, it became clear that the rationale for deindexation was not only to lock in low inflation but also to conduct monetary policy more effectively in a setting where real shocks become increasingly important.

Central bankers in developing economies, following the lead of many of their counterparts in industrial economies, have started using short-term interest rates as their main instrument for conducting monetary policy. This practice raises the question of whether a particular monetary regime is better suited than others for conducting monetary policy in a low-inflation environment. The shift of monetary regimes, in many industrial and developing countries alike, from targets based on the exchange rate or monetary growth to targets based on inflation, justifies an analytical approach to this question. Most inflation-targeting countries use short-term interest rates as their policy instruments. (See Loayza and Soto, 2002, for recent studies on the worldwide experience with inflation targeting.)

The paper by Carlos Végh in this volume analyzes the costs and benefits of different monetary regimes and policy rules in a setting like the one just described. Végh derives some basic equivalences for alternative monetary policy rules. He shows that under conditions of inflation inertia, the following three rules are exactly equivalent: a fixed growth rate of a monetary aggregate; a nominal interest rate combined with an inflation target; and a real interest rate combined with an inflation target. However, he also shows that implementation of these rules becomes increasingly complex. The first rule does not require a feedback or policy rule on the part of the central bank. The second rule is based on the central bank's response to the inflation gap. The third rule requires the central bank to respond to both the inflation gap and the output gap, as in a conventional Taylor-type policy. (See Taylor, 2002, and Loayza and Schmidt-Hebbel, 2002, for recent analytical and empirical studies of policy rules.) If the country aims to reduce stabilization costs, all three rules must respond to the output gap. From the policy perspective, the worldwide trend toward substituting nominal interest rules for monetary aggregate growth targets may reflect both the equivalence between the rules described in this paper and the well-known practical difficulties in controlling monetary aggregates under standard conditions of instability of money demand.

References

Aizenman, J. 1984. "Optimal Wage Re-negotiation in a Closed and Open Economy." *Journal of Monetary Economics* 13(2): 251-62.

————. 1987. "Wage Indexation." In *The New Palgrave: A Dictionary of Economics*, edited by J. Eatwell, M. Milgate, and P. Newman, 838-40. London: Macmillan.

Azariadis, C. 1975. "Implicit Contracts and Underemployment Equilibria." *Journal of Political Economy* 83(6): 1183-1203.

Baily, M. N. 1974. "Wages and Unemployment under Uncertain Demand." *Review of Economic Studies* 41(1): 37-50.

Ball, L. 1994. "Credible Disinflation with Staggered Price-Setting." *American Economic Review* 84(1): 282-89.

Barro, R. 1979. "On the Determination of the Public Debt." *Journal of Political Economy* 87(October): 940-71.

Bohn, H. 1990. "Tax Smoothing with Financial Instruments." *American Economic Review* 80(December): 1217-30.

Bonomo, M., and R. García. 1994. "Indexation, Staggering and Disinflation." *Journal of Development Economics* 43: 39-58.

Breedon, F. 1995. "Bond Prices and Market Expectations of Inflation." *Bank of England Quarterly Bulletin* 35(2): 160-65.

Bruno, M. 1993. "Inflation and Growth in an Integrated Approach." NBER Working Paper 4422. Cambridge, Mass.: National Bureau of Economic Research.

Calvo, G. A. 1988. "Servicing the Public Debt: The Role of Expectations." *American Economic Review* 78(4): 647-61.

Calvo, G., and P. Guidotti. 1990. "Indexation and Maturity of Government Bonds: An Exploratory Model." In *Public Debt Management: Theory and History*, edited by R. Dornbusch and M. Draghi. Cambridge University Press.

Calvo, G., and C. Végh. 1992. "Currency Substitution in Developing Countries: An Introduction." *Revista de Análisis Económico* 7(1): 3-27.

Campbell, J. Y., and R. J. Shiller. 1996. "A Scorecard of Indexed Government Bonds." NBER Working Paper 5587. Cambridge, Mass.: National Bureau of Economic Research.

Dornbusch, R., and M. H. Simonsen. 1983. *Inflation, Debt and Indexation*. MIT Press.

Edwards, S. 1993. "Exchange Rates as Nominal Anchors." *Weltwirtschaftliches Archiv* 129(1): 1-32.

Fischer, S. 1977. "Wage Indexation and Macroeconomic Stability." *Carnegie-Rochester Conference Series on Public Policy* 5: 107-48.

———. 1985. "Contracts, Credibility, and Disinflation." In *Inflation and Unemployment: Theory, Experience, and Policy-Making*, edited by V. E. Argy and J. W. Nevile. London: George Allen and Unwin.

———. 1988. "Real Balances, the Exchange Rate and Indexation: Real Variables in a Disinflation." *Quarterly Journal of Economics* 103(1): 27-49.

———. 2001. "Exchange Rate Regimes: Is the Bipolar View Correct?" Distinguished Lecture on Economics in Government, sponsored by the American Economic Association and the Society of Government Economists, delivered at the meetings of the American Economic Association, New Orleans, January 6.

Fisher, I. [1911] 1997. *The Purchasing Power of Money*. In *The Works of Irving Fisher*, vol. 4, edited by W. J. Barber. London: Pickering and Chatto.

———. 1928. *The Money Illusion*. New York: Adelphi.

———. 1934. *Stable Money*. New York: Adelphi.

Friedman, M. 1974. "Monetary Correction." In *Essays on Inflation and Indexation*, edited by H. Giersh and others. Washington: American Enterprise Institute for Public Policy Research.

Fuhrer, J., and G. Moore. 1995. "Inflation Persistence." *Quarterly Journal of Economics* 110(1): 127-59.

Goldfajn, I., and R. Valdés. 1999. "The Aftermath of Appreciations." *Quarterly Journal of Economics* 114(1): 229-62.

Gray, J. A. 1976. "Wage Indexation—A Macroeconomic Approach." *Journal of Monetary Economics* 2(2): 221-35.

———. 1978. "On Indexation and Contract Length." *Journal of Political Economy* 86(1): 1-18.

Loayza, N., and K. Schmidt-Hebbel, eds. 2002. *Monetary Policy: Rules and Transmission Mechanisms*. Santiago: Central Bank of Chile.

Loayza, N., and R. Soto, eds. 2002. *Inflation Targeting: Design, Performance, Challenges*. Central Bank of Chile.

Lucas, R. E., and N. L. Stokey. 1983. "Optimal Fiscal and Monetary Policy in an Economy without Capital." *Journal of Monetary Economics* 12(July): 55-93.

Persson, T., and L. E. O. Svensson. 1984. "Time-Consistent Fiscal Policy and Government Cash-Flow." *Journal of Monetary Economics* 14(November): 365-74.

Simonsen, M. H. 1983. "Indexation: Current Theory and the Brazilian Experience." In *Inflation, Debt, and Indexation*, edited by R. Dornbusch and M. H. Simonsen. MIT Press.

Taylor, J. 2002. "The Monetary Transmission Mechanism and the Evaluation of Monetary Policy Rules." In *Monetary Policy: Rules and Transmission Mechanisms*, edited by N. Loayza and K. Schmidt-Hebbel. Santiago: Central Bank of Chile.

Van Gompel, J. 1994. "Stabilization with Wage Indexation and Exchange Rate Flexibility." *Journal of Economic Surveys* 8(3): 251-82.

Walker, Eduardo, and Fernando Lefort. 1999. "Pension Reform and Capital Markets: Are There Any (Hard) Links?" Unpublished paper. Washington: World Bank.

Causes and Consequences of Indexation: A Review of the Literature

Oscar Landerretche
Massachusetts Institute of Technology

Fernando Lefort
Pontificia Universidad Católica de Chile

Rodrigo Valdés
Ministerio de Hacienda de Chile

Automatic price adjustment mechanisms, or indexation, have arisen in a variety of economies with distinct macroeconomic environments and in different moments in time.[1] Examples include the labor market indexation implemented in various European countries in the postwar era, the indexation of financial instruments that served to develop a series of depressed Latin American financial markets in the 1960s and 1970s, and the exchange rate parity indexation recommended in the 1990s as a way of stimulating export-based growth. In the presence of inflation, most economies feature some type of indexation of contracts. These practices sometimes arise spontaneously in the market and sometimes are promoted by the authority itself, either via norms or, more directly, via the choice of exchange rate regime or an issue of indexed public debt.

The indexation of wages and the exchange rate has a considerable macroeconomic impact. It can alter the trend in the inflation rate—including its level, volatility, and persistence—and thereby affect the

At the time of writing, Oscar Landerretche, Fernando Lefort, and Rodrigo Valdés were affiliated with the Central Bank of Chile.

1. A price is considered indexed when there are clauses that specify the existence of a periodic adjustment rule that links the exchange rate of this nominal price to the evolution of some price index. The existence of indexation implies that a price change obeys an explicit or implicit rule, which may be based on time (fixed intervals) or variable states (triggers) or both.

Indexation, Inflation, and Monetary Policy, edited by Fernando Lefort and Klaus Schmidt-Hebbel, Santiago, Chile.

costs and benefits of stabilization programs. Indexation can also modify the economy's response to nominal and real shocks, which changes the objectives and requirements of the political economy. Financial indexation, in turn, can alter the level of saving in an economy and modify the way in which monetary policy is carried out. Finally, the effects of indexation may be reinforced when combined with indexing mechanisms in different markets.

This paper examines the specific factors that lead different markets in an economy to use contracts featuring indexation clauses. At the same time, we examine the macroeconomic implications of and motives behind indexation in labor, foreign exchange, and financial markets, and we review the literature on indexation to determine the potential macroeconomic effects of each type of indexing mechanism and the advisability of establishing or maintaining some degree of indexation. Finally, the paper also focuses on the impact of indexation mechanisms on inflation.

Studying the causes and consequences of indexation is important for several reasons. First, the need to control inflation, its costs, and the ability of the authority to achieve stabilization vary with the different forms of indexation. Monetary policy, therefore, could be adjusted to reflect the degree of indexation in the economy. Second, it is possible to modify the degree of indexation, but this first requires an evaluation of the costs and benefits that indexation generates. Third, governments need to know whether the authority should guide the market in decisions on indexation or whether the market can achieve optimal solutions on its own. For example, should the authority issue indexed bonds? Should it provide direct incentives for nominalizing the labor market? Finally, the design of an exchange rate regime should be grounded in an investigation of the problem of indexation.

Other papers review and analyze the literature on indexation, but they usually concentrate on one particular market, effect, or country.[2] This paper, in contrast, encompasses several markets, focussing the discussion on theoretical issues and analyzing the effect of indexation on the inflationary process.

2. For example, Van Gompel (1994) and Riveros (1996) review the problem of stabilization and labor market indexation. Campbell and Shiller (1996) focus on aspects of financial indexation, and Jiménez (1993) studies experiences of financial indexation in Latin America. Williamson (1985) and Dornbusch and Simonsen (1983) examine the relation between indexation and inflation in different countries. Simonsen (1995) presents empirical and theoretical aspects of the Brazilian case.

The paper is organized as follows. Section 1 presents the causes of indexation in different markets, as well as the main effects on the functioning of both the market in particular and the economy as a whole. Thus section 1.1 studies labor market indexation; section 1.2 analyzes financial indexation; and section 1.3 examines exchange rate indexation. Section 2 focuses on the relation between indexation and inflation. Section 2.1 studies the effect of labor market and exchange rate indexation on the persistence and volatility of the inflationary process, and section 2.2 reviews the effect of indexation on both the level of inflation and the ability of the authority to undertake an anti-inflationary policy. Finally, section 3 presents the summary and conclusions.

1. The Origin and Effects of Indexation

This section discusses the origin, effects, and characteristics of the different forms of indexation. For convenience, we divide indexation practices into three groups, depending on whether they affect the labor, financial, or foreign exchange markets. Although indexation always seeks to defend some relative price in the face of inflation, indexation practices respond to different specific needs in each market. This section aims to explain why they exist and what contracts with indexation clauses imply in each of the three markets.

1.1 Indexation in the Labor Market

In an economy in which there are negotiation costs, some degree of rigidity in nominal wages is inevitable as a result of contracts that fix the nominal wage for a set period of time. These labor contracts establish that throughout the period in which the contract is in force, the average real wage corresponds to the equilibrium at the moment of negotiation. In the presence of inflation, the real wage will be eroded quickly over the life of the contract, such that the effective real wage will be above the equilibrium value at the beginning of the contract and below the equilibrium toward the end. One way of minimizing this cost-splitting effect is to include indexation clauses in the labor contracts.

Wage indexation is the existence of a wage adjustment rule that ties the growth rate of nominal wages to the movement of an index representing the price trend. The chosen index is usually one that is publicly available at a low cost, such as the consumer price index (CPI).[3] Such rules serve as a substitute for the frequent renegotiation of wage contracts and as a defense against the erosion of real wages due to inflation. Although a given indexation practice can originate in the law, indexation generally appears spontaneously in environments characterized by moderate and persistent inflation.

When wages are perfectly indexed, it is the real wage that is fixed. The literature on the optimal degree of wage indexation tries to determine the advantages—in terms of output stability—of fixed nominal wages versus fixed real wages. Because real wages should not be affected by nominal shocks, the greater the relative importance of nominal shocks in an economy, the greater is the optimal degree of indexation. This section examines this intuition, qualifying it on the basis of the characteristics of the economy under analysis and the specified labor contract.

Wage Indexation from a Microeconomic Perspective

Wage indexation is a characteristic of wage contracts established at the microeconomic level. This section analyzes the origin of wage indexation from the point of view of implied contracts theory. Two factors induce the generalization of indexation practices in the creation of wage contracts: the simultaneous existence of inflation and wage negotiation costs and a greater risk aversion among the workers than among the employers. Indexation also generates potential distributive effects.

Wage Negotiation Costs versus Maladjustment Costs. Wage indexation arises as a contractual arrangement between the worker and the firm as a way of avoiding having to renegotiate and recalculate wages in the face of periodic variations in the inflation rate. In this sense, indexation is a substitute for renegotiation, and the relative price between the two is given by the level and variance of inflation, the costs of renegotiation, and the costs of having a maladjusted real wage.

3. Riveros (1996) discusses the advisability of using this and other indicators. The paper concludes that all indexes are imperfect because they either don't reflect the producer's price or they don't reflect cost-of-living increases (for example, the wholesale price index, or WPI). Behind this lies the fact that no price index exactly reflects the inflation that heterogeneous actors face in the presence of changes in relative prices.

The existence of wage renegotiation costs makes lengthening the duration of contracts desirable. Indexation keeps the agreed real wage relatively constant, which makes it possible to extend the period between negotiations, for a certain intensity and variability of real shocks. Of course, the greater the relative importance of real shocks on the sector and the greater the cost of having a maladjusted real wage, the shorter will be the desired length of the contract. On the other hand, high, volatile inflation will induce generalized wage indexation due to the rapid erosion of real wages between negotiations.[4]

Distribution of Risk. The second microeconomic justification for wage indexation is related to the problem of the distribution of risk. If firms are better able than workers to reduce diversifiable risk, then optimal contracts will set stable real wages in exchange for a reduction in their level taken as a risk premium. In the case of nondiversifiable risk, such as inflation, achieving the same effect requires a greater degree of risk aversion on the part of workers relative to their employers.[5]

Indexation clauses reflect the existence of an implicit insurance against unexpected variation in the inflation rate, which is justified because the financial market is incomplete with regard to this type of risk. Workers will pay a premium in terms of a lower wage than what might be offered on a spot job market, in exchange for which they receive a fixed real wage by virtue of their risk aversion. The employer, in turn, gains by paying a lower wage as a result of the firm's relative neutrality in the face of risk. Wage indexation as stipulated in such contracts would be perfect if all actors had the same expectations regarding inflation and if precise, day-to-day information on the movement of the general price level were available.[6] In the absence of these conditions, indexation must be based on lagged inflation, with the distance between adjustments inversely related to the variability of inflation.

4. Gray (1978) and Aizenman (1984) show how shortening the duration of a contract reduces welfare losses caused by the deviation of the contract wage from the spot market wage. This phenomenon will be produced to the extent that the frequency of shocks is high. An optimal degree of indexation is thus associated with an optimal contract length.

5. Rationality of wage contracts as a means of securing workers is discussed and formalized in Baily (1974); Azariadis (1975); Shavell (1976).

6. Shavell (1976) analyzes the problem of implied insurance assuming the existence of perfect indexation. Simonsen (1983) considers implied insurance in the case of imperfect indexation.

Finally, the existence of these microeconomic justifications for wage indexation has important political implications. If the authority is not able to affect the inflationary process, or if changes are produced in the fundamental variables that determine the components of an optimal labor contract, then it will be very difficult to induce private actors to alter their indexation practices.[7]

Distributive Effects. Indexation probably modifies the redistributive effects of inflation significantly, although its effects are little explored in the literature. One possibility is that indexation worsens the distribution of income because only some actors—usually the richest—manage to secure protection against inflation, while the rest suffer a fall in real wages in the event of inflation. Riveros (1996) reviews precisely this case, using segmented labor market models. In that scenario, indexation only operates in the formal market, where the most skilled workers are located. Consequently, with indexation protecting real wages against inflation shocks, the distribution of income worsens. If the adjustment process requires a fall in real wages in the formal sector, indexation will impede the adjustment and cause unemployed workers in this sector to be displaced to the informal sector, further worsening the situation for workers in that sector.

The variability of real wages can also be considered an income distribution problem. In those terms, perfect indexation would be a good distributive mechanism, because it maintains a constant real wage. There is evidence, however, that the real wage is highly variable when indexation is used.[8] The reason for this is that indexation is imperfect because it is calculated with a lag, because of the dual markets mentioned above, and, most important, because it does not eliminate periodic renegotiations of real wages between workers and firms. The Chilean case is demonstrative in this sense: the typical contract lasts two years and is adjustable every six months. The real wage can be quite flexible during negotiations (Jadresic, 1995).

Finally, the existence of indexation changes the negotiating position of workers *vis-à-vis* firms. Whenever labor market participants must negotiate forms of quasi-income (for example, stemming from investments or specific training and from employee search costs), the distribution of these rents depends on the negotiating power of

7. Landerretche and Valdés (1997) analyze nine episodes of wage nominalization. In all nine cases, nominalization stemmed from the need to control inflationary inertia or from the degree of unemployment in the labor market.

8. Riveros (1996) cites works that present this evidence.

the different parties and on their external options.[9] Indexation most probably changes these parameters, thereby affecting the distribution of this type of income.

Optimal Degree of Wage Indexation in a Macroeconomic Context

From a macroeconomic perspective, wage indexation presents three main questions. What effect does wage indexation have on inflation? What effect does it have on output variability, and what rules can be recommended for determining the optimal degree of indexation? Section 2, below, analyzes the first question in detail, while this subsection reviews the literature on the remaining two issues.

An extreme position on the optimal degree of wage indexation holds that the adoption of generalized indexation in wage and financial contracts is desirable in order to reduce the collateral effects of a program for lowering the inflation rate (Friedman, 1974).[10] The application of indexation mechanisms is justified because it reduces both the political and economic costs associated with stabilization programs and the authority's incentives for maintaining a positive inflation rate. This analysis, in effect, implicitly equates a stabilization program with a nominal shock to the economy. It does not consider real shocks, which are a key component of the analysis presented in the previous subsection.

Nominal versus Real Shocks. The point of departure for a formal macroeconomic analysis of wage indexation is Gray (1976).[11] That paper's most important contribution is to show that the optimal degree of wage indexation in an economy depends on the relative importance of nominal shocks versus real shocks. In particular, the greater the variance of nominal shocks relative to real shocks, the higher is the optimal level of wage indexation.

Gray (1976) uses a traditional neoclassical model that incorporates wage rigidity in the short term and uncertainty. He assumes

9. Pissarides (1988) analyzes this issue from the perspective of a labor market search model.

10. Van Gompel (1994) reviews the literature on wage indexation and the problem of stability.

11. Gray's paper, like the literature it generated, studies the optimal degree of contingent wage indexation, that is, when wages are adjusted instantly from one period to the next.

that when the labor market is out of equilibrium, effective employment is determined all across the demand for work. The economy is subject to nominal and real shocks, and the objective function is to minimize output variance. Nominal shocks do not affect the labor demand and supply functions, such that perfect indexation (at 100 percent of past inflation) insulates the real economic activity level from nominal shocks by maintaining a constant real wage. In contrast, real shocks shift the demand for work and thus require adjustments in the real wage to stabilize the level of employment and economic activity. Indexation thus exacerbates the effect of a real shock on economic activity by maintaining a constant real wage.

This analysis shows that maintaining 100 percent indexation to the price level is not optimal in the presence of real shocks. Assuming that minimizing output variability is a prerequisite for social welfare, the optimal indexation level is less than 100 percent, with the exact level depending on the relative variances of the stochastic nominal and real components.[12] An interesting implication of this result is that given these conditions, optimal indexation does not insulate the real sector of the economy from monetary variability. Fischer (1977b) arrives at this same conclusion using a similar model.

This simple idea can be analyzed further by altering the base model. For example, if wages are allowed to be indexed to some indicator of real economic activity, it can be demonstrated that optimal indexation consists of 100 percent indexation based on past inflation and partial indexation based on the real activity level. These contracts reproduce the equilibrium that would be obtained if wages were determined ex post after the realization of shocks, and they thus effectively insulate the real sector from monetary shocks (Karni, 1983).

A supposed key to this general result of Gray's and Fischer's is that the demand for labor as a whole determines the employment level. When employment is determined by the demand for labor, indexation serves to insulate output and employment from monetary fluctuation and real demand shocks, but it increases output variability in the case of real supply shocks. In contrast, if employment is determined by trends in the labor supply, indexation can contribute to reducing fluctuations in employment in the case of real shocks

12. Gray (1978) shows that when the length of the contract is allowed to vary, optimal contract length will be longer for a lower degree of uncertainty in the economy.

(Cukierman, 1980).[13] The intuition for this result is as follows: perfect, contingent indexation maintains a constant real wage; when the economy is subjected to a real supply shock, employment and the economic activity level are not affected because the real wage remains constant.

The literature provides two additional extensions of optimal indexation. When the economy has more than one sector and when these feature different levels of productivity, the optimal indexation rule will take into account not only aggregate variables such as the price level, but also variables that are specific to the sector. In this way, each sector can partially insulate itself from aggregate nominal and real shocks, as well as from sectoral shocks. Duca and VanHoose (1991) apply the optimal indexation rule set out by Karni (1983) to an economy with two sectors, only one of which is indexed. They show that in this case, the optimal indexation rule corresponds to partial indexation based on the price level, together with an indicator of sectoral benefits. Finally, the optimal degree of indexation will be the same for workers at different levels of productivity if all can include indexation clauses in their contracts.

Kovanen (1992) analyzes the optimal degree of indexation when the work force features heterogeneity in the form of productivity differentials. Without contributing further intuition, the paper concludes that if indexation does not occur at the same time for all workers, both positive and negative externalities can be produced from the group that is indexed to the group that is not. In particular, the optimal degree of indexation will vary for the different groups of workers. Less skilled workers will prefer that more skilled workers not be indexed if they themselves do not have this option, whereas more skilled workers will always prefer an indexed economy.

Open Economy. An extension in the optimal indexation literature that deserves special attention is that of the open economy. A new element is introduced into the analysis, namely, the dependence of the optimal wage indexation level on the prevailing exchange rate regime. This dependence can be easily appreciated using a simple model for a small, open economy composed of just one sector. Under a fixed exchange rate, the economy's price level depends entirely on

13. Cukierman (1980) also shows that the results found by Gray (1976) and Fischer (1977b) are not affected by relaxing the assumption that the demand for money is inelastic with regard to the interest rate.

external shocks, such that its variations will typically be orthogonal to productivity shocks. Consequently, a 100 percent wage indexation will be desirable in order to insulate the real wage from all fluctuations in the price level. Under a flexible exchange rate, productivity shocks will affect the exchange rate and, therefore, the price level. Given the existence of a degree of covariance between price and output, establishing a system of partial wage indexation is advantageous for minimizing the variance of output. Output will not be completely insulated from external shocks under a flexible exchange rate combined with an optimal indexation level, but this arrangement is more effective than the alternative of a fixed exchange rate and perfect indexation in terms of minimizing output fluctuations (Flood and Marion, 1982). Better results can be obtained in an open economy through the combined use of partial wage indexation and exchange rate practices.

Aizenman and Frenkel (1985) present a stochastic model in which they seek to minimize the variance of employment. They obtain optimal levels of wage and exchange rate indexation through joint optimization. In this model, the optimal indexation rules completely eliminate any losses of welfare, and in some cases one of the two types of indexation is redundant (namely, when they are based on the same information and have the same objectives). Devereux (1988) studies a similar problem, but in this case the flexibility of the political instruments for reacting to shocks is restricted. The instruments are therefore incapable of eliminating welfare losses due to shocks. The paper obtains an optimal solution for exchange rate indexation that is independent of productivity shocks and a wage indexation that responds to the intuition of Gray and Fischer (and that is independent of external shocks). Turnovsky (1983) also examines the problem of joint optimization.

Another interesting aspect of this discussion is the relation between the optimal wage indexation level and the economy's degree of openness. Consider an economy with two sectors, tradables and nontradables, in which the relative price between tradables and nontradables is exogenously determined. In this context, a relatively larger tradables sector implies a greater optimal wage indexation level and thus a greater magnification of productivity shocks. Aizenman (1985) shows how a greater proportion of tradable goods implies a greater exposure to international prices, which reduces the economic relevance of the endogenous determination of the relative price of tradable and nontradable goods.

Lags in Indexation. Most of the literature on the optimal wage indexation level assumes that the automatic adjustments are realized simultaneously with variations in the price level. The consequence of this is obvious: this type of indexation implies fixed real wages. The literature reviewed up to this point is based on an analysis of the effect on output stability of the choice between fixed nominal wages (without indexation clauses) and fixed real wages. However, wages are usually indexed to lagged inflation.

Fischer (1977b) presents a taxonomy of wage contracts in an attempt to analyze this problem. Nonindexed contracts specify the nominal wage for the periods $t + 1$ and $t + 2$, and they aim to keep the expected real wage constant through the use of projections over the existing price level at the start of the contract. Indexed contracts can be of two types. First, contemporaneously indexed contracts can be adjusted to reflect events that occur after the signing of the contract. This type of contract minimizes the variance of the real wages in comparison with predetermined nominal wages. The second type of indexed contract is based on actual inflation between periods. These contracts can stabilize output in the face of nominal shocks if the shocks tend to persist through time. In the presence of transitory nominal shocks or real shocks, however, the second type of contract will tend to destabilize output.

Jadresic (1996b) analyzes the problem of optimal indexation with lagged adjustment and concludes that the Gray-Fischer results are not upheld. In this case, the wage indexation tends to destabilize output independently of the nature of the shocks.

In sum, wage indexation essentially corresponds to an alternative and partial form of nominal rigidity. Furthermore, introducing lagged inflation into the wage equation generates costs in the implementation of an anti-inflationary policy. Various authors analyze such consequences of wage indexation, and their results are discussed in section 2.2.

1.2 Financial Indexation

Financial indexation is a form of contract in which the value of the nominal payments in question is made contingent on some price or price index. As in the case of wage indexation, financial indexation can originate in contracts between private parties or in the denomination of the public debt. Either way, financial indexation allows the creation of a financial instrument that is practically riskless in terms of inflation.

Market Completion and Risk

Indexing financial instruments fills a role in terms of market completion. This is especially important in the case of long-term instruments: if these are nominal, they have no capacity for insulating their proceeds form inflationary surprises.

To evaluate the role of indexed financial instruments in protecting against inflationary risk, one should compare long-term indexed securities with a strategy of rolling over short-term nominal securities. While long-term nominal securities are clearly associated with a high inflationary risk, short-term securities are not, since the nominal rates are "instantly" adjusted. The problem, however, is that a strategy of rolling over short-term securities creates a real rate risk. On the one hand, the nominal value is locked, thereby eliminating inflationary risk, but on the other hand, shifts in the future real interest rate affect the yield on a contract that was initiated in the past (Campbell and Shiller, 1996). Thus the great merit of long-term indexed securities (when short-term nominal securities are also an option) is that they constitute an insurance against changes in the real interest rate. In the case of pensions and other long-term markets such as housing loans, this risk is probably not negligible and is highly valued.

The optimal management of public debt and risk presents incentives not only for indexing the public debt but also for keeping it nominalized. An argument for the latter is that nominal debt provides the government with implicit insurance. Because periods of high government spending (or low receipts) are correlated with periods of high inflation, the government experiences a positive correlation between expenditures and capital gains in the bond market (Bohn, 1988 and 1990; Calvo and Guidotti, 1990). Contrary to this intuition, Barro (1996) recommends fully indexing the public debt to avoid variations in the tax structure (which is assumed to be distorting). Indexed debt prevents nominal shocks from changing the real value of the debt and thus changes the tax sequence consistent with intertemporal restriction and the minimization of costs stemming from tax distortions. The key to this reasoning is the existence of a convex loss function associated with distorting taxes and the possibility of issuing explicitly contingent debt (which implies exhausting the possibilities for implicit insurance).

Additional arguments hold that the government should issue indexed bonds when these are not available in the private market.

Fischer (1983b) shows that this issue can help distribute risk across generations, although the use of direct taxes is equally necessary. The basic function in this case is to allow actors to transfer a supply of resources that does not change in the different states of nature. In simple terms, the bonds would offer a rate that is free from inflation risk, which would not exist under other conditions. Private actors would not choose to issue this type of bond because—in the case of the United States and other developed markets before 1975—the low variability of inflation would not be sufficient to offset the initiation costs (Fischer, 1977a).[14] Obviously, once indexed bonds existed in the private capital market, the government would not need to continue issuing them to generate a riskless rate.

Inflation Expectations and the Real Interest Rate: Coexistence of Nominal and Indexed Bonds

An important benefit of issuing short- and medium-term nominal and adjustable bonds is that the coexistence of both types of instruments allows the authority to infer important information for monetary policy. Essentially, the coexistence of both types of bonds facilitates the estimation of the market's inflation expectations for the different terms and periods, which, in turn, allows an evaluation of the state of the policy.

The existence of private indexed bonds (in addition to nominal public bonds) is not sufficient for the calculation of expected inflation, because they involve risk premiums that are difficult to quantify. The calculation does not require that the bonds have the same maturity, however, as long as the longer-term bonds are actively traded on a secondary market. Of course, the greater the number of maturities available, the richer will be the information that can be extracted.

The formula for calculating inflation expectations is relatively simple once the nominal and adjustable yields on both types of bonds are known. The estimation uses Fischer's equation and expectations theory for yield curves.[15] The first step is to calculate the prices (yields) of

14. Fischer (1977a) examines different theories that explain the lack of indexed bonds in the private sector in developed countries. He rejects explanations based on a tax treatment that supposedly benefits nominal bonds, on a correlation between utilities and the price level that would transform nominal bonds into a form of implicit insurance for firms, and on the problem of a call clause option.

15. See Breedon (1995) for a review of indexed bonds in the United Kingdom (gilt-edged securities).

adjustable and nominal zero-coupon bonds starting with observed market prices; this generates nominal and indexed yield curves.[16] Using the adjustable rate (of zero-coupon bonds) as a proxy for the real rate and following Fischer's equation, we calculate inflation expectations (plus a premium for inflation risk) over different periods:

$$\pi^e_{t,t+\tau} + \rho = i_{t,t+\tau} - r_{t,t+\tau} \, ,$$

where $\pi^e_{t,t+\tau}$ is expected inflation for the period t to $t + \tau$, ρ is the inflation risk premium, and r and i are the implied rates on adjustable and nominal zero-coupon bonds, respectively, that mature in $t + \tau$. The expectations hypothesis holds that the long-term rate is an average of the expected short-term rates. Thus if one supposes a constant inflation risk premium, then the expected inflation rate for the period $t + \tau$ is calculated as follows:

$$\pi^e_{t+\tau} = \pi^e_{t,t+\tau} - \pi^e_{t,t+\tau-1} \, .$$

The biggest problems with calculating expectations on the basis of indexed bonds are as follows: first, expectations theory is never precisely realized, given the existence of maturity premiums that vary over time; second, if the inflation risk premium varies systematically over time, the expectations estimation can be improved by modeling this change on the premium; and finally, expected changes in future taxes—especially differential changes between real and nominal yields—can ruin the results (Campbell and Shiller, 1996). However, the high periodicity and speed with which one can calculate inflation expectations using this method make it far superior to market surveys.[17]

Debt Drawdown and Inflation

Many countries have implemented actions such as establishing the independence of the central bank in order to address the fiscal

16. On using coupon bonds to calculate the yield curve on zero-coupon bonds, see Campbell, Lo, and MacKinlay (1996, chap. 10). See Herrera and Magendzo (1997) for an application of the expectations calculation for adjustable rates in the case of Chile.

17. Evidence from indexed markets and surveys in developed countries shows that long-term inflation expectations adjusts very slowly to changes in short-term inflation. Inflation expectations thus have a "long-term" memory (Gagnon, 1996).

authority's inability to generate perfect compromise mechanisms. These are not perfect substitutes, however, and credibility may be questioned. It is therefore advantageous to consider other actions that increase the credibility of the authority's anti-inflationary efforts. Such actions include holding the public debt in short-term, indexed, or foreign-denominated bonds, which aims to prevent the authority from "massaging" and drawing down the value of the debt via inflation (Lucas and Stokey, 1983; Calvo, 1988). Indexation, therefore, is a type of compromise mechanism that controls the government's time inconsistency.

Holding the debt in short-term and indexed bonds demonstrates to the public that the authority has nothing to gain from inflating the economy (except for possible Phillips-curve-type earnings), since the interests are immediately adjusted and the real value of the debt does not change. In a game scheme such as that developed in Barro and Gordon (1983), therefore, equilibrium inflation expectations are lower under short-term and indexed debt, as is effective inflation.[18]

Indexed debt is more effective than short-term debt in protecting the credibility of the public authority because even with short-term (not instantaneous) debt, the government stands to gain from inflating the economy.[19] Moreover, managing internal liquidity can be complicated with nominal short-term debt, since large volumes of expirations must be absorbed by the market each time the debt comes due. Indexation is preferable to foreign-denominated debt, as well: the value of the latter covaries with the richness of the country through changes in the real exchange rate, resulting in negative insurance.

Financial Indexation and Saving

One of the main arguments in favor of indexing financial instruments is that it is essential in economies with moderate to high inflation for increasing private saving in terms of both flow (personal and business saving) and stock through the development of the capital market (market size and term length). The idea is that protecting yields against inflationary shocks will generate important incentives for increasing saving and establishing long-term contracts. This argument must be qualified along several dimensions.

18. Section 2.2 discusses indexation and the inflation level in more detail.

19. A fitting question is whether the authority would have a greater motivation for liquidating the debt (which is equivalent to defaulting on some percentage) than for simply partially defaulting. One potential explanation lies in the authority's political ability to convince the public that some type of exogenous inflationary shock occurred and that they did not want to default.

First, increases in financial saving are not necessarily accompanied by increases in effective national saving.[20] Private family saving appears to depend more on the economic cycle than on the rate of return (which could be modified with indexation). Empirical evidence on the relation between saving and interest rates (for example, Deaton, 1992, 59-75) indicates that saving is not very sensitive to the real level of "normal" interest rates. There is some evidence, however, that negative rates do strongly influence saving levels (Dornbusch and Reynoso, 1989), indicating that indexation might be advantageous in economies that are susceptible to spikes in the inflation rate.

This does not necessarily invalidate the argument that indexation is desirable, since increased financial saving can provide a more efficient way of channeling resources toward productive investment. The development of the financial system gradually improves the quality of the projects that are carried out, for at least two reasons: first, intermediation allows the harmonization of project maturities with what the public is willing to accept (Diamond and Dybvig, 1983), and second, intermediaries act as monitors in the investment process (Diamond, 1984). International evidence indicates that financial development is associated with higher investment and growth rates (King and Levine, 1993).

In many developing economies, high inflation rates have coexisted with the regulatory restriction of capital markets. Financial liberalization might be better than indexation for increasing financial saving under such circumstances. Once the capital markets have been liberalized, indexation will probably have only a marginal effect on financial saving. Financial indexation modifies the variance (and other superior moments) of the distribution of the yields on the different instruments. It is not correct to associate it with a change in the level (net of risk premiums) of the expected rates of return when it occurs in a liberalized system in which the nominal rates are adjusted to inflation (through the Fischer effect). Of course, this change of variance can affect the yield through changes in the risk premiums.

A valid argument in terms of the effect of financial indexation on yield levels is based on risk premiums (especially inflation) and liquidity (which is generated by changes in the level of the financial system's development). Nominal securities should demonstrate a positive yield

20. Evidence from Chile shows that what really increases together with the proliferation of indexed saving is financial saving, not total private saving or national saving (Morandé, 1993). Other Latin American countries have had similar experiences (Jiménez, 1993).

differential as a result of the greater inflationary risk that they carry and the insufficient development of the market. One argument against indexing long-term securities in the United States was the eventual balkanization of the market (Campbell and Shiller, 1996). Issuing instruments of similar terms and different denominations could thus imply a loss of liquidity: when actors can operate in two different markets, it requires more work in information gathering. Even when these arguments are valid in terms of yields (and are thus important in terms of welfare and resource allocation), their effect on saving is probably low, especially considering that real interest rates today are usually positive.

Finally, there is a potential relation between financial indexation and (quasi-) fiscal saving. Within the debate on the launching of long-term indexed bonds in the United States, for example, it was argued that indexation would be beneficial in creating saving for the treasury, since it would eliminate inflationary risk premiums on government debt.[21] Assuming that such premiums exists, one could argue that the saved resources are only transfers between the government and the private sector, such that they do not represent real saving. If the government generates saving, it only reduces future taxes. Indexation or nominalization, therefore, should not be evaluated on the basis of the fiscal saving it generates (Campbell and Shiller, 1996). In terms of public finances, both the operation and the composition of the open market are irrelevant (Stiglitz, 1983; Wallace, 1981).

Three factors undermine this argument. First, given that the taxes that are avoided are distorting, the policy does, in fact, constitute effective saving (though probably to a lower magnitude than initially estimated). Second, if foreigners hold a portion of debt, the saving on interest involves more than simple transfers. Third, the lack of Ricardian equivalence means that the transfers are not fully compensated by the actions of the public and thus does increase total saving.

1.3 Exchange Rate Indexation

The prevailing exchange rate regime in an economy can have important consequences for inflation. A fixed exchange rate has frequently been used as a way of introducing a nominal anchor into the economy in the context of an inflation stabilization program. In contrast,

21. This same argument could be used in Chile in that the nominalization of instruments could mean overspending for the treasury.

exchange rate rules that incorporate indexation clauses based on lagged inflation tend to perpetuate the effect of transitory price shocks on inflation. This section briefly discusses the different arguments for and against the different exchange rate regimes and their possible impact on inflation. The latter issue is discussed in more detail in the following section.

Purchasing Power Parity (PPP)

The law of one price in international trade implies that a dollar (or any other currency) should be able to buy the same quantity of a good in different countries. This is known as absolute purchasing power parity (PPP). Formally, it implies that if different goods are consumed in two countries in the same proportion, then the price index of both countries will be related through the equation,

$$H = \frac{P}{P^*} ,$$

where P is the domestic price index, P^* is the price index of the second country, and e is the nominal exchange rate between the two currencies. Because of international arbitrage, absolute PPP implies that the price of a common basket of goods measured in a common currency will be the same in both countries regardless of the type of shock that affects one of the economies.[22]

Of course, there are many reasons that this relation cannot be realized. Many goods are not traded internationally, while others that are traded are not perfect substitutes. Transport costs, tariffs, quotas, and other barriers to international trade also cause prices to deviate. This points to the lack of price equalization at the international level and, therefore, to a more moderate version of PPP theory. In particular, relative purchasing power parity establishes that under the above circumstances, the relative domestic-foreign price can change, but variations in the exchange rate should compensate for such variations in price. That is,

$$\hat{e} = \hat{P} - \hat{P}^* ,$$

where ^ denotes percent change. In other words, PPP theory implies that a freely floating exchange rate will tend to compensate for differences in inflationary trends in the two countries.

22. See Dornbusch (1988) for a detailed study on the implications of PPP.

The available evidence shows that relative PPP holds fairly well for the largest economies in the long term.[23]

The main deviation affecting the exchange rate in the long term has been identified as the Balassa-Samuelson effect. Suppose that each of the two economies produces and consumes tradable and nontradable goods. Now suppose that the productivity of the tradables sector increases in the domestic economy relative to the foreign one. Given the law of one price, increased productivity will imply wage increases both in the sector and in the economy as a whole. Productivity has not increased in the nontradables sector, however, such that the increased wage costs should raise prices in that sector. Prices in the domestic economy thus increase relative to the foreign economy, which tends to generate a real appreciation of the domestic currency.

Although relative purchasing power parity holds fairly well in the long term (correcting for the Balassa-Samuelson effect), evidence indicates that in the short term this relation is much weaker, with deviations from the relative PPP lasting four years, on average.[24] As shown below, this phenomenon is due not only to the institutional arrangements of the nominal exchange rate, but also to short-term price inflexibility.

Choice of Exchange Rate Regime

The above considerations are critical for the choice of an exchange rate regime. Additional factors must also be kept in mind, however. First, it has been suggested that a flexible exchange rate is advantageous because it grants increased autonomy in the determination of monetary and fiscal policy. This is true only to the extent that the authority does not implicitly fix the exchange rate level.

A second factor to be considered is the effect of the exchange rate regime on product stability in the face of different types of shocks. Turnovsky (1976) uses a Mundell-Fleming model to show that a fixed exchange rate is preferable in the presence of monetary shocks as it insulates output from variations in monetary policy, whereas a flexible exchange rate is an advantage in the face of external price shocks. This is due to the fact that under purchasing power parity, movements in the nominal exchange rate tend to compensate for external price shocks. As discussed below, when an economy faces different

23. See Obstfeld (1995) for evidence in this regard.

24. Obstfeld (1995) shows that relative PPP fails dramatically in the short and medium terms.

types of shocks, neither of the two extreme alternatives is optimal, but rather some intermediate alternative of exchange rate intervention will produce the best results.

Third, despite the favorable evidence for relative PPP over the long term, a number of developing countries have opted for a fixed exchange rate during specific periods. The main reason for this practice is that the authority is using the exchange rate as a nominal anchor for the economy in order to bring domestic inflation down to international levels, especially in the context of stabilization programs. Of course, fixing the exchange rate triggers a real appreciation of the currency, given the existence of inflation of nontradables. Part of this appreciation represents equilibrium, due to private earnings associated with economic reforms and the stabilization program itself. A large part of the appreciation, however, stems from indexation to past inflation and credibility problems with the implemented policies. The degree of danger associated with this appreciation process will depend, to a large extent, on the level of the real exchange rate at the moment the nominal exchange rate is fixed.[25]

Fourth, suppose that two countries have similar levels of inflation and output growth and that relative purchasing power parity holds fairly well between them. The choice between a fixed and flexible exchange rate will be irrelevant in this case if prices are flexible in the short term. Evidence shows, however, that the distribution of the real exchange rate in the short term is affected by the prevailing exchange rate regime, which indicates price inflexibility. Consequently, a flexible nominal exchange rate allows one to accommodate relative price shocks without serious consequences in terms' of increased unemployment (in case a real depreciation is required).

Another obvious argument for a flexible exchange rate arises when the countries feature different inflation or output growth rates or both. Experience shows that flexible exchange rate regimes have accommodated differences between countries in these variables for long periods. The problem with flexible exchange rate regimes stems from the great volatility that is generally seen in nominal exchange rates under this regime. Bear in mind that the exchange rate is nothing more than the relative price of two financial claims, and as such, it is subject to fluctuations stemming from changes in expectations and other variables that determine this type of price. It is not a problem

25. For a detailed discussion of this issue, see Dornbusch (1993); Dornbusch, Goldfajn, and Valdés (1995); Edwards (1993, 1996).

if the variability of the exchange rate causes profits or losses for financial investors who deliberately expose themselves to exchange rate risk. In some cases, however, excessive exchange rate volatility can negatively affect the level of international trade or of foreign direct investment received by a country.

There is no reason to assume that the volatility demonstrated by the exchange rate might be due to irrational behavior on the part of the actors involved. Dornbusch's theory of overshooting (Dornbusch, 1976), for example, predicts the rapid and strong adjustment of the nominal exchange rate in the face of changes in monetary conditions. This known effect is simply due to the existence of short-term price rigidity and arbitrage on international assets, which gives rise to uncovered interest rate parity.

There are several alternatives to the extreme cases of fixed and flexible exchange rate regimes. One intermediate exchange rate regime that aims to reduce exchange rate volatility is the dirty float. Under this arrangement, the authority allows the nominal exchange rate to adjust freely in response to relative price shocks, but is disposed to intervene actively whenever it estimates that the nominal exchange rate is deviating from what is considered to be the equilibrium level.

Another much-used alternative in developing countries—and one that is directly related to the topic of indexation—is the crawling peg. This exchange rate regime corresponds to a preannounced exchange rate (similar to a fixed rate) that varies according to the difference between domestic and external inflation. This regime seeks to achieve the stability generated by a fixed exchange rate while avoiding significant appreciation of the real exchange rate. The idea behind this type of exchange rate regime is that relative purchasing power parity holds in the medium term. Deviations stemming from the Balassa-Samuelson effect can be accommodated in the indexation rule. In general, the exchange rate adjustment rule is constructed using domestic inflation in the preceding month, which is why this regime is considered an indexation practice. There are convincing arguments that this administered exchange rate introduces a significant degree of inflationary inertia into the economy. Edwards (1993) discusses this trade-off between exchange rate appreciation and disinflation on the basis of a simple model that is analyzed in the next section.

To allow short-term deviations in purchasing power parity and gain flexibility in managing the exchange rate, the authority can allow the nominal rate to fluctuate freely within a band around the announced exchange rate. If the band is credible, this exchange rate regime tends to soften fluctuations of the exchange rate within the band. The reason for this is that given the authority's performance, when the exchange rate approaches the floor (or ceiling) of the band, expectations for devaluation (or appreciation) increase, which tends to keep the exchange rate within the band (Krugman, 1991). If, on the other hand, the authority's credibility is low and the probability of realignment is estimated to be high, then the extremes of the band will act as magnets, thereby increasing the volatility of the exchange rate (Bertola and Caballero, 1992).

Wage Indexation and the Choice of Exchange Rate Regime

Two aspects of the relation between the degree of wage indexation and the exchange rate regime are particularly interesting. First, the degree of wage indexation affects the optimal choice of the exchange rate regime. Under full, perfect wage indexation, monetary shocks cannot affect the real wage, which makes the choice of exchange rate regime irrelevant with regard to the stability of output. Marston (1992) shows that, in general, the greater the degree of wage indexation, the lower is the difference among exchange rate regimes in the performance of the economic activity level in the face of different shocks.

Second, while this may be valid with regard to output stability, it is not with regard to prices. When wage indexation is not perfect, but rather depends in part on past inflation, a greater degree of exchange rate indexation, in combination with wage indexation, will increase inflationary inertia and variance. These issues are discussed in detail in the next section.

The choice of exchange rate regime and the optimal degree of wage indexation should thus be resolved in a joint optimization program in which the functional objective takes into account the stabilization of the economic activity level as well as the price level. Aizenman and Frenkel (1985) show that when purchasing power parity holds, a greater degree of exchange rate flexibility will generally be required given a greater optimal degree of wage indexation.

2. Indexation and Inflation

This section reviews the interaction between indexation and inflation. The different forms of indexation affect inflation in a variety of ways. Inflationary persistence and variability can increase if several or all of the sectors of the economy are indexed. If monetary policy is linked to endogenous factors in order to ameliorate inflation shocks, then specific real or nominal shocks—however small—that start in a particular market can be propagated and magnified by the indexation clauses. The existing degree of indexation can also affect the long-term inflation level. On the one hand, indexation reduces the costs of inflation, while on the other, it limits the real effects of an inflationary shock, since it is less tempting for the government to generate unexpected inflation. At the same time, the optimal degree of indexation hinges on the level and predictability of inflation. This could generate multiple equilibriums depending on the level and variability of inflation and the degree of indexation. There are also potential interactions between optimal private inflation (such as in wage indexation) and the degree of indexation chosen by the government (such as its debt denomination).

2.1 Indexation, the Exchange Rate Regime, and the Dynamics of Inflation

The main motivation for studying the macroeconomic effects of indexation is the presumption that a greater degree of indexation in the different markets generates a greater degree of inflationary inertia.[26] This section analyzes this proposition, which is generally sustained by economic authorities, as well as the effect of indexation on the variability of inflation. The next section discusses the characteristics of indexation that increase the costs of implementing stabilization programs.

The first step in determining how a random price shock is transmitted to the inflationary process is identifying the degree of homogeneity in the equation governing the price level as a function of lagged prices. If the equation has a unit root, then shocks will have a permanent effect on inflation.

A simple analytical framework from which to start is the decomposition of the inflation in period t into the variations of the price of tradable and nontradable goods:

$$\hat{P}_t = \alpha \hat{P}_{T,t} + (1-\alpha)\hat{P}_{N,t} ,$$

26. With the exception of financial indexation, which probably does not influence inflationary persistence.

where T denotes tradables, N nontradables, and α the participation of tradables in the consumer price index. If we assume that monetary policy is elastic, that the law of one price applies for tradables at all times, and that the prices of nontradables are partially indexed to a lagged indicator (for example, because wages are perfectly indexed to past inflation), we obtain

$$\hat{P}_{N,t} = \theta \hat{P}_{t-1} + \mu_t \text{ and}$$

$$\hat{P}_{T,t} = \hat{e}_t + \hat{P}_t^* + \nu_t \ ,$$

where θ is the degree of indexation of the prices of nontradable goods, $\hat{e}$ is the percentage effective devaluation, * indicates the external nature of a variable, and μ_t and ν_t are price shocks to nontradables and tradables, respectively, with mean zero and variance σ. Additionally, if the exchange rate is administered by the authority and indexed to the differential between domestic and external inflation, we obtain

$$\hat{e}_t = \hat{P}_{t-1} - \hat{P}_{t-1}^* \ .$$

Replacing the tradables and nontradables price equations in the economy's general price equation produces the equation that governs inflation:

$$\hat{P}_t = \left(\alpha + \theta - \alpha\theta\right)\hat{P}_{t-1} + \alpha\left(\hat{P}_t^* - \hat{P}_{t-1}^*\right) + \alpha\nu_t + \left(1-\alpha\right)\mu_t \ .$$

To the extent that there is perfect indexation in nontradables prices (that is, $\theta = 1$) and in the exchange rate relative to the differential of domestic and external inflation rates, the economy's price equation will have a unit root. An inflation shock in the economy will therefore have a permanent effect. The variance of the inflation rate, in turn, will be given by the expression

$$\sigma_{\hat{p}}^2 = \frac{2\alpha^2\sigma^{*2} + \alpha^2\sigma_\nu^2 + \left(1-\alpha\right)^2\sigma_\mu^2}{1-\left(\alpha+\theta-\alpha\theta\right)^2} \ ,$$

where σ^{*2} is the variance of external prices. It follows that if the indexation of nontradables is perfect, the volatility of inflation is infinite. Moreover, a greater degree of indexation generates greater inflationary variability:

$$\frac{d\sigma_{\hat{p}}^2}{d\theta} > 0 \ .$$

In sum, indexation increases both the variance and persistence of inflation. This is due to the fact that in the presence of well-behaved, random shocks, lags in the formation of the inflation rate will cause increases in the rate to be added into the total several times.[27]

The preceding model can be expanded on the basis of Edwards (1993). The law of one price is here assumed to apply ex ante in the tradables market, which means that these prices are adjusted according to expectations for external inflation and devaluation:

$$\hat{P}_{T,t} = (_{\,t-1}\left[\phi\left(\hat{P}_{t-1} - \hat{P}^{*}_{t-1}\right) + \hat{P}^{*}_{t}\right],$$

where ϕ is the degree to which the exchange rate is indexed to the differential between domestic and external inflation and E_{t-1} indicates expectations in the period $t-1$. Full indexation to this differential is precisely the PPP rule discussed above.

Edwards also derives a nontradables price equation based on the market equilibrium for these goods. It is assumed that the demand for nontradables depends on the real exchange rate and that supply is a function of the real wage (measured in nontradables units). The market equilibrium for nontradables is represented as follows:

$$\eta\left(\hat{P}_{N,t} - \hat{P}_{T,t}\right) + \delta\left(\hat{z}_{t}\right) = \varepsilon\left(\hat{W}_{t} - \hat{P}_{N,t}\right),$$

where W_t denotes wage, η is the elasticity of demand for nontradables relative to the real exchange rate, ε is the elasticity of supply for nontradables relative to the real wage in nontradables units, and z_t is an indicator of monetary policy. It is further assumed that the nominal wage is determined jointly by the degree of indexation and changes in inflation expectations. From this we obtain

$$\hat{W}_{t} = \gamma\hat{P}_{t-1} + \left(1-\gamma\right)(_{\,t-1}\hat{P}_{t},$$

where γ is the degree of wage indexation relative to lagged inflation and $1-\gamma$ is the degree of wage indexation relative to inflation

27. Fischer (1983a) shows that the degree of wage indexation increases the variance of the price level. The paper discusses the price level, however, and not the variability of inflation (although that is not significant in a logarithmic context without implicit functions) and creates a static model, which is a consequence of indexing wages to contingent, nonlagged prices.

expectations one period ahead. Combining the equations generates the equation that governs the inflation level:

$$\hat{P}_t = \mathrm{D}_1 \hat{P}_{t-1} + \mathrm{D}_2 \hat{P}^*_{t-1} + \mathrm{D}_3 \hat{z}_t + \psi_t \ ,$$

where ψ_t is a composition of the different shocks to the system and where

$$a_1 = \frac{(\eta + \alpha\varepsilon)\phi + \varepsilon(1-\alpha)\gamma}{(\eta + \alpha\varepsilon) + \varepsilon(1-\alpha)\gamma} \ ,$$

$$a_2 = \frac{(\eta + \alpha\varepsilon)(1-\phi)}{(\eta + \alpha\varepsilon) + \varepsilon(1-\alpha)\gamma} \ , \text{ and}$$

$$a_3 = \frac{-\delta(1-\phi)}{(\eta + \alpha\varepsilon) + \varepsilon(1-\alpha)\gamma} \ .$$

This equation provides the basis for studying the effect of the different forms of indexation on inflationary volatility and persistence, which is summarized in table 1. The table clearly highlights the fact that full, lagged indexation of the exchange rate causes the price equation to have a unit root and, therefore, an explosive variance, independently of the prevailing type of wage adjustment mechanism (cases A and B). In the absence of wage indexation and given a fixed exchange rate (case C), the inflation trend will be determined by the evolution of external inflation and the performance of the economic policy. In this case, the variance of inflation will be finite. Finally, when a fixed exchange rate is combined with full wage indexation to lagged inflation (case D), both domestic and external prices will influence the price trend and thus the variance of inflation.

The price equations analyzed up to this point have considered only a one-period lag. However, while wage negotiations occur continuously in the economy, indexation clauses generally have a duration of six months or a year. This means that the inflation equations can have more than one lag from a monthly perspective. One way to analyze this is to use Bruno's average lag principle (Bruno, 1993 and 1994). Starting with an equation of the type

$$\hat{P}_t = \theta \hat{P}_{t-1} + (1-\theta)\hat{P}_{t-2} + \omega_t \ ,$$

where ω_t is a random shock, the change in inflation can be written as follows:

$$\Delta \hat{P}_t = -(1-\theta)\Delta \hat{P}_{t-1} + \omega_t \ .$$

After a particular realization of the shock denoted by ω, this constitutes a convergent series whose steady state is

$$\Delta \hat{P}_{ss} = \frac{\omega}{2-\theta} \ ,$$

where $\Delta \hat{P}_{ss}$ is steady-state inflation.

Consequently, the greater the concentration of the unit root in recent lags, the greater will be the inflationary response to shocks. This phenomenon can have a considerable impact if it is considered a function of the reaction of actors, who define the average lag as a function of either their inflation expectations or the inflationary trend of the past few months. In that case, the average lag could increase in the face of an acceleration of inflation, which would raise the level of steady-state inflation that would otherwise obtain as a consequence of the shock.

Table 1. Indexation: Inflationary Persistence and Volatility

Case identification	*Exchange rate regime and wage indexation* (θ, γ)[a]	*Inflationary persistence* a_1	*Impact of external inflation* a_2	*Inflationary variability* $\sigma^2_{\hat{p}}$
A	PPP without indexation $(\theta=1, \gamma=0)$	$a_1 = 1$	$a_2 = 0$	Infinite
B	PPP with indexation $(\theta=1, \gamma=1)$	$a_1 = 1$	$a_2 = 0$	Infinite
C	Fixed exchange rate without indexation $(\theta=0, \gamma=0)$	$a_1 = 0$	$a_2 = 1$	Finite
D	Fixed exchange rate with indexation $(\theta=0, \gamma=1)$	$0 < a_1 < 1$	$0 < a_2 < 1$	Finite

Source: Authors' calculations.
a. PPP is purchasing power parity.

There is relatively little evidence on the relation between indexation and inflationary volatility or persistence. The reason for this is that it is difficult to find good instruments for addressing the problem of dual causality between indexation and inflation. Fischer (1983a) tries to solve the problem of dual causality by introducing the 1974 oil shock as a natural experiment. However, the analysis centers on the inflation level, finding that countries with indexation are not substantively better off than others after the oil shock. Landerretche and Valdés (1997), who study nine countries without controlling for causality, find that the indexation periods do not match the periods of inflationary acceleration. They find, rather, that periods of wage indexation feature a higher level of inflation and greater inflationary volatility and persistence. Similarly, they find that the level, variability, and persistence of inflation is greater under PPP regimes than under fixed exchange rate regimes and that the PPP regimes have a higher inflationary level and persistence, although a lower variability, than flexible exchange rate regimes.

Edwards (1993) analyzes the experiments with fixing the exchange rate regime that were carried out in Chile (1979-82), Mexico (1988-89), and Yugoslavia (1990-91). The paper finds that in the Chilean case—unlike the Mexican or Yugoslavian cases—fixing the exchange rate did not modify inflationary persistence. (This is attributed to Chile's inability to nominalize the labor market.) Finally, McNelis (1987) decomposes the persistence coefficient into the effects of exchange rate and wage indexation for Latin America in the 1970s and 1980s. McNelis's findings are consistent with Edwards (1993): in Brazil and Chile, inflationary persistence is dominated by wages; in Argentina, Ecuador, and Peru, inflationary persistence is dominated by the exchange rate; and in Uruguay, the fall in persistence is associated with the general liberalization of the economy.

2.2 Indexation, the Inflation Level, and Monetary Policy

Disinflation Costs and Inflationary Persistence

An area of particular interest in the study of indexation and its effects on the economy has to do with the effect of indexation on the costs incurred during the process of inflationary stabilization and its consequences for inflationary persistence. A stabilization program that aims to rapidly reduce the inflation rate can be considered a nominal shock. Therefore, the best way to minimize disinflation costs in terms of output is to have 100 percent perfect indexation. This idea is what motivates Friedman (1974) to advocate the proliferation of indexed contracts throughout the economy when the authority seeks to disinflate: the nominal magnitudes would be modified at the same time without any impact on real magnitudes. Riveros (1996) qualifies that conclusion, taking into account the fact that real wages may lie outside the full-employment equilibrium at the time the disinflation effort is initiated (for example, due to a trade shock). If that is the case, the adjustment policy, in combination with indexation, may have extremely high costs in terms of unemployment, because real wages could not be adjusted. The intuition behind this qualification is the same as in the Gray-Fischer models, in that it considers the relative importance of nominal and real shocks. Friedman's rule does not consider real shocks, whereas Riveros's qualification shows the exact consequence of a real shock.

In addition, as discussed above in subsection 1.1, wage contracts, in practice, do not stipulate perfect indexation. Most contracts contemplate adjustments that are a function of lagged inflation, which causes the real wage to be affected by nominal shocks. Disinflation costs in this case are greater in the presence of rigid nominal wages. Indexation based on lagged inflation provides retrospective feedback for nominal wages, which pushes real wages upward (or causes them to be more persistent) and deepens the recessive effect of disinflation. Disinflation costs are then determined by the degree of indexation in the contracts and the sensitivity of wages to the unemployment level (Simonsen, 1983; Bonomo and García, 1994).

Disinflation can also have costs in the presence of rigid nominal wages, since these also introduce a degree of inertia. This results from the fact that all contracts established before the initiation of the stabilization program stipulate nominal salaries that implicitly consider expected inflation over the life of the contract.[28]

An interesting case for comparison is that of contracts that fix wages through adjustments based on expected inflation at the

28. Jadresic (1995) analyzes the effects of the duration of nominal and indexed contracts on disinflation costs. Calvo (1983) and Ball (1994a) examine the costs of stabilization in the presence of rigid nominal salaries. They conclude that it is possible to have zero disinflation costs even in the presence of nominal rigidities. The costs reflect, rather, a lack of credibility. Ball (1994b) provides empirical evidence on the determinants of the sacrifice ratio (the cost in terms of growth for every one percent reduction in inflation), using a panel of developed countries.

moment of signing the contract. Such contracts can have a significant effect on stabilization programs. When the amount of the inflation adjustments is specified at the beginning of the contract, the effective duration of the indexation clause is greater than in the case of traditional contracts using lagged inflation. The inflationary inertia introduced into the system is therefore greater, and the costs of disinflation rise (Jadresic, 1996a). Indexed contracts based on expected inflation at the moment of each adjustment are more flexible, since they allow the wage determination to incorporate the lower inflation expectations generated by the stabilization program.

Wage indexation is not the only factor influencing disinflation costs. Another important element is inflationary inertia originating from the prevailing exchange rate regime. As seen in the previous subsection, administered exchange rate systems in which the exchange rate is frequently devalued as a function of the difference between the domestic and external inflation rates introduce inflationary inertia. A number of stabilization programs have tried to get around this effect by using the exchange rate as a nominal anchor. Most of the economies that have subscribed to this type of stabilization program are characterized by widespread indexation practices and an elastic monetary policy. Under such circumstances, it is normal for an important degree of inflationary inertia to persist even after the nominal exchange rate is fixed. The resulting exchange rate appreciation can lead to a loss of the plan's credibility as the relevant actors lose faith in the success of the program. There is no obvious recipe or simple solution in these cases. The lack of credibility may imply that inflationary inertia persists unaltered for a long time after the stabilization program is launched.[29] In contrast, if the stabilization plan is based on monetary control while the exchange rate regime follows a PPP rule, then a stabilization program will encounter rigidities to the extent that past inflation is transmitted to the exchange rate and, in turn, to the prices of imported inputs.[30]

29. Rebelo and Végh (1995) analyze different theories to explain the real appreciation following a stabilization plan based on the exchange rate. The appreciation can reflect a lack of credibility in the program and not a problem of inflationary inertia. Dornbusch (1982b) and Edwards (1993, 1996) discuss the problems of inertia for stabilization programs in the context of adjustment programs in Latin America.

30. For a detailed discussion of this mechanism, see Dornbusch (1982a).

Disinflation Costs, Time Consistency, and Monetary Policy

It is well known that an economy's inflation level cannot depend directly on its degree of indexation. Monetary policy, especially the growth rate of aggregates, must be consistent with the inflation rate. Consequently, an analysis of the interaction between indexation and the inflation level must incorporate decisions on monetary policy as an endogenous variable.

A simple way to construct this endogenous variable is to assume that the authority does not lower inflation more than necessary because such a measure would have negative real effects, namely, unemployment and recession. As discussed above, Friedman (1974) argues that full indexation would avoid these costs. However, lags in indexation generate disinflation costs that are not negligible (at least in the short term) and could explain the existence of a certain level of inflation (Simonsen, 1983).

A more modern conceptual framework for analyzing the role of indexation in generating a response can be derived from Barro and Gordon's model (Barro and Gordon, 1983). In this model, the government faces a problem of time inconsistency due to the existence of a Phillips-curve-type relation, and the government chooses the inflation level given market expectations. The public anticipates the government's action and expects equilibrium inflation, which generates a suboptimal solution of high inflation and unemployment rates.[31]

Following Fischer and Summers (1989), we derive a Phillips curve relation of the following type:

$$U = U^{*} - \mathrm{a}\left(\pi - \pi^{e}\right),$$

where

$$L = \left(U - \kappa U^{*}\right)^{2} + \mathrm{b}\pi^{2},$$

with $\kappa < 1$. Because κ is less than one, the authority has incentives for choosing positive inflation whenever expected inflation is zero.

31. The classic article on time inconsistency is Kydland and Prescott (1977).

This produces a problem of time inconsistency: however much the authority promises low inflation, the promise is not credible because if that were the case, it would no longer be optimal for the government to pursue the low inflation plan. Furthermore, in equilibrium, private actors pass over this problem and expect an equilibrium inflation level that is effectively realized.

Once private expectations are determined, the government selects the inflation level, trying to minimize L subject to the Phillips curve condition. This produces the following first-order condition for the optimal inflation level (from the government's perspective):

$$\pi^* = \frac{a(1-\kappa)U^* + a^2\pi^e}{a^2 + b} .$$

The assumption of rational expectations on the part of private actors implies that

$$\pi^* = \pi^e = \frac{D}{E} U^* (1-\kappa) .$$

Paradoxically, in equilibrium, the government does not achieve a reduction in unemployment and creates inflation. The government would be in a better situation if it had access to mechanisms for making a zero-inflation objective credible.

The generation of dynamic inconsistency does not hinge on a Phillips-curve-trade-off in the short term (in which unemployment changes in response to errors in inflationary projections). Any mechanism that allows the government to benefit from surprising the private sector with unexpected inflation will produce a similar effect. The practice of managing inflation in order to draw down the stock of public debt is a highly relevant example.[32]

Indexing different prices in the economy has two complementary effects in the context of this model. First, indexation helps limit the real effects of transitory shocks, since nominal wages (and other prices) are automatically adjusted to inflation. In terms of the Phillips curve,

32. Lucas and Stokey (1983) discuss this problem. Calvo (1988) studies how drawing down the debt can imply a multiple-equilibrium solution. In that case, the interest rate not only reflects inflation expectations, but also is a direct determinant of inflation through the government reaction (drawdown) function. Guidotti (1993) incorporates the problem of dynamic inconsistency in an optimal indexation model.

the parameter a is reduced, creating a more vertical relation. Wage indexation would be responsible for this effect in the model as presented. Second, the costs of inflation fall with indexation because private actors and the government both protect themselves against price changes. In terms of the government's loss function, the parameter b is reduced. Nonwage indexation contracts also generate this effect.[33]

Fischer and Summers (1989) analyze the implications of these two changes for the inflation level, associating wage indexation with changes in the Phillips curve. Their most important conclusions are that indexation can increase the inflation level (diminishing a and b simultaneously) and that measures for reducing the costs of inflation wind up creating a higher inflation level (by reducing b). In political terms, this may be reflected in less pressure to lower inflation if inflation is not costly, which could eventually have a negative effect on welfare (under the assumption that the government's loss function L extends directly to the general public). Moreover, indexation will be more or less desirable, in terms of welfare, depending on the degree to which the authority can control inflation. If the authority has a limited control on inflation, then a higher level of indexation will be preferable, since in this case the higher inflation generated by dynamic inconsistency represents less of a problem than the real effects of an inflation shock.

Beyond providing a valuable intuition that indexation can increase inflation, the model does not offer a definitive answer with regard to the exact conditions under which inflation rises. Nor does it give a definitive result with regard to what happens to the welfare level—assuming that inflation increases with indexation. Fischer and Summers address this latter problem by analyzing the restrictions that must be imposed on more general loss functions in order to produce a social loss if the costs of inflation are lowered. In those cases, the time inconsistency effect is stronger than the direct effect of lower inflationary costs.

Ball and Cecchetti (1991) and Mourmouras (1993) reach similar conclusions regarding the idea that indexation alters the inflation level. The first of these papers sets up a Barro-Gordon model, expanded to encompass staggered wage adjustments (as in the Fischer-Gray model). The resulting model has the virtue of unambiguously determining weather wage indexation increases inflation. By explicitly including in the labor market a parameter that measures the

33. In a model based on nominal debt, this role would be fulfilled by financial indexation.

level of contract indexation, the authors are able to conclude that an increase in wage indexation unequivocally increases inflation.[34] In terms of the effects described above, lower inflation costs trigger a stronger effect than a lower slope on the Phillips curve. They further conclude that wage indexation unambiguously increases welfare. Mourmouras (1993) uses the Barro-Gordon model with indexation, taking into account the existence of real shocks in the economy. The paper concludes that the inclusion of this shock does not change the intuitions set out by Fischer and Summers.

Indexation can also affect the inflation level by modifying the reputational dynamics between the authority and the general public. For example, expanding the Barro-Gordon model to cover several periods creates the possibility of sustaining a low level of inflation if the public and the authority develop a supergame. In the game, if the authority deviates from its established objective, thereby generating higher inflation than promised, then the public punishes the authority by expecting high inflation for several periods. If the discount rate faced by the authority is sufficiently low, then the government will find it advantageous to keep inflation low and not to deviate. In the context of the game, indexation has several effects on the possibility of maintaining an equilibrium of low inflation. Fischer and Summers (1989) argue that cooperation could improve with regard to maintaining a lower inflation level, because indexation would raise the level of "punishment inflation" (corresponding to the inflation level that would exist in a one-shot game such as that analyzed above). In addition, indexation serves to coordinate public action in the event that the authority needs to be punished, such that indexation again helps to keep the inflation level down. Indexation generates the opposite effect, however, in games in which there is more than one type of government and in which the authority's actions serve to signal the type. If the government carries out measures that reduce the costs of inflation, then the public may think that the government is of the type that is disposed to move the economy to a state of high inflation.

There is little empirical evidence on the relation between indexation and inflation. As mentioned above, Fischer (1983a) analyzes the inflationary response of different countries in the face of

34. The loss from inflation is caused by undesired variability in real wages. Indexation is modeled as if wages were modified instantaneously with price variation in a proportion p of the firms in an economy. Inflation increases when p increases. This conclusion is robust when other inflation costs are included.

the 1974 oil shock, controlling for the degree of indexation and the different forms this takes. He does not find a significant difference in the post-shock inflation performance of countries with high and low levels of indexation. Landerretche and Valdés (1997) analyze the history of nine countries and conclude that indexation correlates positively with the inflation level (without controlling for dual causality).

Inflation and Optimal Indexation

Beyond the stability and output considerations addressed in the classic articles on indexation (Gray, 1976; Fischer, 1977a), additional elements can be incorporated into the analysis of the optimal indexation level. This section reviews arguments on optimal indexation that take into account what happens with inflation, the dynamic inconsistency problems described above, and the political games that different parties sustain.

Waller and VanHoose (1992) consider only the effects of indexation on the inflation-unemployment trade-off, using a Barro-Gordon-type model in which the degree of indexation is chosen through a decentralized mechanism. In this case, they find that the public's choice of indexation level is suboptimal. The authors assume that the direct effect of indexation is to lower inflation, because it makes it less tempting for the government to surprise the private sector with unexpected inflation (that is, the Phillips curve is more vertical). Private actors act atomistically, however, and do not take into account the effect of their actions on the final inflation level. The chosen indexation level is thus lower than is socially desirable.

Another scenario that has been considered in the literature is what happens if the authority determines the level of wage indexation in a centralized fashion, thereby obviating the problem of suboptimality. To determine the optimal level of indexation under these conditions, Milesi-Ferretti (1994) incorporates the existence of nominal and real shocks into a Barro-Gordon-type model. The model considers just the Phillips curve effect of indexation, which this reduces the inflation level by improving the problem of time inconsistency. Milesi-Ferretti's main conclusions are that the indexation level should be higher if nominal shocks are more important (which confirms Gray and Fischer's result) or if the time inconsistency problem is more serious (a reflection of either a more horizontal Phillips curve or less aversion to inflation on the part of the government). These findings are consistent with Devereux (1989), who presents a similar model but in which monetary policy is chosen before the shocks are felt.

Another dimension of optimal indexation that has been analyzed is the interaction between workers' decisions to index wages and the authority's decision to index financial instruments, specifically the government debt. Guidotti (1993) describes the government's and atomistic agent's decisions on indexation as endogenously given, setting up a model covering two periods and three shocks (namely, output, nominal, and government spending shocks). The government is faced with the alternative of loading more indexation into its debt structure to avoid the inflation-producing problem of dynamic inconsistency versus incorporating less indexation in order to use the debt as insurance against raising distorting taxes in bad states of nature (caused by government spending and output shocks).[35] Private agents, in turn, choose their indexation level as in the Gray-Fischer-type models: if nominal shocks are more important, then more indexation is desirable. The key to the model, however, is that a portion of the nominal shocks are endogenous to indexation because of the government's dynamic inconsistency problem.

The main results of this analysis indicate that the government will choose to have less nominal debt (that is, more indexation) whenever spending shocks are less variable, wage indexation is higher, and the variance of the nominal and output shocks is greater. This means that a higher level of wage indexation lowers inflation, because debt indexation increases and reduces the problem of time inconsistency.[36] The workers, for their part, choose a wage indexation level that is not monotonic with regard to debt indexation. At low levels of debt indexation, wage indexation increases with debt indexation, and vice versa. Finally, if the government prefers a more stable output, one can expect less wage indexation and both more and less financial indexation.

A different dimension is exposed through the ways in which different political parties manipulate indexation levels in order to gain (and stay in) power. Milesi-Ferretti (1994) shows that if the decisions on indexation are irrevocable or have a long horizon, then a party

35. Bohn (1988) analyzes the problem of nominal debt as insurance. See section 1.2 in this paper.

36. Even if the government can commit to a certain monetary policy, some degree of indexation is desirable to avoid unwanted changes in the value of the debt.

that is in power and that is more averse to inflation than the average voter will choose to reduce indexation in an election year. This strategy ensures that the average voter will not vote for the other party (which is assumed to be less averse to inflation than the average voter) because if the economy is unindexed the other party would generate a higher-than-desired inflation. Crosby (1995) reaches a similar conclusion in a model in which indexation is used as a method of commitment in the context of a time consistency problem. In this scheme, the parties that are less averse to inflation will try to index wages as a strategy for gaining power, because by doing so they cease to be an "inflationary danger" from the perspective of the voters. The paper analyzes the case of Australia in 1983, in which the liberal government indexed the economy and maintained an excellent inflation record.

Indexation of Monetary Policy Instruments

Indexation and the control of inflation can be examined at a more concrete level, in relation to the implementation of monetary policy. The question is whether it is more advantageous in a widely indexed economy to use a nominal or adjustable interest rate as the main instrument of monetary policy. The answer has to do with the variability exhibited by the chosen instrument.[37]

Real and nominal interest rates are related through Fischer's equation:

$$i_t = R + \pi_t^e ,$$

where R is the ex ante real interest rate and i_t is the nominal interest rate. If indexation is lagged and if the authority wants to prevent arbitrage between adjustable and nominal securities, the equation should be rewritten as

$$L_t = U + \pi_{t-1} .$$

In other words, the adjustable interest rate (r) is equal to the ex ante real rate plus the differential between expected and lagged inflation.

37. See Fontaine (1991) for a discussion of this issue in the context of the Chilean economy.

This implies two considerations with regard to interest rate variability. First, because indexation has lags, the adjustable interest rate on short-term securities does not correspond exactly to the real interest rate in the economy. Second, there is no reason, in theory, that nominal rates should be more volatile than adjustable rates. Of course, once one of the two is chosen as a political instrument and thus controlled by the authority, the other should undergo all pertinent adjustments in order to deter arbitrage.

The answer to the initial question should therefore be phrased in terms of which interest rate is easier to interpret for the purpose of measuring the state of monetary policy, thereby facilitating policymaking. There are two reasons for this. First, the ex post real rate that an individual faces depends on both the adjustable rate and the relative price change between that individual's idiosyncratic price (wage, exchange rate, raw material prices, and so forth) and lagged inflation. For example, if the real exchange rate appreciates, the ex post real rate for an exporter will effectively be lowered. In the case of Chile, this effect is manifested in the fact that it is difficult to find a stable, systematic relation between adjustable rates, output, and inflation (Mendoza and Fernández, 1994).[38] The process of monetary policymaking is based, in the end, on raising interests rates if the spending-output gap is greater than deemed advantageous and then maintaining this increase as long as the gap does not respond. There is not, a priori, a level of rates that is known ex ante to be correct for achieving an inflationary deceleration of a predetermined amount. It is not necessarily correct, therefore, to associate a specific level of adjustable rates with the state of monetary policy.

The second consideration has to do with the monetary policy's transmission mechanism. If the most important variable is either the short-term nominal rate (for example, if the mechanism is based on capital inflows and exchange rate appreciation) or the volume of monetary aggregates (for example, if the mechanism centers on consumer credit in a context of imperfect information), then the optimal choice is a nominal policy. In both examples, the stability of the adjustable (as opposed to the nominal) rate simply

38. In fact, the profitability of three-month adjustable operations are practically as volatile as nominal operations (Mendoza, 1991; Mendoza and Fernández, 1994). In Chile, Valdés (1997) finds a systematic relation between the adjustable interest rate and output growth and between the interest rate and the gap between target and actual inflation.

creates variability in the nominal rate and noise in terms of discovering the true monetary policy. Worse still, it is not even very relevant in terms of affecting aggregate demand, assuming that the transmission mechanisms are those mentioned. The adjustable rate provides a clear policy signal only when the traditional transmission mechanism is in operation, namely, when the medium-term real rate is influenced by the adjustable rate and also determines the changes in aggregate spending and inflation.[39] Tobin (1971), for example, uses this type of reasoning. Because investment critically depends on q and because the closest substitute for q is the indexed bonds rate, adjustable bonds should be used for monetary policymaking.

3. Summary and Conclusions

This paper has analyzed indexing practices in the labor, financial, and foreign exchange markets. Wage indexation derives from the need to halt the erosion of nominal wages by inflation in the presence of negotiation costs. It also represents a form of implicit insurance between the employer and employee. The fixation of the real wage is achieved, theoretically, through the use of perfect indexation. If the stabilization of output or employment is an objective, the optimal degree of perfect wage indexation will depend on the relative importance of nominal versus real shocks to the economy. In practice, however, it is impossible to achieve perfect wage indexation. Wage indexation therefore takes a variety of forms, all of which seek to approximate fixed real wages. In most cases, indexation is not perfect: wage contracts commonly specify indexation clauses as a function of lagged inflation, which complicates the analysis of the optimal degree of indexation. At the same time, other factors, such as the degree of openness in the economy, also influence the optimal indexation level.

Financial indexation, in turn, aims to complete markets by offering an instrument that is effectively free of inflation risk. Such instruments could affect both public and private saving. Analogously, the indexation of financial instruments issued by the economic

39. Mendoza and Fernández (1994) present evidence against the existence of a monetary policy transmission mechanism from adjustable rates to the spending-output gap and inflation, using vector autoregressions. Valdés (1997) does find evidence for this mechanism.

authority provides an incentive for stabilizing inflation, by eliminating the possibility of drawing down the public debt. In the case of exchange rate indexation, the authority has the faculty of including indexation clauses in the exchange rate rule, with the objective of stabilizing the real exchange rate. Exchange rate indexation contributes to inflationary persistence, however. The choice of exchange rate regime and the optimal indexation level must therefore be resolved through a joint optimization that attains some degree of optimal stabilization of economic activity and the price level.

Another interesting aspect of indexation that is explored in the paper involves the consequences of indexation practices on inflation. In particular, wage and exchange rate indexation can have a strong effect on inflationary inertia and variability. An extreme case is that of an economy that combines a high degree of wage indexation with a purchasing power parity rule for the exchange rate. In this case, the nominal anchor tends to be lost, and the magnitude of inflationary inertia is exacerbated. This implies, therefore, that the type and degree of indexation existing in an economy will affect the costs that are incurred during the implementation of a program for stabilizing the price level.

The degree of indexation in an economy affects not only inflationary dynamics, but also the optimal inflation level. On the one hand, indexation (mainly wage indexation) reduces the effect of nominal shocks on real variables, making the Phillips curve more vertical and reducing the incentives for the authority to inflate the economy. On the other, it lowers the costs of inflation and can therefore induce the government to postpone the application of inflation-fighting measures indefinitely.

While the particular effect of each type of indexation on inflation, output, or the real exchange rate is not ambiguous, the general, combined effect of different forms of indexation is. The effect often depends on the particular form of implementation (such as the type of financial instrument or the wage adjustment rule), which can vary considerably. Otherwise, the optimal degree of some type of indexation will depend on the form of the economic authority's loss function or on the stochastic characteristics of the actual situation (that is, on the relative variance of different types of exogenous prices). It is very difficult to isolate all the elements, yet combining them in any single model is also complicated. Therefore the interest of compiling and analyzing them together, in an effort to understand the combined effect.

References

Aizenman, J. 1984. "Optimal Wage Re-negotiation in a Closed and Open Economy." *Journal of Monetary Economics* 13(2): 251-62.

————. 1985. "Wage Flexibility and Openness." *Quarterly Journal of Economics* 100(2): 39-50.

Aizenman, J., and J. Frenkel. 1985. "Optimal Wage Indexation, Foreign Exchange Intervention, and Monetary Policy." *American Economic Review* 75(3): 402-23.

Azariadis, C. 1975. "Implicit Contracts and Underemployment Equilibria." *Journal of Political Economy* 83(6): 1183-203.

Baily, M. N. 1974. "Wages and Unemployment under Uncertain Demand." *Review of Economic Studies* 41(1): 37-50.

Ball, L. 1994a. "Credible Disinflation with Staggered Price-Setting." *American Economic Review* 84(1): 282-89.

————. 1994b. "What Determines the Sacrifice Ratio?" In *Monetary Policy*, edited by N. G. Mankiw. University of Chicago Press for the National Bureau of Economic Research.

Ball, L., and S. G. Cecchetti. 1991. "Wage Indexation and Discretionary Monetary Policy." *American Economic Review* 81(5): 1310-19.

Barro, R. J. 1996. "Optimal Debt Management." NBER Working Paper 5327. Cambridge, Mass.: National Bureau of Economic Research.

Barro, R. J., and D. Gordon. 1983. "A Positive Theory of Monetary Policy in a Natural Rate Model." *Journal of Political Economy* 91(2): 586-610.

Bertola, G., and R. Caballero. 1992. "Target Zones and Realignments." *American Economic Review* 82(3): 520-36.

Bohn, H. 1988. "Why Do We Have Nominal Government Debt?" *Journal of Monetary Economics* 21(1): 127-40.

————. 1990. Tax Smoothing with Financial Instruments." *American Economic Review* 80(5): 1217-30.

Bonomo, M., and R. García. 1994. "Indexation, Staggering and Disinflation." *Journal of Development Economics* 43(1): 39-58.

Breedon, F. 1995. "Bond Prices and Market Expectations of Inflation." *Bank of England Quarterly Bulletin* 35(2): 160-65.

Bruno, M. 1993. *Crisis Stabilization and Economic Reform: Therapy by Consensus*. Oxford: Clarendon Press.

————. 1994. *Inflation, Growth and Monetary ControlWNon-Linear Lessons from Crisis and Recovery*. Paolo Baffi Lectures on Money and Finance. Rome: Banca d'Italia.

Calvo, G. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12(3): 383-98.

———. 1988. "Servicing the Public Debt: The Role of Expectations." *American Economic Review* 78(3): 647-67.

Calvo, G., and P. Guidotti. 1990. "Indexation and Maturity of Government Bonds: An Explanatory Model." In *Public Debt ManagementWTheory and History*, edited by R. Dornbusch and M. Daghi. Cambridge University Press.

Campbell, J. Y., A. W. Lo, and A. C. MacKinlay. 1996. *The Econometrics of Financial Markets*. Princeton University Press.

Campbell, J. Y., and R. J. Shiller. 1996. "A Scorecard of Indexed Government Bonds." NBER Working Paper 5587. Cambridge, Mass.: National Bureau of Economic Research.

Crosby, M. 1995. "Wage Indexation and the Time Consistency of Government Policy." *Scandinavian Journal of Economics* 97(1): 105-21.

Cukierman, A. 1980. "The Effects of Wage Indexation on Macroeconomic Fluctuations: A Generalization". *Journal of Monetary Economics* 6(2) 147-70.

Deaton, A. 1992. *Understanding Consumption*. Oxford: Clarendon Press.

Devereux, M. 1988. "The Optimal Mix of Wage Indexation and Foreign Exchange Market." *Journal of Money, Credit and Banking* 20(3): 381-92.

———. 1989. "A Positive Theory of Inflation and Inflation Variance." *Economic Inquiry* 27(1): 105-16.

Diamond, D. W. 1984. "Financial Intermediation and Delegated Monitoring." *Review of Economic Studies* 51(3): 393-414.

Diamond, D. W., and P. H. Dybvig. 1983. "Bank Runs, Deposit Insurance, and Liquidity." *Journal of Political Economy* 91(3): 401-19.

Dornbusch, R. 1976. "Expectations and Exchange Rate Dynamics." *Journal of Political Economy* 84(6): 1161-76.

———. 1982a. "PPP Exchange-Rate Rules and Macroeconomic Stability." *Journal of Political Economy* 90(1): 158-65.

———. 1982b. "Stabilization Policies in Developing Countries: What Have We Learned?" *World Development* 10(9): 701-08.

———. 1988. "Purchase Power Parity." In *The New PalgraveWA Dictionary of Economics*, edited by J. Eatwell, M. Milgate, and P. Newman. London: Macmillan.

———, ed. 1993. *Policymaking in the Open EconomyWConcepts and Case Studies in Economic Performance*. Oxford University Press for The World Bank.

Dornbusch, R., I. Goldfajn, and R. Valdés. 1995. "Currency Crises and Collapses." *Brookings Papers on Economic Activity* 2: 219-93.

Dornbusch, R., and A. Reynoso. 1989. "Financial Factors in Economic Development." *American Economic Review* 79(2): 204-9.

Dornbusch, R., and M. H. Simonsen. 1983. *Inflation, Debt and Indexation*. MIT Press.

Duca, J. V., and D. D. VanHoose. 1991. "Optimal Wage Indexation in a Multisector Economy." *International Economic Review* 32(4): 859-67.

Edwards, S. 1993. "Exchange Rates as Nominal Anchors." *Weltwirtshaftliches Archiv* 129(1): 1-33.

————. 1996. "A Tale of Two Crises: Chile and Mexico." NBER Working Paper 5794. Cambridge, Mass.: National Bureau of Economic Research.

Fischer, S. 1977a. "On the Existence of Privately Issued Index Bonds in the U.S. Capital Market." In *Inflation Theory and Anti-Inflation Policy*, edited by E. Lundberg. Boulder: Westview Press.

————. 1977b. "Wage Indexation and Macroeconomic Stability." *Journal of Monetary Economics* Supplementary Series 5: 107-47.

————. 1983a. "Indexing and Inflation." *Journal of Monetary Economics* 12(4): 519-42.

————. 1983b. "Welfare Aspects of Government Issue of Indexed Bonds." In *Inflation, Debt and Indexation*, edited by R. Dornbusch and M. H. Simonsen. MIT Press.

Fischer, S., and L. Summers. 1989. "Should Governments Learn to Live with Inflation?" *American Economic Review* 79(2): 382-87.

Flood, R., and N. P. Marion. 1982. "The Transmission of Disturbance under Alternative Exchange-Rate Regimes with Optimal Indexation." *Quarterly Journal of Economics* 97(1): 43-66.

Fontaine, F. A. 1991. "La administración de la política monetaria en Chile: 1985-1989. *Cuadernos de Economía* 83: 109-29.

Friedman, M. 1974. "Monetary Correction." In *Essays on Inflation and Indexation*, edited by H. Giersh and others. Washington, D.C.: American Enterprise Institute for Public Policy Research.

Gagnon, J. E. 1996. "Long Memory in Inflation Expectations: Evidence from International Financial Markets." Working Paper 538. International Finance Discussion Series. Washington: Federal Reserve Board of Governors.

Gray, J. A. 1976. "Wage Indexation: A Macroeconomic Approach." *Journal of Monetary Economics* 2(2): 221-35.

———. 1978. “On Indexation and Contract Length.” *Journal of Political Economy* 86 (1): 1-18.

Guidotti, P. 1993. “Wage and Public Debt Indexation.” *IMF Staff Papers* 40(2): 237-65.

Herrera, L. O., and I. Magendzo. 1997. “Expectativas financieras y la curva de tasas Forward.” Working Paper 23. Santiago: Central Bank of Chile.

Jadresic, E. 1995. “Inflación, nivel de actividad y contratos salariales en Chile.” In *Análisis empírico de la inflación en Chile*, edited by F. Morandé and R. Rosende. Santiago: CEP and ILADES/ Georgetown University.

———. 1996a. “Wage Indexation and Macroeconomic Stability Revisited: The Gray-Fischer Theorem Revisited.” IMF Working Paper 121. Washington: International Monetary Fund.

———. 1996b. “Wage Indexation and the Cost of Disinflation.” *IMF Staff Papers* 43(4): 796-825.

Jiménez, L. F. 1993. *Indización de activos financierosWexperiencias latinoamericanas*. Santiago: United Nations Economic Commission for Latin America and the Caribbean (ECLAC)/Government of the Netherlands.

Karni, E. 1983. “On Optimal Wage Indexation.” *Journal of Political Economy* 91(2): 282-92.

King, R., and R. G. Levine. 1993. “Finance and Growth: Schumpeter Might be Right.” *Quarterly Journal of Economics* 108(3):717-37.

Kovanen, A. 1992. “The Heterogeneity of Labor, Wage Indexation and Welfare.” *European Economic Review* 36(1): 37-49.

Krugman, P. 1991. “Target Zones and Exchange Rate Dynamics.” *Quarterly Journal of Economics* 106(3): 669-82.

Kydland, F. E., and E. C. Prescott. 1977. “Rules Rather Than Discretion: The Inconsistency of Optimal Plans.” *Journal of Political Economy* 85 (3): 473-91.

Landerretche, O., and R. Valdés. 1997. “Indización: historia chilena y experiencia international.” Working Paper 21. Santiago: Central Bank of Chile.

Lucas, R. E., and N. L. Stokey. 1983. “Optimal Fiscal and Monetary Policy in an Economy without Capital.” *Journal of Monetary Economics* 12(1): 55-93.

Marston, R. C. 1992. “Wages, Relative Prices and the Choice between Fixed and Flexible Exchange Rates.” *Canadian Journal of Economics* 15(1): 87-103.

McNelis, P. D. 1987. "Indexing, Exchange Rate Policy and Inflationary Feedback Effects in Latin America." *World Development* 15(8): 1107-17.

Mendoza, E. 1991. "Efficient Arbitrage under Financial Indexation: The Case of Chile." IMF Working Paper 49. Washington: International Monetary Fund.

Mendoza, E., and F. Fernández. 1994. "Monetary Transmission and Financial Indexation: Evidence from the Chilean Economy." IMF Papers on Policy Analysis and Assessments 17. Washington: International Monetary Fund.

Milesi-Ferretti, G. M. 1994. "Wage Indexation and Time Consistency." *Journal of Money, Credit and Banking* 26(4): 941-50.

Morandé, R. 1993. "Indización financiera, ahorro privado e inercia inflacionaria, el caso chileno." In *Indización de activos financierosW experiencias latinoamericanas*, edited by L. F. Jiménez. Santiago: United Nations Economic Commission for Latin America and the Caribbean (ECLAC)/Government of the Netherlands.

Mourmouras, I. A. 1993. "Time Consistency, Indexation and the Cost of Inflation." *Economics Letters* 42(4): 361-65.

Obstfeld, M. 1995. "International Currency Experience: New Lessons and Lessons Relearned." *Brookings Papers on Economic Activity* 1: 119-96.

Pissarides, C. A. 1988. "The Search Equilibrium Approach to Fluctuations in Employment." *American Economic Review* 88(2): 363-68.

Rebelo, S., and C. Végh. 1995. "Real Effects of Exchange-Rate-Based Stabilization: An Analysis of Competing Theories." In *NBER Macroeconomics Annual 1995*, edited by B. S. Bernanke and J. J. Rotemberg. MIT Press.

Riveros, L. 1996. "Adjustment, Inflation and Equity Effect: A Literature Survey on Wage Indexation." Unpublished paper. Universidad de Chile.

Shavell, S. 1976. "Sharing Risk of Deferred Payment." *Journal of Political Economy* 84(1): 161-69.

Simonsen, M. H. 1983. "Indexation: Current Theory and the Brazilian Experience." In *Inflation, Debt and Indexation*, edited by R. Dornbusch and M. H. Simonsen. MIT Press.

———. 1995. *P0 anos de indexão*. Rio de Janeiro: Fundão Getulio Vargas.

Stiglitz, J. E. 1983. "On the Relevance or Irrelevance of Public Financial Policy: Indexation, Price Rigidities, and Optimal Monetary

Policies." In *Inflation, Debt and Indexation* edited by R. Dornbusch and M. H. Simonsen. MIT Press.

Tobin, J. 1971. "An Essay on the Principles of Debt Management." In *Essays in Economics*, vol. 1. Chicago: Markham.

Turnovsky, J. 1976. "The Relative Stability of Alternative Exchange Rate Systems in the Presence of Random Disturbances." *Journal of Money, Credit and Banking* 8(1): 29-50.

————. 1983. "Wage Indexation and Exchange Market Interventions in a Small Open Economy." *Journal of Money, Credit and Banking* 15(1): 51-80.

Valdés, R. 1997. "Transmisión de la política monetaria en Chile." Unpublished paper. Santiago: Central Bank of Chile.

Van Gompel, J. 1994. "Stabilization with Wage Indexation and Exchange Rate Flexibility." *Journal of Economic Surveys* 8(3): 251-82.

Wallace, N. 1981. "A Modigliani-Miller Theorem for Open-Market Operations." *American Economic Review* 71(1): 267-74.

Waller, C. J., and D. D. VanHoose. 1992. "Discretionary Monetary Policy and Socially Efficient Wage Indexation." *Quarterly Journal of Economics* 107(4): 1451-60.

Williamson, J. 1985. *Inflation and IndexationWArgentina, Brazil and Israel*. Washington: Institute for International Economics.

Stabilization, Persistence, and Inflationary Convergence: A Comparative Analysis

Sebastian Edwards
University of California at Los Angeles and National Bureau of Economic Research

Fernando Lefort
Pontificia Universidad Católica de Chile

The role of inflationary persistence has become a recurrent theme in discussions on stabilization programs (Fischer, 1986). This has particularly been the case in recent debates on the merits of exchange-rate-based stabilization plans. Some authors claim that anti-inflationary programs based on predetermined nominal exchange rates are effective in reducing inflation. Others argue, however, that in the context of stubborn inflationary inertia these type of programs are bound to generate real exchange rate overvaluation and, in some cases, can even result in major crises.[1]

Discussions on the selection of exchange rate regimes in developing countries and transitional economies have also dealt with persistence issues. For example, critics of exchange rate systems based on a crawling peg—including backward-looking exchange rate bands, such as the one operating in Chile since 1984—argue that this type of system tends to generate a very high degree of inflationary inertia, which can become highly destabilizing in the presence of shocks to fundamentals. Those that favor a fixed exchange rate system, on the other hand, argue that one of the most important merits of this regime is

At the time of writing, Fernando Lefort was affiliated with the Central Bank of Chile.

We benefited from discussions with Guillermo Calvo and Ed Leamer. We are grateful to Mike Gavin and Rodrigo Vergara for helpful comments and to Alejandro Jara and Oscar Landerretche for excellent research assistance.

1. See, for example, Bruno (1993); Dornbusch and Warner (1994); Edwards (1993).

Indexation, Inflation, and Monetary Policy, edited by Fernando Lefort and Klaus Schmidt-Hebbel, Santiago, Chile.

that it tends to generate a rapid (almost instantaneous) elimination of inflationary inertia; this helps stabilize prices at a relatively low cost in terms of output.

In his work on chronic inflationary experiences in four Latin American countries, Pazos (1990) points out that backward-looking wage indexation is bound to generate a high degree of inertia, serious destabilizing forces, and a costly and protracted inflationary process.[2]

More recently, there has been increasing interest in analyzing inflationary persistence in the context of staggered-contracts models of the U.S. economy. Fuhrer and Moore (1995), for example, argue that standard Taylor-type models (Taylor, 1980) fail to generate the degree of inflationary persistence observed in the U.S. data. They propose an alternative model in which wage setters care about relative real wages over the length of the contract. They show that in this case inflation demonstrates considerable persistence over time. Their empirical analysis—based on autocorrelations and impulse response functions—supports their model: in the period 1965-91 inflation in the United States did indeed experience a considerable degree of inertia. Like most studies on the subject, however, Fuhrer and Moore's paper assumes that the degree of inflationary inertia in the United States has been invariant throughout the period under study. There is no reason, of course, for this to be the case. Indeed, one would expect that as the average length of contracts and the expectations formation process change, so will the degree of inertia. A changing degree of inflationary persistence through time would indeed have important policy implications, especially regarding the output costs of disinflationary programs.[3]

The purpose of this paper is to analyze empirically the importance of inflationary persistence in a group of sixteen advanced and developing countries. We do this by examining the time series properties of inflation, using both univariate and multivariate techniques, on the basis of monthly data from 1970 through the end of 1996. We ask several key questions. What has been the degree of persistence, if any, in the inflationary processes? Has inflation exhibited a unit root in any of the countries in the sample? Has inertia been stable through time, or has it experienced significant changes? In those countries where inertia has varied, are the changes associated with specific policy actions, such as the implementation of exchange rate-based stabilization programs? Is the degree of inertia associated with the level of inflation?

2. For inertial models based on staggered contracts, see Calvo 1983; Fischer 1986; Taylor 1980.

3. On the costs of disinflation see, for example, Ball (1991).

Is there preliminary evidence suggesting that the degree of inflationary inertia is associated with institutional arrangements governing the existence of indexation in the labor or financial markets?

The paper is organized as follows: the next section provides a brief discussion of alternative ways of measuring inertia. Section 2 presents a preliminary data analysis. We begin the analysis by providing a brief description of the data set and explain the criteria used for selecting the sample. We then present results from our analysis of inflationary persistence using the full sample (1970-94). In section 3 we provide a detailed comparative analysis of inflationary inertia in sixteen countries. We perform a battery of tests, including rolling augmented Dickey-Fuller tests, sequential Perron tests to test the unit root hypothesis in the presence of structural breaks, and sequential Quandt likelihood ratio tests to analyze the instability of the autoregressive coefficients. We then turn to the estimation of rolling measures of persistence. For all countries we estimate rolling autoregression (AR[1]) coefficients and report rolling estimates of the dominant root from rolling AR(2) estimates. We then provide an analysis of the connection between our estimates of inertia and the levels of inflation in the countries in the sample. Section 4 provides a discussion of the evolution of inflationary inertia in three countries that at one point or another have relied on a nominal exchange rate anchor to achieve price stability: Chile, Israel, and Mexico. Our interest here is to investigate the extent to which these programs have reduced the degree of inflationary inertia. We close in section 5 with concluding remarks.

1. Measuring Inflationary Persistence: Analytical Issues

A central purpose of this paper is to provide simple, reliable measures of inflationary persistence for a set of countries.[4] A large literature, both theoretical and applied, addresses the persistence displayed by economic time series. Applications include the analysis of real gross domestic product (GDP), commodity prices, and inflation in the United States. The measurement of inflationary persistence can be approached either from the perspective of a particular theoretical model or through a model-free strategy. While the model-based approach

4. In this paper, we use the terms inflationary inertia and inflationary persistence interchangeably. See the discussion later in this section for formal definitions.

has some clear advantages, including its elegance and the existence of sharp hypotheses, it also has some limitations. Obstfeld (1995), for example, has persuasively argued that model-based measures of inertia are overly restricted and are subject to misspecification problems that can result in serious biases. This paper follows Obstfeld's recommendations by analyzing the degree of inflationary inertia from a model-free perspective.[5]

In general, identifying the degree of persistence displayed by a particular time series takes place on two levels. First, we might be interested in determining whether a series is covariance stationary, given that in a stationary series the effect of a shock eventually dies out. In other words, the impulse response is zero if T is large enough. Nonstationary time series exhibit very high persistence, with all shocks qualifying as permanent ones. Second, within the class of stationary time series, some may exhibit higher persistence in the sense that the effect of the shock takes longer to wear off. Measures like the largest autoregressive root, the half-life, and the impulse-response function have been used elsewhere for this purpose. In this paper we consider two approaches to measure inertia.

There are several ways of finding out whether a series is nonstationary. Consider the following univariate process:

$$y_t = \mu + \alpha(\mathrm{L})\varepsilon_t \quad \text{and} \tag{1}$$

$$\alpha(\mathrm{L})\,\varepsilon_t = \varepsilon_t + \alpha_1\varepsilon_{t-1} + \alpha_2\varepsilon_{t-2} + \dots \,, \tag{2}$$

where

$$\sum_{j=0}^{\infty} \left|\alpha_j\right| < \infty \,,$$

the roots of $\alpha(z) = 0$ lie outside the unit circle, and $\{\varepsilon_t\}$ is a white-noise sequence with mean zero and variance σ^2. The process described by equations 1 and 2 is a covariance-stationary process. In terms of the persistence displayed by the process, the most interesting property is that the dynamic multiplier (or impulse response function) goes to zero as time goes on:

$$\lim_{s\to\infty} \frac{\partial y_{t+s}}{\partial \varepsilon_t} = 0 \,. \tag{3}$$

5. See Edwards (1996, 1998) for inflationary analyses based on credibility models.

That is, the effect of a shock eventually dies off. Consider, instead, the following unit root process:

$$(1-\mathrm{L})y_t = \delta + \beta(\mathrm{L})\,\varepsilon_t \ , \tag{4}$$

where it is required that $\beta(1) \neq 0$.[6] In this case, an innovation in ε_t has a permanent effect on y_t. To see this, notice that

$$\frac{\partial y_{t+s}}{\partial \varepsilon_t} = 1 + \ \beta_1 + \ \beta_2 + \cdots + \beta_s \ ,$$

and therefore

$$\lim_{s\to\infty} \frac{\partial y_{t+s}}{\partial \varepsilon_t} = \beta(1) \ . \tag{5}$$

Three main approaches have been used to detect extreme persistence (nonstationarity) in economic time series. Campbell and Mankiw (1987a, b) use a parametric approach to analyze the time series properties of real gross national product (GNP). Their test makes use of the fact that a nonstationary process requires $\beta(1) \neq 0$, by calculating impulse-response functions obtained from the estimation of autoregression moving average (ARMA) representations of the first-differenced series. A second approach outlined in Cochrane (1988) provides a nonparametric assessment of the same question. Intuitively, Cochrane's test, known as the variance-ratio test, exploits the fact that if y_t is a random walk [β (L) $\neq$ 1] then the variance of its s-differences grows linearly with s, while if it is stationary, this variance approaches a constant.[7] Consequently, the variance ratio is simply

$$\mathrm{V5}\,(s) = \frac{1}{s+1}\,\frac{9\,(\,y_{t+s+1} - y_t - \mu s\,)}{9\,(\,y_{t+1} - y_t - \mu\,)} \ . \tag{6}$$

6. To understand why it is that this condition is required for nonstationarity of y_t, notice that the stationary process in equation 1 can be first differenced and rewritten as

$$(1-\mathrm{L})y_t = (1-\mathrm{L})\,\alpha\,(\mathrm{L})\varepsilon_t = \beta(\mathrm{L})\varepsilon_t \ .$$

Because y_t is stationary, then $\Delta\, y_t$ is also stationary. Although this process has the same form as equation 4, it is clear that necessarily $\beta(1) = 0$.

7. More generally, let y_t be a nonstationary process of the form indicated in equation 4. If we define V (s) = E ($y_{t+s} - y_t - \mu s$), then

$$\lim_{s\to\infty} \frac{\mathrm{V}(s)}{s} = \sigma^2\,[\beta(1)]^2 \ .$$

This ratio approaches one for a random walk and zero for a stationary time series. It is easy to show that in the general case of a nonstationary time series, the square root of VR(s) would be a lower bound of $\beta(1)$.

A third approach to measuring persistence is known as the unobserved components approach. In this method, the series is modeled as the sum of two components. The best-known decomposition separates the series into a random walk and a stationary component:

$$
\begin{aligned}
&y_t = z_t + c_t \ , \\
&z_t = \mu + z_{t-1} + \eta_t \ , \text{ and} \qquad\qquad (7)\\
&F_t = \gamma(\mathrm{L})\delta_t \ ,
\end{aligned}
$$

where $E(\eta_t \delta_t)$ is arbitrary. This approach measures persistence as the variance of the random walk component relative to the total variance, $\sigma^2_{\Delta z} / \sigma^2_{\Delta y}$.

These three measures of persistence are simply different ways of scaling the spectral density of $\Delta\, y_t$ at zero frequency (Pesaran, Pierse, and Lee, 1993). This last function can be efficiently estimated using the Bartlett kernel,

$$
\hat{s}_{\Delta y}(0) = \frac{1}{2\pi}\left[\hat{\gamma}_0 + 2\sum_{j=1}^{q}\left(1 - \frac{j}{q+1}\right)\hat{\gamma}_j\right]. \qquad (8)
$$

These three approaches are subject to an important limitation, however.[8] For any nonstationary general process there exists some stationary process, which is impossible to distinguish from the former for any finite sample of size T. A way of circumventing this problem and increasing the power in testing for unit root processes is to assume that the series is well represented by a low-order autoregressive process. Although it is generally not possible to refute the hypothesis that a general process is a unit root process, it is usually possible to test the less general hypothesis that a process is an AR(p) process containing a unit root. The most popular unit root tests among applied economists, including the Dickey-Fuller and Phillips-Perron

8. See Hamilton (1994) for a discussion of the observational equivalence problem.

tests, belong to this family, in that they assume that the series is represented by a first-order autoregressive process.

A different way of thinking about inertia is within the class of stationary processes. The stationarity of an ARMA(p, q) model depends on the roots of the autoregressive component lying outside the unit circle, regardless of the roots of the moving average component. This result provides a simple way of measuring the degree of persistence of a stationary series. In the long run, the dynamics of a series will be dominated by the largest root of its autoregressive component. Of course, if the series is stationary, with the modulus of all inverted roots being less than one, the effect of a random disturbance will eventually die off. In the meantime, however, the effect of the shock will last longer for a larger value of the inverted dominant root or eigenvalue. In this paper we use the inverted dominant root of the autoregressive component of the inflationary process of each country as a measure of the degree of inertia displayed by the series.

2. Preliminary Data Analysis

This section presents a preliminary analysis of the time series properties of monthly inflation rates for sixteen countries. Our main interest is to analyze several measures of persistence using a full sample. In the subsequent section, we analyze the stability through time of our inertia measures and try to detect structural breaks in the dynamics of the different inflationary processes.

2.1 The Data

We use data from the International Financial Statistics (IFS) provided by the International Monetary Fund (IMF), on monthly consumer price index (CPI) inflation for the period 1970-94. The sample includes sixteen advanced and developing countries: Argentina, Brazil, Chile, Colombia, France, Germany, India, Israel, Italy, Japan, Mexico, Spain, Sweden, Switzerland, the United Kingdom, and the United States. In selecting these countries we made an effort to cover a wide variety of macroeconomic experiences and inflationary histories. Table 1 presents the average, coefficients of variation, and minimum and maximum of the monthly inflation rates. The diversity of the sample is considerable: while Argentina and Brazil had monthly average inflation rates of around 10 percent, Germany and Switzerland had monthly rates on the order of 0.3 percent.

Table 1. Inflation in Selected Countries, 1970.1-1996.8

Percent and coefficient of variation

Country	*Average inflation rate*	*Coefficient of variation rate*	*Minimum monthly inflation rate*	*Maximum monthly inflation rate*
Argentina	9.3	1.8	–6.0	196.6
Brazil	10.2	1.2	–0.3	80.7
Chile	3.7	1.8	–8.1	87.5
Colombia	1.7	0.6	–2.0	6.9
France	0.5	0.7	–0.3	1.9
Germany	0.3	1.1	–0.5	1.8
India	0.7	1.5	–2.9	4.3
Israel	3.5	1.3	–1.4	27.5
Italy	0.8	0.7	–0.4	3.1
Japan	0.4	2.0	–1.1	4.1
Mexico	2.5	1.0	0.0	15.5
Spain	0.8	1.1	–4.4	9.0
Sweden	0.6	1.1	–0.5	3.3
Switzerland	0.3	1.3	–0.7	2.1
United Kingdom	0.7	1.1	–0.9	4.3
United States	0.4	0.7	–0.5	1.8

Source: Authors' calculations.

2.2 Inflationary Persistence: Full Sample Measures

Table 2 presents nonparametric variance ratio tests, as well as Dickey-Fuller unit root tests for the sixteen countries in the sample.[9] For all countries the variance ratios clearly decrease as k increases.

9. In the frequency domain, a nonstationary series will present a large spectrum at low frequency. The variance ratio is an asymptotically equivalent estimate of the spectral density at frequency zero, and we therefore provide estimates of this statistic. In the time-space representation a series will be nonstationary if it has a unit root in its autoregressive component. Unit root tests like the Dickey-Fuller, Phillips-Perron, and Sargan-Barghawa tests target that feature in a first-order, autoregressive, nonstationary time series. The analysis of the statistical properties of unit root tests is far from being the goal of this paper. However, it is important to keep in mind that most of the unit root tests are linear combinations of the same two statistics and that consequently there is no single, most powerful test of the unit root hypothesis. In this paper we use the Dickey-Fuller test to identify extreme persistence, as this is by far the most popular among applied economists.

We removed existing monthly additive, seasonal components by a standard regression method in all those countries for which the seasonal components are statistically significant. Jaeger and Kunst (1990) show that the method used to seasonally adjust series affects the measured persistence of a series. In particular, filtering the data through X–11 methods spuriously introduces persistence into the series. We therefore used the simpler method of regression on dummies.

The pace at which the ratio decreases is quite different across countries, however, suggesting that the degree of inflationary persistence may be higher in some of these nations than in others. Moreover, the ratio decreases very rapidly in some countries (Switzerland, Japan, and Spain, for example), indicating that inertia was not an issue in the period under study. This is confirmed by the variance ratio plots (which include confidence intervals) presented in figure 1.

It is particularly interesting to contrast Brazil and Mexico, on the one hand, with more developed, low inflation countries like Japan, Switzerland, and Sweden. In the former group, although the variance ratios decrease as k rises, they are still significantly different from zero even for k as large as thirty-six months. In contrast, in the second group of countries, the variance ratios are not significantly different from zero for k between eighteen and twenty-four months.

Table 2 also shows augmented Dickey-Fuller tests for the full sample. The table presents the t statistic for the autocorrelation coefficient obtained in an ordinary least squares (OLS) regression, including intercept, deterministic trend, and four lags of inflation first differences. Using the full sample, we are not able to reject the unit root hypothesis in six of the sixteen countries: France, Israel, and Mexico, at 95 percent confidence and Brazil, Chile, and Italy at 99 percent confidence.

Table 2. Full Sample Nonstationarity Tests

	Seasonal	*Variance ratio test*					
Country	*adjustment*	$k = 3$	$k = 6$	$k = 12$	$k = 24$	$k = 36$	*ADF*[a]
Argentina	No	0.61	0.31	0.21	0.14	0.10	–4.80
Brazil	No	0.76	0.67	0.46	0.32	0.20	–3.89
Chile	No	0.25	0.16	0.08	0.06	0.05	–3.78
Colombia	Yes	0.25	0.15	0.08	0.04	0.03	–6.76
France	Yes	0.34	0.21	0.14	0.10	0.08	–3.40
Germany	Yes	0.28	0.17	0.09	0.06	0.05	–5.54
India	Yes	0.25	0.15	0.08	0.04	0.03	–4.16
Israel	No	0.25	0.15	0.08	0.04	0.03	–2.57
Italy	Yes	0.32	0.19	0.13	0.07	0.06	–3.87
Japan	Yes	0.25	0.15	0.09	0.05	0.04	–5.34
Mexico	No	0.56	0.44	0.28	0.19	0.14	–3.28
Spain	Yes	0.23	0.13	0.07	0.04	0.03	–6.13
Sweden	Yes	0.28	0.15	0.08	0.04	0.03	–6.85
Switzerland	Yes	0.34	0.16	0.08	0.05	0.04	–6.48
United Kingdom	No	0.33	0.16	0.06	0.04	0.03	–5.89
United States	Yes	0.36	0.23	0.14	0.11	0.08	–4.02

Source: Authors' calculations.

a. Critical values are –3.42 (5 percent) and –3.98 (1 percent).

Figure 1. Variance Ratio Test

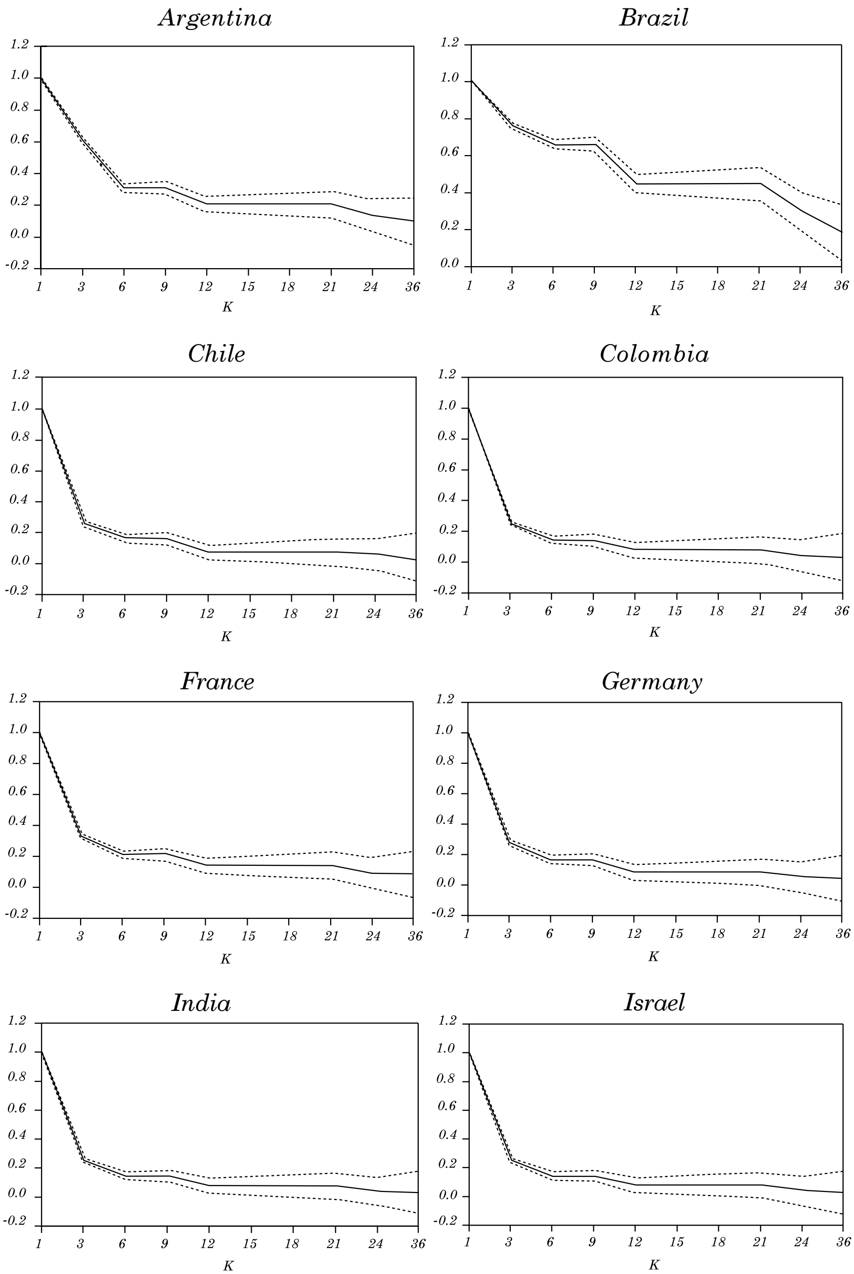
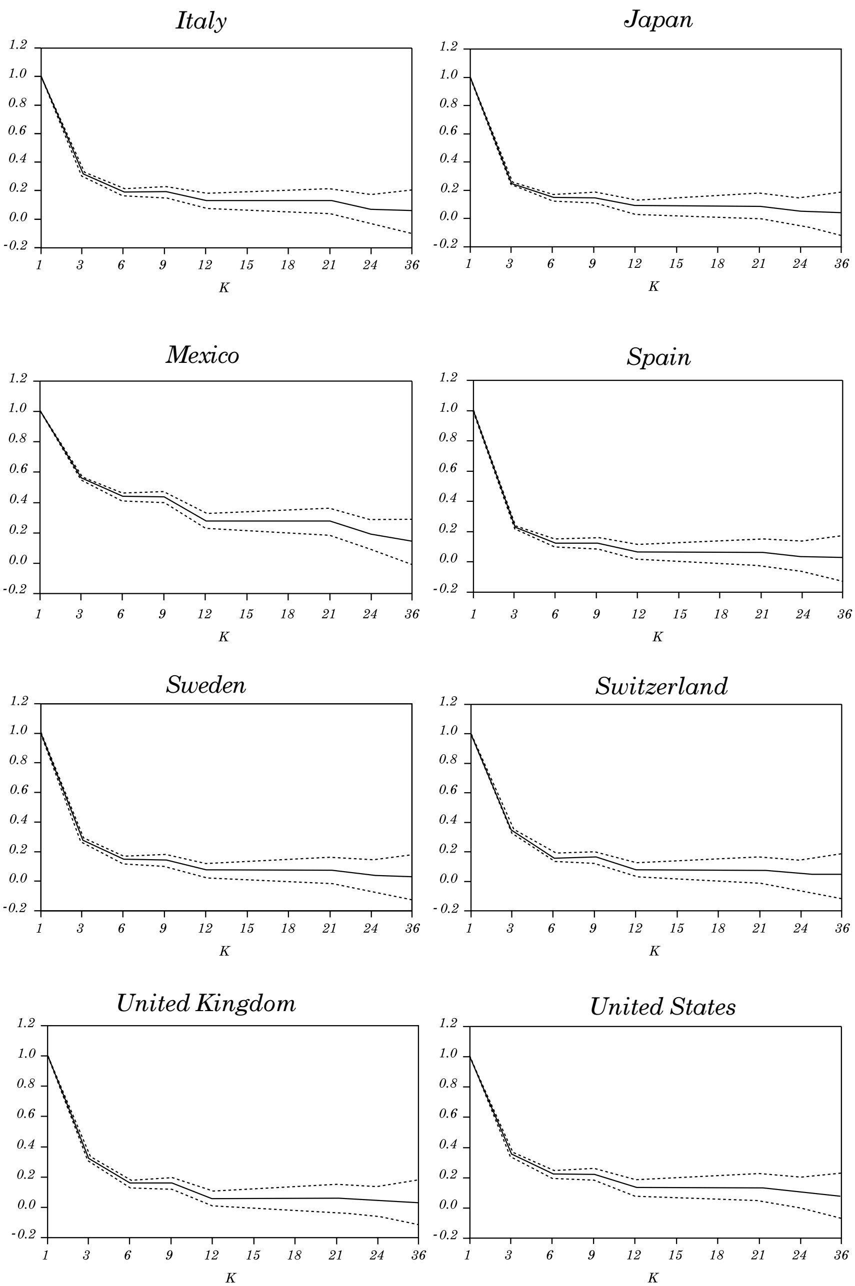


Figure 1. (continued)



A key question from a policy perspective is whether the domestic inflation rate converges with world inflation, and, if so, how fast this convergence takes place. We can statistically distinguish three distinct cases of convergence: (1) inflation has a unit root and thus does not converge to a steady-state value; (2) inflation is white noise, and thus there is no inflationary inertia; and (3) there is some degree of inertia, with inflation converging slowly to its steady-state value. With regard to this latter case, we investigated whether different countries exhibit different speeds of inflationary convergence, proceeding as follows: we fitted MA(1), MA(2), AR(1), AR(2), ARMA(1,1), and ARMA(2,2) for all sixteen countries in the period January 1970 to August 1996. We also fitted higher-order autoregressive models in all those cases in which the correlograms and partial correlograms suggested that these were plausible processes. Table 3 summarizes the results. For each country we indicate whether the series was previously seasonally adjusted, the various models that were fitted to the series, and the Q statistic white-noise residuals.

The results suggest, first, that pure moving average representations generally perform poorly in terms of Q statistics. Second, low-order autoregressive processes seem to provide a good fit for the inflationary process in some countries, namely, Brazil, Colombia, India, Mexico, Sweden, Switzerland, the United Kingdom, and the United States. An AR(1) performs particularly well in Brazil, Colombia, India, and Mexico. The other four cases are well represented by an AR(2) process. Third, some of the more developed, relatively low inflation countries such as France, Germany, Italy, Japan, and Spain show low Q statistics in low-order ARMA representations.[10] However, these models present the standard near root-cancellation problem. In all five cases, a very high inverted AR root has as its counterpart a very high MA inverted root; these results must therefore be interpreted carefully.[11] Consider the case of Germany. The AR(1) and AR(2) representations feature dominant inverted roots of 0.36 and 0.61, respectively. The MA(1), in turn, has a low negative root of –0.29. The ARMA(1,1) and ARMA(2,2) representations, however, both present autoregressive and moving average dominant roots close to unity. Finally, the inflation processes of Argentina, Chile, and Israel do not seem to be well represented by any of the models presented in the table. This situation may be due to the fact that we need to specify a higher-order model

10. Inflation in Germany and Italy could also be fairly well represented by an AR(2) process.

11. To understand this problem, note that the white-noise process $y_t = \varepsilon_t$ can be rewritten by multiplying both sides of the last equation by $(1-\rho L)\varepsilon_t$, such that $(1-\rho L)y_t = (1-\rho L)\varepsilon_t$ is also a valid representation of y_t for any value of ρ.

for inflation, or, as we discuss in the next section, it may result from the existence of a structural break in the inflation autoregressive process.

In summary, with few exceptions, a low-order autoregressive process seems to fit the inflationary process observed for most countries in the sample. The estimated dominant inverted roots differ dramatically across countries, ranging from 0.09 for Spain, 0.16 for Sweden, and 0.38 for Japan, to a high of 0.91 for Brazil.[12]

3. Is the Degree of Persistence Stable through Time?

The preliminary analysis presented in the preceding section assumes that inflationary persistence is stable through time. This need not be the case, however. Since inflationary inertia is clearly dependent on institutional price arrangements, including indexation rules, mechanisms determining staggered contracts, the degree of credibility of the exchange rate policies, and other economic variables, there are good reasons to believe that inflationary persistence will change through time. In particular, one would expect that a change in the exchange rate regime (from a crawling peg to a fixed rate, for instance) will result in a reduction in the degree of persistence.

In this section we investigate whether the data exhibit structural breaks in the degree of persistence. We do this by calculating unit rolling augmented Dickey-Fuller (ADF) tests and sequential Perron tests. The rolling ADF tests were constructed by rolling a thirty-six-month sample along the full period under analysis. For each of these subsamples, we performed an ADF test including a time trend. A full-sample interpretation of this test is that if the minimum t-ratio obtained is larger (in absolute value) than the critical value, then the unit root hypothesis can be rejected for the whole sample.[13] The sequential Perron test provides an alternative to this procedure. We started by performing a sequence of full-sample ADF tests, allowing for a structural break in the intercept as well as in the time trend in each test. The break is sequentially moved one period ahead, until we reached the end of the sample. We then compared the minimum t-ratio obtained in the lagged inflation term

12. For this comparison, we consider the highest inverted root of those models with a relatively good Q statistic and with no indication of the root-cancellation problem.

13. Critical values for this test are provided in Banerjee, Lumsdaine, and Stock (1992). The critical value is tipically larger in absolute value than the standard Dickey-Fuller critical value.

Table 3. Full Sample Measures of Persistence

Country	*Seasonal adjustment*	*Model specification*	*Inverted AR roots*				*Inverted MA roots*		*Q statistic*[a] *p = 5**	*Q statistic*[a] *p = 10***
Argentina	No	AR(1)	0.68	...	...	...	...	...	15.6	62.4
		AR(2)	0.65	0.05	...	...	...	...	12.8	61.0
		MA(1)	...	...	...	...	–0.35	...	18.7	31.4
		MA(2)	...	...	...	...	–0.18 + 0.26i	–0.18 – 0.26i	13.3	23.1
		ARMA(1,1)	0.66	...	...	...	–0.04	...	13.4	61.3
		ARMA(2,2)	0.366 – 0.27i	0.36 + 0.27i	...	...	0.02 + 0.54i	0.02 – 0.54i	2.2	48.9
Brazil	No	AR(1)	0.91	...	...	...	...	...	9.4	13.3
		AR(2)	0.90	0.06	...	...	...	...	8.1	11.5
		MA(1)	...	...	...	...	–0.72	...	491.1	739.5
		MA(2)	...	...	...	...	–0.45 + 0.63i	–0.45 – 0.63i	259.6	397.8
		ARMA(1,1)	0.90	...	...	...	–0.05	...	8.3	11.8
		ARMA(2,2)	0.88	–0.48	...	...	–0.29 + 0.29i	–0.29 – 0.29i	2.3	6.2
Chile	No	AR(1)	0.46	...	...	...	...	...	49.1	92.1
		AR(2)	0.71	–0.37	...	...	...	...	39.3	69.4
		AR(3)	0.85	–0.29 + 0.49i	–0.29 – 0.49i	...	...	...	28.6	46.0
		AR(4)	0.92	–0.05 + 0.70i	–0.05 – 0.70i	–0.64	...	...	4.2	13.3
		MA(1)	...	...	...	...	–0.33	...	137.7	256.6
		MA(2)	...	...	...	...	–0.17 – 0.4i	–0.17 + 0.4i	82.4	159.1
		ARMA(1,1)	0.98	...	...	...	0.83	...	9.2	26.0
		ARMA(2,2)	0.98	–0.97	...	...	0.83	–0.99	9.3	25.2
Colombia	Yes	AR(1)	0.49	...	...	...	...	...	2.9	7.2
		AR(2)	0.54	–0.09	...	...	...	...	2.2	6.4
		MA(1)	...	...	...	...	–0.42	...	21.4	34.1
		MA(2)	...	...	...	...	–0.23 – 0.43i	–0.23 + 0.43i	8.7	18.0
		ARMA(1,1)	0.57	...	...	...	0.11	...	2.5	6.7
		ARMA(2,2)	0.52	–0.27	...	...	–0.01	–0.20	2.1	6.4

Table 3. (continued)

Country	Seasonal adjustment	Model specification	Inverted AR roots				Inverted MA roots		Q statistic[a] p = 5*	Q statistic[a] p = 10**
France	Yes	AR(1)	0.81	...	...	...	...	...	27.8	44.0
		AR(2)	0.89	–0.24	...	...	...	...	24.6	35.4
		AR(3)	0.95	–0.19+0.52i	–0.19–0.52i	...	...	...	11.7	15.1
		MA(1)	...	...	...	...	–0.69	...	327.8	657.0
		MA(2)	...	...	...	...	–0.4 – 0.37i	–0.4 + 0.37i	182.5	373.3
		ARMA(1,1)	0.99	...	...	...	0.69	...	19.4	20.8
		ARMA(2,2)	0.99	–0.22	...	...	0.79	–0.53	4.0	5.8
Germany	Yes	AR(1)	0.36	...	...	...	...	...	20.0	43.1
		AR(2)	0.61	–0.30	...	...	...	...	8.0	18.9
		MA(1)	...	...	...	...	–0.29	...	47.8	93.7
		MA(2)	...	...	...	...	–0.14 + 0.38i	–0.14 – 0.38i	27.9	59.2
		ARMA(1,1)	0.97	...	...	...	0.85	...	3.9	6.1
		ARMA(2,2)	0.97	–0.41	...	...	0.86	–0.50	1.2	3.1
India	Yes	AR(1)	0.50	...	...	...	...	...	19.3	28.3
		AR(2)	0.63	–0.19	...	...	...	...	16.7	23.5
		MA(1)	...	...	...	...	–0.42	...	70.2	96.1
		MA(2)	...	...	...	...	–0.22 – 0.32i	–0.22 – 0.32i	43.1	61.1
		ARMA(1,1)	0.88	...	...	...	0.57	...	10.7	14.0
		ARMA(2,2)	0.90	–0.42	...	...	0.65	–0.57	3.5	6.1
Israel	No	AR(1)	0.75	...	...	...	...	...	45.6	71.6
		AR(2)	0.83	–0.21	...	...	...	...	36.5	57.5
		AR(3)	0.92	–0.18+0.57i	–0.18–0.57i	...	...	...	23.1	31.1
		MA(1)	...	...	...	...	–0.71	...	227.5	451.6
		MA(2)	...	...	...	...	0.39 – 0.06i	0.39 + 0.06i	158.1	302.6
		ARMA(1,1)	0.97	...	...	...	0.64	...	24.8	36.6
		ARMA(2,2)	0.98	–0.43	...	...	0.75	–0.75	99.3	188.2

Table 3. (continued)

Country	Seasonal adjustment	Model specification	Inverted AR roots				Inverted MA roots		Q statistic[a]	
									p = 5*	p = 10**
Italy	Yes	AR(1)	0.67	...	...	...	...	...	30.7	54.4
		AR(2)	0.85	–0.40	...	...	...	...	6.7	17.2
		MA(1)	...	...	...	...	–0.45	...	230.9	437.8
		MA(2)	...	...	...	...	0.25 – 0.54i	0.25 + 0.54i	102.6	220.1
		ARMA(1,1)	0.97	...	...	...	0.69	...	4.8	8.1
		ARMA(2,2)	0.97	–0.85	...	...	0.70	–0.88	49.4	8.1
Japan	Yes	AR(1)	0.38	...	...	...	...	...	38.5	86.5
		AR(2)	0.67	–0.38	...	...	...	...	12.5	35.3
		AR(3)	0.81	–0.29 + 0.43i	–0.29 – 0.43i	...	...	...	4.3	19.9
		MA(1)	...	...	...	...	–0.29	...	79.0	172.7
		MA(2)	...	...	...	...	–0.13 + 0.45i	–0.13 – 0.45i	46.4	112.7
		ARMA(1,1)	0.98	...	...	...	0.84	...	1.9	12.3
		ARMA(2,2)	0.97	0.16	...	...	0.82	0.18	2.0	12.2
Mexico	No	AR(1)	0.86	...	...	...	...	...	6.5	9.5
		AR(2)	0.87	–0.04	...	...	...	...	7.0	10.0
		MA(1)	...	...	...	...	–0.71	...	386.0	624.6
		MA(2)	...	...	...	...	–0.45 + 0.52i	–0.45 – 0.52i	170.5	280.6
		ARMA(1,1)	0.88	...	...	...	0.08	...	7.6	10.5
		ARMA(2,2)	0.86	–0.96	...	...	0.04	–0.99	6.5	9.2
Spain	Yes	AR(1)	0.09	...	...	...	...	...	44.8	111.1
		AR(2)	0.50	–0.44	...	...	...	...	18.0	49.5
		MA(1)	...	...	...	...	–0.06	...	50.5	124.5
		MA(2)	...	...	...	...	–0.02 + 0.39i	–0.02 – 0.39i	29.7	79.2
		ARMA(1,1)	0.99	...	...	...	0.94	...	13.3	20.0
		ARMA(2,2)	0.99	–0.07	...	...	0.91	0.13	4.8	13.8

Table 3. (continued)

Country	Seasonal adjustment	Model specification	Inverted AR roots				Inverted MA roots		Q statistic[a] p = 5*	Q statistic[a] p = 10**
Sweden	Yes	AR(1)	0.16	...	...	...	...	...	10.4	39.1
		AR(2)	0.44	–0.30	...	...	...	...	2.3	24.7
		MA(1)	...	...	...	...	–0.13	...	13.7	47.8
		MA(2)	...	...	...	...	–0.07 + 0.36i	–0.07 – 0.36i	4.5	29.5
		ARMA(1,1)	0.99	...	...	...	0.93	...	4.0	14.6
		ARMA(2,2)	0.99	–0.99	...	...	0.93	–0.98	3.5	15.8
Switzerland	Yes	AR(1)	0.36	...	...	...	...	...	15.8	44.4
		AR(2)	0.62	–0.33	...	...	...	...	1.2	20.0
		MA(1)	...	...	...	...	–0.25	...	38.6	92.9
		MA(2)	...	...	...	...	–0.14 + 0.48i	–0.14 – 0.48i	5.9	38.4
		ARMA(1,1)	0.95	...	...	...	0.82	...	23.3	37.3
		ARMA(2,2)	0.67	–0.97	...	...	0.30	–0.93	0.9	15.2
United Kingdom	No	AR(1)	0.45	...	...	...	...	...	8.7	42.9
		AR(2)	0.62	–0.24	...	...	...	...	3.1	34.7
		MA(1)	...	...	...	...	–0.36	...	45.6	103.2
		MA(2)	...	...	...	...	–0.18 + 0.37i	–0.18 – 0.37i	23.4	73.4
		ARMA(1,1)	0.96	...	...	...	0.79	...	14.3	36.8
		ARMA(2,2)	0.98	0.15	...	...	0.89	–0.07	2.4	21.5
United States	Yes	AR(1)	0.67	...	...	...	...	...	23.7	45.7
		AR(2)	0.82	–0.33	...	...	...	...	5.4	18.1
		MA(1)	...	...	...	...	–0.48	...	183.3	350.6
		MA(2)	...	...	...	...	–0.23 + 0.55i	–0.23 – 0.55i	86.6	162.4
		ARMA(1,1)	0.94	...	...	...	0.58	...	14.6	24.6
		ARMA(2,2)	0.97	0.41	...	...	0.81	0.15	5.4	13.5

Source: Authors' calculations.

a. * Critical values at 95 percent confidence are 9.49 for the AR(1) and MA(1) models; 7.82 for the AR(2), MA(2), and ARMA(1,1) models; 5.99 for the AR(3) model; and 3.84 for the AR(4) and ARMA(2,2) models. ** Critical values at 90 percent confidence are 16.92 for the AR(1) and MA(1) models; 15.51 for the AR(2), MA(2), and ARMA(1,1) models; 14.07 for the AR(3) model; and 12.59 for the AR(4) and ARMA(2,2) models.

with the critical value. Table 4 reports the results obtained with these two tests. We reject the full-sample unit root hypothesis with 95 percent confidence in all cases. The implications are very clear: independently of the autoregressive roots presented in table 3, after allowing for structural breaks and parameter instability, the inflation rate seems to have been stationary for all countries in our sample.

To investigate whether the degree of inertia has been stable, we estimated sequential Quandt likelihood ratio (QLR) tests for each country. We constructed these tests by performing a sequence of full-sample QLR tests using an AR(1) model specification, in which we allowed for a change in the autoregressive coefficient. The break point was moved sequentially along the sample. Again, a full-sample interpretation of this long series of tests is that if the maximum QLR statistic obtained is larger than the 95 percent critical value, then we cannot reject the null hypothesis of an absence of a structural break in the sample.[14] This procedure is not subject to the standard problem of choosing the break point date through data inspection.

Table 4. Unit Root and Trend Break Hypothesis Tests[a]

Country	*Rolling ADF*	*Sequential Perron test*	*Sequential Quandt LR*
Critical value (95%)	–4.85	–4.39	27.87
Argentina	–16.89*	–6.91*	88.63**
Brazil	–5.62*	–4.45*	12.19
Chile	–8.45*	–5.52*	32.10**
Colombia	–7.56*	–9.82*	4.81
France	–6.44*	–6.16*	35.06**
Germany	–6.63*	–8.27*	6.79
India	–6.20*	–9.50*	4.62
Israel	–19.07*	–7.85*	47.20**
Italy	–6.38*	–5.95*	49.49**
Japan	–7.80*	–8.33*	10.55
Mexico	–9.26*	–7.12*	18.81
Spain	–8.39*	–7.58*	38.62**
Sweden	–6.65*	–8.37*	12.37
Switzerland	–6.27*	–8.68*	9.37
United Kingdom	–5.53*	–7.40*	17.81
United States	–5.08*	–6.95*	20.11

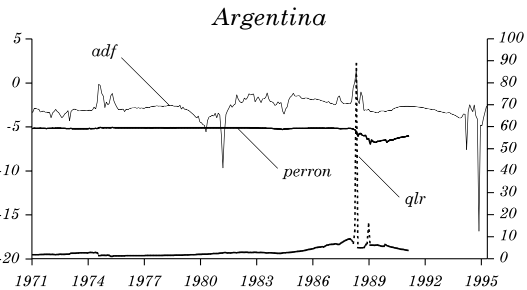
Source: Authors' calculations.
a. * Reject unit root hypothesis at 95 percent confidence. ** Reject nonstructural break hypothesis.

14. For a more detailed analysis of this testing procedure and of its asymptotic and empirical distributions, see Banerjee, Lumsdaine, and Stock (1992).

Column 3 of table 4 summarizes the sequential QLR test results. We strongly reject the hypothesis of an absence of a structural break in the cases of Argentina, Chile, France, Israel, Italy, and Mexico. These results may explain why we were unable to fit a unique ARMA representation for the inflationary processes of Argentina, Chile, and Israel, as reported in section 2. Unfortunately, we were unable to examine the possibility of a structural break following the implementation of the Real Plan in Brazil because the test requires at least fifty observations after an event.

Figure 2 presents the statistics obtained for each of these three procedures. In those cases in which the null hypothesis of an absence of a structural break is rejected, it is possible to determine the approximate date of the break. For Argentina, a structural break in the inflationary process seems to have happened in 1989 at the time of the Alfonsin hyperinflation. Structural breaks are detected in mid-1975 in Chile and in mid-1985 in Israel. Section 4 provides a detailed analysis of the latter two cases, together with Mexico.

Figure 2. Unit Root and Trend Break: Rolling ADF, Sequential Perron, and Sequential QLR



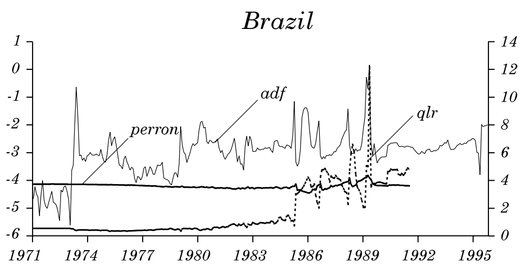


Figure 2. (continued)

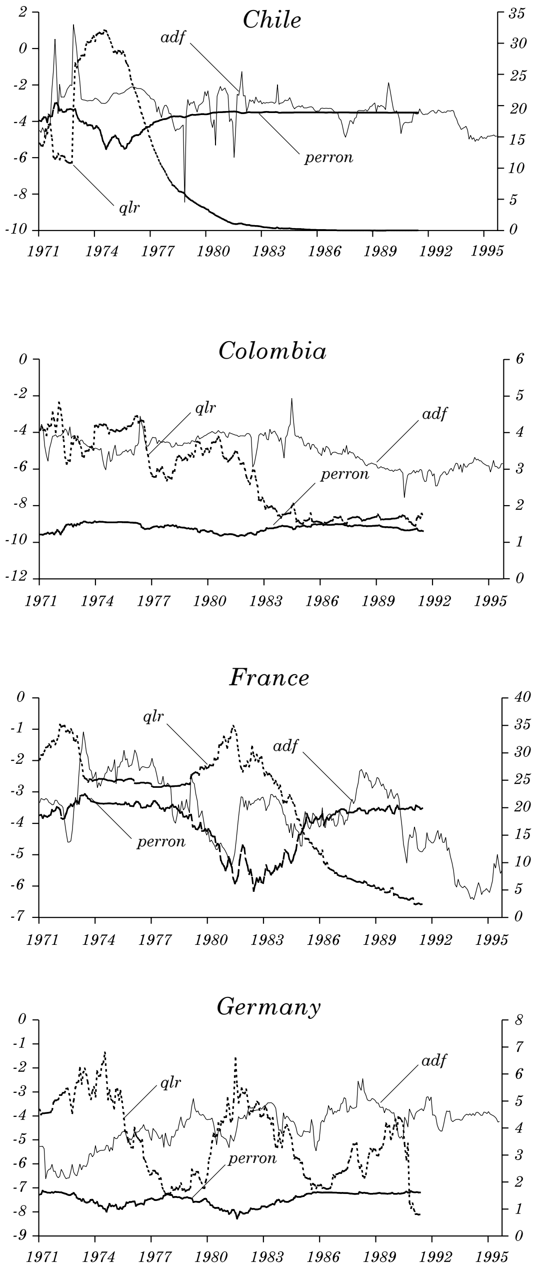


Figure 2. (continued)

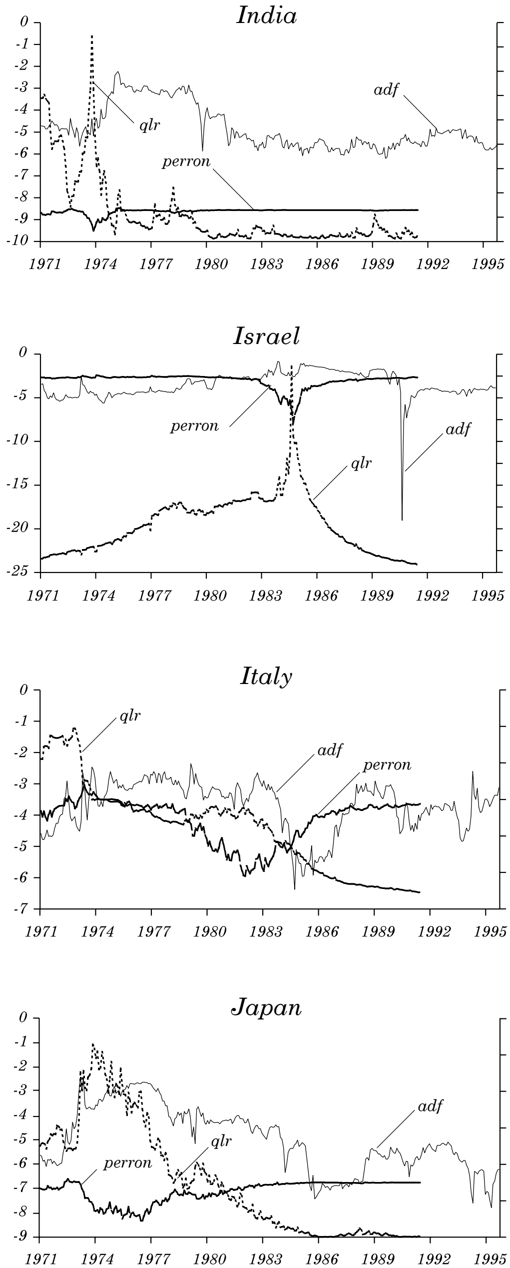


Figure 2. (continued)

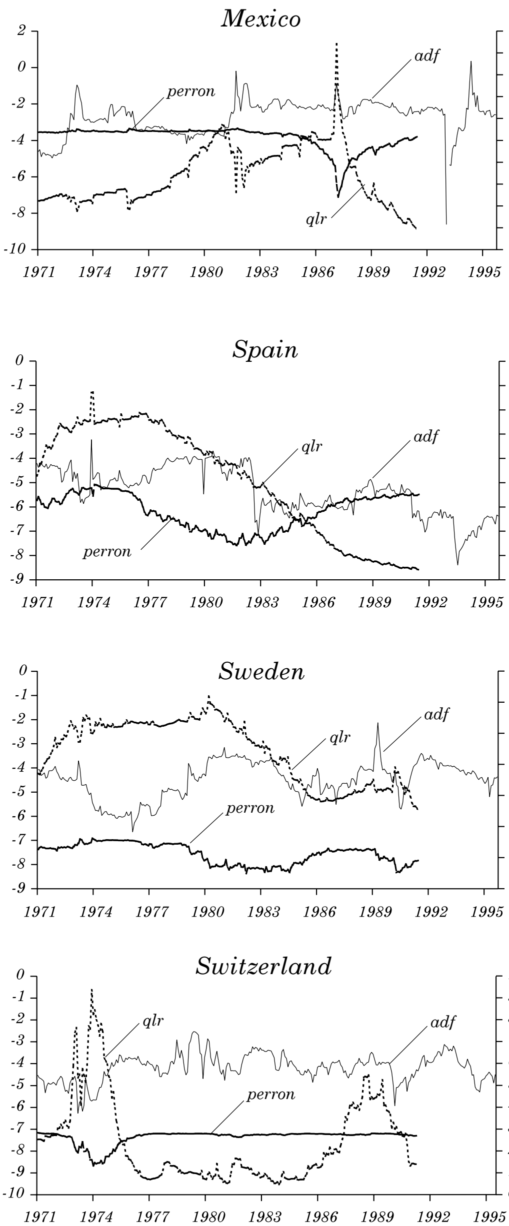
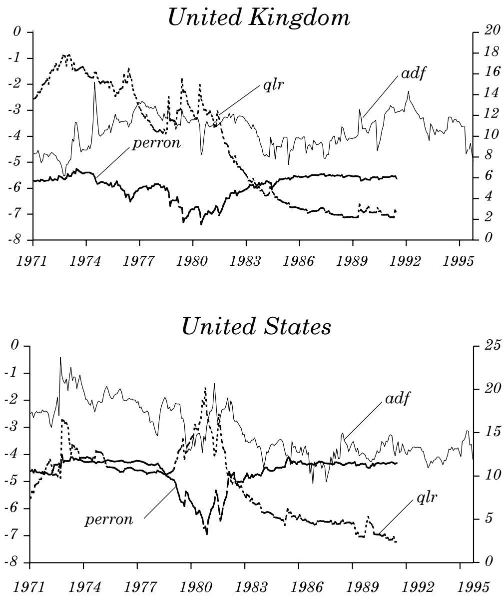


Figure 2. (continued)



3.1 Univariate Rolling Estimates of Inflationary Inertia

For each country we estimated AR(1) and AR(2) rolling regressions to further analyze the changing degree of inertia.[15] Each regression was estimated for a rolling thirty-six-month sample. Figure 3 plots the rolling autoregressive coefficients obtained in the AR(1) regressions, with two standard deviation bands.[16] The figure is quite revealing. First, the rolling AR(1) estimates show an important diversity of country experiences. While the degree of inertia is low and stable in some

15. Two alternative methods for addressing the parameter instability problem are recursive regressions and a Kalman filter. In both methodologies, the estimate at each date considers all the information contained in the sample up to that point. The rolling regression approach is more sensitive to changes in the inertia regime than is the Kalman filter because all the information used for the estimation is renewed at short intervals.

16. In the figure, our convention is to date the autoregressive coefficient obtained in each rolling regression in the last month included in the sample. Monte Carlo exercises showed that when using rolling regressions with thirty-six observations, a structural break is statistically detected when at least twenty months of the new regime are included in the sample. Hence, changes in the rolling coefficients should be associated with events happening one and a half years before the date in the figure.

nations, such as Sweden and Switzerland, in others it is highly volatile during the period under analysis (Israel, for example). Second, AR(1) estimates clearly suggest that in many countries, the degree of inflationary inertia varies significantly through time. This is the case of Argentina, for example, which exhibits no significant inflationary persistence in the early 1970s, a significant increase in inertia in the 1980s, and a marked decline in the 1990s. This latter development is related to the adoption of the convertibility stabilization plan in 1991. The estimates for Italy also suggest a rapid significant change in the degree of inertia. This is consistent with the results on the Quandt rolling structural break test reported above. Third, a number of countries seem to have lost their nominal macroeconomic anchor, at least temporarily. In this case, the AR coefficient is not significantly different from unity at conventional levels. This appears to be the case in Argentina in 1989 and in Brazil in the late 1980s and early 1990s. Fourth, some countries appear to have been able to defeat inflationary persistence, with the estimated coefficients of inertia collapsing from a positive—and in some cases very high—value to a value that is not significantly different from zero. An important question is whether those countries that have succeeded in eliminating inertia have followed similar policy courses. Section 4 addresses this issue with regard to nominal exchange rate policy and analyzes in greater detail the evolution of inertia in three countries that have implemented stabilization programs based on a nominal exchange rate anchor in the last ten years or so.

For most countries the results obtained from the estimation of rolling AR(2) (not reported here) tell a very similar story to those presented for AR(1). Some differences are appreciated in Colombia, France, Israel, Japan, Spain, and Sweden. As reported in table 3, however, the AR(2) representation appears significantly preferable to the AR(1) only for Japan, Spain, and Sweden.

The case of the United States deserves particular attention. Our results strongly suggest that the degree of inflationary persistence has not been stable through time. Between 1970 and 1975, the estimated AR coefficient was not significantly different from zero, suggesting that inflation was characterized by white noise and that there was an absence of inflationary inertia. Starting in 1976, however, the degree of persistence increased markedly. This peaked in the early 1980s, when the point estimate of the AR coefficient was 0.8—a figure not very different from that of the highly inflationary nations of South America. From then onward, inflationary inertia experienced a somewhat gradual decline, until virtually disappearing again in the mid-1990s. These results suggest that analyses that assume a stable degree of persistence, such as that of Fuhrer and Moore (1995), may result in highly misleading policy implications.

Figure 3. Rolling AR(1)

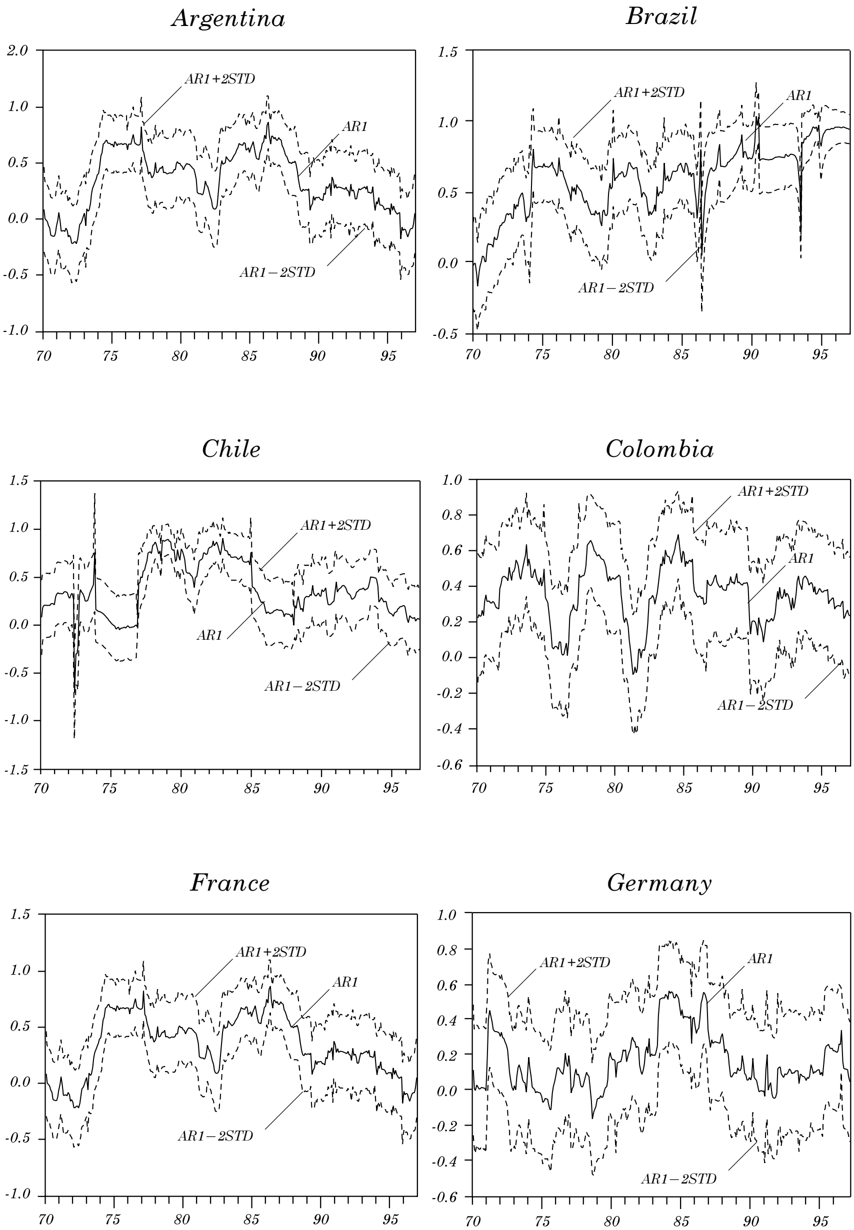


Figure 3. (continued)

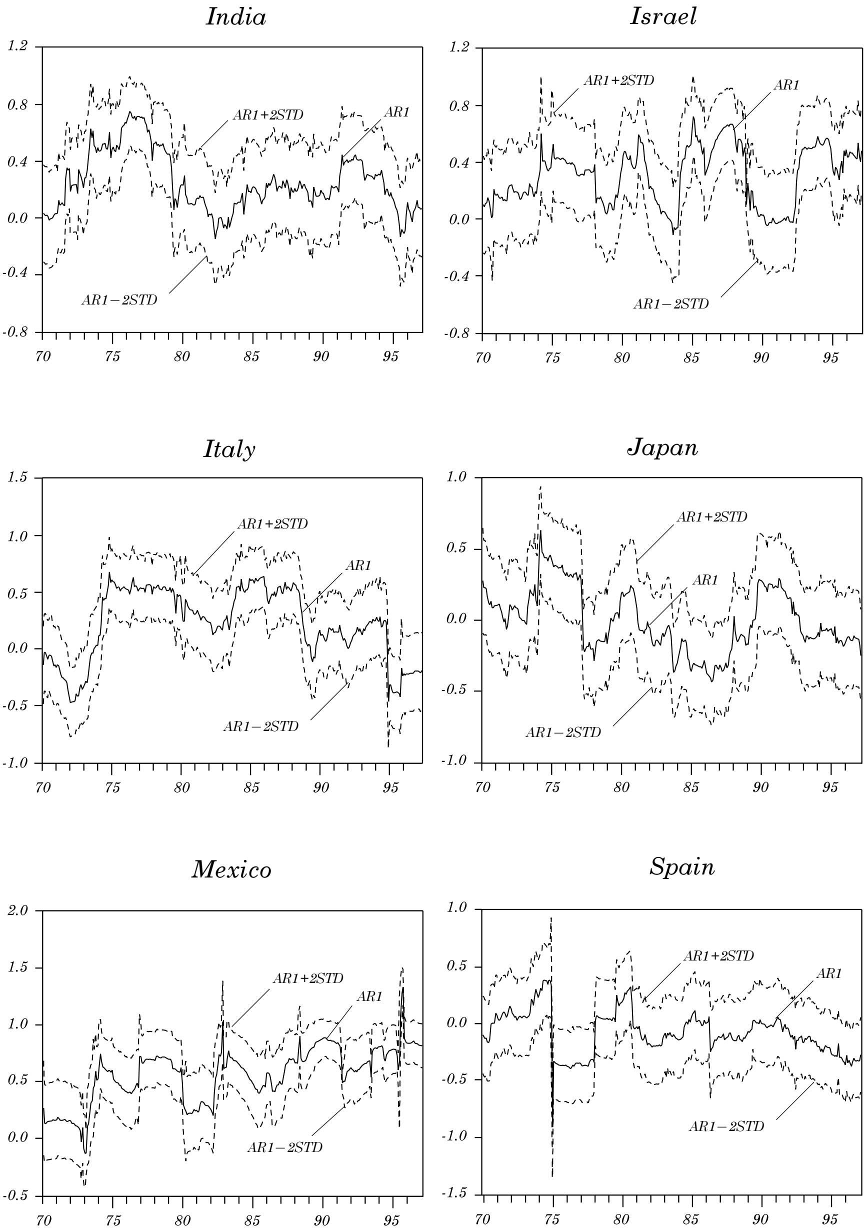
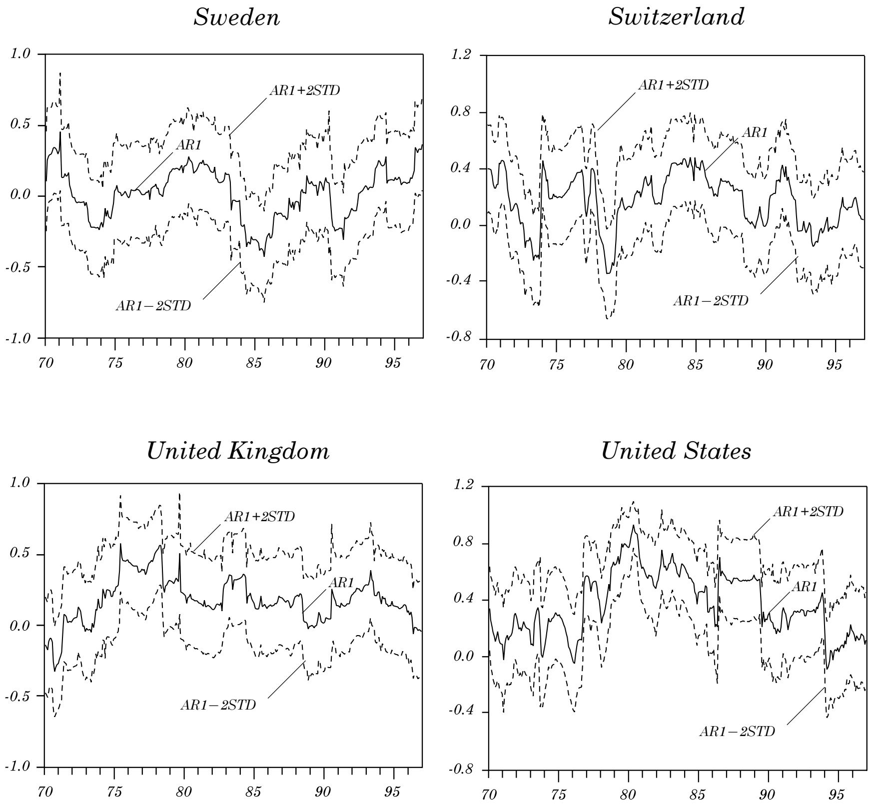


Figure 3. (continued)



3.2 Multivariate-Based Measures of Inflationary Inertia

A possible limitation of the results reported above is that they are based on univariate time series techniques, without controlling for other variables. The omission of possibly important determinants of inflation may introduce some biases in the estimation. To address this potential source of bias, we estimated the same set of AR(1) rolling regressions for some of the countries in our sample including as an additional explanatory variable the growth rate of nominal money

(IFS line 34).[17] The results for Argentina, Chile, Israel, and Mexico (which are not reported here) show that in all four cases, the differences with respect to the results of figure 3 are clearly unimportant. We went a step further in the cases of Chile and Mexico: we reestimated the AR(1) regressions controlling for estimated excess money supply. This latter variable was obtained, in turn, as residuals from error correction-based estimates of the demand for money. The broad results obtained show that our previous results are not affected by the inclusion of additional variables in the analysis.[18]

3.3 Inflation Levels and Persistence

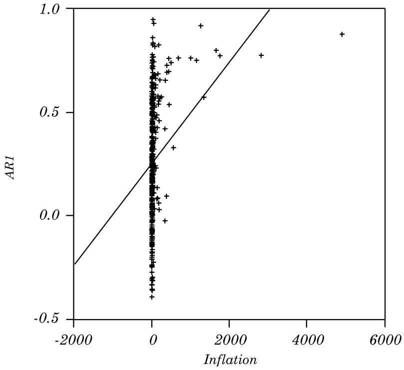
The results summarized in the preceding two subsections present a simple measure of inflationary persistence for a heterogeneous set of countries. A key contribution of this paper is that we have allowed this measure of inertia to vary over time. This exercise provides a rich panel of data on inflationary persistence, which contains both cross-country and time series variation. An interesting question—and one that has important policy implications—is whether countries and periods of time featuring high inflation also tend to present high inertia. Figure 4 displays scatter diagrams of average inflationary inertia (measured as the average autoregressive coefficient obtained in the twelve rolling regressions for each year) and average annual inflation for different subsets of the countries in the sample. Interestingly, these diagrams show that there is a positive relationship between the average level of inflation and the measured degree of inertia. This relationship is present at different levels of average inflation. To demonstrate that this graphic evidence is also statistically significant, we performed panel regressions of inflation on persistence. We used the same information plotted in figure 4 to run panel regressions using pooled least squares, fixed effects, and random effects estimators. We also divided the sample into four different subsamples according to the average level of inflation. The results confirm those presented in figure 4 and discussed above (see table 5). All the regressions show a positive and statistically significant relationship between inflationary persistence and inflation levels. The results are robust to the estimation procedure and the subsample selected.

17. There is no monthly measure of money for several of the countries. For others, the series are too short or too incomplete.

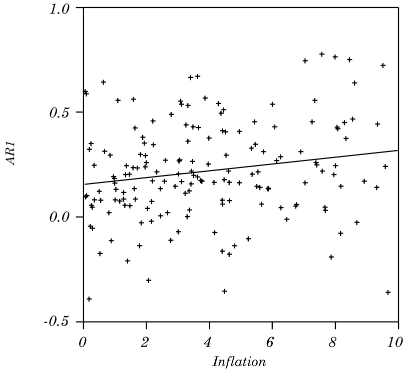
18. We also estimated impulse response functions for alternative subsamples. Although we were unable to make fine timing distinctions, the estimates provided support for the results reported above.

Figure 4. Inflation and Persistence

All countries



All countries: Inflation between 0 and 10 percent



All countries: Inflation between 0 and 100 percent

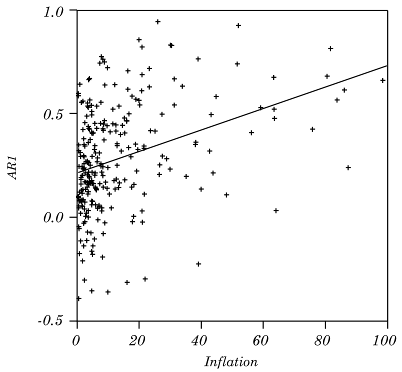
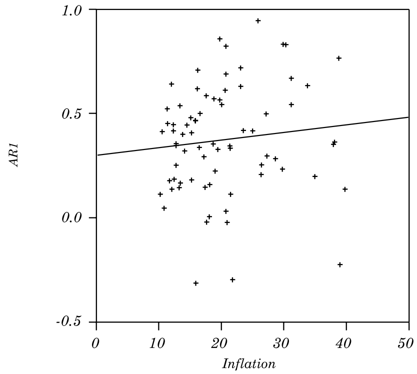
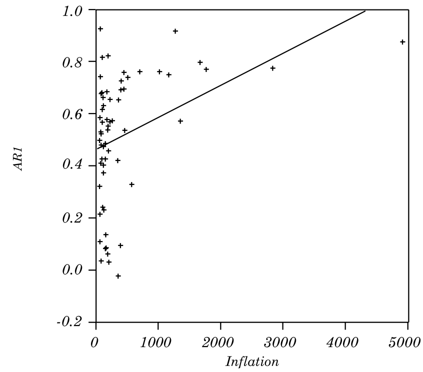


Figure 4. (continued)

All countries: Inflation between 10 and 40 percent



All countries: Inflation over 40 percent



A possible explanation for this finding is that as the inflation level increases, societies develop institutional arrangements to protect themselves from the effects of inflation. Many of these protective measures—and, more specifically, indexation mechanisms—tend to increase the degree of inflationary inertia by adjusting prices according to some measure of past inflation. To find out whether countries with extensive indexation practices indeed exhibit higher inertia, we performed some preliminary nonparametric analyses. These results indicate that it is possible to reject the hypothesis that countries with high indexation and countries with no indexation come from the same sample. Moreover, average inflation rates in high-indexation countries are significantly higher than in countries where there are no generalized indexation practices.[19]

19. These preliminary results are available from the authors on request.

Table 5. Panel Regressions of Inflation on Persistence[a]

Regression method	*Full sample*	$p < 0.1$	$p < 0.4$	$p < 1$	$p > 1$
Pooled least squares	3.371	0.029	0.112	0.223	15.766
	(0.552)	(0.009)	(0.017)	(0.030)	(4.897)
Fixed effects	2.520	...	0.034	...	...
	(0.695)	...	(0.015)	...	...
Random effects	2.825	...	0.037	...	...
	(0.639)	...	(0.014)	...	...
No. observations	416	281	355	375	41

Source: Authors' calculations.
a. Standard errors in parentheses.

4. Inertia and Inflation Convergence: Three Cases

An important goal of most stabilization programs in developing (or emerging) economies is to reduce the domestic inflation rate to levels comparable to world inflation. In other words, stabilization programs are usually aimed at producing inflationary convergence. The speed at which inflation is reduced is important, however. Under fixed nominal exchange rates, a slow inflationary convergence will result in real exchange rate overvaluation and speculation; in the end, it can even generate a crisis. If inertia is eliminated or greatly reduced, inflationary convergence will be achieved rapidly, whereas if inertia is very high, convergence will tend to take a long time.[20] Historically many countries—including a number in our sample—have attempted to achieve inflation convergence by implementing stabilization programs based on the adoption of a rigid (and in some cases totally fixed) nominal exchange rate. In this section we briefly analyze the experiences of three countries in the sample that have adopted stabilization programs based on nominal exchange rate anchors within the last twenty years or so: Chile, Israel, and Mexico. Our main interest is to analyze, in the light of the battery of tests presented in the preceding sections, whether the adoption of this type of program indeed resulted in a reduction or elimination of the degree of inertia. We begin the discussion with a direct comparison of the Chilean and Mexican experiences of the 1970s and 1980s. We then move to the Israeli case.

20. Naturally, in making these statements we are assuming that the fundamental macroeconomic stance is conducive to inflationary reduction.

4.1 Chile (1978-82) and Mexico (1987-94)

The Chilean reform program was initiated in 1975, ten years prior to the launching of the Mexican reforms. Both programs, however, shared a number of features: drastic opening of the economy; ambitious privatization and deregulation; and a stabilization program based on a predetermined, nominal exchange rate anchor, supported by largely restrictive fiscal and monetary policies. Both programs were rooted in the notion that a predetermined rate of nominal devaluation, including a fully fixed nominal exchange rate, would constrain price increases, reduce inflationary expectations, and ensure that monetary and fiscal authorities would behave conservatively. In Chile, the exchange-rate-based stabilization program had two phases: from February 1978 through June 1979 the rate of devaluation was preannounced and deliberately set below the ongoing rate of inflation. In June of 1979 the nominal exchange rate was pegged at 39 pesos per dollar. The authorities announced that this new exchange rate would be in effect for the indefinite future.[21]

The Mexican program followed a somewhat different pattern. Between February and December 1988, the nominal exchange rate was fixed, thereby becoming the fundamental anchor of the anti-inflationary effort.[22] Between January 1989 and November 1991, a system based on a preannounced rate of devaluation was in effect. As in Chile a decade earlier, during this period the actual rate of devaluation was deliberately set below the ongoing rate of inflation as a way of reducing expectations and price increases. The amount by which the peso was devalued was successively reduced from one peso per day in 1989 to 80 cents in 1990, 40 cents in 1991, and 20 cents in 1991. In November 1991, the authorities added some flexibility to the system when they adopted an exchange rate band with a sliding ceiling and a flat floor. This measure was justified on two grounds: it was supposed to discourage short-term capital inflows, and it was supposed to allow some real exchange rate corrections. Until October 1993—when the NAFTA controversy heated up in the United States—the actual peso-to-dollar rate was extremely stable, remaining in the lower half of the band. During 1994, however, and as a result of political and other developments, the

21. Parts of this comparison draw on Edwards (1995). See also Morely's review of Edwards in Morley (1997).

22. From October to December 1987 (the first months of the Pacto), nominal wages provided the anchor for the system. According to Vela (1993) the move to an exchange rate anchor in February 1988 was, in part, the result of labor union pressure.

exchange rate came under considerable pressure, moving towards the top of the band. As is well known, the attempt to widen the band in late December failed badly. It was too little, too late.

Early on, Chilean and Mexican authorities understood that consistent fiscal and monetary policies were a precondition for the success of the exchange-rate-based stabilization programs. In both countries, the primary balance of the public sector was under control even before the adoption of the exchange rate anchor, and monetary policy was largely restrained during most of the period.[23]

The architects of both the Chilean and Mexican programs expected that a predetermined exchange rate would affect inflation through at least two channels. First, a fixed exchange rate in an open economy would impose a ceiling on tradable inflation; second, the new exchange rate policy would generate a major break in inflationary expectations and in inflationary inertia. Mexico's finance secretary, Pedro Aspe, put it the following way: "[Pegging the exchange rate] and... lowering... trade barriers in the tradables sector were indispensable for breaking down inertia. Consensus and a tendency toward purchasing power parity could reinforce each other to bring down inflation" (Aspe, 1993, p. 44).

Despite these similarities, the Chilean and Mexican programs had some important differences. Perhaps the most important referred to wage rate policy. Beginning in 1976, Chile adopted a formal backward-looking wage indexation scheme, through which all wages in the formal sector were periodically raised to compensate for the cumulative inflation rate of the previous period (Edwards and Edwards, 1991, chap. 6). In contrast, the Mexican *Pacto* encompassed a social and economic agreement among the government, the private sector, and labor unions, aimed at establishing guidelines for price, wage, and exchange rate changes.

In both countries inflation was reduced, but at a significantly slower pace than what the authorities had anticipated. As their reforms proceeded and became consolidated, both countries were subject to very large capital inflows which helped finance increasingly large current account deficits and generated a very large real exchange rate overvaluation (Edwards, 1996). In Chile the current account deficit exceeded 12 percent of GDP in 1981, while in Mexico it surpassed 7 percent of

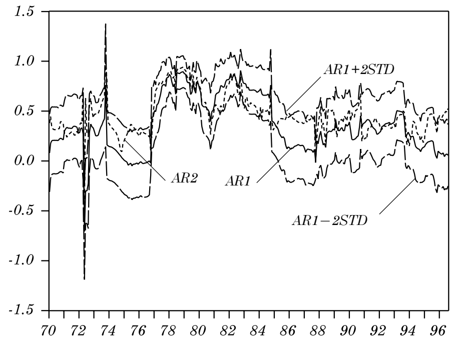
23. In the early years of the Mexican program, monetary policy was guided by a dual objective: on the one hand, the authorities were interested in reducing interest rates, which had reached extremely high real levels in 1987 and 1988, and on the other, they wanted to make sure that domestic credit policy would be consistent with the predetermined nominal exchange rate (Aspe, 1993, p. 37).

GDP in both 1992 and 1993. These very large deficits proved to be unsustainable, and both countries ended up facing major crises: the Chilean crisis erupted in June of 1982; the Mexican crisis in December 1994.

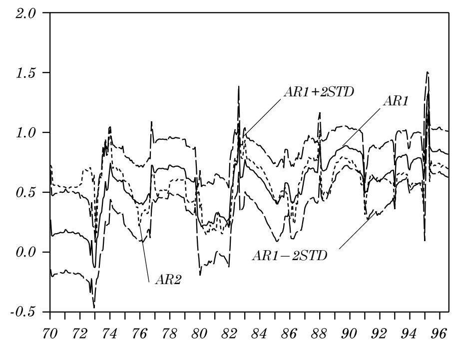
How successful were these two nominal exchange-rate-based stabilization programs in reducing (or eliminating) inflationary inertia? We can address this issue with the aid of the statistical analysis presented in this paper. In particular, we can use the different estimates of inertia developed in the preceding section to analyze whether the degree of inflationary persistence declined after the exchange rate anchor program was enacted, as the architects of the programs had intended. Figure 5 presents once again our estimates of inertia for these two countries using the AR(1) and AR(2) procedures.

Figure 5. Inflationary Inertia: Chile and Mexico

Chile



Mexico



The results are quite interesting. Chile demonstrates a temporary decline in inertia by the end of 1979: both the AR(1) coefficient and the dominant root in the AR(2)-based measure decline temporarily to 0.33. From then on, however, measured inertia started to increase again, reaching more than 0.8 in the months immediately preceding the abandonment of the fixed exchange rate in June 1982. There are two possible explanations for this behavior. First, due to the mandated backward-looking wage indexation mechanism, structural inertia remained in the system despite the adoption of the anchor. Second, as Edwards (1998) argues, the program's credibility was eroded as real exchange rate overvaluation became more and more acute, which led firms to incorporate into their pricing decisions an expected change in the exchange rate regime and a resumption of the crawling peg policy.

Like Chile, Mexico experienced an initial decline in persistence. After a few months, however, measured inertia had once again increased. In mid-1994, seven years into the program, it was still in the range of 0.6 to 0.7. This high degree of inertia contributed to the creation of an acute real exchange overvaluation, which in turn contributed to the unleashing of the Mexican currency crisis of December 1994 (Dornbusch and Warner, 1994).

4.2 Israel

In 1983-84, Israeli inflation averaged almost 300 percent per year. This was the result of serious macroeconomic imbalances, including double digit fiscal deficits and an entrenched and perverse inflationary expectations process. In mid-1985 Israel launched an ambitious stabilization program based on three important elements: a control of the fiscal deficit; a social pact agreed among representatives of labor, government, and the private sector; and a fixed (but adjustable) nominal exchange rate. As in Chile and Mexico, the exchange rate anchor policy was aimed at breaking expectations, placing a ceiling on tradables inflation, and reducing inertia. The program was a success in many ways: in 1986 inflation was 20 percent, down from 185 percent the previous year, and by 1987 it was 16 percent.

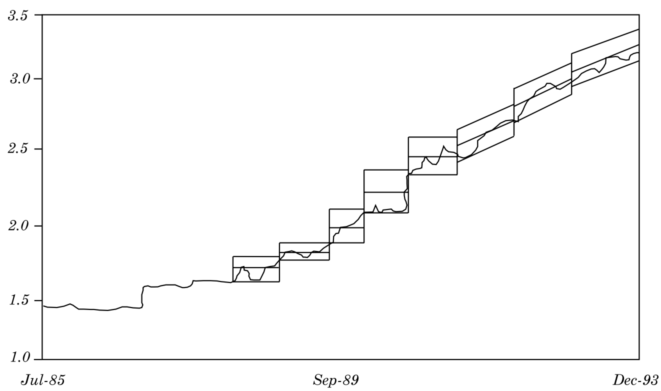
As in Chile and Mexico, this program generated a process of real exchange rate appreciation, which hurt the degree of international competitiveness of Israeli exports. Between 1985 and 1988 this problem was handled through periodic nominal devaluations, which were followed by a new peg. In January 1989, however, a new exchange rate policy based on a crawling exchange rate band was implemented to combine the dual objectives of defeating inflation and avoiding an exchange rate crisis.

Figure 6 presents the evolution of Israel's nominal exchange rate from mid-1985 through December 1993. Initially this band allowed the exchange rate to fluctuate by ±3 percent around a fixed central parity. The width of the band was subsequently increased to ±5 percent, and in December 1991 the sliding band was replaced by a crawling band characterized by a moving central parity based on expected inflation rate differentials.

The move from the sliding to the forward-looking crawling band in late 1991 responded to two factors. First, the sliding band system was generating significant uncertainty. Every time the public expected that a realignment of the central parity was about to take place, speculation increased and domestic interest rates jumped. Second, by basing the rate of the crawl of the band on expected, rather than lagged, inflation, the authorities thought they would affect inflationary expectations and reduce—if not eliminate—inflationary inertia. With the exception of the first band that operated from January through June of 1989, the band width was maintained at ± 5 percent.

The adoption of the forward-looking band was successful in many respects. First, speculation on the realignment of the central parity was greatly reduced, and interest rates declined and became less volatile. Second, exchange rate overvaluation was avoided, and export performance improved significantly. Third, inflationary inertia was

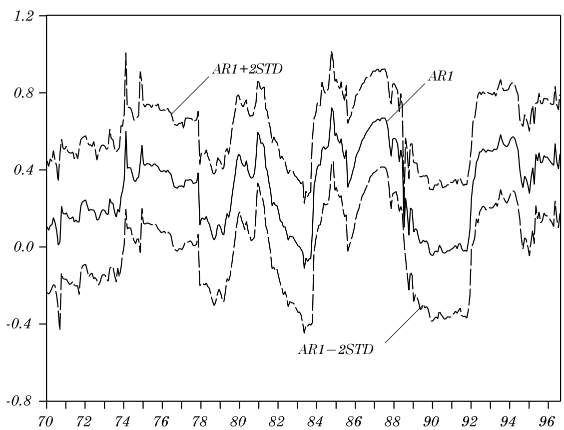
Figure 6. Israel's Exchange Rate Band



greatly reduced in the early 1990s. Fourth, as predicted by the program, inflation declined gradually through 1995. Finally, this band allowed the Israeli economy to accommodate in a nontraumatic fashion changes in fundamentals, including episodes of large capital outflows. In the last quarter of 1992, for example, capital outflows amounted to over 20 percent of international reserves.

From the perspective of this paper, an important question is how the Israeli exchange-rate-based program affected inflationary inertia. This can be addressed by reexamining the inertia measures computed above, which are reproduced in figure 7 for convenience. The figure is highly revealing and provides an interesting contrast against those for Chile and Mexico displayed above. The preferred AR(1) measure of inertia very clearly indicates that by late 1986 inflationary persistence in Israel was already experiencing a rapid collapse. In fact, it is not possible to reject, at conventional significance levels, the hypothesis of a complete absence of inertia between late 1988 and mid-1990. These estimates quite strongly suggest, however, that by 1991 the degree of inertia was once again on the rise, and by 1992-93 it was almost as high as it had been in 1983-86. The most likely explanation for this result is that with inflation in the 20 percent level for the sixth year in a row, it had become clear that the war against inflation had run to a standstill. The program suffered credibility problems, as old indexation practices slowly crept back into the system.

Figure 7. Inflationary Inertia: Israel



5. Concluding Remarks

This paper has empirically analyzed the extent of inflationary inertia in a set of countries. An important contribution of the paper has been to assume that the degree of inflationary inertia can change through time and to associate changes in the time-varying measures of inflationary inertia to specific economic events for a subset of countries. The paper has also discussed preliminary evidence regarding the effect of indexation practices and credibility on inflationary persistence.

We analyzed the time series properties of monthly inflation data from 1970 through the end of 1996. We performed a battery of tests: rolling augmented Dickey-Fuller tests; sequential Perron tests to test the unit root hypothesis in the presence of structural breaks; and sequential Quandt likelihood ratio tests to analyze the instability of the autoregressive coefficients. Results indicate that allowing for structural breaks, it is possible to reject the unit root hypothesis for all countries in the sample, and that it is also possible to reject the hypothesis of an absence of a structural break in the first-order autoregressive coefficient in Argentina, Chile, France, Israel, Italy, and Spain. In addition, the reported estimates of the rolling AR(1) coefficients and the dominant inverted roots of the rolling AR(2) estimates clearly show that inflationary inertia greatly varies both across countries and across time periods within a country. We demonstrated a clear connection between our estimates of inertia and the levels of inflation in the countries in the sample. Episodes (time and place) characterized by a high degree of inflationary persistence also feature a high level of inflation.

We ended the paper by discussing in more detail the evolution of inflationary inertia in three countries that, at one point or another, have relied on a nominal exchange rate anchor to achieve price stability: Chile, Israel, and Mexico. We have shown that the measure of inertia falls at the beginning of these stabilization programs, but then rises back as time goes by and the programs fail to cut inflation down to world levels. Unfortunately, we were not able to analyze the last Argentine stabilization program because of data constraints.

References

Aspe, P. 1993. *Economic Transformation the Mexican Way*. Lionel Robbins Lectures. MIT Press.

Ball, L. 1991. "The Genesis of Inflation and the Costs of Disinflation."*Journal of Money, Credit and Banking* 23(3): 439-52.

Banerjee, A., R. L. Lumsdaine, and J. H. Stock. 1992. "Recursive and Sequential Tests of the Unit-Root and Trend-Break Hypotheses: Theory and International Evidence." *Journal of Business and Economic Statistics* 10(3): 271-87.

Bruno, M. 1993. "Inflation and Growth in an Integrated Approach." NBER Working Paper 4422. Cambridge, Mass.: National Bureau of Economic Research.

Calvo, G. A. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12(3): 383-98.

Campbell, J. Y., and N. G. Mankiw. 1987a. "Are Output Fluctuations Transitory?" *Quarterly Journal of Economics* 102(4): 857-80.

———. 1987b. "Permanent and Transitory Components in Macroeconomic Fluctuations." *American Economic Review* 77(2): 111-17.

Cochrane, J. H. 1988. "How Big Is the Random Walk in GNP?" *Journal of Political Economy* 96(5): 893-920.

Dornbusch, R., and A. Werner. 1994. "Mexico: Stabilization, Reform and No Growth." *Brookings Papers on Economic Activity* 1: 253-315.

Edwards, S. 1993. "Exchange Rates as Nominal Anchors." *Weltwirtschaftliches Archiv* 129(1): 1-32.

———. 1995. *Crisis and Reform in Latin America: From Despair to Hope*. Oxford University Press for the World Bank.

———. 1996. "Exchange-Rate Anchors, Credibility, and Inertia: A Tale of Two Crises, Chile and Mexico." *American Economic Review* 86(2): 176-80.

———. 1998. "Two Crises: Inflationary Inertia in Chile and Mexico." *Economic Journal* 108(448): 680-702.

Edwards, S., and A. Cox Edwards. 1991. *Monetarism and Liberalization: The Chilean Experiment*. University of Chicago Press.

Fischer, S. 1986. *Indexing, Inflation, and Economic Policy*. MIT Press.

Fuhrer, J., and G. Moore. 1995. "Inflation Persistence." *Quarterly Journal of Economics* 110(1): 127-59.

Hamilton, J. D. 1994. *Time Series Analysis*. Princeton University Press.

Jaeger, A., and R. M. Kunst. 1990. “Seasonal Adjustment and Measuring Persistence in Output.” *Journal of Applied Econometrics* 5(1): 47-58.

Morley, S. A. 1997. “Review of Crisis and Reform in Latin America: From Despair to Hope,” by S. Edwards. *Journal of Economic Literature* 35(2): 816-18.

Obstfeld, M. 1995. “International Currency Experience: New Lessons and Lessons Relearned.” *Brookings Papers on Economic Activity* 1: 119-96.

Pazos, F. 1990. “Runaway Inflation: Experiences and Options.” *Cepal Review* 42 (December): 115-30.

Pesaran, M. H., R. G. Pierse, and K. C. Lee. 1993. “Persistence, Cointegration and Aggregation: A Disaggregated Analysis of Output Fluctuations in the U.S. Economy.” *Journal of Econometrics* 56(1-2): 57-88.

Taylor, J. B. 1980. “Aggregate Dynamics and Staggered Contracts.” *Journal of Political Economy* 88(1):1-23.

Vela, A. E. 1993. “Three Essays on Inflation and Stabilization: Lessons from the Mexican Solidarity Pact.” Ph.D. dissertation, University of California at Los Angeles.

Indexed Units of Account: Theory and Assessment of Historical Experience

Robert J. Shiller
Yale University

An indexed unit of account, such as the *Unidad de Fomento* (UF) in Chile, is a money analogue that can be used to price items for sale or to specify amounts to be repaid in the future. While it is in a sense a sort of money, it is not true money since it is not a medium of exchange and it has no physical embodiment like coins, notes, or reserve balances. An exchange rate between the unit and the true money or legal tender (in Chile, the peso) is defined using an index number (such as the consumer price index), and payments are executed in money. Indexed units of account thus facilitate payments that are tied to the index number, without being a means of payment.

How can the indexed unit of account be called an analogue of money when it does not have any physical embodiment? Money, the textbooks have long said, has three attributes: it is a medium of exchange, a store of value, and a unit of account. As a medium of exchange, it is a physical object or account balance that passes from person to person when items are bought and sold. This role is very important because it eliminates the need for ordinary barter, which is an inefficient means of effecting trade as it requires discovering a double coincidence of wants. The store of value function of money allows people to store purchasing power between transactions, which allows them to transact more efficiently, even though money is not the primary medium for long-term storage of value. This function is central to the cash-in-advance theoretical literature in monetary

I am indebted to Michael Bordo, Robert Hall, Michael Krause, Gil Mehrez, Felipe Morandé, Andrew Powell, James Tobin, and Salvador Valdés-Prieto for helpful comments and discussions. Jinku Lee provided research assistance. Research support was provided by the Central Bank of Chile.

Indexation, Inflation, and Monetary Policy, edited by Fernando Lefort and Klaus Schmidt-Hebbel, Santiago, Chile.

economics. The third function, the unit of account, is that prices are quoted in money units.

The use of an indexed unit of account, such as the UF in Chile, separates the first two functions from the third. A distinction can then be made between the unit of account and the currency or legal tender or between the money of account and the money (see Keynes, 1930, p. 3). In Chile, the peso serves as the medium of exchange and the store of value (and also partly fills the unit of account function), while another unit of account, the UF, is fixed in real terms. Prices are often quoted in UFs.

This paper reviews the history of and reasons for the use of an indexed unit of account and then asks why there might be an advantage to separating the three functions of money, allowing a unit of account that is not the same as the currency. I argue not only that the Chilean UF is an excellent idea that should be imitated around the world, but also that another indexed unit of account, defined in terms of nominal incomes rather than the consumer price index, should also be created. Moreover, I consider whether the indexed units of account should be "monetized" by creating institutions to allow transactions to be carried out in reference to the units of account. With automated debit card, credit card, and electronic funds transfer systems, it may be possible to specify all prices in terms of indexed units of account, thus effectively indexing all prices.

CHILE'S *UNIDAD DE FOMENTO*

The *Unidad de Fomento* (UF) was introduced in Chile in January 1967 by the Superintendencia de Bancos e Instituciones Financieras, a government regulatory agency. As far as I have been able to determine, the UF is the world's first successful indexed unit of account. That is, it is the first case of indexation being achieved by quoting prices in a money-like unit, rather than relying on an indexation formula.

Chile had issued an earlier unit of account in 1960, namely, the *Unidad Reajustable* or UR, which was based both on price and wage indexes, but it was not very successful. The UF is an amount of currency related to the *Índice de Precios al Consumidor* (IPC), the Chilean consumer price index. The UF was originally calculated three times a year, and it was calculated monthly between 1975 and 1977, but daily adjustments in the UF have been made since 1977. The UF is now a lagged daily interpolation of the monthly consumer price index. The formula for computing the UF on day t is

$$UF_t = UF_{t-1} \times \left(1 + \pi\right)^{1/d} ,$$

where π is either the inflation rate for the calendar month preceding the calendar month in which t falls if t is between day ten and the last day of the month (and d is the number of days in the calendar month in which t falls) or the inflation rate for the second calendar month before the calendar month in which t falls if t is between day one and day nine of the month (and d is the number of days in the calendar month before the calendar month in which t falls). Since the inflation rate for a calendar month is computed using the consumer price index for that month and for the preceding month, the UFs within a given calendar month will depend on the consumer price index for each of the three preceding months. In April, for example, the UFs for April 1 through 9 depend on the consumer price index for January and February and for April 10 through 30 on the consumer price index for February and March.

UFs were not generally used by the public until the early 1980s, about fifteen years after their introduction, though only a few years after the values were produced on a daily basis (Levin, 1995). The UF is now widely used in Chile.

Most bank deposits in Chile are thirty-day nonindexed deposits or ninety-day indexed deposits whose rates are expressed in terms of the UF. Interest rates on the indexed deposits are expressed as a premium over the UF. On maturity, the deposits are converted back to pesos at the current UF rate. Because indexed and unindexed bank deposits coexist, one might say that the Chilean banking system is partially indexed using the UF. Deposits denominated in U.S. dollars are also permitted for maturities over thirty days. The UF is used in Chile for nearly all mortgages, car loans, and long-term government securities. All taxes are expressed in UFs. Pension payments are automatically tied to the UF. Executive stock options sometimes have strike prices denominated in UFs. The UF is widely used for rent payments. Alimony and child support payments are often denominated in UFs. Office properties for sale are usually quoted in UFs. Houses for sale are often quoted in UFs, though pesos are also used. The UF is not so commonly used for listing the selling prices of automobiles, however, nor is it used directly for setting salaries. Wages and salaries are denominated in pesos and only indirectly influenced by the UF, in that the change in the peso value of the UF is taken into account in wage and salary deliberations.

Historical Antecedents of Indexed Units of Account

While the UF is apparently the first successful unit of account indexed to a true price index, units of account separate from money have been used for millennia. Historically, units of account precede money altogether. Trade in terms of precious metals, rather than any money, preceded the invention of coinage in the seventh century B.C. Units of weight, such as the talent or the shekel, evolved into units of money when coins were minted with specified relations to the weight. Because governments could not be trusted to maintain the weight of the coinage, however, a tradition developed of writing contracts in units that did not correspond to any current coins. Einaudi (1953, pp. 234–35) describes the situation as follows:

> Today each country has only one monetary unit: the lira, the franc, mark, pound sterling, or dollar. This is the system established by the French assemblies at the end of the eighteenth century.... Prior to the French Revolution, the monetary system of most European countries was based on altogether different principles. Contemporary authors could take these principles for granted and did not have to explain them to others. Their strange terminology causes us, who live in another world, to wander for a while in a dark forest. By and by, we finally understand the tacit assumptions of their discourses. The key, needed to interpret the apparent confusion of the monetary treatises written prior to the eighteenth century, is the disjunction between a monetary unit and a standard of value and of deferred payment and another monetary unit used as a medium of exchange.

In medieval and Renaissance times, even contracts that were explicitly written in terms of units of currency that were circulating as coins sometimes were understood to be executed in terms of some other measure. For example, in Milan in 1445, a debt of one florin would not be paid with one of the gold florin coins, but rather in an amount computed under the assumption that the florin was still worth 384 silver deniers—and not the 768 deniers that the florin coin was then worth (see Cipolla, 1956).

Since there were often no coins in circulation that corresponded to these units, the actual units of account were sometimes called imaginary money or, alternatively, *moneta numeraria*, money of account, ideal money, political money, or ghost money. From the time of Charlemagne, trade and contracts in Europe were substantially based on the *moneta numeraria* called the pound, (or, equivalently, the livre or lira), which was always worth 20 sous (shillings) and each sou worth 12 deniers (pence) (see Einaudi, 1953). Ultimately, the standard of value represented by this system was the silver denarius issued by Charlemagne in the late eighth and early ninth centuries—coins that were no longer circulating, or even seen, later in the middle ages and in the Renaissance. Charlemagne's denarius weighed one-240th of a troy pound; the earlier Roman denarius had gone through repeated debasements and was not a unit of account in medieval or Renaissance times. Because they are even fractions, the sou (at twelve deniers) and pound were natural units of account, but Charlemagne never issued coins representing these values. Actual exchange was executed in terms of current coinage, which had many names from the realms that issued them, including angels, blanks, crowns, crazies, doblons, dollars, douzains, ducats, ducatoons, écus, farthings, florins, guilders, louis, moutons, nobles, obols, phillipi, reals, sovereigns, stivers, and testoons. Many of these would circulate simultaneously in each country, a situation that would have created tremendous confusion if there had not been a standard unit of account.

Aspects of this ancient system did, of course, continue into the nineteenth century as a result of governments' efforts to maintain bimetallic standards with fixed exchange rates between the coins of different metals. This practice sometimes caused the coin of lower value to disappear from circulation, a tendency that is predicted in Gresham's Law. In other cases, people began to adopt the convention that only one of the coins would be the money of account, while the other's price was allowed to float against it despite government proclamations to the contrary (see Rolnick and Weber, 1986).

The only aspect of the UF that was really new when it was introduced in 1967, therefore, is that it was based not on a single commodity but on a representative consumer basket. This innovation was indeed significant, since the management of risks is much better handled in terms of such an index rather than in terms of a single good. It is not surprising that the innovation represented by the UF was not adopted in ancient or medieval times, despite the apparent simplicity of the idea of index numbers. There was no published theory of index numbers, and there was no governmental authority that could plausibly have attempted to start a new social convention of denominating contracts in terms of such indexed units. The advantage of defining contracts in terms of the single commodity, the precious metal, rather than the currency, was obvious enough to ensure that the practice would continue over the centuries, but the next step, the indexed unit of account, was not at all obvious or easy.

UF Analogues in Other Countries

The European Currency Unit (called the ecu) might be regarded as a UF analogue, in that it is based on an index of currencies. The ecu, which was created in 1979, was defined as a basket of European currencies. It was regarded as less vulnerable to runaway inflation than were the individual currencies, since it was essentially a diversified portfolio of currencies. Partly for this reason, a substantial amount of European private long-term debt was ultimately denominated in ecus (see Bordo and Schwartz, 1989). (A more important reason for the private use of the ecu may have been circumventing exchange and capital controls.) Since the ecu is not based on a broad index of prices, wages, or incomes, however, I would not call it a true indexed unit of account.

A number of examples of true indexed units of account can be found outside of Chile. While these are not yet as ingrained in their countries' economies as the UF is in Chile, they do represent important beginnings. In 1993 Ecuador created a unit of account modeled after the UF. It is called the *Unidad de Valor Constante* (UVC) (see Polit, 1994). Mexico similarly copied the Chilean UF in 1995 by creating a unit of value called the *Unidad de Inversión* (UDI). The UDIs began at a par of one to one with the peso on April 4, 1995, and the peso value of the UDI increases one to one with consumer inflation. The Bank of Mexico publishes the value of the UDI on the 10th and 26th of every month based on the national consumer price index. Mexican banks offer UDI-denominated instruments and use the interpolated published values of the UDI to make daily advances.

Colombia has also copied the UF, with its *Unidad de Poder Adquisitivo Constante* (UPAC), or unit of constant purchasing power.

The UPAC is used for mortgage loans and for financing construction by savings and housing corporations (see Bernardez, 1996).

Uruguay has a unit of account called the *Unidad Reajustable* (UR), which is used to index government pension payments and, since 1996, to index government bonds. The UR is based on a wage index, rather than a consumer price index; I discuss the possible advantages of such a variation on the UF below.

In the Ukraine, a unit of account called the *uslovnaya edinitsa* (conventional unit) or y.e. has been used since 1995. Prices in stores, as well as houses, cars, and other items advertised for sale in newspapers, are often denominated in these units. The units came into use after the government prohibited pricing in foreign currencies during a period of high inflation in 1995. Despite their superficial similarity to the indexed units of Latin America, however, these units are not true indexed units of account. In fact, the government does not even decree the definition of the units. When the unit is used in ordinary advertisements, such as in an advertisement for a home for sale, it is understood to be a disguised price in the U.S. dollar. Other definitions of the unit are also used. Stores post their conversion rate from y.e. to the currency, which often deviates substantially from the dollar exchange rate.

DEINDEXATION

While the *Unidad de Fomento* is being copied by several countries, other Latin American countries are currently moving to deindex the economy, to reduce or even eliminate the reliance on indexation schemes. Now that the inflation rate is down throughout most of Latin America, many feel that it is time to return to economic institutions that are more akin to those in the rest of the world.

Deindexation proposals are not new in Chile. In 1986, the Pinochet government reacted to complaints from debtors such as farmers with a proposal to freeze the UF and at the same time to extend the repayment of debts. Fortunately, the UF was not frozen, as such a move would have damaged confidence in any future effort to revive the UF.

In the fall of 1996 Nicolás Eyzaguirre, the research director of the Central Bank of Chile, gave a speech in which he questioned whether the widespread use of the UF indexation system should be reconsidered, as it represented a possible obstacle to low inflation in the future. According to Eyzaguirre, “It is a unique paradox, unlike any other in the world: an extremely low inflation rate with all business and financial contracts protected against inflation."[1] An editorial in the Chilean newspaper *La Nación* concurred:

> Indexation emerged in Chile at a time when high inflation rates compelled the government to adopt precautions in order to strengthen the financial market. The situation has changed, as all the indicators prove, but the indexation mechanism persists and has now become an obstacle to current anti-inflationary aims rather than a palliative. At any rate, putting an end to indexation is not easy because it has become indispensable to the way our economy functions. The economy's different actors have already made contracts based on the system of indexation, contracts which cannot be modified from one day to the next. We need to discover ways of gradually removing the system from our economy.... If we really want to reach inflation rates of two or three percent—an aim set by the Central Bank as ideal—we are going to have to do away with indexation.[2]

Bankers Trust issued a report in 1993 asserting a similar position:

> BT concludes that tight monetary policies won't be enough to cut inflation significantly. The government could instead abolish the *Unidad de Fomento* (UF), the unit of measure that sets worker salary expectations and also is applied as a variable index to virtually all mortgages, car loans, and government debt securities.

On 14 August 1997, Carlos Massad, president of the Central Bank of Chile, gave a speech at the Latin American meeting of the Econometric Society in Santiago, in which he expressed the opinion that the UF should be phased out in a matter of some years.

In Mexico, spokesmen for the Mexican Businessmen's Council (Coparmex) and the newsletter *El Inversionista Mexicano* (EIM) have already criticized the UDI as being inflationary (see Levin, 1995).

Fortunately, deindexation does not seem likely to involve scrapping the indexed units of account any time soon. In Chile, for example, deindexation in the short run may mean little more than lengthening the maturities of nonindexed debt from the very short maturities that currently predominate to something intermediate.

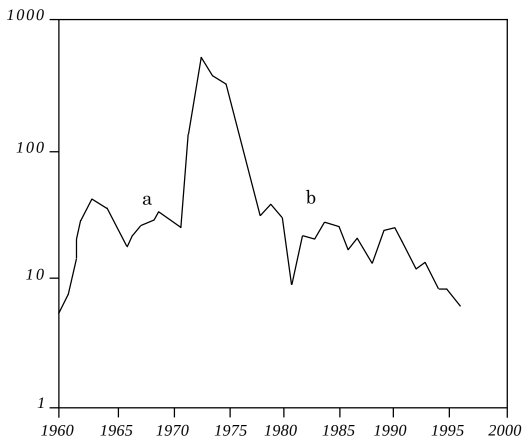
1. "The Counterweight of an Indexed Economy," *La Nación,* 1 November 1996.
2. "The Counterweight of an Indexed Economy," *La Nación,* 1 November 1996.

Dealing with the Inflationary Bias Caused by Indexation

Figure 1 plots the inflation rate in Chile since 1960. Point A marks the date 1967, when the *Unidad de Fomento* was first introduced. Point B on the figure marks 1982, when the *Unidad de Fomento* first became commonplace (roughly speaking). The figure gives no evidence that the introduction of the UF was inflationary.

Still, the concern is legitimate that any indexation scheme for wages and salaries may contain an inflationary bias. When one indexes wages and salaries, one immediately sets expectations. In contrast, when wages or salaries are set in currency units, inflation naturally erodes real buying power. The natural base of comparison for wage and salary changes is thus one of declining real value. If indexation causes wages and salaries to be defined in such terms that the base of comparison is constant or growing in real terms, then worker expectations will tend to rise. This may trigger a vicious cycle, in which inflation expectations yield higher prices and then even higher expectations. This vicious cycle is part of the neostructuralist model of inflation in Latin America.

Figure 1. Annual Inflation Rate in Chile, Based on Consumer Price Index, Annual Data, 1960-96, in Percent



a. Date when UF was created
b. Approximate date when UF became widely used. Log scale is used on vertical axis.

Morandé and Schmidt-Hebbel (1997) find "significant evidence for explicit indexation mechanisms in the behavior of exchange rate depreciation and wage growth, contributing to large observed inflation inertia." Jadresic (in this volume) holds that "unless policymakers are firmly committed to maintaining low inflation, wage indexation to lagged inflation is relatively more likely to increase average inflation." The inflationary impact of wage indexation cannot be summarized so simply, however, since one must consider the alternative to indexation of wages. Jadresic concludes that "wage indexation to lagged inflation can reduce the cost of disinflation if the alternative to indexed wage contracts are contracts that specify preset time-varying wages."

A basic fact of human behavior that is relevant for understanding the impact of indexation is that people are very reluctant to accept a nominal wage cut (see Akerlof, Dickens, and Perry, 1996; Card and Hyslop, 1996). People don't want to have to admit to their families that their wage or salary has been cut. However, economic conditions may sometimes necessitate wage or salary cuts. People seem much more willing to accept real wage cuts caused by consumer price inflation that is greater than their wage increase. Indexed units of account for wage and salary contracts need some kind of humane face-saving mechanism to allow people to deal better with the truth about their incomes.

The face-saving mechanism that I propose is an indexed unit of account that has a slight downward bias, so that over long intervals, wages or salaries that are constant in terms of this unit will decline gradually in real terms; this will be made more concrete below. In countries like Chile, where deindexation is being discussed, a proposal that is more constructive than the proposal to abolish the UF might be to introduce the option of a second UF with a downward bias relative to inflation.

MONEY ILLUSION AND THE NEED FOR INDEXED UNITS OF ACCOUNT

The difference between a government's promoting indexation (such as by setting an example with indexed government debt) and a government's establishing an indexed unit of account might appear to be a very subtle one, little more than a difference in presentation. Indeed, most of the world has not paid much attention to the indexed units of account in Chile and elsewhere, to the extent that some major surveys on indexation published in Chile hardly address the UF (see Sáez, 1982; Morandé, 1996; Landerretche and Valdés, 1997).

However, the difference between an indexed unit of account and a simple indexation scheme is fundamental. It relates to the way people use money or, one might say, to the "moneyness" of the indexed units of account.

Simon Newcomb, an astronomer renowned for establishing a worldwide unified system of astronomical constants, long ago criticized economists who argued that rational people ought to be able to make proper allowances for inflation in their contracts without any special institutions. He argued that money occupies a special niche in people's thinking:

> So far as the investigations of Walker and other economists extend, their reasoning appears to be perfectly sound. We consider, however, that their results are to a certain extent ill founded from the circumstance of their leaving out of sight one of the most important factors of the problem, namely the effect of changes of the standard of living producing a universal deception among the community in respect to the increase or diminution of wealth. This factor is so important as to need very close consideration (Newcomb, 1879, p. 230).

Because of this universal deception, Newcomb argued, people will always be deceived if their contracts are made in terms of currencies:

> All men in this and other countries are accustomed from youth to measure the increase or diminution of wealth by dollars or other denominations supposed to be units of value.... Even when the facts are understood, the idea that the change is in the value of the commodities measured, and not in that of the dollar itself, is so natural that a long and severe course of mental discipline is necessary to get rid of it. Indeed, we question whether the most profound economist can be entirely successful in this respect (Newcomb, 1879, p. 230).

Newcomb proposed what he called the dollar of uniform value, as measured by the average of commodities. He called his proposal a multiple standard of value since it is based on a weighted average price of multiple commodities. He argued, therefore, that the conventional unit of account must be replaced by a unit that is tied to an average of prices of commodities.

Irving Fisher, the most prominent advocate of indexation in the United States, wrote a book entitled *The Money Illusion* about just this inability of people to appreciate the subtleties of price level movements (Fisher, 1928). The term money illusion has been part of economists' vocabulary ever since. Like Newcomb, Fisher advocated a compensated dollar, whose purchasing power would be absolutely constant, so that people would not be hampered by money illusion (Fisher, [1911] 1997, 1913a).

The experimental research of Shafir, Diamond, and Tversky (1997) carefully documents the idea that people do indeed have powerful tendencies to make errors in dealing with inflation and that they tend to want to anchor their decisions in terms of currency units. These authors find not only that people make simple mistakes by failing to take inflation into account in their decisionmaking, but also that people behave as if they really have their preferences in terms of currency units rather than money. They find, for example, that people report feeling better off when their wages are increased (in terms of currency) even if they fully understand that prices have increased just as much.

People have serious problems in learning to adopt indexation schemes. Efforts to start indexed government debt in countries with moderate inflation (including Australia, Canada, Sweden, the United Kingdom, and the United States) have met with a very lukewarm public response (see Campbell and Shiller, 1996). Even in some high inflation countries there is little public use of indexation. In Turkey, where inflation rates have been running in the vicinity of 100 percent a year for years and where inflation has not been below 20 percent a year since the late 1970s, there is still very little indexation. The Turkish government did not successfully introduce indexed debt until 1996, and even then the amounts were very small. Private debt is unindexed, except for some indexed savings accounts created by banks at the urging of the government. Remarkably, alimony and child support payments are usually denominated in the Turkish lira, even though the payments are part of schedules that may last a lifetime. The real value of these payments will clearly be reduced to nearly zero in only a few years. (Recipients of these payments regularly apply to the courts for a modification of the payments, which is a costly and difficult procedure that raises many painful issues.) Why don't they just index the payment scheme?

I recently conducted a study (1999), involving interviews and questionnaires to learn why people in both the United States and Turkey are so little interested in indexation. The results are complex and hard to describe in a short space, in part because it is not easy to characterize people's misunderstanding of economic principles. Money illusion appears to be an important factor in reducing interest in indexation. On rejecting indexation, many people say, “I just want to know how much money I will be getting,” as if they regarded money as an end in itself. This appears to be pure money illusion à la Newcomb and Fisher. As mentioned above, many people will openly admit, if asked, that they feel better about a pay increase in money terms even if they fully understand that prices have risen just as much.

More is at work in inhibiting public interest in indexation, however, than just pure money illusion. One factor identified in my study of the United States and Turkey is that people have incorrect theories about the correlation of inflation with real incomes. There is a widespread belief that inflation coincides with stunning reversals in real incomes of ordinary people. The wage-lag hypothesis, long discredited by economists (see Alchian and Kessel, 1960), is alive and well in the public imagination. This is one reason why alimony and child support payments are usually not indexed in the United States and Turkey: people think that if inflation is high, then an indexed alimony and child support payer would not be able to keep up with the increased payments. People also largely believe that inflation hurts firms' profits as well. The idea that the effects of unforecastable inflation are primarily a redistribution between debtors and creditors is not well understood. Inflation is viewed as hurting everybody (see also Shiller, 1997).

Another important reason why people resist indexation is that people do not appreciate the uncertainty that inflation generates in price levels at distant dates (Shiller, 1999). Even in Turkey, where the price level has drifted over orders of magnitude, people seem not to appreciate the uncertainty about future price levels. When I asked Turkish respondents, on the questionnaire, to give a range in which the Turkish price level would probably fall in ten years, the median ratio between the high and low limits of the range was 1.5 to 1. This must be a grotesque understatement of the uncertainty about future price levels. In part, the judgment error probably arises because the media do not give much attention to the true uncertainty that price levels have over long periods. Another factor is the difficulty that the public apparently has in understanding the power of compounding. Even in countries with low inflation, people just haven't thought about how much difference it makes over long time spans if, for example, the inflation rate is 2 percent every year versus 6 percent every year. These differences do not sound like very much, but in fact the difference in real values of fixed cash payments between these two inflation rates is in the ratio of 1.47 to 1 in ten years and 2.16 to 1 in twenty years.

Indexed units of account, such as the UF in Chile, solve deep and ingrained problems that people have in taking account of the effects of inflation. These units help promote indexation where it would not otherwise occur, or where it would occur only haphazardly or incompletely.

Coordination Problems and Indexed Units of Accounts

The creation by some authority like the government of an indexed unit of account may also solve a sort of coordination problem that otherwise would inhibit indexation. A coordination problem appears when there is an advantage to everyone taking some action together (like adopting some form of indexation) but the actions are not as beneficial when taken individually. If no steps are taken to help people coordinate, then the actions may never be taken. Coordination problems are central to monetary theory. Indeed, the medium of exchange function of money itself may be regarded as helping deal with the coordination problems that would arise when, in a barter economy, people have difficulty locating a double coincidence of wants.

Coordination problems can be solved by social conventions. We all drive on the right-hand side of the road, for example. It wouldn't matter if we all drove on the left-hand side of the road, but it would be a disaster if half of us chose one side and half the other. Once a social convention is established, the coordination problem is solved and people have little or no incentive to change it.

Why don't people in the United States quote prices in CPIs in the absence of any government initiative to create indexed units of account? People could name the price of a product as, say, ten CPIs, meaning that they will charge in dollars ten times the latest CPI. The reason people do not may have to do, in part, with a coordination problem of deciding together that we will do this. Until such a decision is made, individuals will not find it in their individual interest to try to convince people to take the other side of indexed contracts.

Until there is a social convention on how and when to index, people will find it costly to try to come to an agreement on indexation. There are many questions. On what date does the price change? Which CPI should be used? (There are many definitions available.) What do the economists who compute the CPI think about which unit should be used? At present, in countries where no indexed unit of account exists, each person must answer these questions alone. It is thus not surprising that there is no tendency to quote prices in CPIs.

Another coordination problem involves smoothing the CPI. Prices should not be defined only in terms of the latest CPI because the CPI is vulnerable to sudden jumps from month to month. This is particularly true in the case of indexing financial contracts to the CPI. A unit of account like the UF would smooth out the CPI movements. Otherwise, there would be important jumps in deposit balances on the dates of new announcements of the CPI. Smoothing the CPI has thus been another fundamental aspect of the functioning of the UF as an analogue of money.

WHY SEPARATE THE UNIT OF ACCOUNT FROM CURRENCY?

What is the point of separating the medium of exchange and store of value functions, which are carried out by currency, from the unit of account function, which is effected through the *Unidad de Fomento* and other examples? Many argue that the reliance on indexed units of account like the UF is nothing more than a sign of failure to maintain the currency unit in constant buying power, and that what the authority really should do is just stop inflation dead.

Irving Fisher (1913a) thought that keeping an indexed unit of account separate from the medium of exchange would not be sensible partly because of "laborious calculations in translations from the medium of exchange into the standard of deferred payments and back again." This argument is reminiscent of the arguments made today for the common currency in Europe, by people who are tired of the currency exchanges that they must make whenever they cross a border. Making these exchanges, and also making calculations between the indexed unit of account and the currency, may seem unnecessarily complicated. It is perhaps for this reason that the UF is not used to quote everyday prices in Chile.

The inconveniences generated by keeping a separate unit of account are not really large. In this age of computers, the complications created by the need to calculate how many pesos corresponds to a UF, or the calculations necessary for currency exchanges, can hardly matter. Indeed, the distinction between the currency and the separate unit of account will inevitably become blurred once credit card companies allow charges to be made directly in the units of account and banks allow checks to be written in terms of the units of account. (This has not happened yet, as far as I have been able to determine.)

Still, keeping the indexed unit of account separate from the currency does involve some slight inconveniences, and so one naturally asks, why not merge the two? Why not just keep the price level steady? The problem with this solution is that the history of inflation around the world does not create any optimism that it is possible to stop inflation dead, at least without some kind of fundamental structural institutional change. In the course of history inflation has often been temporarily stopped, but producing lasting price stability, over many decades, has proved illusive. While economists have proposed other schemes for achieving automatic price stability (notably Hall, 1983, 1997), there is no guarantee that such schemes will fully succeed in their objective. If these alternative schemes are not sure to succeed, it may be better for all longer-term contracts to be defined in terms of a unit of account, which is itself a proxy for a price index, so that the indexation cannot fail.

Simon Newcomb (1879) and Irving Fisher ([1911] 1997) thought they had a mechanism whereby an indexed unit of account could also be a medium of exchange and store of value. They believed they could achieve just this by defining the currency itself as an indexed unit of account. In effect, they wanted to print pieces of paper called UF and use these as money. Newcomb and Fisher were writing at the time of the international gold standard. Any government could merely promise, they argued, to regularly adjust the quantity of gold in its currency so that the real buying power of the gold represented by the currency was kept constant. This proposal became known as the compensated dollar plan after it was published by Irving Fisher (1913a).

There is a potential difficulty, however, in the government's efforts to maintain a compensated dollar. In order to guarantee that the real buying power of the compensated dollar is constant, the government must promise to make the currency freely convertible into gold and back at all times. The problem then, as recognized by Irving Fisher, is that speculators might be able to make large trading profits at the government's expense. As Fisher (1913a) pointed out, if the mint price were \$18 per ounce and if it were known that the mint price would shortly be \$18.50 per ounce, then speculators could redeem their dollars into gold and buy back their dollars at \$18.50. If the buying power of the currency is indeed to be kept steady, then the price index on which it is based must include the prices of many things that are not traded on speculative markets. Notably, it must include the price of services. Any price index that includes these will almost surely be serially correlated, forecastable into the future. If the buying power of gold falls far enough, the government could find itself obligated to pay out more gold than it has. Given this possibility, public fears that the compensated dollar plan may have to be abandoned could force abandonment of the plan.

Fisher's proposed solution to this problem is that the government would impose a 1 percent bid-asked spread when exchanging gold for compensated dollars, and that the maximum movement of the gold content of the dollar would be 4 percent per annum. This would help prevent speculation, he said. It would also make the buying power of the dollar unresponsive to large changes in the price of gold. Fisher wrote an article (1913b) in which he presented simulations with actual historical data for the period 1896-1911, indicating that speculation and the limit on the change in the gold content would not have been an important problem. He points out that as long as the bid-asked spread, or brassage charge, exceeds the maximum allowed monthly change in the gold content of the dollar, there is no riskless arbitrage profit to be obtained by buying and redeeming dollars over a zero time interval (actually overnight) at month end. Any attempt to profit from the predictable changes in the gold content would then involve some risk, and so presumably such attempts would be limited in importance. Despite the success of his simulations for that period, however, the potential fluctuations in the buying power of gold could be large enough to cause the formula value of the dollar to fluctuate beyond 4 percent in a year, and this possibility suggests serious problems with the compensated dollar plan. Note, for example, that the buying power of gold doubled between 1979 and 1980 and then fell back nearly to its 1979 level by 1982. Fisher's simulations do not address the full complexity of the problem of speculation with the compensated dollar, a problem that involves such issues as the simultaneous determination of the real price of gold and the money supply with public expectations both of future changes in the gold content of the dollar and of the probability of the event that the compensated dollar plan will be suspended.

Fisher's proposals generated much discussion, among both academics and the general public. Fisher reports a list of 344 articles about his idea, many of them critical (Fisher, [1914] 1997). The story of the campaign for the compensated dollar, or the Fisher plan, is recounted in Fisher (1934, appendix I, pp. 374-89). He found much opposition to his proposal, apparently mostly misinformed, but nonetheless effective in preventing its serious consideration. He later abandoned the proposal without disavowing it: "I had never believed that the compensated dollar plan was the only possible plan, nor even ideally the best.... I am therefore still in favor of it for America, as part of a general plan, although, for simplicity, the method recently adopted in Sweden (a managed currency independent of gold) seems better." (Fisher, 1934, p. 382). He seems to have grown tired of his campaign for a compensated dollar, given the difficulty of convincing the public of its merits, and his attention was distracted by other plans. The significant risks of inflation with the new managed currency independent of gold were not so apparent at the time as they are now, and so the relative attractiveness of the compensated dollar plan was not so prominent.

Fisher's original plan for a compensated dollar defined in terms of gold might possibly be workable today, but it seems to involve more uncertainties as to its ultimate success than are associated with the use of indexed units of account. At this stage in history, of course, there is no reason to return to a monetary system that creates any special function for gold. The potential problems of speculation in the currency-gold ratio, to which Fisher alluded, are shortcomings of the compensated dollar plan. In the age of computers, keeping the unit of account separate from the medium of exchange is not such a problem as it was in Fisher's day. Given the apparent difficulty of guaranteeing the real value of currency, contracts can instead be written in terms of price indexes themselves, that is, in terms of units of account, leaving the medium of exchange function for conventional money.

Should Indexed Units of Account Be Settled on Nominal Income Indexes as Well as on Consumer Price Indexes?

While the Chilean example illustrates the use of a single indexed unit of account in a country, there may be reasons to adopt multiple units of account. I have in mind here creating an additional unit of account, beyond the CPI-based unit of account, that is related to a measure of national economic prosperity, such as personal income.

Indexed units of account were first developed in Chile to solve a pressing problem of high inflation. At that time, it would not have mattered very much, compared to the magnitude of the problem of existing nominal contracts, whether the units were denominated in terms of a consumer price index or in terms of nominal income. It was probably natural to create them in the simplest, most direct way possible, so as to facilitate public acceptance. Public acceptance of the UFs was not assured, and it did not come immediately. The concept of the UFs could be explained more easily in terms of a price index than in terms of nominal income indexes.

The problems caused by tying the UF to the consumer price index in Chile have not gone unnoticed, however. Critics of the UF in Chile have said, for example, that the UF causes problems for mortgage lenders in periods of high inflation, since the UF-denominated mortgages are adjusted daily, whereas salaries are denominated in pesos and are adjusted annually (see Bernardez, 1996).

While some appear to think that this problem should be solved by deindexing, this is not at all a reason to eliminate the indexed units of account. It is, rather, a reason to define additional units that are related to income measures. A number of policymakers have recognized this point. In fact, in 1960 the Chilean government created an indexed unit of account, called the *Unidad Reajustable* (UR), that depended on both wage and price indexes. Although the effort apparently was not very successful, when the UF was created in 1967 there were two indexed units of account simultaneously in use in Chile, namely, the CPI-based UF and the wage-CPI-based UR. Moreover, the Chilean government drafted a bill in 1991 "that would establish a new, optional mechanism for adjusting mortgages by linking them to wages rather than the inflation rate."[3] While a wage-indexed unit of account never got far in Chile, Uruguay did establish a wage-based indexed unit of account, also called the *Unidad Reajustable* (UR), which is in use there today.

When indexed units of account are established in times and places characterized by moderate inflation, then the relative importance of getting the index right becomes central. By moderate inflation I mean the 1 to 5 percent inflation that is common in many countries of the world today, which is small on a year-to-year basis, but large and variable enough to create substantial uncertainty over longer periods.

In an extreme case in which the problem of inflation is utterly solved, such that no inflation ever occurred at all, there would be no need of indexed units of account tied to inflation itself. In this extreme case, however, there may still be a role for indexed units of account tied to income measures.

The importance of creating an optional mechanism for indexing to some income measure such as wages goes far beyond the issue of

3. "Bill Seeks Mortgage Link to Wages, Not Inflation," Lagniappe Letter, May 3, 1991 (via Latin American Information Services).

mortgage loans. In fact, creating units of account tied to some such measure is central to the fundamental problem of individuals' optimal risk management.

Life Cycle Savings

The overlapping generations model is a useful construct for considering what kind of intertemporal contracts ought to be made and how these should be indexed. This analysis is inspired by Fischer (1983), Merton (1983), and others.

First, consider some rudimentary examples. To simplify exposition, suppose that there is no population growth, such that all generations have the same number of individuals. The population is represented as belonging to either of only two generations, and only the young earn income. Suppose also that the utility is additively separable and that future income is uncertain. Then, utility is

$$U = u\left(c_y\right) + \delta u\left(c_0\right) ,$$

where c_y is real consumption while young and c_0 is real consumption while old, u(.) is an instantaneous utility (or felicity) function, and δ is a discount factor representing the subjective time preference that people have. Suppose also that there is no storage or investment, and that there is a social planner who wishes to reallocate the income in each time period between the two generations that are alive at the time.

Since the two generations have the same number of individuals, and since the utility function is additively separable, the social planner at time *t*, who has just learned the level of per capita income y_t at time *t*, must merely allocate the total income to maximize the utility function where, however, the consumption is the consumption of different people alive at the same time. The social planner needs only solve the problem,

$$\operatorname*{Max}_{T_t} u\left(Y_t - T_t\right) + \delta u\left(T_t\right) ,$$

where T_t is the transfer from young to old at time *t*. The issue is how this transfer depends on Y_t. Consider the constant relative risk aversion utility function $u(c) = -c^{(1-\gamma)}$ that has been widely used in empirical literature as a sensible representation of people's utility. Then the optimal transfer is

$$T_t = \frac{Y_t}{\left(1+\delta^{-1/\gamma}\right)} \ .$$

The transfer is thus directly proportional to income. This means that the optimal redistribution would be indexed to income (namely, nominal income measured in currency) and not to the consumer price index. The same redistribution could be achieved in terms of a social contract based on an indexed unit of account that is tied not to the consumer price index but to total income. This transfer could be effected if young people buy government bonds that pay out in units of account indexed to income (for example, to save for their retirement), and at the same time they are taxed (credited) by the government for any shortfall (surplus) in making the transfer to the then-old people.

For the above model, table 1 shows the welfare loss, as a fraction of income, that is effected by indexing the units of account to the consumer price index rather than to income, where feasible. Note the words, where feasible. In considering any scheme of indexing payments to the elderly, it must be recognized that in some states of the world it will not be easy—and perhaps not even possible—to make the fixed real payment to the elderly, if national income is not large enough to make the payments. Indexed social security plans do not actually provide fixed real payments in all states of the world, even if that is what is promised. Analyzing such social security plans is a bit like analyzing so-called fixed exchange rates: everyone knows that the

Table 1. Simulated Optimal Fixed Real Transfers from Young to Old[a]

Standard deviation	*Optimal transfer*	*Welfare loss*
0.100	0.477	0.008
0.200	0.436	0.025
0.300	0.400	0.039
0.400	0.373	0.042

Source: Author's calcuations.
a. Based on a Monte Carlo simulation as described in text, assuming a coefficient of relative risk aversion of 3.00, with zero subjective discount rate, and an iid lognormal distribution for generational incomes, with zero mean and standard deviation shown. Transfers are capped at 70 percent of income and represent the fraction of expected income and welfare loss from maintaining capped fixed real transfers instead of income-related transfers in an overlapping generations model.

exchange rates will in fact be changed if extreme conditions prevail. For the purpose of constructing table 1, I assumed that if the fixed real transfer to the old generation were more than 70 percent of total income available, then the transfer would be capped at 70 percent of total income.

It is assumed for this table that the income of each generation has the same lognormal distribution with zero mean of log income; values are shown for various assumptions about the standard deviation of log income. The table assumes that the transfer made in the consumer price indexed case (so that the real transfer is constant unless it is greater than 70 percent of total income) is the optimal one that maximizes expected utility. A Monte Carlo experiment with 100,000 iterations was used to derive the table, since analytical expressions for the values are not obtainable.

The table shows, for example, that the welfare loss from fixing the amount transferred subject to feasibility is about 4 percent of total income in the case in which the standard deviation is 0.3 or 30 percent. (A standard deviation of 30 percent for real national income in 30 years is not an unreasonable estimate of the uncertainty, given evidence on the variability of national incomes. See Shiller, 1993.) A welfare loss of around 4 percent indicates a very substantial advantage to tying payments to income, given the virtually zero cost of creating indexed units of account.

The above analysis assumes a constant relative risk aversion utility function. One might, as an alternative, suppose that the utility function is not of the constant relative risk aversion variety, but rather is constant absolute risk aversion, that is, exponential utility $u(c) = -\exp(-\lambda c)$. In the context of the above model, the optimal transfer from young to old is then

.

Now, the optimal transfer has both a component indexed to nominal income (whose real value Y_t appears in the first term) and a component indexed to the consumer price index (whose real value is represented by the second term). For reasonable values of the parameters δ and λ, the first term is likely to dominate. In fact, it is not clear that there are any reasonable' parameters for the exponential utility; this utility function has the odd property that negative consumption while young is not only possible, but also no disaster.

A utility function that implies that the transfer between generations should be defined in fixed real terms would have the younger generation infinitely less concerned with income fluctuations than is the older generation:

$$U = u\left(c_0\right) + c_y \ ,$$

where $u(c_0)$ is concave, while U depends linearly on c_y. With this utility function, young people again are not particularly concerned with the possibility of negative consumption. It is hard to imagine why there should be such a sharp distinction between the attitudes of the young and old toward poverty.

This simple overlapping generations model deals only with transfers between generations, but the basic principles that it illustrates can obviously be extended to other models. Just as there is an advantage to defining a social security system to tie payments to incomes, there will be an advantage to defining all sorts of payments specified in long-term contracts to income-indexed units of account.

Monetized Indexed Units of Account

As indexed units of account become increasingly accepted, there may come a day when institutions are developed that allow all prices or incomes to be denominated in terms of indexed units of account and all exchanges made in terms of the units. I will call the units in such an arrangement monetized indexed units of account, because although they are not really money, they have the appearance of money in that all transactions are made in terms of the units.[4]

In contrast to Newcomb's or Fisher's day, the use of indexed units of account could now be made so easy, through the use of debit card, credit card, or electronic transfer systems, that the presence of the medium of exchange itself might become virtually invisible to most people. Money might be seen only in the account balances representing the individual's cash budget constraint, although even these balances could be translated daily into indexed units of account. Money may

4. My use of the term monetized is different from the usual sense in economics, since the units will still have to be translated into money by the clearing house for transactions.

then have importance only for account balances and at the clearing house for transactions.

The question arises: how can the price or income index that defines the indexed unit of account then be computed? One may be concerned whether it would be possible to define a price or income index to serve as the basis of an indexed unit of account if all prices are quoted in terms of the same unit. This concern appears to be misplaced. There is no problem in defining a consumer price index or an income index in terms of money, the ultimate medium of exchange, even if all prices or incomes are specified in terms of an indexed unit of account. Because the money equivalent of the indexed unit of account at time t is known at time t, based as it is on lagged information, the prices or incomes quoted in terms of the indexed units of account can always be converted into money terms. Therefore, the consumer price index or income index can always be computed.

One may then wonder how changes in the supply of or demand for money, the medium of exchange, will find their way into the price level, if all prices are specified in terms of indexed units of account. Here again, there appears to be no cause for concern. Whenever there is an excess supply of the medium of exchange, for example, the immediate effect should be an increase in some prices expressed in terms of the indexed units of account. Those prices that are relatively less sticky should be affected first. Their price rise should then cause an increase in the price or income index, which would then effectively communicate the price increases to the currency value of the indexed unit of account itself. Ultimately, as the consumer price index or income index moves toward its new equilibrium value, these less sticky indexed unit of account prices can return to their original values, all the adjustment being incorporated by the exchange rate between the indexed unit of account and the currency. An example of such an adjustment process is given in Shiller (1999).

Defining Indexed Units of Account for the United States

A table that defines two indexed units of account for the United States, units which I call units of price (UP) and units of income (UI), and gives their conversion into U.S. dollars is now available on a daily basis on my web site, www.econ.yale.edu/~shiller/uf-usa4.html. Both are based on government statistics, so the underlying data are likely to be available for the foreseeable future. Since the formulas defining the units (formulas used to construct the tables) are also provided on my web site, these would appear to be usable indexed units of account at the present time. It is, of course, unlikely that many people will use my units. I present them here by way of illustration and example, with the hope that the U.S. government will someday define such units.

The unit of price is based on the U.S. consumer price index, and it is closely analogous to the Chilean UF. This unit might be used to price houses, rents, catalog items, and other items that sell slowly. Pricing in terms of the unit of price means that the price would stay roughly constant relative to a broad market basket of consumer items.

The unit of income is based on growth-corrected per capita personal income. The growth correction divides the per capita personal income by a growth trend line. The growth correction is included here to deal both with possible upward biases in the index as a measure of individual income growth and with the psychological resistance to nominal wage cuts (see Shiller, 1999). This unit might be used, for example, to specify annuity or mortgage payments or for labor contracts. Specifying payments in terms of the unit of income ensures that the payments will be roughly a constant fraction of per capita personal income.

Of these two indexed units of account, the unit of price, rather than the unit of income, might be most readily accepted by the public, since it is tied to a consumer price index as in the Chile case. There is widespread public appreciation of the importance of inflation, and so the public needs much less convincing when the index is tied to the usual measure of inflation, namely, the consumer price index. That an income index may also be used for much the same purpose may not be so obvious to many people. There appears to be less public appreciation of real national income variations than of inflation variations through time. Still, it seems likely that if the two units of account are introduced together, and if people see these two as parallel alternatives, then substantial numbers of people will find ample reason to use the unit of income in appropriate circumstances.

Conclusion

Governments of all nations of the world should create indexed units of account for their citizens. It is virtually costless for them to do so.

All the governments need to do is decide on a price and income index, decide on a smoothing method, begin publishing daily values for the unit of account in terms of currency, and make some commitment that the index will continue to be calculated on a consistent basis and without future freezes or other interference. It is also possible that the indexed unit of account could be created by some other agency that can commit to continuing to produce the index in the indefinite future (as in Brazil, where production of the consumer price index was privatized after concerns were expressed about government mishandling of the statistics). Still, some government involvement in establishing the index is probably important for its success. The introduction of the units of account might also be accompanied by policies encouraging the creation of institutions, such as debit cards, credit cards, and checking accounts, that are designed to facilitate quoting everyday prices in terms of the units of account.

To summarize briefly the arguments given above for indexed units of account, the creation of indexed units of account might be considered similar, in a sense, to the creation of daylight savings time (although the units of account are likely to be much more important in economic significance). Technically speaking, if everyone were perfectly rational, there would be no need to set our clocks forward one hour in the summer; we could all just decide to get up an hour earlier. But everyone knows that will never happen. One reason is that there is a coordination problem in getting people to start their business an hour earlier. Coordination problems appear if people in some workplaces arrive at work earlier while their clients and suppliers do not. By analogy, people could just decide to raise all deferred payments in keeping with inflation, just as they could all decide to get out of bed an hour earlier, but if some do this and some do not, or if some use one price index formula and some use another, then a coordination problem will arise here, too. Another advantage of daylight savings time goes beyond the coordination problem. There is the problem of human habit, of looking at the clock and unthinkingly deciding that it is time to do this or that. The advantage to daylight savings time, as opposed to making a collective decision to do everything an hour earlier in the summer, very plainly has something to do with the persistence of such habits. The same advantage is created by indexed units of account. Just as there was apparently no collective decision to change the times of most daily activities seasonally in the years before daylight savings time, the alternative to the indexed units of account is really a lack of consistent indexation or, more probably, no indexation at all. And with no indexation, the ability to make long-term contracts itself will suffer.

The alternative to the indexed units of account is essentially the same system of fiat money and nominal pricing and contracts that most of the world has experienced since the 1930s. While it has not been a disaster, this system has an absurd quality to it. People make contracts in terms of pieces of paper whose value is ultimately decided by political bodies with vague instructions to promote the general welfare, who have succumbed to political pressures in the past by abandoning their concern for the real value of those pieces of paper. People who are owed money normally have no legal recourse if the real value of the amounts owed is wiped out. Such a system would appear to have been invented by a prankster, who wanted to keep surprising people and stirring up discontent. In viewing the deindexation proposals, one wonders, why would anyone want to return to such a system?

The current move toward deindexation in many countries that had formerly experienced hyperinflation is perhaps motivated in part by the feeling that the indexation was a palliative introduced to deal with an extreme crisis. Now that the crisis is past, it may be reassuring to many to see the indexation ended. I think that the history of the development of indexation, and of the indexed units of account in particular, should have another interpretation. The indexation and the indexed units of account were indeed begun in times of great stress, but the same is true of many other great innovations. Daylight savings time, for example, was introduced during World War I, as an effort to deal with a wartime energy shortage. Such innovations should be viewed as a blessing stemming from an otherwise stressful time, and the system of indexation should not be dismantled in times of lower inflation. The United States does not have much indexation, and has never experienced the indexed units of account, for example, because it has never, in modern times, had the experience with high inflation that might have shaken it from its complacency about nominal contracting.[5]

5. That is, the Unites States has not had really high inflation since the Revolutionary War in the late eighteenth century. It is interesting to note that the very first indexed bond issue in world history occurred in the United States in 1780; see W. Fisher (1913).

References

Alchian, A., and R. A. Kessel. 1960. "The Meaning and Validity of the Inflation Induced Lag of Wages behind Prices." *American Economic Review* 50(4): 43–66.

Akerlof, G., W. Dickens, and G. Perry. 1996. "The Macroeconomics of Low Inflation." *Brookings Papers on Economic Activity* 1: 1–76.

Bankers Trust. 1993. "Chile: Focus on Inflation." *Bankers Trust Research* (July 14).

Bernardez, C. 1996. "Chile's Unidad de Fomento." *Derivatives Week* 5(29): 7.

Bikhchandani, S., D. Hirshleifer, and I. Welch. 1992. "A Theory of Fashion, Custom, and Cultural Change." *Journal of Political Economy* 100(5): 992–1026.

Bordo, M. D., and A. J. Schwartz. 1989. "The ECU—An Imaginary or Embryonic Form of Money: What Can We Learn from History?" In *The ECU and European Monetary Integration,* edited by P. DeGrauwe and T. Peeters. London: Macmillan Press.

Campbell, J. Y., and R. J. Shiller. 1996. "A Scorecard for Indexed Government Debt." In *NBER Macroeconomics Annual*, edited by B. S. Bernanke and J. J. Rotemberg, 155–288. MIT Press.

Card, D., and D. Hyslop. 1996. "Does Inflation Grease the Wheels of the Labor Market?" In *Reducing Inflation: Motivation and Strategy,* edited by C. Romer and D. Romer. University of Chicago Press for the National Bureau of Economic Research.

Cipolla, C. M. 1956. *Money, Prices and Civilization in the Mediterranean World: Fifth to Seventeenth Century.* Princeton University Press for University of Cincinnati.

Einaudi, L. 1953. "The Theory of Imaginary Money from Charlemagne to the French Revolution." In *Enterprise and Secular Change,* edited by F. C. Lane and J. Riemersma. Homewood, Ill.: Richard D. Irwin, Inc.

Fischer, S. 1983. "Welfare Aspects of Government Issue of Indexed Bonds." In *Inflation, Debt and Indexation,* edited by R. Dornbusch and M. H. Simonsen. MIT Press.

Fisher, I. [1911] 1997. *The Purchasing Power of Money*. In *The Works of Irving Fisher,* edited by W. J. Barber, vol. 4, London: Pickering and Chatto.

————. 1913a. "A Compensated Dollar." *Quarterly Journal of Economics* 27 (February): 213–35.

———. 1913b. Appendixes I, II, and III in "A Compensated Dollar." *Quarterly Journal of Economics* 27: 385–97.

———. [1914] 1997. "Objections to a Compensated Dollar Answered." *American Economic Review* 4: 818–39. In *The Works of Irving Fisher,* edited by W. J. Barber, vol. 4, London: Pickering and Chatto,

———. 1928. *The Money Illusion.* New York: Adelphi Company.

———. 1934. *Stable Money.* New York: Adelphi Company.

Fisher, W. 1913. "The Tabular Standard in Massachusetts History." *Quarterly Journal of Economics* 27 (May): 417–51.

Hall, R. E. 1983. "Optimal Fiduciary Monetary Systems." *Journal of Monetary Economics* 12: 33–50.

———. 1997. "Irving Fisher's Self-Stabilizing Money." *American Economic Review* 87: 436–38.

Jadresic, E. 2002. "The Macroeconomic Consequences of Wage Indexation Revisited." This volume.

Keynes, J. M. 1930. *A Treatise on Money,* vol. 1. New York: Macmillan.

Landerretche, O., and R. Valdés. 1997. "Indización: historia chilena y experiencia internacional." Working Paper 21. Santiago: Banco Central de Chile.

Levin, B. F. 1995. "Working through the Web with UDIs." *Business Mexico* (June). Mexico City: American Chamber of Commerce of Mexico.

Merton, R. C. 1983. "On Consumption Indexed Public Pension Plans." In *Financial Aspects of the United States Pension System,* edited by Zvi Bodie and John Shoven, 259–89. University of Chicago Press for the National Bureau of Economic Research.

Morandé, F. G. 1996. "Indización financiera, ahorro privado e inercia inflacionaria: el caso de Chile." Ilades/Georgetown University.

Morandé, F. G., and K. Schmidt–Hebbel. 1997. "Inflation Targets and Indexation in Chile." Paper presented at the International Conference on Indexation, Inflation, and Monetary Policy, Santiago. Banco Central de Chile.

Newcomb, S. 1879. "The Standard of Value." *North American Review* (September): 223–37.

Polit, L. 1994. "Ecuador: Ecuador's Stock Market; Latin Equities Directory." *Latin Finance* (April).

Rolnick, A. J., and W. E. Weber. 1986. "Gresham's Law or Gresham's Fallacy?" *Journal of Political Economy* 94(1): 185–99.

Sáez, R. E. 1982. "Evolución de la indexación en Chile." Notas Técnicas 49. Santiago: La Corporación de Investigaciones Económicas para Latinoamérica (March).

Shafir, E., P. Diamond, and A. Tversky. 1997. "Money Illusion." *Quarterly Journal of Economics* 112(2): 341–74.

Shiller, R. J. 1993. *Macro Markets: Creating Institutions for Managing Society's Largest Economic Risks.* Oxford University Press.

———. 1997. "Public Resistance to Indexation: A Puzzle." *Brookings Papers on Economic Activity* 1: 159–211.

———. 1999. "Designing Indexed Units of Account." NBER Working Paper 7160. Cambridge, Mass.: National Bureau of Economic Research.

Optimal Management of Indexed and Nominal Debt

Robert J. Barro
Harvard University

In standard macroeconomics, fiscal policy involves choices about expenditures, taxes, and debt issue. The different kinds of public spending may be distinguished with respect to their interactions with private decisions. For example, some public activities influence private production and some interact with households' choices of consumption and leisure. Taxes may also be differentiated by types; levies may fall on labor income, capital income, consumption, bodies, and so on.

The fiscal authority also chooses its type of debt obligations. These decisions include the maturity structure of the debt, whether to issue nominal bonds or bonds indexed to either the price level or a foreign currency, whether debt payments should be contingent on other variables such as government expenditures and the state of the business cycle, and so on. These kinds of decisions are less familiar to macroeconomics, although some aspects have been studied by Lucas and Stokey (1983); Persson and Svensson (1984); Bohn (1988, 1990); Calvo and Guidotti (1990); Alesina, Prati, and Tabellini (1990); Giavazzi and Pagano (1990); Chari, Christiano, and Kehoe (1994); Missale and Blanchard (1994); and Marcet, Sargent, and Seppala (1996).

Optimal debt management can be conceptualized in three stages. First, if taxes are lump sum and the other conditions for Ricardian equivalence hold, as in Barro (1974), then the division of government financing between debt and taxes is irrelevant. Thus the whole level of public debt will be indeterminate from an optimal-tax standpoint. Second, if taxes are distorting—for example, because the amount paid depends on an individual's labor income or consumption—then the timing of taxes will generally matter, as in Barro (1979). This consideration tends to motivate smoothing of tax rates over time and thereby can make determinate the levels of debt at various dates. However, this element does not pin down the composition of debt,

Indexation, Inflation, and Monetary Policy, edited by Fernando Lefort and Klaus Schmidt-Hebbel, Santiago, Chile.

say, by maturity. Finally, if there is uncertainty about levels of public outlay, the tax base (for example, aggregate consumption or GDP), and asset prices, then the kinds of debt that the government issues will matter. In particular, the government may want to smooth tax rates over states of nature, and this consideration may dictate an optimal structure of the public debt. For example, it may be desirable for debt payouts to be conditioned on the level of government spending, or it may be possible to design the maturity structure of the indexed debt so as to insulate the government's financing costs from shifts in riskless real interest rates.

The strategy in this paper is to assume that the government desires to smooth the path of taxes when confronted by a path of exogenous, but stochastic, outlays. Other analyses, such as Zhu (1992) and Barro (1995), show that this objective can be derived, under some conditions, from the more fundamental objective of expected utility maximization for the representative household. The analysis assumes that policymakers can make effective commitments about the form of future fiscal actions. Hence, unlike Lucas and Stokey (1983) and Persson and Svensson (1984), the debt composition is not set to ensure that policies are time consistent.

1. Public Finance with Tax Smoothing

The real public outlay for period t is G_t. This outlay is exogenous and stochastic. The government sets its real tax revenue for period t at the value T_t. The precise nature of the taxes is left unspecified. However, these levies are assumed to be distorting in such a way that the policymaker wishes to minimize the overall expected deadweight loss, as given from the perspective of an initial date, time 0, by

$$E_0 \sum_{j=1}^{\infty} w_j \left(T_{j+1} - T_j \right)^2 \ , \tag{1}$$

where $w_j > 0$ represents weighting factors. The idea here is that variations in taxes over time cause distortions that the government would like to avoid. This objective will motivate smoothness in T_j across time and states.[1]

1. The form of equation 1 is natural for consumption taxes in the absence of a labor-leisure choice, such that distortions reflect only variations in tax rates over time, not the levels of tax rates. With a labor-leisure choice, terms involving the levels of consumption or labor-income tax rates would also appear. The tax-smoothing behavior considered below is sometimes optimal in this extended setting. See Zhu (1992) for a general discussion of the optimality of tax smoothing.

If one incorporates levies on a tax base, such as income, consumption, or property, then distortions are likely to increase more than in proportion with the amount of taxes when expressed in relation to the tax base. Therefore, T_t and G_t should be construed as ratios to the tax base. Uncertainty with regard to the tax base is analogous to uncertainty with respect to the level of public outlays, and a rise in G_t can be viewed alternatively as an increase in government expenditure or a decrease in the tax base.

Indexed public debt issued at time *t* pays the certain real amounts B_{t1}, B_{t2},… in periods $t + 1$, $t + 2$,…. These payouts can represent coupons or principal. The real market prices of this debt at time *t* are P_{t1}, P_{t2},…. These asset prices are taken to be exogenous and stochastic, although the model could be extended to allow the choices of debt policy to affect the asset prices.

The government will also wish, in this model, to issue debt with payouts that are contingent on the realizations of G_t. The amount of this debt issued at date 0 and due at date *t* can be structured so that it pays off one unit less for each unit by which G_t exceeds its date-zero expectation, E_0G_t.[2] This debt can also be set up so that it pays a (positive or negative) noncontingent amount at date *t*, expressed as $\beta_0 E_0 G_t$. This amount is assumed to be set so that the market value of contingent debt at date 0 is nil. That is, β_0 is the premium (set at time zero) per unit of *G*-contingency. The amount payable in each period *t* on the contingent debt is therefore $\beta_0 E_0 G_t + (E_0 G_t - G_t)$. Since a high G_t represents bad times—because high public outlay and a low tax base will typically be associated with low consumption—and the contingent debt pays off badly at these times, the premium β_0 tends to be positive.

The government can achieve perfect tax smoothing in this model, that is, it can minimize the sum in equation 1 by attaining $T_1 = T_2 = \ldots$. First, the government issues the kind of *G*-contingent debt that has just been described. This issue effectively converts the path of uncertain outlays, G_1, G_2,..., into a path of known outlays, $\hat{G}_1 = E_0 G_1(1+\beta_{01})$, $\hat{G}_2 = E_0 G_2(1+\beta_{02})$,…. This contingent debt issue ensures that the government's tax smoothing will not be disturbed by surprises in the future levels of public outlays (and tax bases).

Second, the government has to manage its noncontingent debt to get the timing of taxes right, in other words, to ensure equal values of T_t even when the certainty-equivalent outlays, $\hat{G}_t$, vary over time.

2. The debt therefore pays off badly when public outlays are surprisingly high or when the tax base is surprisingly low. The latter contingency is analogous to the GDP-linked bonds described by Shiller (1993).

This problem would be simple if the future prices of noncontingent debt, P_{tj}, were known with certainty at date 0, that is, if riskless real interest rates were not subject to fluctuation. In that case, any maturity structure of the noncontingent debt—for example, one-period debt—could be used. The only concern, as in Barro (1979), would be to get the total quantity of debt issue correct in each period. However, this procedure does not work if the P_{tj} are subject to uncertainty. In this case, unanticipated shifts in these asset prices and, hence, in the government's refinancing costs can affect the government's budget constraint and thereby disturb the smoothing of taxes.

The quantities of noncontingent public debt of the various maturities at date 0 must satisfy the constraint

$$\sum_{j=1}^{\infty} B_{0j} P_{0j} = V_0 , \tag{2}$$

where V_0 is the total market value of government debt (plus or minus) outstanding at date 0. This equation says that the government can rearrange its noncontingent debt as it wishes at the going market prices to achieve a desired distribution by maturity.

The government's full outlay for the first period—including the noncontingent payout B_{01} established at date 0—is $\hat{G}_1 + B_{01}$. This quantity is nonstochastic because the uncertainty in G_1 has been hedged by the issue of G-contingent debt. If taxes are successfully smoothed, then the revenue in each period is the same value, T. If there is a gap between the full outlay and revenue in period one, then the difference must be financed by noncontingent debt issue (plus or minus) at the prevailing prices of noncontingent debt, P_{1j}. However, if each of these asset prices contains an independent random element, then any debt issues of this type will cause tax smoothing to fail, because the realizations of the asset prices will have an impact on required levels of future taxes.[3] Full tax smoothing thus requires a balance between full outlay and revenue in period one:

$$T = \hat{G}_1 + B_{01} . \tag{3}$$

Since no new debt is issued and no old debt is retired in the first period, the full outlay for the second period is $\hat{G}_2 + B_{02}$. The same

3. The assumption here is that Ponzi games are precluded and, hence, an effect on the government's budget in any period must, for given public outlays, show up eventually in taxes.

reasoning as that applied to period one implies that this outlay for period two must equal the tax revenue, T. Proceeding forward in time, the conclusion is that the form of equation 3 must hold for every period t:

. (4)

Multiplication of both sides of equation 4 by P_{0t} and summation from $t = 1$ to ∞ leads, after substitution from equation 2, to a formula for T:

$$T = \frac{V_0 + \sum_{j=1}^{\infty} P_{0j} \hat{G}_j}{\sum_{j=1}^{\infty} P_{0j}} . \tag{5}$$

This result says that the constant flow of real taxes in each period equals the permanent flow of spending, which includes the required financing on the initial debt, V_0, plus the permanent flow of outlay. The last quantity weighs each amount $\hat{G}_j$ by the present-value factor, P_{0j}. For example, if the one-period, noncontingent real interest rate were the constant r, such that $P_{0j} = 1/(1 + r)^j$, then

$$T = \hat{G}_t + B_{0t}$$

$$T = r\left[V_0 + \sum_{j=1}^{\infty} \left(\frac{1}{1+r} \right)^j \hat{G}_j \right]. \tag{6}$$

Substituting the result from equation 5 into equation 3 yields the amount of noncontingent debt of each maturity:

$$B_{0t} = \frac{V_0 + \sum_{j=1}^{\infty} P_{0j} \hat{G}_j}{\sum_{j=1}^{\infty} P_{0j}} - \hat{G}_t \quad . \tag{7}$$

Hence, the amount of debt with maturity t is the difference between permanent outlay (including the financing of any initial debt) and the certainty-equivalent outlay for period t.

Suppose, as an example, that each period has the same level of certainty-equivalent outlay, $\hat{G}_t$. In this case, the terms involving the outlays cancel in equation 7, and the quantity of debt for each period is a constant, given by[4]

$$B_{0t} = \frac{V_0}{\sum_{j=1}^{\infty} P_{0j}} \cdot \tag{8}$$

One way to look at this answer, in terms of pure discount bonds, is that the maturity structure of the noncontingent debt has no holes.[5] The government arranges the debt at the outset so that the real amounts to be paid in each future period (up to $t = \infty$) are the same.[6] However, because of the discounting on future real payouts (that is, a declining time path of the P_{0j}), the current market value of the outstanding debt declines steadily with maturity.

From the standpoint of coupon bonds, the government should structure its debt as indexed perpetuities (consols).[7] These issues pay a uniform and perpetual stream of real coupons but have no principal payments.

The prescription for consols may seem to entail a maturity structure of the public debt that is much longer than that observed in practice. When governments issue real bonds, however, the stated maturity and, more pertinently, the average duration of the real payouts tend to be long. For example, when Great Britain was on the gold standard in the eighteenth and nineteenth centuries, nominal obligations were effectively real. At that time, the public debt was mainly long term ("funded") and often took the form of consols.[8] The U.S.

4. If the one-period, noncontingent real interest rate is the constant r, then $B_{0t} = rV_0$.

5. This result on the desirable maturity structure of the public debt therefore differs from the suggestion of Friedman (1959, p. 63): "I can find no valid argument for the present policy of issuing a wide variety of securities.... The alternative suggestion follows.... Issue... debt in two standard forms, one short-term... the other moderately long-term. The short security might be a 90-day bill.... The longer security might best be a consol—that is, a perpetuity.... A less extreme break would be to make it, let us say, an eight- or ten-year maturity. I do not myself believe that the precise maturity of the debt outstanding is of great significance".

6. Alesina, Prati, and Tabellini (1990) and Giavazzi and Pagano (1990) argue on different grounds—to avoid confidence crises—that similar amounts of public debt should come due in each period.

7. Lucas and Stokey (1983) argue that consol debt may also be desirable on time-consistency grounds. In some situations, this maturity structure deters the government from making tax changes that would affect the term structure of real interest rates.

8. See Mitchell and Deane (1962, pp. 401-09).

debt issued under the gold standard before World War I was also primarily long term; for example, most of the U.S. government bonds outstanding in 1916 had remaining maturities in excess of twenty years.[9]

Many developed countries have recently issued indexed bonds, and these securities tend to be long term. For example, the United Kingdom has issued indexed coupon bonds with maturities as long as thirty-eight years, which is nearly infinity. Other countries that have issued coupon bonds include Canada with a thirty-year maturity, Australia with twenty years, and Israel with fifteen years (see Bank of England, 1995). Sweden has issued discount bonds with maturities of nineteen years (the duration of a consol would be nineteen years if the real discount rate were around 5.5 percent). The United States, which began to issue indexed bonds only in 1997, began with a ten-year maturity. More generally, the observed short maturity for public debt in modern times applies mainly to nominal bonds in the context of a paper monetary standard.[10] Nominal debt is considered in a later section.

Returning to equation 7, if the expected outlays differ across periods, then the debt structure no longer consists precisely of consols. A period with a high level of certainty-equivalent outlay would have a correspondingly reduced level of debt coming due. For example, if a war or a major building project were anticipated for period t, then the debt would be structured at date 0 so that little debt would mature during period t. Otherwise, the government would have to borrow a lot in period t at a financing cost that is uncertain at time 0. The practical relevance of this result is unclear, however, because it depends on the government having advance information about the future time pattern of public outlays.

If there were a positive drift in G_t—which has to be interpreted in the model as a drift in public spending as a ratio to GDP or some other measure of the tax base—then equation 7 calls for a negative trend in B_{0t}. The maturity structure of the debt would, in this case, be shorter term than a consol.

If the ratio of public outlay to the tax base had no drift but the levels of government spending and the tax base were each drifting upward (as would be expected with secular growth of the economy), then the optimal B_{0t} would have a corresponding upward drift. Therefore, the maturity structure of the debt would be longer term than a consol.

9. See Board of Governors of the Federal Reserve System (1943, p. 411).

10. The usually stated maturity for nominal bonds overstates the duration not only because of the coupon payments but also because no account is taken of the diminished real value of future payouts due to inflation.

2. A Limitation to Noncontingent Public Debt

A striking property of the previous solution is that the government arranges its debt obligations fully at date 0 and then never issues or buys back debt in subsequent periods. All the government does with respect to debt in future periods is, first, make contingent payments based on the realizations of G_t and, second, make the previously agreed noncontingent payouts (of roughly consol form). These findings rely on the assumption that the government can use G-contingent debt effectively to convert its path of uncertain outlays into a deterministic path. The results would be different if the government were precluded from issuing G-contingent debt. However, the reason for this preclusion would likely not be on technical grounds involving the construction of the appropriate type of instrument. In countries with sophisticated financial markets and in which accurate national-accounts data are available without substantial delays, creating this kind of debt contract would not be a problem.

The likely source of difficulty involves moral hazard: if debt payouts are contingent on the level of public outlay, then the government is likely to overspend, perhaps even to fight too many wars.[11] The government might further be tempted to manipulate the statistics on spending to create the appearance of a contingency that warranted poor payouts on the debt. This problem might be acute because the relevant contingency involves not only the computation of the level of public outlays, but also the scaling of these outlays in relation to some concept of a tax base.

11. Such illustrious economists as Adam Smith and David Ricardo argued that governments have an excessive tendency to fight wars when the available method of war finance is too convenient. In their contexts, the overly convenient method of finance was viewed as debt issue rather than current taxation, but the point about moral hazard is the same. Smith (1791, p. 427) said, “Were the expense of war to be defrayed always by a revenue raised within the year… wars would in general be more speedily concluded and less wantonly undertaken. The people feeling, during the continuance of the war, the complete burden of it, would soon grow weary of it, and government, in order to humour them, would not be under the necessity of carrying it on longer than it was necessary to do so.” Ricardo (1951, pp. 186-87) pointed out that wartime spending could be financed by taxes, borrowing, and borrowing with the establishment of a sinking fund and then commented, “Of these three modes, we are decidedly of the opinion that the preference should be given to the first.… When the pressure of war is felt at once, without mitigation, we shall be less disposed wantonly to engage in an expensive contest, and if engaged in it, we shall be sooner disposed to get out of it, unless it be a contest for some great national interest.” Ricardo clearly copied this idea from Smith, and it is therefore odd that Ricardo went on to point out the economic equivalence of the three methods of paying for government spending (a point that Smith did not seem to recognize).

Suppose then that the government is limited to noncontingent debt, taken here to be indexed bonds of various maturities. It would be technically straightforward to carry out the exercise of smoothing taxes as much as possible in the sense of the objective in equation 1 while limiting the government to the use of noncontingent debt. (For a sketch of this exercise, see, for example, Giavazzi, 1997.) Instead of using indexed debt that was an approximation to a consol, the government would want to exploit any covariance between the future G_t and the future prices of noncontingent debt, P_{tj}. For example, it is likely that a surprisingly high level of public outlay, G_t, would be associated with high riskless real interest rates and, hence, lower-than-expected values of P_{tj}. Moreover, this effect tends to be greater at longer maturities, where asset prices are more sensitive to changes in real discount rates. (This effect also depends on the extent to which a current surprise in G_t signals a long-term change in the level of public outlays.) The likely conclusion is that the government could usefully hedge some of the uncertainty in the G_t by tilting the maturity structure toward more long-term debt and less short-term debt (or even toward the holding of short-term assets). The optimal maturity structure would thus tend to be even more long term than the consol structure derived before.

This kind of analysis would be valid if the rationale for the omission of *G*-contingent debt were technical problems in setting up the right kinds of financial contracts. In this case, it might be desirable to create the *G*-contingency indirectly by exploiting the covariance between G_t and some other variable, such as the P_{tj}, for which contingencies were feasible (in the case above by selecting the maturity structure of the noncontingent debt).

The argument is invalid, however, if—as seems plausible—the main reason for the omission of the *G*-contingent debt involves moral-hazard problems of the sort described above. In that case, the same moral-hazard problem arises when the contingency on G_t is attained indirectly. For example, if the maturity structure of the noncontingent public debt were skewed toward the long end, and if an increase in G_t tended to depress the prices of long-term debt relative to short-term debt, then the government would still have an excessive incentive to spend, including to fight too many wars. (The government would not have an incentive to overstate the statistics on G_t, however, unless the asset prices reacted to the stated values of the G_t rather than to the actual values.)

If the moral-hazard problem is so serious that it motivates the government to explicitly use *G*-contingent debt to a zero extent, then it seems that it would also motivate the government to indirectly use G-contingent debt to a zero extent. That is because the indirect contingency has the same moral-hazard problem but is otherwise less efficient than the direct method. For example, the indirect contingency achieved by skewing the maturity structure of noncontingent debt toward the long end has the problem of making the government's future financing costs sensitive to shifts in P_{tj} that are independent of the movements in G_t. The avoidance of this sensitivity was the rationale for the consol financing in the first place.

Thus my conjecture is that the full solution to the model with moral hazard—when this hazard is sufficient to preclude G-contingent debt issue—is that the government will also optimally avoid the exploitation of the covariance between G_t and P_{tj}. To avoid this exploitation, the government will have to maintain the maturity structure of the indexed debt that was optimal when G-contingent debt was available, that is, the consol-type structure.

Even if the last conjecture is correct, the preclusion of G-contingent debt is important because it implies that the government will have to react to the realizations of G_t by altering the amount of debt outstanding. For example, a surprisingly high level of public outlay, as in a war, will be accompanied by the issue of new consol debt, whereas surprisingly low levels of outlay will cause retirement of outstanding debt. This form of action describes pretty well the observed behavior of the British government over more than two centuries (see Barro, 1987).

3. Nominal Bonds

Suppose now that the government can issue nominal debt with varying maturities. Let b_{0j} be the nominal amount committed in period 0 to be paid in period j and p_{0j} the associated time 0 real market price of these bonds. The real value of the future payouts depends on the realizations of future price levels. Future real prices of the nominal bonds, p_{tj}, depend on the price level for period t and on the prospects at time t for future inflation and real interest rates, which together determine nominal discount rates.

The probability distribution for inflation is treated here as exogenous to the government's fiscal choices, and the distortions caused by inflation are assumed not to interact with those of other taxes. Bohn (1990) also takes this approach.

The stochastic properties of inflation are assumed to reflect some empirical regularities. One of these regularities, applicable to the paper monetary standards of modern times, is that innovations to inflation are highly persistent. In fact, the inflation rate is close to being nonstationary in post-World War II data, say for the United States and the United Kingdom.

Another apparent regularity is that innovations to inflation tend to signal bad times ahead in the long run. U.S. quarterly data from 1957 to 1994 reflect this pattern: the contemporaneous correlation of a measure of unexpected inflation with the real return on the stock market is negative and surprisingly large in magnitude (–0.4).[12] In contrast, the short-term relation between the inflation rate and real GDP tends to be positive; that is, inflation is mildly procyclical.[13]

An additional feature of inflation is its positive correlation with wartime spending, especially for such large conflicts as World War I, World War II, and the Napoleonic Wars (see Barro, 1987). However, for the moderate fluctuations of government spending that show up in the U.S. data since World War II, there is no significant relation between innovations to inflation and movements in government expenditure.

The issue of nominal public debt would be a mistake in the model described at the outset, in which *G*-contingent and indexed debt instruments are available. Unanticipated inflation and unanticipated changes in the future prices of nominal debt cause fluctuations in financing costs, which would create unnecessary variations in taxes and thereby generate some departure from perfect tax smoothing in the sense of the objective in equation 1.

If indexed bonds are unavailable and the government is therefore forced to issue nominal bonds, then the maturity of the nominal debt could be designed to hold down fluctuations in taxes. Since innovations to inflation tend to persist, the prices of long-term nominal bonds would be more volatile than those of short-term bonds. Therefore,

12. The series on expected inflation comes from an autoregression moving average (ARMA) process with deterministic seasonals for consumer price index (CPI) inflation, with the estimated coefficients updated each quarter to use only lagged data. The inflation rate is computed from monthly, seasonally unadjusted values of the CPI for January, April, July, and October. Real stock returns are the growth rate of the Standard and Poor's 500 index less CPI inflation plus the Standard and Poor's 500 dividend yield.

13. The departure of the price level from its trend, however, tends to be countercyclical. See Kydland and Prescott (1990) and Barro and Grilli (1994, pp. 14-15).

the greater the volatility and persistence of inflation, the more the government would shift toward short-term issues to minimize the effect of unanticipated inflation on financing costs.

In the United States, for example, the average maturity of the public debt (weighted by nominal amounts of principal outstanding) fell from around nine years in 1946 to less than three years in 1976, then returned to five to six years in recent times.[14] It seems reasonable that these changes were caused by shifts in the variance of inflation, which was low from the mid-1950s to the early 1970s, high until the mid-1980s, and low again in recent years. Although a shortened maturity of the public debt is a sensible response to more volatile inflation (given that the debt takes a nominal form), this shift also makes the government's refunding costs more sensitive to movements in real interest rates. The whole point of the use of indexed consols in the original model was to leave the government's financing expenses—and, hence, its path of real taxes—invariant with changes in riskless real interest rates. This insulation is eliminated by a reliance on short-term nominal (or real) debt.[15]

Bohn (1988, 1990) and Calvo and Guidotti (1990) argue that nominal debt may be a desirable form of funding because of the covariance of inflation with other variables, such as G_t in the present model. The usual idea is that a high G_t tends to go along with high inflation. This pattern partly reflects the positive correlation between inflation and government spending (especially apparent for large wars) and partly the negative correlation between inflation and long-run economic activity (and, hence, the tax base). Since nominal bonds pay off badly in real terms when inflation is surprisingly high, this kind of debt has some of the characteristics of the G-contingent debt that was considered before. For example, the presence of nominal bonds allows the government to effect partial default via inflation during wartime.

The covariance between inflation and G_t would be of no advantage and would provide no case for nominal public debt issue if G-contingent debt were already available and exploited. However, if this type of debt were precluded, then it might seem worthwhile to issue nominal bonds.

14. See Council of Economic Advisers, *Economic Report of the President* (1966, 1997).

15. The significance of this lost insulation depends on the volatility of riskless real interest rates. From an empirical standpoint, the extent of this volatility can be gauged from the U.K. experience with indexed government bonds. From 1982 to 1995, the two-year-ahead real forward rate (for the subsequent six months) ranged from around 2 to 5.5 percent, whereas the rate twenty years ahead varied from about 2.5 to 4.5 percent.

The gain from the negative covariance of the real returns on these bonds with G_t might outweigh the costs from independent variation in inflation, which would generate volatility in the real returns on nominal debt and thereby adversely affect the stability of real taxes.

The problem with this line of argument is the same as the one that arose in the previous discussion of the maturity structure of indexed bonds. If the reason for the exclusion of G-contingent debt is moral hazard, then this same problem arises for indirectly G-contingent debt. In the previous section, therefore, it did not seem desirable to skew the maturity structure of indexed bonds to create a negative covariance between G_t and the government's financing costs. Similarly, it seems inadvisable to use nominal debt as another way to generate a negative covariance between G_t and financing costs. Nominal debt seems always to be inferior to explicitly G-contingent debt because it entails the same moral hazard but also introduces unnecessary randomness in real financing costs and, hence, in real taxes.

One way to generate a role for nominal government bonds is to assume that the government is already involved with nominal obligations in some other way. For example, the government has nominal monetary obligations outstanding. Surprise increases in inflation (likely engineered by the monetary authority) benefit the government's budget by depreciating the outstanding real cash balances and perhaps by signaling a higher prospective flow of seigniorage income. But then the government would have to hold nominal assets—not debts—to offset this effect and thereby insulate the overall budget situation from surprise inflation.[16] Similarly, if the indexing of government bonds involves a lag in the formula—that is, if the adjustments of nominal coupons and principal are based on lagged inflation—then the government effectively already has some nominal debt outstanding. The way to offset this exposure of real obligations to inflation would be for the government to hold some other nominal assets.

A rationale for a positive quantity of nominal government bonds along these lines would require the government to have other outstanding claims that suffer in real value when inflation is surprisingly high. The tax system can have this feature under some circumstances, especially if liabilities are specified in nominal terms and taxpayers have opportunities for delaying payment to the government. Then the

16. Persson, Persson, and Svensson (1987) argue that insulating the government's budget constraint from surprise inflation can also be desirable on time-consistency grounds, that is, to deter the government from engineering surprise changes in inflation.

nominal public debt could be an instrument that keeps the government's budget constraint invariant overall with shocks to inflation. In this case, however, the previous analysis of indexed and *G*-contingent debt would be fully separable from the behavior of inflation and nominal debt. In particular, the consol form of indexed financing would still be desirable.

4. Concluding Observations

This paper has analyzed public debt management from an optimal-tax perspective. The approach seems inevitably to favor indexed bonds that have long, consol-like durations. One might be able to explain the observed tendency for indexed debt to be shorter term than consols by allowing for the potential of government default.

The analysis suggests little role for nominal government bonds, except perhaps as devices to offset other kinds of nominal exposure that the government possesses. One might possibly go further here by introducing commitment problems into the optimal-tax problem, but it is hard to see how these considerations will favor the use of nominal public debt.

One possible reaction to these results is that the case for nominal government bonds must rely not on orthodox public-finance considerations, but rather on short-run macroeconomics, which is often thought to have something to do with sticky prices. This is reassuring: to understand the desirable role for nominal government bonds one has only to understand macroeconomics and business fluctuations.

References

Alesina, A., A. Prati, and G. Tabellini. 1990. "Public Confidence and Debt Management: A Model and a Case Study of Italy." In *Public Debt Management: Theory and History*, edited by R. Dornbusch and M. Draghi. Cambridge University Press.

Bank of England. 1995. *The U.K. Index-Linked Gilt-Edged Market: Future Development*. Overview papers for the Bank of England conference of September 1995.

Barro, R. J. 1974. "Are Government Bonds Net Wealth?" *Journal of Political Economy* 82 (November/December): 1095-118.

————. 1979. "On the Determination of the Public Debt." *Journal of Political Economy* 87 (October): 940-71.

————. 1987. "Government Spending, Interest Rates, Prices, and Budget Deficits in the United Kingdom, 1730-1918." *Journal of Monetary Economics* 20 (September): 221-47.

————. 1995. "Optimal Debt Management." NBER Working Paper. Cambridge, Mass.: National Bureau of Economic Research (October).

Barro, R. J., and V. Grilli. 1994. *European Macroeconomics*. London: Macmillan.

Board of Governors of the Federal Reserve System. 1943. *Banking and Monetary Statistics*. Washington: National Capital Press.

Bohn, H. 1988. "Why Do We Have Nominal Government Debt?" *Journal of Monetary Economics* 21 (January): 127-40.

————. 1990. "Tax Smoothing with Financial Instruments." *American Economic Review* 80 (December): 1217-30.

Calvo, G., and P. Guidotti. 1990. "Indexation and Maturity of Government Bonds: An Exploratory Model." In *Public Debt Management: Theory and History*, edited by R. Dornbusch and M. Draghi. Cambridge University Press.

Council of Economic Advisers. 1966, 1997. *Economic Report of the President*. The Executive Office of the President. Washington.

Chari, V. V., L. J. Christiano, and P. J. Kehoe. 1994. "Optimal Fiscal Policy in a Business Cycle Model." *Journal of Political Economy* 102 (August): 617-52.

Friedman, M. 1959. *A Program for Monetary Stability*. New York: Fordham University Press.

Giavazzi, F. 1997. "Comments on Optimal Funding Policy." In *The Debt Burden and Its Consequences for Monetary Policy*, edited by M. King and G. Calvo. London: Macmillan.

Giavazzi, F., and M. Pagano. 1990. "Confidence Crises and Public Debt Management." In *Public Debt Management: Theory and History,* edited by R. Dornbusch and M. Draghi. Cambridge University Press.

Kydland, F. E., and E. C. Prescott. 1990. "Business Cycles: Real Facts and a Monetary Myth." *Federal Reserve Bank of Minneapolis Quarterly Review* (Spring): 3-18.

Lucas, R. E., and N. L. Stokey. 1983. "Optimal Fiscal and Monetary Policy in an Economy without Capital." *Journal of Monetary Economics* 12 (July): 55-93.

Marcet, A., T. J. Sargent, and J. Seppala. 1996. "Optimal Taxation without State-Contingent Debt." Unpublished paper. Stanford University (January).

Missale, A., and O. J. Blanchard. 1994. "The Debt Burden and Debt Maturity." *American Economic Review* 84 (March): 309-19.

Mitchell, B. R., and P. Deane. 1962. *Abstract of British Historical Statistics.* Cambridge University Press.

Persson, M., T. Persson, and L. E. O. Svensson. 1987. "Time Consistency of Fiscal and Monetary Policy." *Econometrica* 55 (November): 1419-31.

Persson, T., and L. E. O. Svensson. 1984. "Time-Consistent Fiscal Policy and Government Cash-Flow." *Journal of Monetary Economics* 14 (November): 365-74.

Ricardo, D. 1951. *Funding System.* In *The Works and Correspondence of David Ricardo,* edited by P. Sraffa, vol. IV. Cambridge University Press.

Shiller, R. J. 1993. *Macro Markets: Creating Institutions for Managing Society's Largest Economic Risks.* Oxford: Clarendon Press.

Smith, A. 1791. *An Inquiry into the Nature and Causes of the Wealth of Nations,* 6th edition. London: A. Strahan and Cadell.

Zhu, X. 1992. "Optimal Fiscal Policy in a Stochastic Growth Model." *Journal of Economic Theory* 58: 250-89.

MONETARY POLICY, INTEREST RATE RULES, AND INFLATION TARGETING: SOME BASIC EQUIVALENCES

Carlos Végh
University of California at Los Angeles

Monetary policy in small open economies is typically cast as a choice between an exchange rate anchor (fixed or predetermined exchange rates) and a money anchor (floating exchange rates). Under such regimes, the growth rate of the nominal anchor is set according to the desired long-run inflation rate. After undergoing a not necessarily painless adjustment process, the economy would eventually reach the long-run inflation rate.

In practice, however, policymakers have certainly not restricted themselves to such a limited menu of policy instruments. Pure floating rates are, at best, rare, as policymakers typically intervene in foreign exchange markets to smooth exchange rate fluctuations or achieve some international reserves target. While predetermined exchange rates are more common, it is still the case that, more often than not, policymakers adjust the devaluation rate in response to changes in the domestic and external environment or engage in real exchange rate targeting.[1]

At an even more fundamental level, policymakers increasingly view short-term nominal interest rates as the main nominal anchor. In developed countries, short-term interest rates are, by and large, the most common policy instrument (see Batten and others, 1990). The most prominent example is, of course, the United States: the Federal Reserve conducts monetary policy by setting the federal funds rate (the interest rate at which commercial banks borrow overnight). When

I am grateful to Eduardo Borenzstein, David Gould, Esteban Jadresic, Fernando Lefort, Paul Masson, and Klaus Schmidt-Hebbel for helpful comments and discussions.

1. See, for instance, Bruno (1993); Calvo, Reinhart, and Végh (1995); Lahiri (1997).

Indexation, Inflation, and Monetary Policy, edited by Fernando Lefort and Klaus Schmidt-Hebbel, Santiago, Chile.

inflation raises its ugly head, the Federal Reserve engages in a gradual tightening of monetary policy by raising the federal funds rate.

In developing countries, short-term interest rates have also played a key role in the conduct of monetary policy. In the mid-1980s, for instance, countries such as Argentina and Brazil supported repeated stabilization attempts by hiking interest rates on short-term government debt to increase demand for domestic assets and thus prevent speculative attacks against the domestic currency (see Calvo and Végh, 1995). In the case of Mexico, analysts point to the monetary authorities' reluctance to raise interest rates as a key factor in triggering the December 1994 crisis. In the wake of Thailand's decision to abandon its fixed exchange rate system in July 1997, Brazil and Hong Kong repeatedly raised interest rates to thwart currency speculators.

With the advent of indexed government debt, some countries—Chile being the most notable example—have actually used the interest rate on such instruments (that is, a real interest rate) as the main policy instrument (see, for example, Corbo and Fischer, 1994). Even when policymakers do not set a real interest rate, a real interest rate target seems to be very much on their minds. Reinhart (1993), for instance, argues that the Federal Reserve may be viewed as aiming at setting a real interest rate that is consistent with full-employment output. In fact, the level of the federal funds rate in real terms is often an important consideration in whether to raise further interest rates.

In practice, the use of interest rates as the main policy instrument has often taken place in conjunction with some inflation target. In other words, policymakers set an inflation target—explicitly or implicitly—and change interest rates with the aim of achieving such a target. When inflation targets are explicitly announced, such policies have been referred to as inflation targeting (see Leiderman and Svensson, 1995; Masson, Savastano, and Sharma, 1997). Inflation targeting has been implemented in industrial countries such as Australia, Canada, Finland, New Zealand, Spain, Sweden, and the United Kingdom. Although, in principle, a myriad of policy instruments could be used to achieve a given inflation target, in practice short-term interest rates have served as the main policy instrument. Hence, the most common manifestation of inflation targeting appears to be an inflation target accompanied by some explicit or implicit interest rate rule that is designed so as to achieve the target. Among developing countries, Chile seems to come the closest to using an inflation targeting scheme (see Masson, Savastano, and Sharma, 1997).

At an analytical level, the use of nominal interest rates as a policy instrument has raised some important questions regarding its impact on prices and inflation. Nominal interest rate targeting may lead to an indeterminate price level under flexible prices (Sargent and Wallace, 1975) or indeterminate inflation rate under sticky prices (Calvo, 1983). Indeterminacy problems can be avoided by explicitly introducing a government budget constraint (Auernheimer and Contreras, 1993); by designing appropriate interest rate rules (see, for instance, Reinhart, 1992); or by letting policymakers set the interest rate on liquid bonds issued by the government (Calvo and Végh, 1995, 1996). Policy rules that rely on real interest rates may also easily lead to various indeterminacies (Reinhart, 1993). The use of the real interest rate as a policy instrument has received particular attention in the case of Chile (see, for example, Rojas, 1993; Corbo and Fischer, 1994; Mendoza and Fernández, 1994). Although some important insights have followed from this large literature, the profession is still far from reaching any sort of consensus on the comparative advantages of different instruments and policy rules.

This paper starts from the premise that in order to assess different policy rules, it is useful to establish some basic equivalences among policy rules. Equivalent policy rules are defined as rules that yield exactly the same dynamics in response to, say, a long-term reduction in the inflation rate. In a formal sense, finding equivalent policy rules is a trivial exercise. Consider the exercise of a permanent reduction in the rate of monetary growth in a closed-economy model. This exercise will generate as an outcome some equilibrium path for the nominal interest rate. Clearly, if policymakers could announce a credible inflation target (which would anchor the long-run inflation rate) and set that same path for the nominal interest rate, the monetary growth rate would endogenously fall on impact and remain at that lower level forever. These two policy rules—the fixed money growth rule and the interest rate rule—would therefore be equivalent.

In the real policy world, however, this formal equivalence will be relevant only if the endogenous path of the nominal interest rate in the fixed money growth rule is a linear function of observable variables, such as the deviation of the actual inflation rate from its long-run steady state. In that case, an interest rate rule that sets the interest rate according to the deviation of the actual inflation rate from an inflation target would achieve the same results. Otherwise, policymakers would not be able to implement the interest rate rule that replicates the fixed money growth rule.

This paper illustrates, in the context of a closed-economy model, the existence of some basic equivalences among policy rules (that is, policy rules that can be implemented in practice). Inflation is assumed to be a predetermined variable, reflecting the highly inertial nature of inflation in many countries with moderate inflation. The paper starts by comparing the use of a money anchor, a nominal interest rate anchor, and a real interest rate anchor, whereby policymakers set a fixed level of the corresponding policy instrument (that is, there is no feedback mechanism). It is shown that only a money anchor (that is, a *k*-percent money growth rule) yields a well-behaved system. A fixed level of either the nominal interest rate or the real interest rate leads to unstable dynamics. This first result, which is here derived for the case of sticky inflation, is thus in the spirit of the indeterminacies found in the literature. In theory, then, there is no substitute for a *k*-percent rule. In practice, however, there are well-known problems associated with *k*-percent rules, such as the instability of monetary aggregates and the choice of the appropriate monetary aggregate.

The paper then investigates the existence of simple interest rate rules that could replicate the *k*-percent money growth rule. The following rule is analyzed: let policymakers announce an inflation target and then change the nominal interest rate according to the difference between the current inflation rate and the inflation target. Provided that the inflation target is fully credible, such a policy generates the same qualitative dynamic adjustment as the one delivered by the *k*-percent money rule. In fact, a simple case is found (when real money demand is of the Cagan type and thus has a constant interest rate semielasticity) in which the inflation target-cum-interest rate rule exactly replicates the *k*-percent money growth rule. In other words, the adjustment of the economy to the announcement of a lower inflation target exactly replicates the response of the economy to a lower rate of monetary expansion. The paper then analyzes the following real interest rate rule: let policymakers announce an inflation target and change the real interest rate according to the difference between (a) the current inflation rate and the inflation target and (b) deviations of output from its full-employment level. Under a constant semielastic money demand, this rules also replicates the *k*-percent money growth rule.

These three rules—the *k*-percent money rule, an inflation target-cum-nominal interest rate rule, and an inflation target-cum-real interest rate rule—are identical for a Cagan money demand. However, as the analysis moves away from the more traditional instrument (a monetary aggregate) toward less traditional ones (a nominal interest rate and then a real interest rate), the feedback mechanisms multiply and the policy regime becomes more complicated. This should prove a useful conceptual benchmark. In practice, this increased level of complexity would need to be weighted against whatever practical advantages may exist. For instance, setting a short-term nominal interest rate may be operationally easier than setting a constant growth of the money supply.

The three equivalent policy rules just mentioned imply an adjustment toward a lower long-run inflation rate that involves a prolonged period of deflation (defined as inflation falling below its long-run level during the adjustment process). This is needed for real money balances to achieve a higher steady-state level. In practice, policymakers may want to avoid this deflationary period since it essentially implies that the monetary policy stance is too tight. As the analysis shows, policy rules that respond to the output gap may prevent this deflationary period and ensure a monotonic fall of the inflation rate toward its lower steady-state value. Under certain conditions, these three policy rules deliver exactly the same outcome: an inflation target combined with a money growth rule that responds to the output gap; an inflation target combined with a nominal interest rate rule that responds to both the inflation gap and the output gap; and an inflation target combined with a real interest rate rule that responds to both the inflation gap and the output gap. It is still the case that the money growth rule is the simplest of the three rules. But, again, a nominal interest rate rule can achieve the same results without adding too much complexity (since policymakers can easily monitor the inflation gap).

A final word of caution before proceeding to the formal analysis. The equivalence results derived in this paper provide a useful conceptual benchmark. No generality is claimed, however. Quite to the contrary, the whole point of the exercise is to find conditions (however strong) under which different policy rules are equivalent. As is typical of applied economic theory (think, for example, of the Ricardian equivalence or the Modigliani-Miller theorem), the idea behind this analysis is that understanding admittedly extreme cases in which such equivalences hold should then make it easier to identify the main factors explaining deviations from the benchmark in the real world. In this context, a model in which some basic policy equivalence results hold should provide a useful starting point for thinking about different monetary policy rules and instruments. Put differently, the idea is to provide a useful conceptual benchmark for thinking about these issues, rather than to construct a model that replicates the real world.

The paper proceeds as follows. Section 1 develops the basic model. Sections 2, 3, and 4 analyze the use of the money supply, the nominal interest rate, and the real interest rate as policy instruments, respectively. Section 5 derives the first equivalence proposition. Section 6 analyzes policy rules aimed at avoiding excessively tight monetary policy and derives the second equivalence proposition. Section 7 concludes.

1. The Model

Consider a closed economy inhabited by a very large number of identical consumers. Agents have perfect foresight. The Fischer equation holds, so that $i_t = r_t + \pi_t$, where i_t is the nominal interest rate, r_t is the real interest rate, and π_t is the inflation rate.

1.1 Consumers

The lifetime utility of the representative consumer is given by

$$\int_0^\infty u\left(c_t\right)\exp\left(-\beta t\right) \mathrm{d}t \ , \tag{1}$$

where c_t denotes consumption, $\beta(> 0)$ is the subjective discount rate, and the function $u(\cdot)$ satisfies $v'(\cdot) > 0$ and $v''(\cdot) < 0$.

Consumers hold two assets: a bond (indexed to the price level and in zero net supply in the aggregate) and money. Let a_t denote the household's financial wealth in real terms. Hence,

$$a_t = b_t + m_t \ , \tag{2}$$

where b_t and m_t denote the real stocks of bonds and money, respectively. The bond earns a nominal return of i_t.

In this economy, trading is a costly activity in terms of resources. Consumers hold money in order to reduce transactions costs. Transactions costs are thus given by $v(m_t)$, where $v'(m) < 0$ and $v''(m) > 0$.[2]

The consumer's flow constraint is given by

$$\dot{a}_t = r_t a_t + y_t + \tau_t - c_t - i_t m_t - v\left(m_t\right) , \tag{3}$$

where y_t denotes the output of the good and τ_t are lump-sum transfers from the government.

2. See Dornbusch and Frenkel (1973). Since transactions costs do not depend on consumption, the derived real money demand will not depend on consumption, either.

The consumer chooses (c_t, m_t) for all $t \in [0, \infty)$ to maximize lifetime utility (equation 1), subject to equation 3, for given paths of r_t, y_t, τ_t, and i_t, and a given value of a_0. The first-order conditions for this standard optimal control program are the following:

$$u'(c_t) = \lambda_t \ , \tag{4}$$

$$-v'(m_t) = i_t \ , \quad \text{and} \tag{5}$$

$$\dot{\lambda}_t = \lambda_t(\beta - r_t) \ , \tag{6}$$

where λ_t is the current value multiplier associated with constraint 3. Equation 4 indicates that, at an optimum, the household equates the marginal utility of consumption to the marginal utility of wealth. Equation 6 is the law of motion of the multiplier. Condition 5 states that, at an optimum, the benefits derived from holding an additional unit of real money balances will be equal to the corresponding opportunity cost. This equation implicitly defines a money demand function:

$$m_t = L(i_t) \ , \tag{7}$$

where $L'(i_t) = -\dfrac{1}{v''(m_t)} < 0$.

Differentiating equation 4 with respect to time and combining it with equation 6 leads to the familiar Euler equation:

$$\dot{c}_t = \frac{u'(c_t)}{-u''(c_t)}(r_t - \beta) \ . \tag{8}$$

Hence, if the real interest rate is above the rate of time preference, today's consumption is expensive relative to tomorrow's, and so consumption will increase over time.

1.2 Government

The government plays no active role. It gives back to consumers the proceeds from money creation and transactions costs, which are paid out as lump-sum transfers. The government's constraint is thus

$$\tau_t = \mu_t m_t + v(m_t) \ . \tag{9}$$

The fact that $v(m_t)$ appears in the government's flow constraint reflects the assumption that $v(m_t)$ is a private cost for consumers but not a social cost. Formally, one can think of some federal agency providing (at zero cost) the transactions costs needed by consumers. The profits of this federal agency are returned to households as lump-sum transfers. This assumption is made to eliminate wealth effects associated with changes in inflation, which would unnecessarily complicate the analysis.

1.3 Supply Side

Output is endogenous and assumed to be demand determined; that is, $y_t = c_t$. The inflation rate is assumed to be predetermined at each point in time. This formulation is meant to capture a situation in which widespread backward-looking indexation of prices and wages imparts a high degree of inertia to the inflation rate.[3] The change in the inflation rate is given by

$$\dot{\pi}_t = \gamma\left(\mu_t - \pi_t\right) + \alpha\left(c_t - \bar{y}\right), \tag{10}$$

where $\bar{y}$ denotes the full-employment level of output. Equation 10 says that the inflation rate will increase whenever it is below the rate of money growth, μ_t, or whenever aggregate demand exceeds full-employment output.

1.4 Equilibrium Conditions

Since bonds are so-called inside money in this economy, aggregate bond holdings must be zero:

$$b_t = 0\ . \tag{11}$$

Of course, substituting this equation and goods market equilibrium, $y_t = c_t$, into the consumer's flow constraint (equation 3) yields the government's budget constraint (equation 9), which is simply a manifestation of Walras Law.

Finally, and for further reference, since $m = M/P$ by definition, it follows that

$$\dot{m}_t = m_t\left(\mu_t - \pi_t\right). \tag{12}$$

3. Widespread indexation has long characterized countries with chronic inflation. See, for instance, Dornbusch and Simonsen (1987); Edwards (1991); Bruno (1993).

2. A Fixed Money Growth Rule

As a benchmark, consider the case in which policymakers set the initial level and the growth rate of the nominal money supply (denoted by $\bar{\mu}$). Hence, equations 10 and 12 become

$$\dot{\pi}_t = \gamma\left(\bar{\mu} - \pi_t\right) + \alpha\left(c_t - \bar{y}\right) \quad \text{and} \tag{13}$$

$$\dot{m}_t = m_t\left(\bar{\mu} - \pi_t\right). \tag{14}$$

Substituting the Fisher equation and equation 5 into equation 8 produces

$$\dot{c}_t = \frac{u'\left(c_t\right)}{u''\left(c_t\right)}\left[\beta + v'\left(m_t\right) + \pi_t\right]. \tag{15}$$

Equations 13, 14, and 15 constitute a differential equation system in π_t, m_t, and c_t, for a given value of the policy variable $\bar{\mu}$. Both π_t and m_t are predetermined variables.

The system's steady state is given by

$$\pi_{ss} = \bar{\mu} \tag{16}$$

$$c_{ss} = \bar{y}, \quad \text{and} \tag{17}$$

$$-v'\left(m_{ss}\right) = \beta + \bar{\mu}. \tag{18}$$

Linearizing this system around the steady state yields

$$\begin{bmatrix} \dot{\pi}_t \\ \dot{m}_t \\ \dot{c}_t \end{bmatrix} = \begin{bmatrix} -\gamma & 0 & \alpha \\ -m_{ss} & 0 & 0 \\ u'\left(\bar{y}\right)/u''\left(\bar{y}\right) & \left[u'\left(\bar{y}\right)v''\left(m_{ss}\right)\right]/u''\left(\bar{y}\right) & 0 \end{bmatrix} \begin{bmatrix} \pi_t - \bar{\mu} \\ m_t - m_{ss} \\ c_t - \bar{y} \end{bmatrix}.$$

The trace and determinant of the matrix associated with the linear approximation are, respectively,

$$\text{Tr} = -\gamma < 0 \quad \text{and} \tag{19}$$

$$\Delta = -\alpha\, m_{ss} \frac{u'(\bar{y})v''(m_{ss})}{u''(\bar{y})} > 0 \ , \tag{20}$$

which implies that there is one positive root and two roots with negative real part.[4] Since there are two predetermined variables, the system exhibits saddle-path stability: for given initial values of π and m, c will adjust so as to position the system along its unique, perfect-foresight equilibrium path.

Let δ_i, i=1, 2, denote the two negative roots, with $\delta_1 > \delta_2$. Let $\mathbf{h}_{ij}$, j = 1, 2, 3, denote the elements of the eigenvector associated with root δ_i. For i = 1, 2, it follows that

$$\begin{bmatrix} -\gamma - \delta_i & 0 & \alpha \\ -m_{ss} & -\delta_i & 0 \\ u'(\bar{y})/u''(\bar{y}) & [u'(\bar{y})v''(m_{ss})]/u''(\bar{y}) & -\delta_i \end{bmatrix} \begin{bmatrix} \mathbf{h}_{i1} \\ \mathbf{h}_{i2} \\ \mathbf{h}_{i3} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} . \tag{21}$$

Therefore,

$$\frac{\mathbf{h}_{i1}}{\mathbf{h}_{i2}} = -\frac{\delta_i}{m_{ss}} > 0 \ . \tag{22}$$

As becomes clear below, this provides a crucial piece of information when it comes to deriving the dynamic behavior of the system.

Setting to zero the constant corresponding to the unstable root, the solution to this dynamic system takes the form

$$\pi_t - \bar{\mu} = w_1 \mathbf{h}_{11} \exp(\delta_1 t) + w_2 \mathbf{h}_{21} \exp(\delta_2 t) \ , \tag{23}$$

$$m_t - m_{ss} = w_1 \mathbf{h}_{12} \exp(\delta_1 t) + w_2 \mathbf{h}_{22} \exp(\delta_2 t) \ , \quad \text{and} \tag{24}$$

$$c_t - \bar{y} = w_1 \mathbf{h}_{13} \exp(\delta_1 t) + w_2 \mathbf{h}_{23} \exp(\delta_2 t) \ , \tag{25}$$

4. In what follows, and to simplify the exposition, it is assumed that the roots with negative real part are real numbers. It can be checked that roots will be real (complex) numbers when γ is large (small) relative to α. This makes intuitive sense, because as can be seen from equation 13, a relatively large γ ensures that the rate of change of the inflation rate is relatively more responsive to the inflation rate differential.

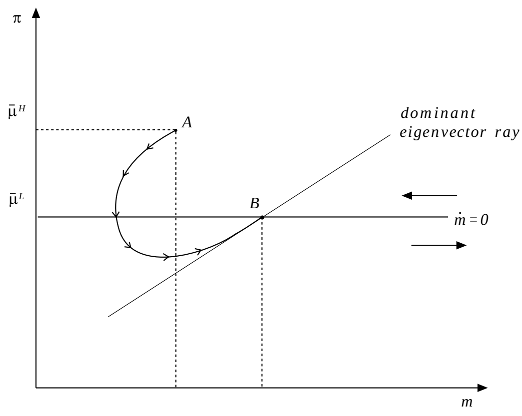
where w_i, i = 1, 2, denote the constants associated with root δ_i. Since $\delta_2 - \delta_1 < 0$, it follows that

$$\lim_{t\to\infty} \frac{\pi_t - \bar{\mu}}{m_t - m_{ss}} = \frac{\mathbf{h}_{11}}{\mathbf{h}_{12}} > 0 \, .$$

This implies that as t becomes large, inflation and real money balances will converge to their steady-state values from the same direction. Put differently, the dominant eigenvector ray, which is illustrated in figure 1, is positively sloped (see Calvo, 1987). Graphically, the system must converge asymptotically to the dominant eigenvector ray. Equation 14 also indicates that when $\pi_t > \bar{\mu}$ (or when $\pi_t < \bar{\mu}$), real money balances are falling (or rising). The corresponding directional arrows are drawn in figure 1.

We now have all the elements needed to study how this economy adjusts to an unanticipated and permanent fall in the monetary growth rate. Suppose that in the initial steady state (that is, for $t < 0$), the monetary growth rate is $\bar{\mu}^H$. At $t = 0$, policymakers announce an unanticipated and permanent reduction of the money growth rate from $\bar{\mu}^H$ to $\bar{\mu}^L$, where $\bar{\mu}^H > \bar{\mu}^L$. In terms of figure 1, the initial high-inflation steady state is at point A. The new steady state—with lower inflation and higher real money balances—is at point B. Given the conditions that must be satisfied by a convergent path, the economy must follow the arrowed path illustrated in figure 1.[5]

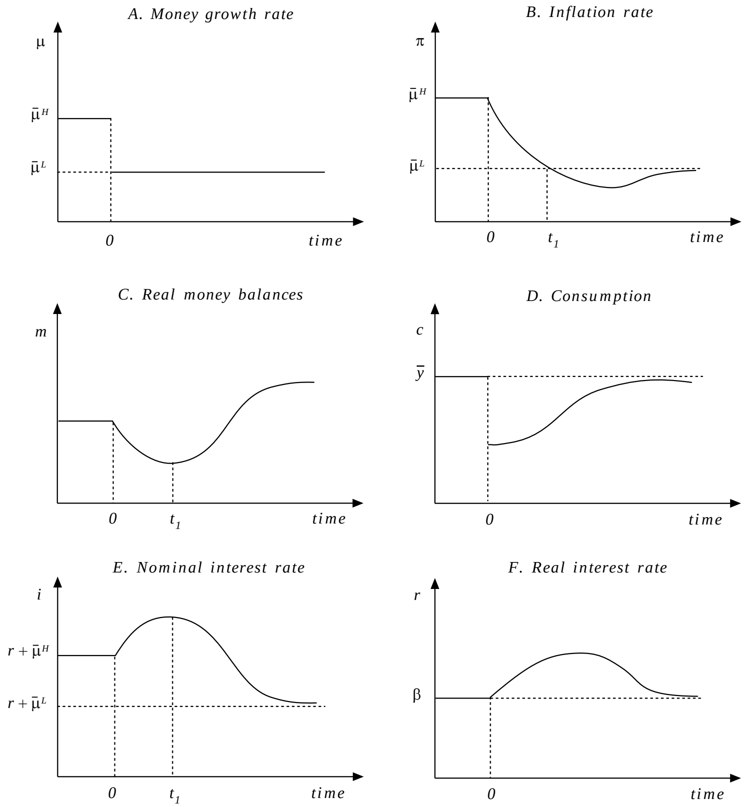
Figure 1. Dynamics in the (m, π) Plane



5. It can be ruled out that starting from point A, the system will first head in a northwestern direction. In other words, $\dot{\pi}_0 < 0$. To show this, one first must show that consumption jumps downwards on impact (see the appendix).

Figure 2 illustrates the time path of the main variables. The paths of inflation and real money balances follow directly from figure 1. Since the inflation rate is a predetermined variable, the reduction in the rate of monetary growth implies that real money balances fall in the early stages. Given the path of m_t, the path of i_t follows from equation 5. The nominal interest rate must rise early on to accommodate the lower level of real money balances. Since $r_t = i_t - \pi_t$, the path of r_t follows from the paths of i_t and π_t.[6] The fact that r_t is above β during the entire adjustment process implies that after jumping downward on impact, consumption rises throughout.

Figure 2. Reduction in Money Growth Rate



6. In principle, the possibility that the slope of the path of r_t changes sign more than once cannot be ruled out. What is important, however, is that during the adjustment process, r_t will always be above its unique steady-state value.

The intuition behind these results is as follows. The permanent reduction in the monetary growth rate implies that, in the new steady state, inflation—and thus the nominal interest rate—will be lower. Hence, real money demand in the new steady state will be higher. How will this increase in real money balances come about? Since the nominal money stock does not jump at $t = 0$ (it is a policy variable), the only way for the economy to generate higher real money balances is for the inflation rate to fall below the lower rate of monetary growth, $\bar{\mu}^L$. Inflation thus needs to undershoot its long-run value in order for real money balances to eventually begin to rise toward their higher steady-state value. In other words, tight monetary policy (in the form of a sharp reduction in the monetary growth rate) forces the economy to undergo a deflationary period. This tight monetary policy manifests itself in high nominal and real interest rates in the early stages of the stabilization program.

It will prove useful to derive analytically the time paths of the nominal and real interest rates. Differentiating first-order condition 5 and recalling that $\dot{m}_t / m_t = \bar{\mu} - \pi_t$, it follows that

$$\dot{i}_t = m_t v''(m_t)\left(\pi_t - \bar{\mu}^L\right). \tag{26}$$

Along the adjustment path, the nominal interest rate thus depends on the difference between the current inflation rate and the long-run inflation rate (which equals $\bar{\mu}^L$). This already suggests that an inflation target combined with an interest rate rule whereby the nominal interest rate is raised if the actual inflation rate is above the inflation target may yield a similar dynamic path to the *k*-percent money growth rule.

With regard to the real interest rate, the Fischer equation and equations 13 and 26 can be used to obtain

$$\dot{r}_t = \left[\gamma + m_t v''(m_t)\right]\left(\pi_t - \bar{\mu}^L\right) - \alpha\left(c_t - \bar{y}\right). \tag{27}$$

Hence, the real interest rate increases whenever inflation is above its long-run value and falls if consumption is above the full-employment level of output. The intuition for the latter channel is as follows: other things being equal, when consumption is above its full-employment level, the inflation rate is rising (recall equation 13), which implies that the real interest rate is falling. Again, this suggests that an inflation target combined with a real interest rate rule that responds to both the output gap and the gap between the current inflation rate and an inflation target should yield similar dynamics to the k-percent money growth rule.

3. The Nominal Interest Rate as an Instrument

3.1 A Pure Interest Rate Peg

Suppose that policymakers set the nominal interest rate at a constant level, $\bar{i}$. This is achieved by letting the money supply adjust to whatever level is needed for the targeted interest rate to prevail. It will be shown that an interest rate peg leads to a multiplicity of equilibrium paths.

If $i_t = \bar{i}$, it follows from first-order condition 5 that $\dot{m} = 0$ and, therefore, that $\pi_t = \mu_t$. Equation 10 then becomes

$$\dot{\pi}_t = \alpha\left(c_t - \bar{y}\right). \tag{28}$$

Taking into account the Fisher equation, the Euler equation 8 can be rewritten as

$$\dot{c}_t = \frac{u'\left(c_t\right)}{u''\left(c_t\right)}\left(\beta + \pi_t - \bar{i}\right). \tag{29}$$

Equations 28 and 29 constitute a differential equation system in π_t and c_t, for a given value of $\bar{i}$. At the steady state, $c_{ss} = \bar{y}$ and $\pi_{ss} = \bar{i} - \beta$. Linearizing the system around the steady state,

$$\begin{bmatrix} \dot{\pi}_t \\ \dot{c}_t \end{bmatrix} = \begin{bmatrix} 0 & \alpha \\ u'\left(\bar{y}\right)/u''\left(\bar{y}\right) & 0 \end{bmatrix} \begin{bmatrix} \pi_t - \pi_{ss} \\ c_t - \bar{y} \end{bmatrix}.$$

The trace and determinant of the matrix associated with the linear approximation are given by, respectively,

$$\mathrm{Tr} = 0 \quad \text{and}$$

$$\Delta = -\alpha \frac{u'\left(\bar{y}\right)}{u''\left(\bar{y}\right)} > 0.$$

This implies that there are two complex roots with real part equal to zero.[7] The dynamic system exhibits a vortex and is thus unstable. For a given initial value of the inflation rate (except if it happens to be the steady-state value), there is no value of consumption that places the economy on a convergent path. All possible values imply that the system will oscillate forever without ever reaching the steady state. In this model, therefore, a pure nominal interest rate peg does not provide a sensible way of conducting monetary policy.

Intuitively, the problem lies in the fact that under a pure interest rate peg, the economy loses its nominal anchor as the rate of monetary growth passively accommodates inflation. Indeed, as made clear by equation 28, there is no long-run value of the inflation rate (that is, no nominal anchor) to guide the inflation rate to a specific value. In contrast, under a *k*-percent money rule (recall equation 13), the rate of change of the inflation rate is affected by the difference between the current inflation rate and its long-run value.

3.2 A Nominal Interest Rate Rule with an Inflation Target

Consider the following policy regime: policymakers announce an inflation target, $\bar{\pi}$, and follow the interest rate rule

$$\dot{i} = \theta(\pi_t - \bar{\pi}), \tag{30}$$

whereby the nominal interest rate is gradually raised (reduced) whenever the inflation rate is above its target.[8] (In this setup, the nominal interest rate is, by construction, a predetermined variable.) Differentiating first-order condition 5 and using equation 30 produces

$$\dot{m}_t = \frac{-\theta}{v''(m_t)}(\pi_t - \bar{\pi}) \,. \tag{31}$$

7. The roots are given by $\delta_{1,2} = \pm z\sqrt{-\alpha[u'(\bar{y})/u''(\bar{y})]}$, where $z^2 = -1$.
8. All policy parameters are positive unless otherwise indicated.

Combining equation 31 with equations 10 and 12 yields

$$\dot{\pi}_t = \frac{\gamma\,\theta}{m_t v''(m_t)}\left(\overline{\pi} - \pi_t\right) + \alpha\left(c_t - \overline{y}\right). \tag{32}$$

This last equation, together with equations 15 and 31, forms a dynamic system in π_t, m_t, and c_t whose dynamic properties are qualitatively the same as those of the system described by equations 13, 14, and 15 for the fixed money growth rule. Thus, if at time 0, policymakers announce a reduction in the inflation target and follow policy rule 30, the economy will follow (in qualitative terms) the adjustment process depicted in figure 2, except for μ_t.

Note that μ_t is now an endogenous variable whose path is given by

$$\mu_t = \frac{\theta}{m_t v''(m_t)}\overline{\pi} + \left[1 - \frac{\theta}{m_t v''(m_t)}\right]\pi_t. \tag{33}$$

To fix ideas, note that $m_t v''(m_t)$ is the inverse of the absolute value of the semielasticity of real money demand (denoted by η^s); that is,

.

If real money demand is of the Cagan type (that is, it exhibits a constant semielasticity), then it follows from equation 33 that on impact m_t will fall by more than the inflation target if $\eta^s > 1/\theta$ and by less if $\eta^s < 1/\theta$. In the case in which $\eta^s = 1/\theta$, $\mu_t = \overline{\pi}$ for all t, and the system behaves exactly as it does under a fixed money growth rule. In other words, an outside observer would not be able to tell whether a given reduction in the long-run inflation rate was brought about by a permanent reduction in $\overline{\mu}$ or by the announcement of a lower inflation target together with interest rate rule 30.

4. The Real Interest Rate as Policy Instrument

4.1 A Pure Real Interest Rate Peg

Suppose that policymakers set the real interest rate at the constant value . A necessary condition for such a real interest rate peg to be consistent with a convergent equilibrium path is that $\bar{r} = \beta$. Otherwise, consumption would either increase or decrease forever, as follows from equation 8. The peg $\bar{r} = \beta$ therefore implies that $\dot{c}_t = 0$. Hence, $c_t = \bar{y}$ for a convergent path to exist. From equation 10,

$$\dot{\pi}_t = \gamma\left(\mu_t - \pi_t\right). \tag{34}$$

Recalling the Fisher equation, it then follows from equations 7 and 34 that

$$\dot{\pi}_t \left[\frac{1}{\gamma} - \frac{L'\left(i_t\right)}{L\left(i_t\right)} \right] = 0 \ ,$$

which implies that along a perfect-foresight equilibrium path, $\dot{\pi}_t = 0$. Intuitively, if the monetary growth rate were above the inflation rate, real money balances would be increasing over time. The nominal interest rate would need to fall over time for money market equilibrium to hold. Since the real interest rate is constant, this implies that the inflation rate would be falling over time. In contrast, if the monetary growth rate were above the inflation rate, equation 34 indicates that inflation must be increasing over time. The only consistent path is for inflation to remain flat over time.

Let $\pi_t = \bar{\pi}$. Along a perfect-foresight equilibrium path, $\mu_t = \bar{\pi}$, $i_t = \bar{r} + \bar{\pi}$, and $m_t = L(\bar{r} + \bar{\pi})$. The economy is thus always in a stationary equilibrium. This equilibrium is not uniquely determined, however. To see this, suppose that for whatever reason, the public came to expect that the inflation rate will be $2\bar{\pi}$. By the above reasoning, $\mu_t = 2\bar{\pi}$ and $i_t = \bar{r} + 2\bar{\pi}$. Since the nominal interest rate is higher, real money demand would be lower; that is, $m_t = L(\bar{r} + 2\bar{\pi})$. The nominal money stock would fall to accommodate the lower real money demand. In sum, policymakers will validate any inflation rate expected by the public. There is nothing to tie down the level of the constant rate of inflation.

4.2 A Real Interest Rate Rule with an Inflation Target

Consider the following policy regime: policymakers announce an inflation target, $\bar{\pi}$, and follow the real interest rate rule

$$\dot{r}_t = \theta\left(\pi_t - \bar{\pi}\right). \tag{35}$$

Combining equations 7, 10, and 35 generates

$$\dot{\pi}_t = \frac{\theta\gamma\left[L'(i_t)/L(i_t)\right]}{1-\gamma\left[L'(i_t)/L(i_t)\right]}\left(\pi_t - \overline{\pi}\right) + \frac{\alpha}{1-\gamma\left[L'(i_t)/L(i_t)\right]}\left(c_t - \overline{y}\right).$$

Equations 8, 35, and 36 constitute a dynamic system in π_t, c_t, and r_t. Proceeding as in the case of the fixed money growth rule, this dynamic system may be solved by computing the dominant eigenvector ray. In response to an unanticipated reduction in the inflation target, the system adjusts to the new steady state following similar dynamics as in figure 2, except for the behavior of μ_t, which may vary over time.

5. An Equivalence Proposition

The above analysis has shown that both a nominal interest rate rule and a real interest rate rule, in conjunction with an inflation target, will qualitatively yield the same results as a *k*-percent money growth rule. I now discuss a particular case in which these three rules are exactly the same.

Suppose that the transactions cost technology takes the form

, (37)

where χ is a positive parameter.
Using equation 5, the real money demand then becomes

$$m_t = e^{\sigma(\chi - i_t) - 1}. \tag{38}$$

This is a Cagan-type real money demand since it exhibits a constant semielasticity:

$$\eta^s(m_t) \equiv \frac{-\partial L(i_t)}{\partial i_t}\frac{1}{m_t} = \frac{1}{m_t v''(m_t)} = \sigma. \tag{39}$$

Under such a specification, the paths for the nominal interest rate and the real interest rate for the *k*-percent money growth rule studied above are given, respectively, by

$$\dot{i}_t = \frac{1}{\sigma}\left(\pi_t - \bar{\mu}\right) \quad \text{and} \tag{40}$$

$$\dot{r}_t = \left(\gamma + \frac{1}{\sigma}\right)\left(\pi_t - \bar{\mu}\right) - \alpha\left(c_t - \bar{y}\right), \tag{41}$$

as follows from equations 26, 27, and 39. Equation 40 indicates that under a Cagan money demand, the rate of change of the nominal interest rate is a linear function of the gap between the current inflation rate and the long-run inflation rate (given by $\bar{\mu}$). From equation 41, it follows that the rate of change of the real interest rate is also a linear function of the inflation gap and, in addition, of the gap between consumption (aggregate demand) and full-employment output. Recall also from figure 2 that neither the nominal interest rate nor the real interest rate jump on impact (that is, at $t = 0$).

Suppose now that policymakers set an inflation target, $\bar{\pi}$, that pins down the long-run inflation rate and therefore plays the role of $\bar{\mu}$. In conjunction with this inflation target, they follow interest rate rules of the form in equations 40 and 41, whereby the nominal interest rate and the real interest rate are changed gradually over time in response to changes in either the inflation gap or the output gap. Furthermore, suppose that policymakers set the policy reaction coefficients equal to $1/\sigma$ for the inflation gap in the case of the nominal interest rate rule and equal to $\gamma + 1/\sigma$ for the inflation gap and $-\alpha$ for the output gap in the case of the real interest rate rule. Under these conditions, it follows that these two policy rules will be exactly equivalent to the fixed money growth rule studied above.

This equivalence result can be summarized in the following proposition:

Proposition 1: If the transactions technology is given by equation 37, which gives rise to a Cagan money demand function (equation 38) with semielasticity equal to σ, then the following three monetary policy rules are exactly equivalent:

(a) policymakers set a fixed money growth rule,

$$u_t = \bar{\mu} \; ; \tag{42}$$

(b) policymakers announce an inflation target, $\bar{\pi}$ (equal to $\bar{\mu}$), and follow a nominal interest rate rule,

$$\dot{i}_t = \theta \left(\pi_t - \bar{\mu} \right), \tag{43}$$

where $\theta = 1/\sigma$; and

(c) policymakers announce an inflation target, $\bar{\pi}$ (equal to $\bar{\mu}$), and follow a real interest rate rule,

$$\dot{r}_t = \theta^1 \left(\pi_t - \bar{\mu} \right) + \theta^2 \left(c_t - \bar{y} \right), \tag{44}$$

where $\theta^1 = \gamma + 1/\sigma$ and $\theta^2 = -\alpha$.

This policy equivalence implies that if policymakers wish to reduce inflation, any of the three policy regimes are formally equivalent. Assuming that the model is a reasonably good description of reality, the choice between different rules will come down to practical advantages. Several remarks are in order.

First, as one moves from the more orthodox instrument (the money supply) to the less orthodox instrument (the real interest rate), the rules become more complicated in the sense that more feedback mechanisms are required. Hence, in practice, these policy rules will be increasingly complex to implement.

Second, not only is the real interest rate rule the more complicated (as it depends on the output gap, which is clearly difficult to estimate in practice), but it also does not have, in principle, any advantage over the nominal interest rate. In addition, the real interest rate rule requires that the real interest rate be reduced when there is excess aggregate demand, which is the opposite of what the public may think should be done.[9] This might lead to credibility problems.

Finally, in practice, monetary authorities have mostly abandoned money growth rules based principally on the instability of money demand and the problems associated with choosing between

9. Of course, a real interest rate rule of the form in equation 35—which does not respond to the output gap—can still deliver a qualitatively similar adjustment to the fixed money growth rule, although it cannot replicate it exactly. Even in this case, however, the real interest rate does not have any advantages over the nominal interest rate as a policy instrument.

different monetary aggregates. A nominal interest rate rule avoids this problem and therefore might be preferable. This might explain the increasing popularity of inflation targeting regimes, of which rule 30 may be considered a particular case.

6. Avoiding Deflation: Alternative Rules

A legitimate question that may arise is why the fixed money growth rule should be the benchmark against which other rules are compared. Two factors make it the natural benchmark. First, it is the traditional policy instrument par excellence. Second, as shown above, it is the only instrument that can be set with no feedback rules. In the absence of feedback rules, neither the nominal nor the real interest rate can provide a nominal anchor for monetary policy.

A case might still be made for considering other possible benchmarks. The main rationale for doing so is the fact that, as discussed above, a fixed money growth rule represents an excessively tight monetary policy stance, as it requires a prolonged period of deflation (in the sense of the inflation rate falling below its long-run value) in order to build real money balances (see figure 2, panel B). One may therefore wonder whether other rules could avoid this deflationary period and thus provide a better benchmark. Since the excessively tight monetary policy is reflected in an initial fall in consumption, it seems natural to ask whether an interest rate rule that also responds to the output gap would be capable of avoiding the deflationary period.[10]

6.1 A Nominal Interest Rate Rule with Output Feedback

Suppose that instead of equation 30, the interest rate rule takes the form:

$$\dot{i} = \theta\left(\pi_t - \overline{\pi}\right) + \xi\left(c_t - \overline{y}\right). \qquad (45)$$

This rule captures policymakers' concerns about consumption (and thus output) falling below its full-employment level. If consumption is below its full-employment level, the nominal interest rate is reduced.

10. For simplicity, I consider the case in which real money demand is given by equation 38.

Using equations 5 and 10, together with the fact that $\dot{m}_t / m_t = \mu_t - \pi_t$, yields,

$$\dot{\pi}_t = \gamma\theta\eta^s\left(\overline{\pi} - \pi_t\right) + \left(\alpha - \gamma\xi\eta^s\right)\left(c_t - \overline{y}\right). \tag{46}$$

Since the main purpose of the exercise is to provide an example in which a nominal interest rate with output feedback avoids the deflationary period, the analysis considers the case in which $\alpha - \gamma\xi\eta^s = 0$. Equation 46 then simplifies to:

$$\dot{\pi}_t = \gamma\theta\eta^s\left(\overline{\pi} - \pi_t\right). \tag{47}$$

This is a stable differential equation in π_t. It follows immediately that an unanticipated and permanent reduction in the inflation target combined with rule 45 will cause inflation to fall monotonically over time toward its lower steady-state value.

To solve for the whole dynamic system, combine the Fisher equation and equations 45 and 47. This generates the law of motion for the real interest rate:

$$\dot{r}_t = \theta\left(1 + \gamma\eta^s\right)\left(\pi_t - \overline{\pi}\right) + \xi\left(c_t - \overline{y}\right). \tag{48}$$

Unlike in the *k*-percent money growth rule case in which $\dot{r}_t$ depended negatively on excess demand (recall equation 41), here it depends positively. The intuition in this case is as follows. Excess demand does not directly affect the change in the inflation rate, as follows from equation 47. Other things being equal, excess aggregate demand therefore leads to an increase in the nominal interest rate—according to rule 45—and thus in the real interest rate.

Equations 8, 47, and 48 form a differential equation system in π_t, r_t, and c_t. Both π_t and r_t are predetermined variables.[11] Linearizing this system around the steady state,

$$\begin{bmatrix} \dot{\pi}_t \\ \dot{r}_t \\ \dot{c}_t \end{bmatrix} = \begin{bmatrix} -\gamma\theta\eta^s & 0 & 0 \\ \theta\left(1 + \gamma\eta^s\right) & 0 & \xi \\ 0 & -u'\left(\overline{y}\right)/u''\left(\overline{y}\right) & 0 \end{bmatrix} \begin{bmatrix} \pi_t - \overline{\pi} \\ r_t - \beta \\ c_t - \overline{y} \end{bmatrix}.$$

11. By construction i_t is predetermined. Since π_t is also a predetermined variable, so is r_t.

The trace and determinant of the matrix associated with the linear approximation are, respectively,

$$\mathrm{Tr} = -\gamma\theta\eta^s < 0 \quad \text{and}$$

$$\Delta = \frac{u'(\bar{y})}{-u''(\bar{y})}\xi\gamma\theta\eta^s > 0 .$$

The system thus has two negative roots.[12] Let δ_i, i = 1, 2, denote the two negative roots.[13] Let $\mathbf{h}_{ij}$, j = 1, 2, 3, denote the elements of the eigenvector associated with root δ_i. For i = 1, 2, it follows that

$$\begin{bmatrix} -\gamma\theta\eta^s - \delta_i & 0 & 0 \\ \theta\left(1+\gamma\eta^s\right) & -\delta_i & \xi \\ 0 & -u'(\bar{y})/u''(\bar{y}) & -\delta_i \end{bmatrix}\begin{bmatrix} \mathbf{h}_{i1} \\ \mathbf{h}_{i2} \\ \mathbf{h}_{i3} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}.$$

Therefore,

$$\frac{\mathbf{h}_{i2}}{\mathbf{h}_{i3}} = -\frac{\delta_i}{-u'(\bar{y})/u''(\bar{y})} < 0 \cdot$$

Setting to zero the constant corresponding to the unstable root, the solution to this dynamic system takes the form

$$\pi_t - \bar{\pi} = w_1\mathbf{h}_{11}\exp(\delta_1 t),$$

$$r_t - \beta = w_1\mathbf{h}_{12}\exp(\delta_1 t) + w_2\mathbf{h}_{22}\exp(\delta_2 t), \quad \text{and}$$

$$c_t - \bar{y} = w_1\mathbf{h}_{13}\exp(\delta_1 t) + w_2\mathbf{h}_{23}\exp(\delta_2 t),$$

where w_i, i = 1, 2, denote the constants associated with root δ_i. (Note that $\mathbf{h}_{21}$ = 0.) Since $\delta_1 - \delta_2 < 0$, it follows that

$$\lim_{t\to\infty}\frac{r_t - \beta}{c_t - \bar{y}} = \frac{\mathbf{h}_{12}}{\mathbf{h}_{13}} < 0 .$$

12. Since one of the negative roots is $-\gamma\theta\eta^s$, it follows that the two negative roots are real numbers.

13. The roots are $\delta_1 = -\gamma\theta\eta^s$ and $\delta_2 = -\sqrt{\xi\frac{u'(\bar{y})}{-u''(\bar{y})}}$. (It is assumed, with no loss of generality, that $\delta_1 < \delta_2$.)

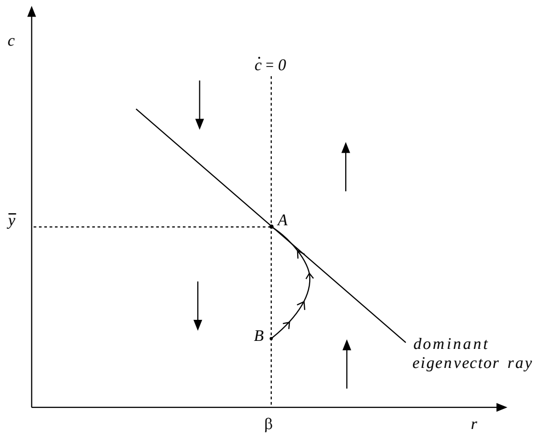
This implies that as t becomes large, the real interest rate and consumption will converge to their steady-state values from opposite directions. In other words, the dominant eigenvector ray is negatively sloped (figure 3). From equation 8, it follows that consumption increases (falls) to the right (left) of $r_t = \beta$. The corresponding directional arrows are drawn in figure 3.

Turning now to the economy's response to a reduction in the inflation target, $\overline{\pi}$, suppose that in the initial steady state (that is, for $t < 0$), the inflation target is $\overline{\pi}^H$. (The initial steady state is denoted by point A in figure 3.) At $t = 0$, policymakers announce an unanticipated and permanent reduction of the inflation target from $\overline{\pi}^H$ to $\overline{\pi}^L$, where $\overline{\pi}^H > \overline{\pi}^L$. In terms of figure 3, the steady state remains at point A. To be on a convergent path, c_t must jump down on impact to a point such as B.[14] The system then follows the arrowed path back to point A.

Figure 4 illustrates the time path of the main variables. If $\theta = 1/\eta^s$, the path of the monetary growth rate is given by

$$\mu_t = \overline{\pi}^L - \frac{\xi}{\theta}\left(c_t - \overline{y}\right). \tag{49}$$

Figure 3. Dynamics in the (*r*, *c*) Plane

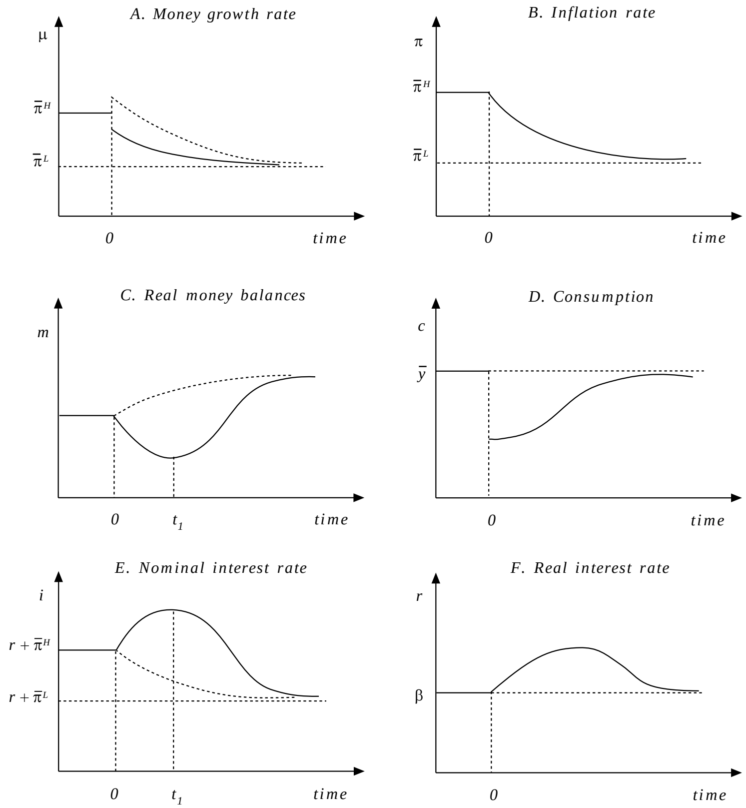


14. If consumption did not jump downwards on impact, the system would diverge in a northeastern direction. To see this notice that, if $c_0 \geq \overline{y}$, then $\dot{r}_0 = \theta\left(1 + \gamma\eta^s\right)\left(\pi_0 - \overline{\pi}\right) + \xi\left(c_0 - \overline{y}\right) > 0$. The rising real interest rate would in turn lead to a rising path of consumption.

Thus the money growth rate will fall on impact by less than the inflation target. During the transition, the money growth rate must be higher than the inflation rate (at least for some period of time) to allow real money balances to grow over time without the need for inflation to fall below its steady-state value. Real money balances fall in the initial stages and increase later on (panel C), while the nominal interest rate increases early on and falls later on (panel D).

Depending on the parameter configuration, the money growth rate could rise on impact (as captured by the dashed path in panel A). In that case, real money balances will grow from the very beginning and the nominal interest rate will fall throughout the adjustment path (dashed paths in panels C and E, respectively).

Figure 4. Reduction in Inflation Target



6.2 A Second Equivalence Proposition

It follows immediately from equation 49 that in conjunction with an inflation target, a money growth rule that responds to the output gap would enable policymakers to reduce inflation while avoiding a protracted deflationary period. Furthermore, a real interest rate rule that takes the form given by equation 48 would also avoid the deflationary period. A key feature of this rule is that now the real interest rate would be raised when the economy is overheated, whereas rule 44 implies the opposite.

This establishes another equivalence between the different policy rules and instruments, which is summarized in the following proposition:

Proposition 2: If the transactions cost technology is given by equation 37, which gives rise to a Cagan money demand function (equation 38) with semielasticity equal to σ, then the following three monetary policy rules are exactly equivalent (under the maintained assumption that $\theta = 1/\eta^{s}$):

(a) policymakers announce an inflation target, $\overline{\pi}$, and follow the money growth rule,

$$\mu_t = \overline{\pi} - \xi\sigma\left(c_t - \overline{y}\right);$$

(b) policymakers announce an inflation target, , and follow the nominal interest rate rule,

$$\dot{i} = \theta\left(\pi_t - \overline{\pi}\right) + \xi\left(c_t - \overline{y}\right), \quad \text{and}$$

(c) policymakers announce an inflation target, $\overline{\pi}$, and follow the real interest rule,

$$\dot{r}_t = \theta^1\left(\pi_t - \overline{\pi}\right) + \theta^2\left(c_t - \overline{y}\right),$$

where $\theta^1 = \theta\left(1 + \gamma\sigma\right)$ and $\theta^2 = \xi$.

It is still the case that the money rule is the simplest one. On the other hand, all rules depend on the output gap, which is naturally difficult to gauge in practice. Given the difficulties associated with money rules, therefore, the nominal interest rate-cum-inflation target policy regime continues to look like a very reasonable alternative to money rules.

7. Final Remarks

This paper has established some basic equivalences among alternative instruments and policy rules in the context of a closed-economy model with sticky inflation. It has shown that a long-run reduction in the inflation rate can be achieved with three different rules—a *k*-percent money growth rule, an interest rate rule, and a real interest rate rule—which deliver exactly the same outcome. The money rule is the simplest, however, as it involves no feedback mechanisms. If policymakers wish to avoid a protracted deflationary period, there are also three different policy regimes that deliver exactly the same outcome.

The goal of the analysis has been to put enough structure into the model so as to establish some basic policy equivalences, which should be helpful in thinking about alternative policy regimes. The main policy conclusion of the analysis is perhaps that a nominal interest rate rule combined with an inflation target can, in principle, replicate exactly the workings of a money growth rule. Taken as a normative result, this provides strong support for using nominal interest rate rules, given the well-known practical difficulties of controlling monetary aggregates. It may explain the dramatic shift in actual policymaking away from monetary targets and toward regimes that essentially involve—implicitly or explicitly—an inflation target and a nominal interest rate rule aimed at achieving that target.

How would the main conclusions of the analysis be affected by relaxing some of the central assumptions? This is an area for future research, but some conjectures may be made. Consider the case of an open economy. In line with the spirit of the model, it could be assumed that the prices of tradables goods are flexible and determined by purchasing power parity, while inflation of home goods is sticky and determined in the same way as in the closed-economy model. Under flexible exchange rates, such a model should generate the same results. The reason is simply that under flexible exchange rates, the money supply remains the main nominal anchor; the same equivalences with interest rate rules would therefore hold. I would thus conjecture that, to a first approximation, the results should hold for flexible exchange rate regimes.

Under fixed or predetermined exchange rates, the nature of the policy rules studied in the paper would need to be modified to account for the fact that the nominal money supply is endogenous. This implies that the nominal interest rate (and real interest rate) could jump on impact, in contrast to this paper's model. One would thus need to study interest rate rules that could include an initial discrete change in interest rates.[15] This may complicate the formal analysis, but I see no reason to believe that it would alter the main message of this paper.

What if the economy were subject to stochastic shocks? While this is an extension worth addressing, conceptually it is not obvious why it should fundamentally alter any of the main conclusions. Suppose there were stochastic shocks to money demand. A *k*-percent money rule would absorb such shocks by variations in nominal (and thus real) interest rates. A nominal (or real) interest rate rule that responded to such shocks should deliver a similar outcome. If, on the other hand, certain types of shock were more prevalent than others, this might affect the choice of instruments along the lines of Poole (1970). It is unclear, however, how such considerations would affect the present analysis, since the type of indeterminacies emphasized by the more modern, rational-expectations literature do not depend on the specific shocks that hit the economy.

15. Of course, the same logic would apply to a closed-economy model in which the real money demand also depended on consumption (which is not the case in this model).

Appendix A

Fixed Money Growth Rule

A.1 Initial Jump in Consumption

Following an unanticipated reduction in the monetary growth rate, consumption must jump downward on impact. The proof proceeds in three stages.

First, different elements of the eigenvectors must be signed. With no loss of generality, let $\mathbf{h}_{11} = \mathbf{h}_{21} = 1$. From equation 22, it then follows that

$$\mathbf{h}_{12} = -\frac{m_{ss}}{\delta_1} > 0 \ , \tag{A1}$$

$$\mathbf{h}_{22} = -\frac{m_{ss}}{\delta_2} > 0 \ , \text{ and} \tag{A2}$$

$$\mathbf{h}_{22} - \mathbf{h}_{12} = m_{ss}\left(\frac{1}{\delta_1} - \frac{1}{\delta_2}\right) < 0 \ . \tag{A3}$$

(To sign the last expression, recall that, by construction, $\delta_1 - \delta_2 > 0$). From system 21, it follows that

$$\mathbf{h}_{i3} = \frac{\gamma + \delta_i}{\alpha} \quad , \tag{A4}$$

where i = 1, 2 .

Second, I solve for the system's constants. The solution to the dynamic system (given by equations 23, 24, and 25) leads to

$$\pi_0 - \bar{\mu}^L = \omega_1 + \omega_2 \ , \tag{A5}$$

$$m_0 - m_{ss} = \omega_1 \mathbf{h}_{12} + \omega_2 \mathbf{h}_{22} \ , \ \text{ and} \tag{A6}$$

$$c_0 - \bar{y} = \omega_1 \mathbf{h}_{13} + \omega_2 \mathbf{h}_{23} \ . \tag{A7}$$

Equations A5 and A6 can be used to solve for ω_1 and ω_2:

$$\omega_1 = \frac{\mathbf{h}_{22}\left(\pi_0 - \bar{\mu}^L\right) - \left(m_0 - m_{ss}\right)}{\mathbf{h}_{22} - \mathbf{h}_{12}} < 0 \quad \text{and} \tag{A8}$$

$$\omega_2 = \frac{m_0 - m_{ss} - \mathbf{h}_{12}\left(\pi_0 - \overline{\mu}^L\right)}{\mathbf{h}_{22} - \mathbf{h}_{12}} > 0\ , \tag{A9}$$

where the signs follow from equations A1, A2, and A3 and the fact that $\pi_0 - \overline{\mu}^L > 0$ and $m_0 - m_{ss} < 0$.

Finally, the expression for the initial jump in consumption can be signed. Substituting equations A4, A8, and A9 into equation A7 yields

$$c_0 - \overline{y} = \frac{1}{\alpha}\left[\frac{m_0 - m_{ss}}{m_{ss}}\delta_1\delta_2 + \left(\gamma + \delta_1 + \delta_2\right)\left(\pi_0 - \overline{\mu}^L\right)\right] < 0\ . \tag{A10}$$

To sign the last expression, note that $\gamma + \delta_1 + \delta_2 < 0$, which follows from the fact that $\delta_1 + \delta_2 + \delta_3 + \gamma = 0$ (recall, from equation 19, that the system's trace is $-\gamma$) and $\delta_3 > 0$. Equation A10 implies that $c_0 < \overline{y}$. Consumption thus jumps downward on impact (that is, at $t = 0$).

A.2 Sign of $\dot{\pi}_0$

To check that the system will not initially head in a northwestern direction starting from point A (in terms of figure 1), it is enough to show that $\dot{\pi}_0 < 0$. To that effect, equation 13 can be used to show that

$$\dot{\pi}_0 = \gamma\left(\overline{\mu}^L - \pi_0\right) + \alpha\left(c_0 - \overline{y}\right) < 0\ , \tag{A11}$$

since $\overline{\mu}^L - \pi_0 < 0$ and, as just shown, $c_0 - \overline{y} < 0$.

References

Auernheimer, L., and B. Contreras. 1993. "A Nominal Interest Rate Rule in the Open Economy." Unpublished paper. Texas A&M University.

Batten, D. S., M. P. Blackwell, I. S. Kim, S. E. Nocera, and Y. Ozeki. 1990. "The Conduct of Monetary Policy in the Major Industrial Countries: Instruments and Operating Procedures." Occasional Paper 70. Washington: International Monetary Fund.

Bruno, M. 1993. *Crisis, Stabilization, and Reform: Therapy by Consensus*. Oxford University Press.

Calvo, G. A. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* (September): 383-98.

———. 1987. "Real Exchange Rate Dynamics with Nominal Parities." *Journal of International Economics* 22: 141-55.

Calvo, G. A., C. M. Reinhart, and C. A. Végh. 1995. "Targeting the Real Exchange Rate: Theory and Evidence." *Journal of Development Economics* 47 (June): 97-133.

Calvo, G. A., and C. A. Végh. 1995. "Fighting Inflation with High Interest Rates: The Small Open Economy Case under Flexible Prices." *Journal of Money, Credit and Banking* 27: 49-66.

———. 1996. "Disinflation and Interest-Bearing Money." *The Economic Journal* 106: 1546-63.

Corbo, V., and S. Fischer. 1994. "Lessons from the Chilean Stabilization and Recovery." In *The Chilean Economy*, edited by B. P. Bosworth, R. Dornbusch, and R. Laban, 29-80. Washington: Brookings Institution.

Dornbusch, R., and J. Frenkel. 1973. "Inflation and Growth: Alternative Approaches." *Journal of Money, Credit and Banking* 5: 141-56.

Dornbusch, R., and M. H. Simonsen. 1987. *Inflation Stabilization with Incomes Policy Support: A Review of Recent Experience in Argentina, Brazil, and Israel*. New York: Group of Thirty.

Edwards, S. 1991. "Stabilization and Liberalization Policies in Central and Eastern Europe: Lessons from Latin America." NBER Working Paper 3816. Cambridge, Mass.: National Bureau of Economic Research.

Lahiri, A. 1997. "Controlling Capital Flows: Targeting Stocks versus Flows." Unpublished paper. University of California at Los Angeles.

Leiderman, L., and L. Svensson, eds. 1995. *Inflation Targets*. London: Centre for Economic Policy Research.

Masson, P. R., M. A. Savastano, and S. Sharma. 1997. "The Scope for Inflation Targeting in Developing Countries." IMF Working Paper 130. Washington: International Monetary Fund.

Mendoza, E., and F. Fernández. 1994. "Monetary Transmission and Financial Indexation: Evidence from the Chilean Economy." Papers on Policy Analysis and Assessment 17. Washington: International Monetary Fund.

Poole, W. 1970. "The Optimal Choice of Monetary Policy Instruments in a Simple Macro Model." *Quarterly Journal of Economics* 84: 192-216.

Reinhart, V. 1992. "The Design of an Interest Rate Rule with Staggered Contracting and Costly Transacting." *Journal of Macroeconomics* 14: 663-88.

———. 1993. "Real Interest Rates in the Monetary Policy Process." Unpublished paper. Board of Governors of the Federal Reserve System.

Rojas, P. 1993. "El dinero como un objetivo intermedio de la política monetaria en Chile." *Cuadernos de Economía* 30 (August): 139-78.

Sargent, T. J., and N. Wallace. 1975. "Rational Expectations, the Optimal Monetary Instrument, and the Optimal Money Supply Rule." *Journal of Political Economy* 83: 241-54.

Indexation, Inflationary Inertia, and the Sacrifice Coefficient

Luis Oscar Herrera
Central Bank of Chile

When inflation is chronic, firms develop indexation practices that automatically tie the growth of prices, wages, and other contracts to the performance of some comprehensive price index. The microeconomic advantages of indexation are evident and derive from the immunization of the relative price system against the extravagances of inflation. From a macroeconomic perspective, however, this practice has been criticized for perpetuating the inflationary thrust, accentuating its volatility, and influencing the process of relative price adjustments in the face of real shocks. Those in charge of monetary policy generally oppose indexation under the argument that it raises the costs of reducing or controlling inflation, and its elimination has been considered a prerequisite for ensuring the success of the drastic stabilization plans that have been implemented in countries with a long history of inflation.

This position, however, is not fully shared in the academic literature. Essentially, one segment of the literature indicates that indexation favors the stabilization of output and facilitates the reduction of inflation. The best-known proponent of this position is Friedman (1974), who argues that automatic adjustments reduce the costs of anti-inflationary policies, because they accelerate the speed with which the monetary effects are transmitted to prices and wages and thus reduce the impact on output. Gray (1976) and Fischer (1977) reach the same conclusion, arguing that indexation stabilizes output when monetary shocks predominate, as in an inflationary stabilization plan. This favorable interpretation of indexation is also reflected in empirical literature that uses the coverage of automatic adjustment practices as a measure of wage flexibility that reduces the costs of price stabilization (Ball, 1994b).

An important criticism of this line of argument is that it implicitly assumes that indexation is synchronized and immediate (Simonsen, 1983). The conclusions are substantially modified when these assumptions

Indexation, Inflation, and Monetary Policy, edited by Fernando Lefort and Klaus Schmidt-Hebbel, Santiago, Chile.

are removed and replaced by lagged, uncoordinated indexation, as shown in the works of Bonomo and García (1994) and Jadresic (1995).[1] The objective of the current paper is to study the relation between price and wage indexation and the costs of reducing inflation in terms of output; this relation is known as the sacrifice coefficient. The analysis complements earlier works by Ball (1994a), Bonomo and García (1994), and Jadresic (1995, 1996a, 1996b).

The emphasis, however, is on the consequences of the frequency of indexation and other characteristics of labor contracts for both the sacrifice coefficient and the output and price trends in an economy that is undergoing an anti-inflationary stabilization program.

A priori arguments indicate that the relation between the sacrifice coefficient and the frequency of indexation is not monotonic: as the frequency of indexation increases, the economy approaches immediate, synchronized adjustment. In this case, the performance of an economy that is responding to changes in monetary policy converges with that of an economy characterized by fully flexible prices, which brings the sacrifice coefficient to zero.

This work examines in depth the relation between the sacrifice coefficient and the frequency of indexation, as well as the consequences for recommendations on monetary policy. The methodology used is to simulate the response of an economy characterized by Calvo-type staggered contracts, which are extended to include automatic adjustment clauses based on past inflation. The renegotiation of these price and wage contracts is unsynchronized, such that there is a constant probability of reopening contracts in any given moment. Intermediate contract openings in which only the nominal level is corrected are also possible, in order to return the contract to its real level prior to renegotiation. The microeconomic explanations for this real rigidity are outside the scope of this paper, but they are assumed to be in line with the literature on menu costs (Mankiw and Romer, 1991). Following Calvo, the supply structure serves as the basis for deriving a very simple model using parameterized, linear, differential equations for the frequency of real renegotiation and nominal adjustments.

The main consequence of automatic contract adjustments is to introduce inertia into the inflationary process, that is, in the first derivative of

1. The literature drawing on Barro and Gordon (1983), which emphasizes the strategic aspects of implementing monetary policy, is inconclusive with regard to the impact of indexation on inflation and the authority's incentives to exploit the inflation-unemployment trade-off.

the price level. This stands in contrast to the original formulation by Calvo (1983) or Taylor (1979), which exhibits inertia only in the price level.

The next section derives the theoretical model of aggregate supply, while subsequent sections analyzes the response of prices and output in the face of three types of inflationary reduction programs. Specifically, section 2 describes a gradual inflationary reduction plan with full credibility and simulates the model for different combinations of parameters, concentrating on the frequency of indexation. Section 3 carries out the same study in the context of a shock plan, and section 4 examines the impact of a gradual plan with partial credibility. Finally, the main conclusions of the paper are presented, together with the implications for the persistence of moderate inflationary processes.

1. The Model

The model, which is derived in continuous time, describes an economy consisting of a continuum of firms in monopolistic competition.[2] The relative price that maximizes each firm's immediate utilities is increasing in the level of aggregate output:

$$p^{*} - P = \mathrm{v}Y \ , \tag{1}$$

where $0 < \mathrm{v} < 1$, Y is the output level, p^{*} is the firm's optimal price, and P is the aggregate price level. Money and monetary policy enter the model through the quantitative equation for money:

$$M - P = Y \ , \tag{2}$$

where M is the money supply.[3] The optimal price in terms of M and P is deduced from equations 1 and 2:

$$p^{*} = \mathrm{v}M + (1 - \mathrm{v})P \ . \tag{3}$$

This structural modeling of demand is analogous to that used by Ball (1994a), Bonomo and García (1994), and Jadresic (1991, 1995).

2. With the exception of the supply equation, the model is analogous to that used by Ball (1994a), Bonomo and García (1994), and Jadresic (1995).

3. Alternatively, the model can be extended for the case of an open economy and the real exchange rate can replace the role of real money in the determination of output.

It differs from these works in the specification of aggregate supply, which is an extension of the model outlined in Calvo (1983) and which introduces automatic adjustments. Calvo's model incorporates a formulation in which the duration of the contracts is exponentially distributed, in contrast to the fixed horizon used in the other studies cited. This artifice simplifies the calculation and facilitates the study of the consequences of alternative types of wage contracts on stabilization costs.

Each firm sporadically corrects its price. These adjustments are random events that occur with a constant probability, independently both of previous corrections undertaken by the firm and of current and past corrections undertaken by other firms in the economy. The price adjustments can be either nominal or real. Nominal adjustments correct the price to reflect the degree of inflation that has accumulated since the last price revision. Real adjustments integrally revise the contract, that is, in both its nominal and real components. Nominal adjustments occur with a probability θ per unit of time, and real adjustments occur with probability γ per unit of time. Therefore, in each moment dt, a portion of contracts, $(\gamma + \theta)\mathrm{d}t$, is revised, of which the fraction

$$\lambda = \frac{\gamma}{\gamma + \theta}$$

is fixed on the basis of both actual and future conditions, while the remaining contracts only correct for past inflation.

The firm's effective nominal price is divided into two components:

$$p(\tau, \tau') = z(\tau) + q(\tau, \tau') \ , \tag{4}$$

where $z(\tau)$ is the real premium negotiated in τ and $q(\tau)$ is the nominal component of the contract signed in τ and revised in τ', equal to the prices $P(\tau')$ prevailing at that moment. The firms are indexed in (τ,τ') as corresponds to the moment in which they signed the real and nominal components, respectively.

The firm sets the real premium knowing that the real and nominal revisions are sporadic. The objective is to equalize the expected average price during the life of the contract with the average optimal price that is expected in this same period,[4]

$$z(t) + \int_t^{\infty} q(t,s)\gamma e^{-\gamma(s-t)}\,\mathrm{d}s = \int_t^{\infty} p^*(s)\gamma e^{-\gamma(s-t)}\,\mathrm{d}s \ . \tag{5}$$

4. Equation 5 can be interpreted as the optimal result of a quadratic approximation of the firm's true objective function. The discount factor is ignored for simplicity and to maintain coherence with Ball's and Jadresic's derivations.

In addition, the nominal component $q(t,s)$ of the contracts signed in t are defined by the following equation:[5]

$$q(t,s) = e^{-\theta(s,t)} P(t) + \int_t^s \theta e^{-\theta(t',t)} P(t')\mathrm{d}t'. \tag{6}$$

Differentiating z relative to t produces

$$\frac{\mathrm{d}z(t)}{\mathrm{d}t} = \gamma\left[z(t) + P(t) - p^*(t)\right] - \frac{\gamma}{\gamma+\theta}\Pi(t), \tag{7}$$

where $\Pi(t)$ is the immediate inflation rate.

The price level is obtained by aggregating current prices for the different cohorts of firms. It is assumed that the distribution of the cohorts is stationary, such that the distribution in τ (the moment of the last real adjustment) is exponential in $(-\infty,t)$ with parameter γ, and the distribution in τ' (the moment of the last nominal adjustment) is exponential between $(-\infty,t)$ with parameter $\gamma + \theta$. The general price level is then derived as

$$P(t) = \int_{-\infty}^{t} z(\tau)\gamma e^{-\gamma(\tau-t)}\mathrm{d}\tau + \int_{-\infty}^{t} P(\tau')(\gamma+\theta)e^{-(\gamma+\theta)(\tau'-t)}\mathrm{d}\tau'. \tag{8}$$

This equation generalizes Calvo's model (1983) to include adjustments for past inflation ($\theta \neq 0$). As in Calvo (1983) and Taylor (1979), the price level is predetermined, and it is not fully adjusted in response to either expected or unexpected changes in the money supply. This gives rise to the nonneutrality of the money supply and monetary policy. The innovation of this supply equation relative to the earlier models is that inflation, the first derivative of the price level, also exhibits inertia.

The immediate inflation rate is obtained by differentiating the price level equation:

$$\Pi(t) = \gamma z(t) + \theta\left[P(t) - Q(t)\right], \tag{9}$$

where $Q(t)$ is the average price level implicit in the nominal component of the contracts in force, that is, the second integral on the right

5. Equation 6 is obtained from the solution to the differential and border equations: $\frac{\mathrm{d}q(s,t)}{\mathrm{d}s} = \theta\left[p(s) - q(s,t)\right]$ and $q(t,t') = p(t)$.

hand side of equation 8. This equation decomposes inflation into two parts. The first component reflects the premium on the price level in new contracts, $z(t)$. This factor can change instantaneously in response to both observed and anticipated changes in the economy's monetary and nonmonetary conditions. The second component comprises the model's innovation relative to Calvo. The variable $P(t) - Q(t)$ is a predetermined variable that reflects the average size of the nominal corrections stemming from indexation.

Algebraic work generates an alternative form to equation 9, which more clearly reveals the determinants of inflation in the model:

$$\Pi(t) = \underbrace{\gamma \int_0^\infty \gamma e^{-\gamma\tau} \nu Y(t+\tau)\,d\tau + \frac{\gamma}{\gamma+\theta}\int_0^\infty \gamma e^{-\gamma\tau}\,\Pi(t+\tau)\,d\tau}_{\textit{expectations}}$$

$$+ \underbrace{\frac{\theta}{\theta+\gamma}\int_0^\infty (\theta+\gamma) e^{-(\gamma+\theta)\tau}\,\Pi(t-\tau)\,d\tau}_{\textit{inertia}} . \tag{10}$$

Current inflation is determined by expectations with regard to the output gap and future inflation, together with the evolution of lagged inflation. Equation 10 demonstrates that the frequency of indexation, θ, has effects on both expectations and inertia. Greater frequency reduces the weight of future inflation, because automatic indexation keeps this component up to date and increases the weight of lagged inflation, with greater weight on recent observations of the inflation rate. This structural supply equation reveals that empirical inflationary inertia can be generated by both indexation and inertia in the expectations components.

In Calvo's model, as well as in Taylor (1979), this is equivalent to assuming that $\theta = 0$, which implies that the inflation rate is totally flexible and anticipatory, even when the price level exhibits inertia. This flexibility in the inflation rate is not supported empirically, however. This variable generally exhibits a high degree of positive serial autocorrelation, although few empirical studies explicitly express the identifying assumptions that are necessary for distinguishing between structural inertia stemming from indexation and inertia in the inflation fundamentals.

Finally, the variable Q follows the differential equation

$$\frac{dQ(t)}{dt} = (\gamma+\theta)\left[P(t) - Q(t)\right]. \tag{11}$$

The system's path is summarized by the three differential, constant coefficient equations 8, 10, and 11, which are written in matrix terms as

$$\frac{\mathrm{d}\,\mathbf{X}(t)}{\mathrm{d}t} = \mathbf{A}\,\mathbf{X}(t) + \mathbf{B}\,\mathrm{E}\left[M(t)\right], \tag{12}$$

where the vector $\mathbf{X}(t) = [z(t), P(t), Q(t)]'$ and the matrices **A** and **B** are 3x3 and 3x1, respectively. The dynamic system defined by **A** has two negative characteristic values, which are convergent, and one positive, which is divergent, such that the dynamic equilibrium has a saddle-path configuration. The variables $P(t)$ and $Q(t)$ are predetermined, and the variable $z(t)$ is adjusted to situate the system on the convergent path.

The dynamic-system solution requires stipulating the performance of the exogenous variable in the system (that is, monetary policy or the money supply). This topic is addressed in the following sections.

2. Gradual Stabilization with Full Credibility

2.1 Gradual Stabilization

This section studies an inflationary stabilization experiment that is analogous to that proposed by Ball (1994a), but extended to include indexation of contracts. Given the assumption that $t \leq 0$, money grows at a constant rate equal to π, and the firms expect that this situation will be maintained forever.

$$M(t) = \pi t \text{ and} \tag{13a}$$

$$\frac{\mathrm{d}\,M(t)}{\mathrm{d}t} = \pi\ , \tag{13b}$$

where $t < 0$.

It is assumed that this situation has been maintained for a long time, such that the economy is in a stationary state defined by the conditions

$$\frac{\mathrm{d}\,z(t)}{\mathrm{d}t} = 0\ , \tag{14a}$$

$$\frac{\mathrm{d}\,Q(t)}{\mathrm{d}t} = \pi\ , \text{ and} \tag{14b}$$

$$\frac{\mathrm{d}\,p(t)}{\mathrm{d}t} = \pi\ , \tag{14c}$$

These three conditions give rise to the conclusions that in the long run, the price level should equalize the money supply, the inflation rate is π, and the real premium, z, is constant:

$$\bar{z}(t) = \frac{\pi}{\theta + \gamma} , \tag{15a}$$

$$\bar{p}(t) = \pi t , \quad \text{and} \tag{15b}$$

$$\overline{Q}(t) = \bar{p}(t) - \frac{\pi}{\theta + \gamma} , \tag{15c}$$

where $t < 0$.

If $t = 0$, however, the central bank announces an unexpected plan for gradual inflationary reduction, exponentially bringing the issue rate to zero with velocity μ:

$$\frac{\mathrm{d}M'(t)}{\mathrm{d}t} = \pi e^{-\mu t} , \tag{16}$$

where $t \geq 0$ and M' is the announcement of the money growth rate.[6] The dynamic-system solution is described in the appendix.

2.2 Choice of Parameters

The model is derived in terms of final prices, but the empirical counterpart to the parameters γ and θ is calibrated according to the typical characteristics of wage contracts in Chile. In this case, equation 8 is reinterpreted to represent the average level of nominal wages in the economy, and firms are assumed to set their prices with a constant margin over the unitary labor costs.

Jadresic (1991) uses data on collectively negotiated contracts and econometric estimates of the aggregate performance of the wage index. He concludes that the typical wage contract in the Chilean economy stipulates semiannual automatic adjustments and biannual renegotiation. If these values are taken as a measure of the respective distributions, then $\gamma = 0.5$ and $\gamma + \theta = 2.0$, and thus the fraction

6. Ball (1994a) and Bonomo and García (1994) examine the case in which the issue rate is linearly brought to zero. This modification does not change the qualitative conclusions obtained in the present paper.

that takes future economic conditions into account when renegotiating their contracts is $\lambda = 0.25$.[7]

However, other moments in the empirical distribution of adjustments are not satisfactorily adjusted through the exponential function imposed by the theoretical model. Jadresic (1995) indicates that the frequency of adjustment is very concentrated in the semiannual time frame, at least within the collectively negotiated contracts. In 1990, nearly 10 percent featured adjustment clauses between one and three months, 80 percent between four and six months, and 10 percent over six months. This distribution contrasts with that generated by the exponential function with $\gamma = 0.5$ and $\gamma + \theta = 2.0$, in which 38 percent of workers have adjustments less than or equal to three months and 62 percent have adjustments less than or equal to six months. The tails of the exponential distribution are wider at both extremes. This suggests that the impact of announcements on monetary policy are transmitted more rapidly to prices, because a greater fraction of workers adjust their prices in the short term. At the same time, however, the real effects are delayed longer, because the tail of the distribution is longer.

The parameter v reflects the complementarity of the price decisions. Ball (1994a, 1994b) and Bonomo and García (1994) use v = 1.0 and v = 0.25, whereas Jadresic (1991, 1995) only considers v = 1.0. For the purpose of comparison with the results in these articles, v is set at 0.25 in the tables and figures presented in this paper; the discussion signals quantitative and qualitative differences between this case and v = 1.0.

2.3 Output, Money, and Inflation

In the base exercise, the parameters are set at $\gamma = 0.5$ and $\gamma + \theta = 2.0$. Inflation starts at 6 percent, and the money growth rate falls at the velocity of $\mu = 0.46$. The average life of the stabilization program—that is, the time it takes the money growth rate to reach 3 percent—is eight quarters. The model defined by equation 12 determines the price and output trends, which are used to generate some indicators that summarize the results of the stabilization plan.

Figure 1 plots the trends in money, output, and inflation. For $t = 0$, which represents the moment in which the policy is announced and the beginning of the monetary adjustment process, the figure shows

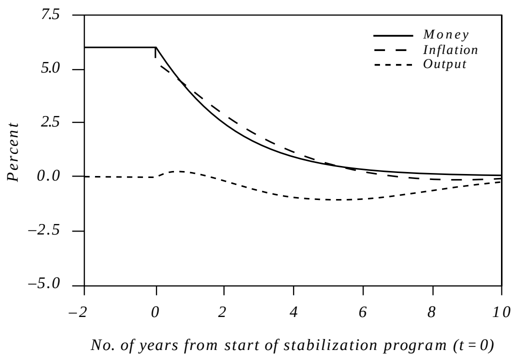
7. Alternatively, if this fraction is interpreted as the median, then $\gamma = 0.35$ and $\gamma + \theta = 1.39$.

an immediate, moderate drop in the inflation rate, from 6.0 to 5.3 percent. The firms and workers that renegotiate prices anticipate the gradual expansion of the disinflation process and incorporate it into their price decisions. This contributes to immediately reducing the real premium, *z*, relative to its historical level, which slows the pace of inflation despite the fact that the money issue rate initially stays at its historic level of π = 6.0 percent. Consequently, the economy enters a slightly expansionary phase, with real money balances and production growing above the long-term rate. The inflation rate continues to fall, but more slowly than the growth rate of money, because there is a holdover of inflation in those prices that need to recover their real historic level and also because the economy is expanding.

The expansionary process comes to an end after two quarters, when the accumulated output gap reaches just 0.2 percent. From this moment on, the inflation rate exceeds the money growth rate, and real balances and, therefore, output begin to fall. In the seventh quarter, the economy enters a persistent, though not very deep, recession. The economy hits bottom in the fifth year, with a negative output gap of –1.0 percent, and then gradually and variably begins to recover its long-term level.

The accumulated losses in the contractionary period exceed the gains observed in the expansionary period, such that the process of inflationary stabilization gives rise to a net sacrifice. The sacrifice coefficient, *S*,

Figure 1. Trends in Output, Money, and Inflation under Gradual Stabilization and Full Credibility[a]



Source: Author's calculations.
a. Model simulation of the base exercise (θ = 1.5 and γ = 0.5), with gradual stabilization velocity (μ = 0.46) and ν = 0.25.

is defined as the accumulation through time of output losses caused by each point of permanent inflation reduction:

$$S = -\int_{t}^{\infty} \frac{y\,\mathrm{d}t}{\pi}\ .$$

In the base exercise, this equation yields $S = 0.92$.[8]

Inflation falls slowly, but the trend is relatively in line with the money issue rate. It takes nearly seventeen quarters for inflation to reach 1 percent; in the case of the money issue rate, it takes almost fifteen quarters.

Considering that the model is highly stylized, it is surprising that the sacrifice coefficient predicted for this experiment by the model is realistic and falls in the center of the range typically observed in empirical studies on stabilization experiences. Ball (1994b) examines a large sample of disinflation processes in industrialized countries for the period 1960-91. The observed values for S vary between 0 and 3.6, with a sample average of 0.8 (annual data) and 1.4 (quarterly data).

2.4 Frequency of Wage Adjustments

The effect of indexation on the inflationary dynamics of the economy and on the costs of stabilization are evaluated in table 1 and figure 2, which show, respectively, the sacrifice coefficient and the trends in inflation and output for different combinations of the frequency of indexation (θ) and real adjustment (γ). As the table indicates, for an economy without indexation ($\gamma = 0.5$ and $\theta = 0.01$), the model predicts a negative sacrifice coefficient ($S = -5.30$), that is, a net output gain associated with stabilization. The corresponding panel in figure 2 shows the output and inflation trends for a subset of the result in table 1. For $t = 0$, inflation falls immediately and more drastically than in the former example, from 6.0 to 2.2 percent. Its later convergence is slower, however, taking almost twenty-one quarters to reach 1 percent. The initial drop in inflation is larger because the nominal component of the renovated contracts has a much longer effective duration (as does the real component), which causes the premium, z, to encompass a larger fraction of the expected reduction in the money issue rate. The difference between the inflation rate and the money issue rate strongly expands the economy, peaking at the end of eleven quarters with a positive gap of 3.9 percent. The convergence with long-term equilibrium is monotonic, such that the economy never enters a recessive phase.

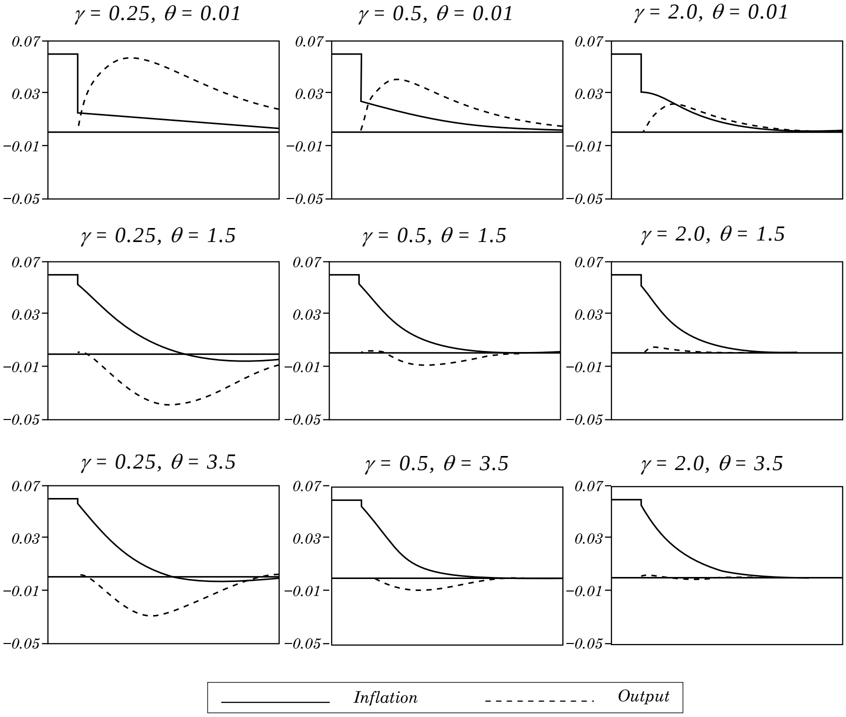
8. The qualitative results of the model under study are independent of the initial inflation rate, while the quantitative results are directly proportional to it. Thus the coefficient S is independent of the initial inflation level.

Table 1. The Sacrifice Coefficient under Gradual Stabilization and Full Credibility as a Function of the Frequency of Nominal Indexation and Real Adjustments[a]

Frequency of nominal indexation (θ)	*Frequency of real adjustments (γ)* 0.25	0.50	1.00	2.00	10.00
0.0	–11.30	–5.30	–2.04	–0.68	–0.04
0.5	6.64	0.01	–0.75	–0.43	–0.03
1.5	5.04	0.92	–0.11	–0.20	–0.03
3.5	3.13	0.76	0.08	–0.06	–0.02
10.0	1.46	0.40	0.09	0.00	–0.01

Source: Author's calculations.
a. The sacrifice coefficient, *S*, was derived for the indicated combinations of γ and θ based on an adjustment velocity in the money growth rate of μ = 0.46, with ν = 0.25.

Figure 2. Output and Inflation Trends and the Frequency of Nominal and Real Adjustments[a]



Source: Author's calculations.
a. Model simulation with gradual stabilization velocity (μ = 0.46) and ν = 0.25 for different values of the frequency of nominal (θ) and real (γ) adjustments.

This counterintuitive result is characteristic of models featuring staggered prices and gradual stabilization. Given gradual stabilization and full credibility, firms and wage earners anticipate the success of the stabilization program and incorporate in advance the impact of the reduction of the money issue rate on prices. This induces an initial expansion of output, because prices fall more rapidly than the money stock. Ball uses a Taylor-type model to demonstrate that neither absolute nor net output losses are generated by a linear reduction of the issue rate with a duration greater than or equal to 0.68 times the length of the contracts.

This theoretical result directly contradicts both a long macroeconomic tradition and most of the available empirical evidence. However, introducing indexation into the aggregate supply reverses this result. The automatic adjustments create inertia in the inflationary process, which severely restricts the conditions of credibility and gradual implementation that are necessary for triggering a net expansion in the economy, rather than a net sacrifice coefficient, in response to the reduction of inflation. Bonomo and García (1994) conclude that by introducing nominal adjustments over half the life of the contract, the minimum duration of the linear stabilization process that avoids the recessive cycle is just under three times the length of the contract. Indexation also affects the timing of the announcement of the stabilization program. In the model without indexation, the initiation of a moderate stabilization process should be announced in advance by at least one and a half times the average contract length in order to avoid a recession. In the model with indexation, the minimum period increases to four and a half times. The authors conclude that even when automatic adjustments increase the frequency of the nominal price adjustments, indexation increases the costs of the disinflation process.

The pernicious effect of indexation on stabilization costs is corroborated in this paper, but this does not mean that greater indexation, in the sense of more frequent adjustments for accumulated inflation, will necessarily be damaging for economic performance. The effect of the frequency of indexation on stabilization costs is not monotonic. The costs of stabilization rise when the frequency of indexation increases from zero to positive, but for some value of θ, the marginal impact becomes negative again to the extent that the economy recovers nominal neutrality. Essentially, when the adjustment is almost instantaneous, the economy recovers its neutrality in the face of nominal policies, and the costs of stabilization (and the sacrifice coefficient) approach zero. This result is consistent with the findings of Friedman (1974), Gray (1976), and Fischer (1977).

For $\gamma = 0.5$, increasing indexation from a semiannual to a quarterly frequency reduces the accumulated net output losses from 5.5 to 4.6 percent, and the sacrifice coefficient falls from 0.92 to 0.76 (see table 1). The trend is plotted in figure 2. The initial impact on inflation is slightly lower, but inflation then falls more rapidly in conjunction with the money issue rate. The pattern is similar to that found in the base exercise, but the size and duration of the cycle's expansionary and contractionary phases are smaller. When the frequency increases to a monthly rate, the costs of stabilization are reduced by half ($S = 0.40$). The stabilization costs also fall if the frequency is reduced from semiannual to annual, and the sacrifice coefficient reaches just 0.01. Thus within the structures examined, and given the typical biannual structure of price contracts, semiannual adjustment has the highest associated stabilization costs, since both increases and decreases in the frequency of indexation reduce the costs.

Changes in the frequency of real adjustments, γ, also have a nonmonotonic impact on stabilization costs. Infrequent adjustments tend to generate a positive expansionary effect, but as the frequency increases, the economy tends to recover its nominal neutrality.

The relation between the frequency of nominal and real adjustments, however, should be one of substitution. As described above, the typical contract in the Chilean economy has a two-year horizon with semiannual adjustments. In the U.S. economy, the typical contract is shorter, usually lasting one year, and it does not contemplate intermediate indexation; staggered contracts have an average duration of three years (Taylor, 1998). There is thus a substitution between the frequency of indexation and the frequency of full renegotiation. In this light, it is relevant to reexamine the analysis presented in table 1, compensating for the changes in the frequency of indexation with changes in the frequency of real adjustment. Table 2 shows the sacrifice coefficient associated with combinations of the total frequency of adjustments, $\gamma + \theta$, and the proportion,

$$\lambda = \frac{\gamma}{\gamma + \theta},$$

which represents the fraction of prices that are renegotiated in each moment with attention to the future evolution of the economy. The results point to an inverse (and monotonic) relation between these two parameters and the sacrifice coefficient. As the frequency of real or nominal adjustments increases, for any given value of λ, the sacrifice coefficient approaches zero, and as the proportion of prices that are fixed with attention to future prices and the future output gap rises, the sacrifice coefficient again approaches zero.

Table 2. The Sacrifice Coefficient under Gradual Stabilization and Full Credibility as a Function of the Frequency of Adjustments[a]

Real adjustments as fraction of total (λ)	*Frequency of total adjustments ($\gamma + \theta$)*				
	0.5	*1.0*	*2.0*	*4.0*	*10.0*
0.10	113.80	40.00	7.09	1.22	0.09
0.25	35.30	6.46	0.92	0.07	–0.02
0.50	4.78	0.01	–0.31	–0.14	–0.03
0.75	–2.66	–1.49	–0.58	–0.19	–0.03
0.90	–4.70	–1.90	–0.65	–0.20	–0.04

Source: Author's calculations.
a. The sacrifice coefficient, S, was derived for the indicated combinations of $\gamma + \theta$ and λ based on an adjustment velocity in the money growth rate of $\mu = 0.46$, with $\nu = 0.25$.

3. Immediate Stabilization with Full Credibility

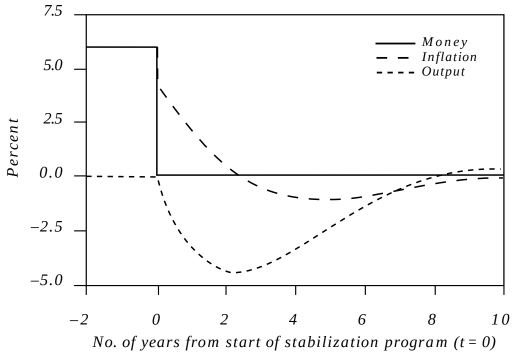
The speed at which the stabilization program is implemented affects the output and inflation trends, as well as the net costs of the program. The faster the reduction in the money growth rate, the shorter the duration and narrower the scope of the initial boom and the greater the depth of the later recession—and thus the greater the total costs of the stabilization process. This section analyzes the case of a sudden, drastic stabilization program (see figure 3). The issue rate moves immediately from π to zero, and equation 16 is replaced by

$$\frac{\mathrm{d}M'(t)}{\mathrm{d}t} = 0 . \tag{17}$$

where $t \geq 0$. This equation corresponds to the extreme case in which μ tends toward infinity.

Table 3 shows the inflation and output trends for the case of immediate stabilization with the parameters of the base exercise ($\gamma = 0.5$ and $\theta = 1.5$). For $t = 0$, inflation initially falls to 4.5 percent and then continues falling until it reaches 1 percent after a year and a half. Because the inflation rate exceeds the issue rate, the economy immediately enters a recession, which bottoms out after nine quarters with a gap of nearly 4.5 percent. The economy then slowly recovers its long-term level, and minor cyclical fluctuations are produced. The total cost of the stabilization process is equivalent to 18 percent of output (that is, $S = 2.0$), as compared to the lower cost of 6 percent described in the previous section.

Figure 3. Trends in Output, Money, and Inflation under Immediate Stabilization and Full Credibility[a]



Source: Author's calculations.
a. Model simulation of the base exercise ($\theta = 1.5$ and $\gamma = 0.5$), with immediate stabilization velocity and $\nu = 0.25$.

A comparison of table 3 and table 1 generates two observations. First, relative to gradual stabilization, the cost of immediate stabilization in terms of output increases for all combinations of the parameters. The sacrifice coefficient is positive in all cases. Second, the qualitative standard of the relation between the frequency of indexation and the sacrifice coefficient remains nonmonotonic. In comparison with the base example ($\gamma = 0.5$ and $\theta = 1.5$), increasing the frequency of indexation from semiannual to quarterly adjustments reduces the sacrifice coefficient from 3.0 to 2.2, while reducing the frequency from semiannual to annual adjustments increases the sacrifice coefficient to 3.25. The total elimination of indexation, however, reduces the sacrifice coefficient to just 0.21. Thus a partial reduction of the indexation frequency does not necessarily reduce the costs of stabilization, although its total elimination does.

Table 3. The Sacrifice Coefficient under Immediate Stabilization and Full Credibility[a]

Frequency of nominal indexation (θ)	*Frequency of real adjustments (γ)*				
	0.25	*0.50*	*1.00*	*2.00*	*10.00*
0.0	1.51	0.21	0.03	0.00	0.00
0.5	13.20	3.25	0.66	0.11	0.00
1.5	9.25	3.00	0.83	0.19	0.00
3.5	6.10	2.18	0.72	0.21	0.01
10.0	3.25	1.24	0.46	0.16	0.01

Source: Author's calculations.
a. The sacrifice coefficient, *S*, was derived for the indicated combinations of γ and θ based on an adjustment velocity in the money growth rate of $\mu = 10{,}000$, with $\nu = 0.25$.

4. STABILIZATION WITH PARTIAL CREDIBILITY

Thus far, the analysis has assumed full credibility. The announcement of a stabilization program is unexpected, but it is fully incorporated into the expectations and decisions of the price formation. This section investigates the consequences of relaxing this assumption, introducing the possibility of abandoning the announced plan before its completion. It is assumed that the monetary authorities begin to implement the money path defined below (equation 18), but in each moment there is a probability h that the stabilization effort will be stopped at that point. If the central bank abandons the plan, then expectations are that the issue rate will remain forever at the level prevailing at that time. Consequently, if the plan is abandoned in τ, the issue rate follows the path,

$$\frac{\mathrm{d}M'(t)}{\mathrm{d}t} = \begin{cases} \pi e^{-\mu t}, & \text{where} \quad 0 \le t \le \tau \\ \pi e^{-\mu \tau}, & \text{where} \quad t > \tau . \end{cases} \tag{18}$$

The probability h measures the program's credibility; a higher value for h indicates a lower credibility.

4.1 Expected Trend with Partial Credibility

The effective trend for the system depends on the stochastic realization of abandoning the program. Given the system's linearity, however, the expected system trend can be calculated on the basis of the expected money trend defined in equation 18. This can be written as

$$\mathrm{E}\left[m(t)\right] = \frac{h\pi t}{h+\mu} + \frac{\mu\pi\left(1-e^{-(h+\mu)t}\right)}{(h+\mu)^2} . \tag{19}$$

The dynamic system should verify the following limit conditions:

$$p(0) = 0 , \tag{20a}$$

$$Q(0) = -\frac{\pi}{\theta+\gamma} , \quad \text{and} \tag{20b}$$

$$\lim_{\tau\to\infty} \mathrm{E}\left[z(\tau)\right] = \frac{h}{h+\mu}\,\frac{\pi}{\theta+\gamma} . \tag{20c}$$

Table 4 shows the expected sacrifice coefficient associated with the different frequency parameters for the case of gradual stabilization with partial credibility.[9] The parameter h is set arbitrarily at 0.69, which is equivalent to a 0.5 probability of the program's being abandoned within a year. In all cases, the expected cost of the stabilization effort is higher than for the corresponding case with full credibility presented in table 1. The expectation that the program will be abandoned early delays the incorporation of the expected money trend into the evolution of recontracted prices. This reduces the length and breadth of the initial expansion, as well as the length and depth of the contractionary phase in those cases featuring recession. This observation confirms the results achieved by Ball (1994a, b) and Bonomo and García (1994) in the context of models based on staggered wages with a fixed horizon.

As in the previous cases, the expected stabilization costs remain nonmonotonic relative to the frequency of indexation. Essentially, table 4 qualitatively replicates the results in table 1, but at a higher cost level. Increasing the frequency of indexation from semiannual to quarterly and from quarterly to monthly reduces the expected sacrifice coefficient. However, lowering the frequency of indexation to annual adjustments or to zero also reduces the sacrifice coefficient.

A reduction in the credibility of the stabilization program (expressed in an increase in the credibility parameter, h) increases the costs associated with every case in table 4, but it does not alter the nature of the qualitative results. When the program's credibility is reduced by half (h = 1.38), the sacrifice coefficient rises from 1.8 to 2.2 in the base example. Increasing the frequency from semiannual to quarterly indexation reduces the coefficient to 1.6, while the move to annual indexation reduces it to 2.0.

Table 4. The Sacrifice Coefficient under Gradual Stabilization and Partial Credibility[a]

Frequency of nominal indexation (θ)	*Frequency of real adjustments (γ)*				
	0.25	*0.50*	*1.00*	*2.00*	*10.00*
0.0	–4.4	–2.6	–1.2	–0.5	0.0
0.5	9.9	1.5	–0.2	–0.3	0.0
1.5	7.0	1.8	0.2	0.0	0.0
3.5	4.4	1.3	0.3	0.0	0.0
10.0	2.2	0.7	0.2	0.0	0.0

Source: Author's calculations.

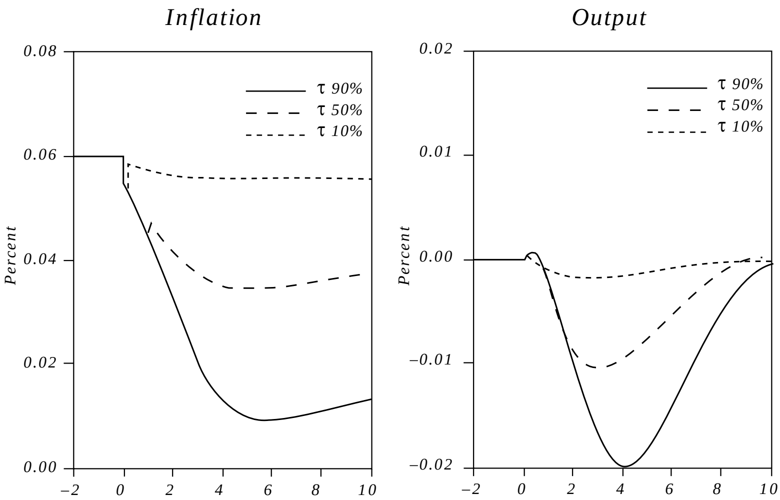
a. The sacrifice coefficient, S, was derived for the indicated combinations of γ and θ based on an adjustment velocity in the money issue rate of μ = 0.46, with ν = 0.25 and a credibility parameter of h = 0.69.

9. In this case, the sacrifice coefficient is defined as $E(S) = -\frac{h+\mu}{\mu\pi}\int_t^{\infty} E y \, dt$.

4.2 Effective Realizations with Partial Credibility

In addition to calculating the expected inflation and output trends, the model can be used to obtain their evolution for effective realizations of τ, which is the date at which the stabilization program is abandoned. The expected money and price trends are calculated in each moment for $t < \tau$, conditional on the implementation of the program up to that point, and the implications for the price and output trends are derived for that moment. The expected money and price trends are then recalculated for τ, conditional on the program's abandonment at that point, and the implications for the output trend are derived from τ forward. Figures 4 and 5 show the inflation and output trends for three different abandonment dates and different frequencies of indexation. The abandonment dates are calculated to represent the tenth, fiftieth, and ninetieth percentiles of the probability distribution of τ; they therefore provide a reference for the distribution of the results for each configuration of the parameters. Figure 4 illustrates the case of quarterly indexation, and figure 5 the case of monthly indexation.

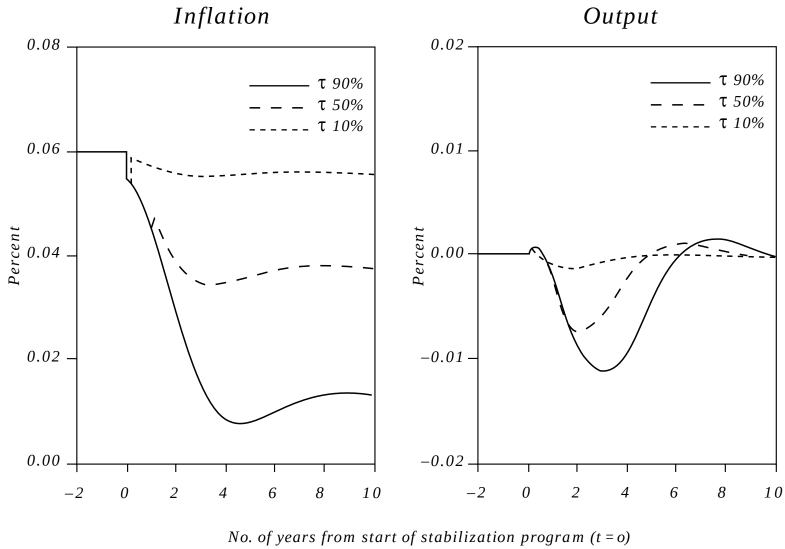
Figure 4. Trends in Output, Money, and Inflation under Gradual Stabilization, Partial Credibility, and Semiannual Indexation[a]



Source: Author's calculations.

a. Model simulation of the base exercise (θ = 1.5 and γ = 0.5), with gradual stabilization velocity (μ = 0.46), partial credibility (h = 0.69), and ν = 0.25. The program is abandoned in τ = 10 percent, τ = 50 percent, and τ = 90 percent.

Figure 5. Trends in Output, Money, and Inflation under Gradual Stabilization, Partial Credibility, and Monthly Indexation[a]



Source: Author's calculations.
a. Model simulation of the base exercise ($\theta = 11.5$ and $\gamma = 0.5$), with gradual stabilization velocity ($\mu = 0.46$), partial credibility ($h = 0.69$), and $\nu = 0.25$. The program is abandoned in $\tau = 10$ percent, $\tau = 50$ percent, and $\tau = 90$ percent.

A comparison of the depth and breadth of the economic cycle for the different degrees of indexation reveals that more frequent indexation reduces the volatility of output. When indexation is monthly and the stabilization program is extended beyond expectations ($\tau = 90$ percent), this produces a recession that reaches its low point in the course of the third year, with a maximum gap slightly greater than 1 percent, and the economy accumulates a cost of 3.2 percentage points of output ($S = 0.7$). When the indexation is semiannual (the base exercise), the total cost increases to 9.9 percentage points of output ($S = 1.9$). In the absence of automatic indexation, the initial expansionary effect predominates and the economy receives a net benefit.

These results fully support the intuition outlined in Gray (1976) and Fischer (1977). In the face of monetary shocks such as the implementation of a stabilization program, greater indexation reduces the volatility of output and increases the volatility of inflation.

5. Conclusions

The analysis presented above gives rise to two basic conclusions. First, price and wage indexation increases the costs of reducing inflation. In the model of price (or wage) formation characterized by rational expectations and a degree of adjustment inflexibility, indexation introduces inertia into the inflationary process and increases the sacrifice coefficient. For the base model, given semiannual average adjustment and biannual contracts, the sacrifice coefficient fluctuates between 0.9 and 3.0, depending on the type stabilization program (gradual versus drastic) and its credibility.

Second, the relation between the frequency of adjustment and the sacrifice coefficient is nonmonotonic. The costs of stabilization increase when the frequency of indexation moves from zero to positive, but for some value of θ the marginal impact returns to negative as the economy recovers its nominal neutrality. Therefore, decreasing the frequency of indexation in the economy, which usually happens when inflation is low, does not necessarily reduce the sacrifice coefficient, and increasing the frequency of adjustment is not necessarily damaging. In the base model, the semiannual adjustment structure constitutes a minimum, such that any movement—whether toward more or less frequent adjustments—reduces the cost of stabilizing inflation.

This last observation helps explain the persistence of moderate inflationary processes of 20 to 40 percent. The sacrifice coefficient tends to increase for intermediate levels of indexation such as annual, semiannual, or quarterly, but it drops to practically zero when adjustments are made monthly. If this adjustment frequency responds positively to the inflation level, then the economy may find itself caught in a trap of moderate inflation. For low levels of average inflation, individuals and firms do not index their contracts. This keeps the costs of the stabilization plan at relatively low levels, and the benefits are felt almost immediately. This holds when the plan enjoys full credibility and is designed under a strategy of gradual implementation. As the average inflation level increases and individuals and firms begin to use automatic adjustment practices to protect themselves from inflation, the costs of the stabilization program rise significantly and the program's impact on inflation is delayed. The effects are multiplied when the plan's credibility is questionable. These conditions reduce the net benefits associated with the plan, or at least the short-term benefits observed by the authorities, such that inflation tends to take root in the economy while there are no political incentives to reduce it. When both the level of inflation and the frequency of indexation rise, the benefits of reducing inflation increase. At some point the stabilization costs begin to fall, until the authorities once again have incentives for reducing or eliminating inflation.

APPENDIX

The Model Solution with Gradual Stabilization and Full Credibility

The dynamic system formed by equation 12 is written as

$$\frac{\mathrm{d}\mathbf{X}(t)}{\mathrm{d}t} = \mathbf{A}\,\mathbf{X}(t) + \mathbf{B}\,\mathrm{E}\left[M(t)\right] .$$

The homogeneous part of the system has the following general solution for $\overline{\mathbf{X}}(t)$:

$$\overline{\mathbf{X}}(t) = C_1\,\mathrm{v}_1\,e^{\lambda_1 t} + C_2\,\mathrm{v}_2\,e^{\lambda_2 t} + C_3\,\mathrm{v}_3\,e^{\lambda_3 t} ,$$

where λ_i and v_i are the characteristic values and vectors associated with the rectangular matrix $\mathbf{A}$ and where C_1, C_2, and C_3 are constants determined on the basis of the limit conditions that should satisfy the system, namely,

$$p(0) = 0 ,$$

$$Q(0) = -\frac{\pi}{\theta + \lambda} , \text{ and}$$

$$\lim_{\tau \to \infty} z(\tau) = 0 .$$

One of the equation's characteristic values is negative; it can therefore be eliminated to ensure that the system converges with its stationary state.

The general solution for the dynamic system formed by equation 12 takes the form

$$\mathbf{X}(t) = \overline{\mathbf{X}}(t) + K_1 + K_2\,e^{-\mu t} ,$$

where $t \geq 0$ and the constants K_1 and K_2 are determined by the indeterminate coefficient method. The solution for the model featuring immediate stabilization corresponds to the limit of the above solution when $\mu \to \infty$.

References

Ball, L. 1994a. "Credible Disinflation with Staggered Price-Setting." *American Economic Review* 84(1): 282-89.

———. 1994b. "What Determines the Sacrifice Ratio?" In *Monetary Policy*, edited by N. G. Mankiw. University of Chicago Press for the National Bureau of Economic Research.

Barro, R. J., and D. Gordon. 1983. "A Positive Theory of Monetary Policy in a Natural Rate Model." *Journal of Political Economy* 91(2): 586-610.

Bonomo, M., and R. García. 1994. "Indexation, Staggering and Disinflation." *Journal of Development Economics* 43(1): 39-58.

Calvo, G. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12(3): 383-98.

Fischer, S. 1977. "Wage Indexation and Macroeconomic Stability." *Journal of Monetary Economics Supplementary Series* 5: 107-47.

Fischer, S., and L. Summers. 1989. "Should Governments Learn to Live with Inflation?" *American Economic Review* 79(2): 382-87.

Friedman, M. 1974. "Monetary Correction." In *Essays on Inflation and Indexation*, edited by H. Giersh and others. Washington: American Enterprise Institute for Public Policy Research.

Gray, J. A. 1976. "Wage Indexation: A Macroeconomic Approach." *Journal of Monetary Economics* 2(2): 221-35.

Jadresic, E. 1991. "Wages, Indexation, and Aggregate Supply". Ph.D. dissertation, Harvard University.

———. 1995. "Inflación, nivel de actividad y contratos salariales en Chile." In *Análisis empírico de la inflación en Chile*, edited by F. Morandé and R. Rosende. Santiago: CEP and ILADES/Georgetown University.

———. 1996a. "Wage Indexation and Macroeconomic Stability: The Gray-Fischer Theorem Revisited." IMF Working Paper 121. Washington: International Monetary Fund.

———. 1996b. "Wage Indexation and the Cost of Disinflation." *IMF Staff Papers* 43(4): 796-825.

Mankiw, N. G., and D. Romer, eds. 1991. *New Keynesian Economics*, vol. 1: *Imperfect Competition and Sticky Prices*. MIT Press.

Simonsen, M. H. 1983. "Indexation: Current Theory and the Brazilian Experience." In *Inflation, Debt and Indexation*, edited by R. Dornbusch and M. H. Simonsen. MIT Press.

Taylor, J. B. 1979. "Staggered Wage Setting in a Macro Model." *American Economic Review* 69(2): 108-13.

———. 1998. "Staggered Price and Wage Setting in Macroeconomics." NBER Working Paper 6754. Cambridge, Mass.: National Bureau of Economic Research.

The Macroeconomic Consequences of Wage Indexation Revisited

Esteban Jadresic
Central Bank of Chile

Since the mid-1970s, the macroeconomic consequences of wage indexation has been the subject of considerable research. Starting with an enthusiastic proposal for indexation by Friedman (1974) and two influential papers by Gray (1976) and Fischer (1977), the academic literature has examined the effects of wage indexation on the costs of disinflation and the level of inflation, the effects of wage indexation on the behavior of an economy hit by alternative types of shocks, the relation between wage indexation and exchange rate and monetary policy, the type of indexation indicators that are best suited for macroeconomic stability, and so on. The sizable literature that has emerged on the subject is reviewed by Carmichael, Fahrer, and Hawkins (1986), Aizenman (1987), Devereux (1994), Van Gompel (1994), Riveros (1996), and Landerretche, Lefort, and Valdés (in this volume).

Following Gray's (1976) analysis, most of the academic literature on this subject studies the effects of wage indexation under the key assumption that indexing is with respect to current inflation. This assumption implies that wage indexation helps to stabilize the real wage, which in standard models has strong implications on the behavior of the economy. For instance, it directly implies the well-known proposition that wage indexation would help to maintain full employment when shocks are nominal and would exacerbate employment and output fluctuations when shocks are real. As emphasized by Fischer (1977, 1985, 1988) and Simonsen (1983), however,

At the time of writing, Esteban Jadresic was affiliated with the International Monetary Fund.

I would like to thank Patricio Arrau, Eliana Cardoso, Miguel Kiguel, Fernando Lefort, Klaus Schmidt-Hebbel, and Peter Wickham for helpful comments.

Indexation, Inflation, and Monetary Policy, edited by Fernando Lefort and Klaus Schmidt-Hebbel, Santiago, Chile.

standard wage indexation is not based on current inflation. Indexed wage contracts typically adjust wages to the evolution of prices infrequently and with a lag, such that cost-of-living adjustments are determined according to lagged inflation rather than current inflation.

The fact that typical cost-of-living adjustments are based on lagged inflation is central because it implies that standard wage indexation defines a nominal rather than a real type of rigidity. As shown below, the basic implication of wage indexation to lagged inflation is a distinct and nontrivial dynamic behavior of nominal wages, stemming from both the direct effect of the indexation clauses and the indirect effect of those clauses on the outcome of wage negotiations. Because these mechanisms for wage adjustments can only respond to inflation with a lag, wage indexation need not stabilize or even affect the real wage, as the real wage can vary with changes in current inflation.[1] Similarly, the aggregate consequences of wage indexation generally depend on the nature of monetary policy, among other factors. An obvious corollary is that there is no a priori reason why the effects of actual wage indexation should necessarily resemble those implied by the assumption that wages are indexed to current inflation.

Until recently, the formal academic literature has not explicitly explored the consequences of contracts that index wages to lagged inflation. As mentioned above, most of this literature assumes that wage indexation is based on current inflation. Moreover, while Fischer (1977, 1985, 1988) examines in detail the effects of wage contracts with certain lagged indexation rules, the formulas he considers do not correspond to the typical indexation rule by which current wages are adjusted according to past inflation. Similarly, while Simonsen (1983) is persuasive in arguing that disinflation under lagged wage indexation is costly—unlike disinflation under perfect wage indexation—his formal model is not based on an explicit consideration of wage contracts indexed to lagged inflation. In consequence, his model cannot be used to compare the effects of indexed wage contracts with those of nonindexed wage contracts, which is the most relevant comparison in practice.

I attempt to fill part of the gap in the literature on wage indexation in three recent papers (Jadresic, 1996, 1998, 2002). These papers have in common the explicit modeling of wage indexation as a

1. For instance, in an economy in which labor productivity is constant and firms' individual demand curves are isoelastic, optimal price setting can imply a constant price-wage ratio regardless of whether wages are indexed or nonindexed.

clause in long-term contracts that grants periodical cost-of-living adjustments according to the inflation rate cumulated since the last wage revision. In addition, they evaluate the consequences of wage indexation by comparing the behavior of the economy in the presence of contracts with indexation clauses against two main alternative standards of reference. The first is defined by the behavior of the economy under long-term contracts that specify preset time-varying wages during the life of each contract. The second yardstick is defined by the behavior of the economy under short-term contracts that specify fixed wages during the life of each contract.

This paper reviews the main lessons emerging from the above papers and explores a further implication of indexing wage contracts to lagged inflation, namely, the consequences of wage indexation during exchange-rate-based stabilization. While the paper provides some background to the issues being examined, it is not the intent here to provide a general review of the literature on wage indexation, which has been surveyed elsewhere. Rather, the focus of the paper is on the macroeconomic consequences of indexing wages to lagged inflation. The paper reviews the consequences of wage indexation to lagged inflation on the aggregate wage, the cost of disinflation under money- and exchange-rate-based stabilization, the variability of output under alternative types of shocks and policy regimes, the choice of exchange-rate regime, and the level and variability of inflation.

Two main lessons emerge from this review. First, the standard analysis of wage indexation in the academic literature provides a very misleading picture of the consequences of the typical type of wage indexation observed in real life. In particular, the assumption that wages are indexed to current inflation is of little usefulness even as a gross approximation of the issue. Second, taking into account the lags in actual wage indexation validates the views that most policymakers and applied observers seem to have on the consequences of wage indexation, although with some qualifications.

The paper is organized as follows. Following this introduction, section 1 briefly reviews previous approaches to model wage indexation. Section 2 presents the model of wage contracts indexed to lagged inflation in the papers mentioned above and two models of nonindexed wage contracts that can be used as benchmarks for comparison purposes. Sections 3 through 5 examine the implications of using these models on the macroeconomic issues listed above. Section 6 summarizes these implications and extracts the main lessons that emerge from the analysis.

1. Models of Wage Indexation in the Previous Literature

To avoid confusion, it is useful to pinpoint the meaning of wage indexation. The definition adopted here is provided by Aizenman (1987) in his survey article for the *New Palgrave Dictionary of Economics*: "Wage indexation is a mechanism designed to adjust wages to information that cannot be foreseen when the wage contract is negotiated. A wage contract with indexation clauses will specify the wage base (i.e., the money wage applicable in the absence of new information), the indexation formula that will be used to update wages, and how often updating will occur. Most traditional discussion has focused on wage indexation to the price level...."

According to this definition, the mere adjustment of wages to reflect inflation does not qualify as wage indexation. What is special about indexation is that it is a mechanism that enables wages to adjust to new information without the need to renegotiate the contract. If the adjustment of wages in line with inflation is due to the outcome of wage renegotiations or to a preset path of wage adjustments agreed at the time the contracts were signed, such adjustment in general cannot be attributed to wage indexation. To discern the effects of wage indexation, one should compare the effects of wage contracts that include indexation clauses against the effects of wage contracts without those clauses.

1.1 Wage Indexation to Current Inflation

Following Gray's (1976) original analysis, the standard model in the academic literature assumes that wage indexation adjusts wages according to the changes in the current price level. The model considers only one period, say period t. Right before the beginning of this period, wage contracts are negotiated. During the period, macroeconomic shocks are realized. Given a degree of indexation λ, the change in wages (w_t) is assumed to be

$$w_t = \lambda \pi_t \, , \tag{1}$$

where π_t is the inflation rate in period t. (Unless otherwise indicated, variables are hereafter measured in log terms, with lowercase letters representing their first differences and capital letters their levels.)

Given this specification, the effects of wage indexation are studied by varying the degree of indexation. Under full wage indexation λ is taken to be unit and the real wage is thus assumed to be fixed. The absence of indexation corresponds to $\lambda = 0$, which assumes that without indexation the contract's nominal wage is fixed. Intermediate degrees of indexation correspond to partial wage indexation.

The direct implication of this approach is that wage indexation helps to stabilize the real wage. This effect might be irrelevant if the contracts negotiated between firms and workers are fully efficient. In standard macroeconomic models, however, in which these contracts establish wage conditions while employment is determined by labor demand, this increased real wage rigidity due to wage indexation has strong implications for the behavior of the economy. The best known is that wage indexation would stabilize output when shocks are nominal but destabilize output when shocks are real. Other implications are mentioned below.

1.2 Lagged Wage Indexation

The above approach is simple and has strong implications, but it has long been recognized that standard wage indexation is based on lagged rather than current inflation. Because of the lags in the availability of information about aggregate price indexes, actual cost-of-living adjustments due to indexation tend to be based on past inflation. Possibly more important, wage revisions due to indexation in practice are not done in every possible period. With infrequent indexation, even if current consumer price indexes (CPIs) were available in every period, wage adjustments are not proportional to current inflation, but rather to inflation cumulated since the last wage revision.

Despite the information lags and the infrequency of the cost-of-living adjustments, indexed contracts could approximately fix the real wage by establishing trigger-point indexation, a type of indexation in which wages are revised whenever accumulated inflation is larger than a given threshold. Similarly, indexed contracts could effectively fix the real wage by specifying ex post lump-sum payments between the parties so as to compensate them for the differences between past and actual inflation. In practice, however, trigger-point wage indexation seems to have been the exception, and indexed contracts with ex post compensations for changes in inflation rates have not been reported. The fact that actual indexed contracts do not attempt to really fix the real wage might well be a consequence of the problems highlighted by the literature on wage indexation to current prices.

Fischer (1977) was the first to attempt to formally model the consequences of lagged wage indexation. However, the indexing formula he examined in the main model of his paper is not the usual indexation rule by which current wages are adjusted to past inflation. Fischer assumed, rather, that indexed wages are set equal to the one-period-ahead expectation of the price level. In consequence, current wages in his model are adjusted according to the difference between the one-period-ahead expectations on the current and past price level. In the case of a two-period model, this wage adjustment rule can be written as

$$w_t = \mathrm{E}_{t-1} P_t - \mathrm{E}_{t-2} P_{t-1} \, , \tag{2}$$

where P_{t-i} is the price level in period $t - i$ (i = 0, 1) and E_{t-j} is the expected value operator on the basis of information available at the end of period $t - j$ (j = 1, 2).

Fischer (1977) admits that the indexing formula he considers in that paper (and in Fischer, 1985) might be a far cry from the indexing formula used in practice. Thus it is not surprising that in a later paper, Fischer (1988) introduces an alternative indexation formula. His alternative formula, however, also differs from the usual rule by which wages are adjusted according to lagged inflation. Specifically, he considers contracts that last for two periods and assumes that indexed wages during the second period of the contract are set on the basis of the actual price level in the first period of the contract. He further assumes that wages during the first period of the contracts are set on the basis of the one-period-ahead expectations of the price level during that period. This specification implies that the wage adjustment due to indexation in period t is equal to the one-period-ahead prediction error of the first period of the contract:

$$w_t = P_{t-1} - \mathrm{E}_{t-2} P_{t-1} \, . \tag{3}$$

Thus the cost-of-living adjustment formula implied by this specification also differs from the usual rule by which wages are adjusted according to lagged inflation.

Despite Fischer's formal attempts to model lagged wage indexation, the best-known reference on wage indexation to lagged inflation is probably Simonsen (1983). Simonsen's approach is to postulate a nominal wage adjustment rule of the form

$$w_t = \lambda \pi_{t-1} + (1-\lambda) \mathrm{E}_{t-1} \pi_t + \mu \, Gap_t \;, \tag{4}$$

where Gap_t is the gap between actual and full-employment output and μ is a positive parameter. (For simplicity, I have dropped a term measuring the change in labor productivity included in Simonsen's original specification.) Simonsen interprets the first term of the right-hand side of equation 4 as the contribution of indexation to lagged inflation to the adjustment of wages, with λ measuring the degree of wage indexation.

Simonsen's approach to wage indexation is used extensively in the applied literature on wage indexation, frequently under the assumption that $\mu = 0$. It is not clear how to interpret his model, however, since equation 4 is not derived from an explicit analysis of the implications of alternative wage contracts. For instance, sizable empirical and analytical research is based on the assumption that aggregate inflation is determined by an expression similar to the right-hand side of equation 4, in which the first and second terms are denominated by the backward-looking and forward-looking component of inflation, respectively. These models often interpret the backward-looking component of inflation as stemming from adaptive expectations rather than from indexation. Alternatively, this component could stem from other characteristics of the contracts and of the working of the economy. In Simonsen's model, there is no specific reason why the comparison of cases in which $\lambda = 1$ or $\lambda > 0$ with cases in which $\lambda = 0$ would necessarily indicate anything about the consequences of having full or partial wage indexation versus no wage indexation.[2]

2. Below it becomes clear that the wage adjustment rule implied by the explicit consideration of contracts with indexation clauses differs from equation 4. Indeed, while the first term on the right-hand side could be interpreted under certain assumptions as coming mainly from indexation clauses based on lagged inflation, the remainder of equation 4 does not appropriately capture the effects on wages of periodic contract renegotiation. One unappealing consequence of this specification problem is that according to equation 4, policymakers could maintain output permanently above full employment by engineering a continuously rising inflation rate.

Other models of lagged wage indexation have been developed to analyze the consequences of centralized wage policies, but they typically refer to case-specific rules. Morandé (1985), for example, formally examines the consequences of a mandatory rule that imposes a floor on the base wage negotiated in collective agreements. Such a wage rule was applied in Chile at the beginning of the 1980s, but it was abolished in 1983.

1.3 Standards of Reference

Evaluating the consequences of wage indexation requires not only specifying the nature of the adjustment of wages under indexation, but also defining the standard of reference against which those consequences are measured. In Gray's (1976) popular model, nonindexed wages are wages that remain fixed in nominal terms during the (only) period of reference. In Fischer's (1977, 1985 and 1988) analyses, in contrast, nonindexed wages correspond to wages that were preset in nominal terms when the contracts were signed, but that might be time varying. An example of this type of wage setting can be found in the unionized sector of the U.S. labor market, where three- or four-year contracts often specify a fixed wage increase every year. The differences in the standards of reference that can be used to evaluate the effects of wage indexation should be kept in mind in considering the analysis in the following sections.

2. A Model of Wage Indexation to Lagged Inflation

While the models of wage indexation presented in the previous section might be useful for some purposes, they do not model the consequences of wage contracts indexed to lagged inflation. This section presents a model that explicitly considers the consequences of this type of contract, as well as two models of nonindexed wage contracts that define alternative standards of reference for evaluating the effects of the indexed contracts. The analysis is based on the models developed in Jadresic (1991). Bonomo and García (1994) develop a model of wage indexation that is similar in spirit, but that incorporates continuous time and contracts granting only one cost-of-living adjustment during the life of each contract.

They use their model to examine the effects of wage indexation during disinflation; I refer to their results below.

2.1 A Model of Wage Contracts Indexed to Lagged Inflation

This section focuses on the behavior of the aggregate wage. The analysis takes the structure of the contracts as given and assumes uniform staggering. Wage indexation is modeled explicitly as a contract clause that grants periodic adjustments in the contract wage according to a lagged value of the inflation cumulated since the last wage revision.

As mentioned above, indexed wage contracts generally do not provide full protection against fluctuations in the price level. Although they stipulate periodic wage revisions that depend on actual inflation, these revisions normally are not granted in every period and are based on a lagged value of the inflation cumulated since the previous wage adjustment. In Chile, for instance, where most wage contracts are indexed, cost-of-living adjustments are typically granted every six months based on 100 percent of the inflation cumulated since the last wage revision (Jadresic, 1992, 1995; Maturana, 1992; García, 1995). In the United States, indexed wage contracts observed in the unionized sector typically specify a quarterly or annual cost-of-living adjustment, based on a fraction of the inflation measured during the previous period (Hendricks and Kahn, 1985; Kaufman and Woglom, 1986). Because of delays in the availability of consumer price indexes, the cost-of-living adjustments in these countries are typically based on an n-month lagged value of cumulated inflation, with n equal to one in the case of Chile and two or three in the case of the United States.

To model the consequences of indexing wages to lagged inflation, consider a group of wage contracts that last for N periods and that contemplate cost-of-living adjustments based on 100 percent of past inflation every n periods. Suppose that these contracts are renegotiated in a uniformly staggered fashion, and that N/n is an integer larger than one, in accordance with what is seen in actual indexed contracts. Brief reasoning implies that in every period $1/N$ of the wages are renegotiated, $1/n - 1/N$ are adjusted according to the indexation clause, and $1 - 1/n$ are kept unchanged. If the cost-of-living adjustments are defined in terms of inflation cumulated between the last wage increase and the last period before the adjustments, then the average wage increase in period t is

$$w_t^I = \left(\frac{1}{n} - \frac{1}{N} \right) \sum_{s=1}^{n} \pi_{t-s} + \frac{1}{N} x_t = \frac{1}{n} \sum_{s=1}^{n} \pi_{t-s} + \frac{1}{N} \left(x_t - \sum_{s=1}^{n} \pi_{t-s} \right), \tag{5}$$

where x_t is the initial nominal increase of the wages renegotiated at time t. The superscript I over w_t denotes that this variable measures the change in the aggregate wage when contracts are indexed.

To complete the model of aggregate wage adjustment, one needs to specify what determines x_t. Extrapolating from simple studies of lagged wage indexation, one might be tempted to simply assume that the second term of the right-hand side of equation 5 is either a positive function of the output gap or merely a constant. If contracts are revised, however, x_t must be agreed on in the wage negotiations between firms and workers.

To model x_t, I postulate that the outcome of the wage negotiations maximizes the expected value of a quadratic function of the average real wage implied by each contract.[3] This specification implies that the initial nominal wage of each contract is set so as to make the expected value of the average real wage of the contract equal to a target real wage, with the latter depending on the wage setter's expectations for the exogenous variables that enter their objective function. If contracts that begin at time t are negotiated with information on events that occurred up to time t – 1, this can be written as x_t is such that

$$\mathrm{E}_{t-1} \text{ (contract's average real wage)} = \mathrm{E}_{t-1} \left(\frac{1}{N} \sum_{s=0}^{N-1} \Omega_{t+s} \right), \tag{6}$$

3. The goal of maximizing a nonlinear function of the real wage is implied by different microeconomic models of wage determination, including the union wage model and the efficiency wage model. The specification of the maximand as a quadratic function of the real wage is used to introduce expected variables in a log-linear manner and can be interpreted as a second-order approximation of the actual objective function. The assumption that the average real wage, rather than its present value, matters simplifies the algebra.

where the right-hand expression represents the target real wage for the contracts signed for period t to $t + N - 1$ based on information available at the end of $t - 1$. To simplify comparisons made below, this target real wage is specified as an average of period-specific target real wages $E_{t-1}\Omega_{t+s}$ between $s = 0$ and $s = N - 1$. Defining precisely what determines the target real wage is not important here; this issue will be addressed below.

Given the structure of the contracts, this specification for the behavior of wage setters can be used to obtain expressions for x_t, as functions of past and current expectations about the target real wage and inflation in different dates and as functions of past inflation. The resulting expression can then be replaced in equation 5 to obtain an equation for aggregate wage adjustment. For space reasons, the derivation is not presented here (see Jadresic, 1996, for the derivation in the case $n = 1$). The general solution is

$$w_t^I = \frac{1}{N}\sum_{s=1}^{n}\pi_{t-s} + \frac{1}{N}\left(1 - \mathrm{L}^N\right)\mathrm{E}_{t-1}\left\{\frac{1}{N}\sum_{s=0}^{N-1}\left[\Omega_{t+s} + \Phi_n(s)\pi_{t+s}\right]\right\}, \qquad (7)$$

where $\left[\Phi_n(s)\right]_{n=0}^{\infty} = \{n\ n-1 \ldots 1\ n\ n-1 \ldots 1 \ldots\}$ and L is the standard lag operator.

The first term on the right-hand side of this equation captures the familiar link between current wage adjustments and past inflation that is associated with wage indexation to lagged inflation. In proportion $1/n - 1/N$ this term stems from the indexation clauses contained in the contracts not revised during the reference period. In proportion $1/N$ it also corresponds to a benchmark adjustment in the revised wage contracts, with respect to which a "plus" or "minus" initial adjustment is granted. In the aggregate, this term implies that the elasticity of current wage adjustment with respect to an unexpected shock in the last period's inflation rate is equal to $1/n$.

The second term captures the effect of the initial wage revisions. These revisions can break the mechanical link between aggregate wage changes and past inflation. Whether this happens depends on the wage setters' target real wage and expected inflation during the life of the new contracts, as compared to the target real wage and inflation expectations they held when they signed the contracts that just ended. For example, if the inflation rate expected (at $t - 1$) for the n periods to come rises relative to the inflation rate that was expected (at $t - n - 1$) for the last n periods, then the aggregate wage will grow faster than past prices.

The second term on the right-hand side of equation 7 implies that the elasticity of the current aggregate wage with respect to a change in expected inflation is equal to $(n + 1)/2N$. (This assumes that current and future inflation rates are all expected to change by the same amount.) This elasticity would be zero if wage indexation were relative to the current price level: in that case all the wage adjustments would be postponed until the changes in inflation actually occurred. This is not the case here, however, because with indexation to lagged inflation the anticipation of a permanent increase in inflation reduces the expected real wage and leads wage setters to grant larger initial wage increases; the size of this effect is proportional to $(n + 1)/2$. The impact of this effect at the aggregate level is multiplied by $1/N$, as this effect is filtered by the fraction of contracts negotiated in each period.

2.2 Alternative Standards of Reference

Because wage indexing helps to prevent the cost of too frequent negotiations, in practice indexed wage contracts are long-term contracts; for instance, the typical duration of indexed contracts in the unionized sector of the U.S. labor market is three years or more, and in Chile it is two years. Different standards of reference can be used to evaluate the effects of these contracts. One possibility is to compare the indexed wage contracts against similarly long-term contracts that specify preset time-varying wages during the life of each contract, like the nonindexed contracts observed in the unionized sector of the U.S. labor market. Another possibility is to compare these indexed wage contracts against shorter-term contracts that specify a fixed wage during the life of each contract, like the one-year contracts that seem more common in the rest of the world.

Contracts with Preset Time-Varying Wages

Consider first the case in which the nonindexed contracts specify preset time-varying wages, such as Fischer's (1977) nonindexed contracts. In this case, wage setters can go beyond the attempt to achieve an average expected real wage and instead target a specific real wage for each period. With uniform staggering, this leads to

$$w_t^P = \frac{1}{N}\sum_{s=1}^{N} \mathrm{E}_{t-s}\left(\pi_t + \omega_t\right) + \frac{1}{N}\left(1 - \mathrm{E}_{t-N-1}\right)\sum_{s=1}^{N}\left(\pi_{t-s} + \omega_{t-s}\right), \qquad (8)$$

where $\mathrm{E}_{t-s}\omega_t$ is the expected change in the target real wage between $t-1$ and t according to information at $t-s$, and so forth. The superscript P over w_t is used to denote that the change in the aggregate wage refers to contracts with preset time-varying wages. Here the length of these contracts is assumed to be the same as the length of the indexed contracts.

The first term on the right-hand side of equation 8 contains the adjustment of wages stemming from the changes in expected prices and the target real wage, according to the information that was available at the time the contracts were signed. The second term captures the effect of updating wages in the recently negotiated contracts, which depends on the discrepancy between the inflation rates and target real wages forecast in the previous negotiation with respect to their actual values.

In equation 8, the elasticity of the current aggregate wage with respect to a shock in the previous period's inflation rate is smaller than before: $1/N$ rather than $1/n$. Also, if n is larger than one, the elasticity of the current aggregate wage with respect to a shock in expected inflation is smaller: $1/N$ rather than $(n + 1)/2N$.

Contracts with Fixed Wages

Consider now the case of contracts in which wages remain fixed during the term of the agreement, as in Taylor's (1980) contracts. The length of these contracts is denoted by M. If staggering is uniform and if wage setters target an average real wage during the life of each contract, it can be shown that

$$w_t^F = \frac{1}{M}\sum_{s=1}^{M} \pi_{t-s} + \frac{1}{M}\left(1 - \mathrm{L}^M\right)\mathrm{E}_{t-1}\left\{\frac{1}{M}\sum_{s=0}^{M-1}\left[\Omega_{t+s} + \left(M - s\right)\pi_{t+s}\right]\right\}, \qquad (9)$$

where the superscript F over w_t denotes that the change in the aggregate wage refers to contracts with fixed wages.

Equation 9 can be seen as a special case of equation 7 for indexed contracts, one in which the indexation period and the length of the contracts are identical and set equal to M. Accordingly, the first term on the right-hand side of this equation comes from a catch-up wage increase granted in the revised contracts, which compensates for the effect of inflation on the real value of the wages agreed in the negotiations held M periods earlier. The second term corresponds to the wage increase above or below the catch-up term granted in the revised contracts.

There is the issue of defining the duration of the fixed wage contracts used for comparison purposes. In practice, since the duration of fixed wage contracts is usually shorter than the duration of indexed wage contracts, it is most relevant to consider cases where $M < N$. At the same time, since actual indexed contracts typically specify indexation periods equal to or shorter than one year, while the most common fixed wage contracts seem to have a duration of one year, it seems more relevant to consider cases where $M \geq n$. The research reviewed below focuses primarily on such cases, often assuming $M = N/2$ and then exploring the consequences of alternative assumptions when relevant for the purposes at hand.

With this range for M, the elasticities of the current aggregate wage with respect to expected and past inflation under fixed wage contracts can be compared unambiguously with those under indexed contracts. First, equation 9 implies that the response of the current aggregate wage to the expectation of a permanent increase in inflation is proportional to $(M + 1)/2M$, which for $M \leq N$ is always larger than the corresponding response in the case of indexed wage contracts. The intuition is that because fixed wage contracts are front loaded and do not offer any cost-of-living adjustments during their term, these contracts tend to be much more sensitive to changes in inflation expectations when they are renegotiated. Second, equation 9 implies that the response of the current aggregate wage to a shock in last period's inflation rate is proportional to $1/M$, which for $M \geq n$ is always smaller or equal to the corresponding response in the case of indexed contracts.

Table 1 summarizes the elasticities of the current aggregate wage in response of a shock in the previous period's inflation rate and to a shock in expected inflation implied by the alternative wage contracts being considered.

The Target Real Wage

To model the determination of the target real wage, I have generally assumed that wage setters target a real wage that is equiproportional

Table 1. Elasticity of the Current Aggregate Wage[a]

Type of contract	*In response to a shock in previous period's inflation*	*In response to a shock in expected inflation*
Indexed wages	$1/n$	$(n + 1)/2N$
Preset time-varying wages	$1/N$ (–)	$1/N$ (– or =)
Fixed wages	$1/N$ (– or =)	$(M+1)/2M$ (+)

a. The signs in parenthesis indicate whether the elasticity is smaller than (–), larger than (+) or equal to (=) the corresponding elasticity for contracts with indexed wages. It is assumed that n, N, and M are positive integers, and that $n \leq M < N$.

to the expected level of aggregate output (which, under the implicit assumption that the labor force is constant, is the same as the expected level of aggregate output per person in the labor force). Formally, this can be written as

$$\mathrm{E}_{t-1}\,\Omega_{t+s} = \mathrm{E}_{t-1}\,Y_{t+s} \quad , \tag{10}$$

where Y_{t+s} is the level of aggregate output in period $t + s$.

This specification for the target real wage captures the intuition that the real wage tends to increase when the labor market becomes tighter and when the economy becomes richer. In addition, the specification is consistent with the theory and the empirical evidence. From a theoretical perspective, for a given size of the labor force, the assumption that the target real wage is proportional to the level of output is consistent with a supply-wage relation linking the real wage negatively with the rate of unemployment. As emphasized by Blanchard and Katz (1997), such a relation is implied by all the main modern approaches to wage determination based on explicit maximization models, including the matching approach, the efficiency wage approach, and the competitive approach. From an empirical perspective, in turn, the assumption that the target real wage is equiproportional to the expected level of output ensures that the rate of unemployment and the functional distribution of income in the models considered below are constant in the steady state; these features conform with the long-term evidence on these variables. Furthermore, the assumption of equiproportionality between output and the target real wage is consistent with the extensive empirical evidence on the wage curve compiled by Blanchflower and Oswald (1995).[4]

While this is a plausible specification for the target real wage, the driving force for the results presented below lies in the differences in the elasticities of the aggregate wage with respect to past and expected inflation implied by the different types of contract. It seems unlikely, therefore, that the essence of those results would be significantly altered by considering other plausible specifications for the target real wage. For instance, as noted below, assuming that the elasticity of the target real wage with respect to output is different from one tends to make no difference in the basic results.

3. Wage Indexation and the Cost of Disinflation

It is apparent that the wage equations derived in the previous section can have very different consequences from those implied by the assumption that indexation is based on current inflation. But what precisely are those consequences? This section examines the effects of wage indexation on the cost of disinflation.

3.1 Money-Based Stabilization

There is a remarkable contrast between the views of academic researchers and those of policymakers on the effects of wage indexation on the cost of disinflation. On the one hand, the standard academic presumption since Friedman (1974) has been that price escalator clauses facilitate the end of inflation. This presumption is based on the notion that indexation speeds up the adjustment of wages to changes in inflation, and it is implied by the standard model of indexation to current inflation, as well as by the lagged wage indexation models generated by Fischer (1985, 1988). On the other

4. Their central finding from data for a number of regions and periods is that a 1 percent increase in the unemployment rate typically reduces the real wage by about 0.1 percent (Blanchflower and Oswald, 1995). With standard estimates for the Okun's Law coefficient of between 2 and 3 (for instance, see Adams and Coe, 1990) and an unemployment rate on the order of 5 percent, their finding implies that a 1 percent increase in aggregate output would raise the real wage on the order of 1 percent.

hand, as highlighted by Simonsen (1983) and Williamson (1985), policymakers have generally contended that wage indexation causes inflationary inertia and thus makes disinflation more difficult. For instance, the economic authorities in Chile recently pointed to wage indexation to explain why faster disinflation was not possible in the country, and wage indexing was prohibited in Argentina and Brazil during recent stabilization programs.[5]

Until recently, the only published paper to explicitly evaluate the consequences of indexation to lagged inflation during disinflation was Bonomo and García (1994).[6] These authors replicate Ball's (1990) analysis of credible disinflation policies in a closed economy with staggered fixed prices, but they expand the model by adding an indexation rule according to which, at the midpoint of the period between successive price revisions, individual prices are adjusted by the inflation cumulated since the last price revision. As in Ball's earlier work, Bonomo and García (1994) find that certain gradual disinflation policies could cause a boom in the economy if they were credible; under indexation, however, the boom caused by those policies would be followed by a recession, such that the net output gain during the disinflation would be smaller in the indexed economy than in the economy modeled by Ball. They also estimate that the time necessary to reduce inflation without affecting output would be longer in the indexed economy.

Bonomo and García's findings suggest that wage indexation could make disinflation harder. However, since their analysis focuses on gradual and credible policies that cause net booms rather than net recessions, it really does not evaluate whether indexation makes disinflation more costly. Perhaps most important, the paper provides no obvious explanation for the contrasting academic and policymakers' views on the effects of indexation on the cost of disinflation.

To shed light on these issues, Jadresic (1996) examines the costs of disinflation implied by wage equations similar to those presented in the previous section. As in most of the prior literature, the paper focuses on the output loss caused by money-based stabilization. Its results fully dispel the notion that wage indexation necessarily raises or lowers the cost of disinflation, and it

5. For a brief review of the literature on the effects of wage indexation on the cost of disinflation, see the introduction in Jadresic (1996).

6. Formally, they referred to price indexation rather than wage indexation, but this difference is insubstantial.

provides a suitable explanation for the difference between the views of academics and policymakers on the effects of wage indexation on disinflation. The analysis shows that the cost of disinflation in an economy with indexed wage contracts tends to be smaller than in an economy with preset time-varying wage contracts, but larger than in an economy with short-term fixed wage contracts. Thus it turns out that the academic and policymakers' views can both be appropriate depending on the standard of reference used to evaluate the effects of wage indexation.[7]

To illustrate this result, figure 1 shows the behavior of output and inflation implied by the wage equations 7, 8, and 9 after a sudden reduction of money growth, under the simple assumptions that price inflation is equal to wage inflation ($\pi_t = w_t$), and that aggregate output growth is determined by

$$y_t = m_t - \pi_t \ , \tag{11}$$

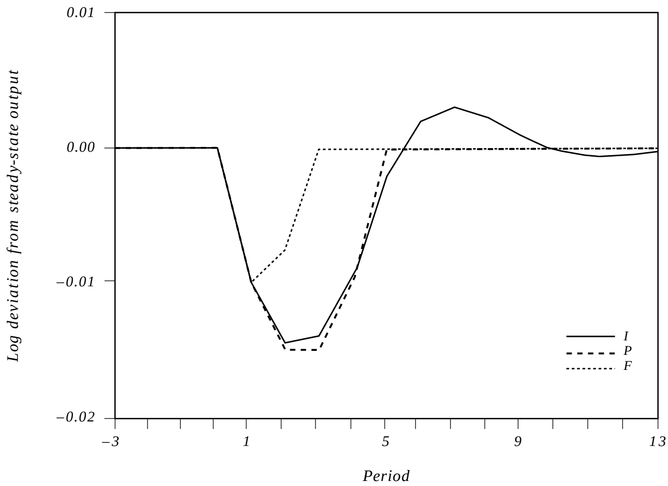
where m_t is the growth rate of money. The figure assumes that the cut in money growth is unanticipated but permanent (equal to 0.01 in log terms) and that $N = 4$, $n = 1$. The short-term fixed wage contracts assume $M = N/2 = 2$. (The less relevant case of $M = N$ is discussed in Jadresic, 2002; it is omitted here for space reasons.)

Figure 1 shows that the net output loss during disinflation is largest when contracts specify preset time-varying wages, smallest when contracts are short-term and specify fixed wages, and intermediate when contracts contain indexation clauses. Note that the cost of disinflation with indexed wage contracts appears to be smaller than with preset time-varying wages.

Disinflation policies with more complex paths for the growth rate of money can eliminate the boom shown above by the indexed economy. For instance, with a monetary policy designed to obtain a linear disinflation in the indexed economy, this economy displays no boom following the recovery but enjoys a faster disinflation and thus a faster recovery to full employment. The path of

7. This explanation accords with the fact that much of the academic literature refers to the United States—where contracts with preset time-varying wages abound in the unionized sector of the labor market and thus seem a relevant yardstick for evaluating the effects of wage indexation—while the policymakers' view alludes essentially to other countries, where fixed wage contracts often provide a more appropriate standard of reference.

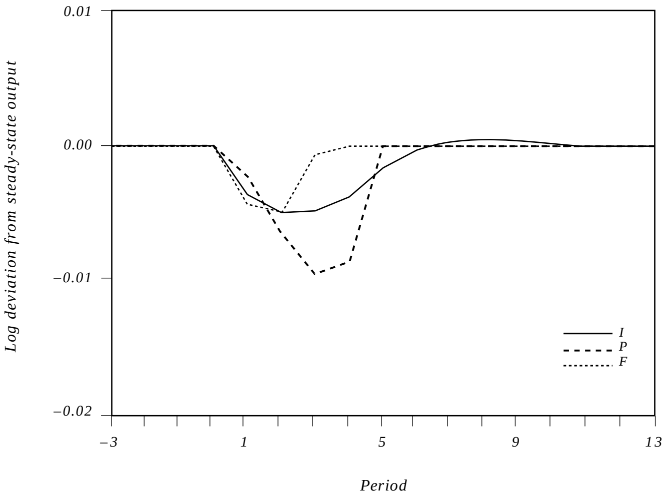
Figure 1. Output during Money-Based Stabilization: Closed Economy



output and inflation during disinflation can also differ from the one depicted in figure 2 for several other reasons, including if there is only partial credibility, if the disinflation is anticipated, if there is a procyclical ratio between prices and wages, if the real wage targeted by wage setters depends on output with an elasticity different from unity, if money demand is interest elastic, and if the economy is open. (The latter case is shown in figure 2, using the model and base case parameters presented below.) The analysis in Jadresic (1996) indicates, however, that the ranking of disinflation costs mentioned above is quite robust under these alternative circumstances: the net output loss during the disinflation tends to be smaller in the indexed economy than in the economy with preset time-varying wage contracts and larger than in the economy with short-term fixed wage contracts.

What is the source of the discrepancies in the behavior of the economies with and without indexation? The answer to this question lies in the different elasticities for the current aggregate wage implied by the contracts under consideration.

Figure 2. Output during Money-Based Stabilization: Open Economy



Compare first the elasticities of the aggregate wage under indexed wage contracts with the elasticities of the aggregate wage under contracts that specify preset time-varying wages. As noted above and shown in table 1, the elasticity of the aggregate wage in response to changes in the past period's inflation rate is always larger when wages are indexed. During disinflation, this feature implies that once initial reductions in the inflation rate have been achieved, the existence of indexation feeds a larger part of those reductions back into wages and inflation in following periods. In comparison with an economy featuring contracts that specify preset time-varying wages, this enhanced feedback from recent inflation to current inflation can permit a faster recovery, create a boom following the recession, or prevent a larger drop of output during the recession caused by the cut in money growth. As a result, the output cost of disinflation in the indexed economy tends to be smaller.

The favorable consequence of indexation for the cost of disinflation due to the effect just described can be reinforced if the indexation period is longer than the basic period in which the preset time-varying wages are kept fixed (in the model, if $n > 1$).

If this is the case, the aggregate wage under indexation is not only more responsive to past inflation, but also more responsive to changes in expected inflation. In comparison with an economy characterized by preset time-varying wages, this effect directly helps to break the inflationary inertia in the indexed economy at the beginning of the disinflation and, as a result, also helps to reduce the output cost of disinflation.[8]

Compare now the elasticities of the aggregate wage under indexed wage contracts with the elasticities of the aggregate wage under fixed wage contracts. As noted above and shown in table 1, the elasticity of the aggregate wage in response to a shock in expected inflation is always smaller when wages are indexed. This implies that wage indexation makes it harder to break the initial inflationary inertia of the economy and thus it tends to deepen the recession associated with a sudden reduction in money growth. Unless some other force dominates, it follows that wage indexation raises the cost of disinflation when indexed wage contracts are compared with fixed wage contracts.

Note, however, that the elasticity of the aggregate wage in response to the past period's inflation rate is larger when wages are indexed if the length of the fixed wage contracts used as the standard of reference is longer than the length of the indexation period, for instance, if the fixed wage contracts have the same duration as the indexed contracts. This observation raises the question of whether, in this case, the enhanced feedback from past to current inflation caused by wage indexation can more than compensate for the adverse effect of indexation on the cost of disinflation caused by the smaller responsiveness of wages to the expected disinflation. In Jadresic (1996), I find that this can be the case if the fixed wage contracts used as the standard of comparison have the same duration as the indexed wage contracts and if the economy is such that early in the disinflation there is a sizable fall in prices independent of wages—stemming, for instance, from a large appreciation of the domestic currency or a sharp drop in marginal costs. However, when the standard of reference is a fixed wage contract half as long as the indexed contract and twice as long of the indexation period, the result that wage indexation raises the cost of disinflation emerges unchanged in the simulations, even in the case of disinflation with sizable initial falls in prices independent

8. This effect is not considered in Jadresic (1996), which assumes $n = 1$.

of wages. More generally, of course, the basic result can always be preserved by using a standard of reference based on short-term fixed wage contracts whose length is equal to or shorter than the indexation period of the indexed contracts.[9]

To summarize, wage indexation can raise or lower the net output loss caused by money-based stabilization depending on the standard of reference. In comparison with contracts specifying preset time-varying wages, indexed wage contracts reduce the cost of disinflation; this is mainly because indexation establishes an automatic feedback from past to current inflation that facilitates disinflation once initial reductions in inflation have been achieved. In comparison with short-term contracts specifying fixed wages, in turn, indexed wage contracts tend to raise the cost of disinflation because indexation reduces the responsiveness of wages during the early stages of disinflation.

3.2 Exchange-Rate-Based Stabilization

The theoretical literature on wage indexation dedicates little specific attention to the effects of wage indexation during exchange-rate-based inflation stabilization.[10] In this case, however, the Gray (1976) model clearly implies that wage indexation would make disinflation easier. For example, with full wage indexation to current inflation, pegging the exchange rate should stop inflation abruptly and without costs. As in the case of money-based disinflation, this

9. To provide an example of the relative elasticities of indexed and fixed wage contracts, consider the case of Chile. Typical indexed wage contracts last for twenty-four months and have an indexation period of six months (with 100 indexation to lagged inflation); the implied elasticities of the current aggregate wage with respect to the inflation rate in the past period and expected inflation are 0.167 and 0.146, respectively. Suppose that the alternative to these contracts are fixed wage contracts that last for twelve months. In this case, the elasticities of the current aggregate wage with respect to inflation in the past period and to expected inflation are 0.083 and 0.542, respectively. Thus the elasticity of the aggregate wage with respect to past inflation for the indexed contracts is twice as large as the same elasticity for the fixed wage contracts, and the elasticity of the aggregate wage with respect to expected inflation for the indexed contracts is close to one-fourth of the same elasticity for the fixed wage contracts.

10. A sizable theoretical literature addresses the relation between wage indexation and monetary and exchange rate policies in open economies, but this literature focuses on other issues (see next section and the surveys listed in the opening paragraph). This gap contrasts with the significant attention that exchange-rate-based stabilization has received elsewhere in the academic literature since the early 1980s. For a review and assessment of the different approaches used in the latter literature, see Rebelo and Végh (1995).

prediction again stands in sharp contrast with the view of policy-makers and applied observers, who tend to believe that wage indexation makes disinflation harder during exchange-rate-based stabilization. For instance, the ban on wage indexation in Brazil and Argentina mentioned above was implemented in a context of exchange-rate-based stabilization plans.[11]

This section explores whether the consequences of wage indexation during a money-based stabilization described above also apply in the context of an exchange-rate-based stabilization. The analysis is based on a Mundell-Fleming economy characterized by a domestic and a foreign good that are imperfect substitutes and by a domestic and a foreign bond that are perfect substitutes. The notation for the variables in this economy is as follows: y_t measures the growth rate of aggregate domestic output; p_t is the rate of change in the price of the domestic good in terms of domestic currency; π_t denotes the inflation rate; i_t represents the nominal interest rate of the domestic bond; m_t is the growth rate of the domestic money supply; and s_t indicates the devaluation rate of the domestic currency. It is assumed that foreign variables are constant in level. The following relations hold in this economy:

$$y_t = -\beta(1-\mathrm{L})(i_t - \mathrm{E}_t\pi_{t+1}) + \gamma(s_t - p_t)\ , \tag{12}$$

$$m_t - \pi_t = y_t - \delta(1-\mathrm{L})\, i_t\ , \tag{13}$$

$$p_t = w_t + \alpha y_t\ , \tag{14}$$

$$\pi_t \equiv \varepsilon p_t + (1-\varepsilon) s_t\ , \text{ and} \tag{15}$$

$$i_t = \mathrm{E}_t s_{t+1}\ , \tag{16}$$

where α, β, γ, δ, and ε are nonnegative parameters.

Equations 12 through 16 represent, respectively, the principle of effective demand in the market for the domestic good, the money

11. The policymaker's view is often illustrated with the aid of Simonsen's (1983) wage equation described above, under the assumption that $\mu = 0$, and an additional inflation equation of the type $\pi_t = \eta w_t + (1-\eta)s_t$, where s_t is the devaluation rate of the domestic currency and η is a parameter between zero and one (see Edwards, 1996, for a recent example). This framework directly implies that pegging the exchange rate when wages are indexed reduces inflation slowly and at the cost of a real appreciation (because it implies $\pi_t = \lambda\eta\pi_{t-1}$ and $s_t - \pi_t = -\lambda\eta\pi_{t-1}$). As noted above, however, this approach does not permit an explicit comparison of the effects of indexed and nonindexed wage contracts, and thus it should only be considered as illustrative of the policymaker's concern.

market equilibrium condition, the pricing equation for the domestic good, the definition of inflation as a weighted average of the rate of change in the price of domestic and foreign goods in domestic currency, and the uncovered interest parity condition for the domestic and the foreign bonds. Equations 12 and 15 implicitly assume the law of one price for the foreign good.

Figure 3 combines equations 12 through 16 with the wage equations presented above to show the effects of an unanticipated, credible reduction in the devaluation rate. The economy is assumed to have been in a steady state with persistent inflation before the new policy is implemented, at time $t = 1$. The output path depicted for each type of contract corresponds to a base case in which $\alpha = 0$, which captures the stylized fact that output does not have strong effects on prices, given wages (Blanchard and Fischer, 1989, pp. 464-67). This base case also assumes $\beta = 0.5$, $\gamma = 0.3$, $\delta = 0.5$, and $\varepsilon = 0.7$, which are comparable in order of magnitude with those considered by Fischer (1988) and Henderson and McKibbin (1993). Also, the base simulations assume $N = 4$ and $n = 1$, with the short-term fixed wage contracts half as long as the indexed contracts. The experiment considers a reduction in the rate of devaluation equal to 0.01 in log terms.

Figure 3. Output during Exchange-Rate-Based Stabilization: Base Case

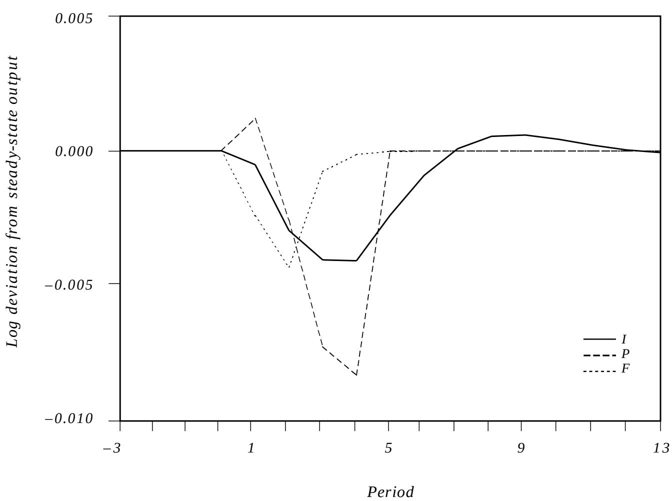


Figure 3 shows that with the base-case parameters, the basic outcome of a sudden reduction of the rate of devaluation is a recession. This result is similar to that found for a money-based stabilization, although now the overall output loss is smaller (compare figure 3 with figure 2; see also table 2) and in the case of contracts with preset time-varying wages, the economy experiences a short-lived initial boom. Most importantly for the purposes of this paper, the figure suggests that the ranking of the disinflation costs is the same as in the case of a money-based stabilization; that is, the largest net output loss occurs when contracts specify preset time-varying wages, the smallest occurs when contracts are short-term and specify fixed wages, and an intermediate level occurs when contracts are indexed. This perception is confirmed by the numerical net output loss reported in the first row of table 2.

To clarify this result, figures 4 and 5 consider two special cases that permit the separation of the two channels through which the

Table 2. Net Output Loss during Exchange-Rate-Based Stabilization[a]

Parameter	*Indexed wages*	*Preset time-varying wages*	*Fixed wages*
Base model[b]	1.32	1.69	0.76
$\beta = 0$	1.26	1.58	0.54
$\gamma = 0$	0.35	0.35	0.35
$\beta = 1$	1.50	1.89	1.61
$\gamma = 0, \beta = 1$	0.70	0.70	0.70
$\gamma = 1$	3.75	5.03	1.99
$\alpha = 0.5$	1.08	1.47	0.64
$\varepsilon = 0.5$	1.16	1.64	0.69
N = 2	0.77	0.81	0.55
N = 2, $\gamma = 0$	0.35	0.35	0.35
N = 8	2.63	4.91	1.45
N = 8, $\gamma = 0$	0.35	0.35	0.35
Net output loss during money-based stabilization[c]			
Base model[b]	1.80	2.72	1.01

a. Sum of log deviation of output from steady-state level in response to a reduction in the devaluation rate of 0.01 in log term (x 100).

b. Assumes $\alpha = 0$, $\beta = 0.5$, $\gamma = 0.3$, $\delta = 0.5$, $\varepsilon = 0.7$, $N = 4$, and $n = 1$.

c. Sum of log deviation of output from steady-state level in response to a reduction in money growth of 0.01 in log term (x 100).

exchange-rate-based stabilization affects aggregate demand. First, figure 4 shows that when demand responds only to the real exchange rate ($\beta = 0$), the exchange-rate-based stabilization causes a recession. This is because the gradual adjustment of wages and inflation causes the reduction of the devaluation rate to trigger a temporary real appreciation of the domestic currency, which reduces the demand for domestic output during the adjustment process. Second, figure 5 shows that when demand responds only to the real interest rate ($\gamma = 0$), the exchange-rate-based stabilization can cause a boom-recession cycle, as noted by Rodriguez (1982) and Dornbusch (1982). This is because the fixing of the exchange rate can reduce the real interest rate during the early stages of the disinflation—as it fixes the nominal interest rate in an inflationary context—which must fall below its steady-state level to reestablish the equilibrium real exchange rate.

The evaluation of the net output losses with and without wage indexation in these two special cases is revealing. When aggregate demand depends only on the real exchange rate, the ranking of

Figure 4. Output during Exchange-Rate-Based Stabilization: Demand Elastic to Real Exchange Rate Only

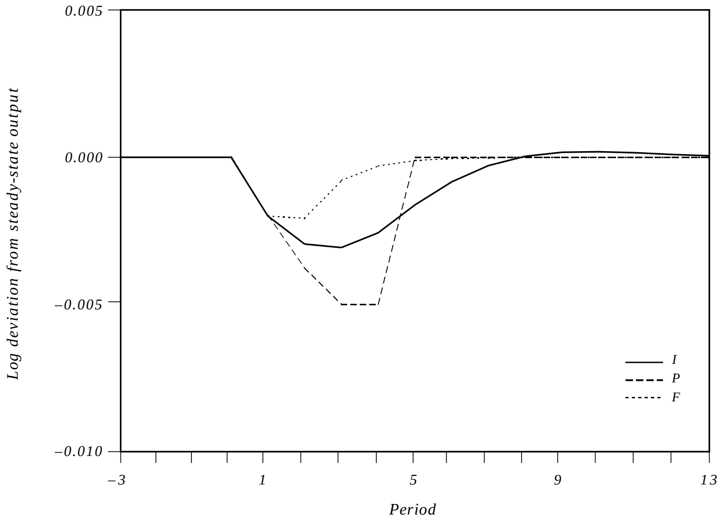
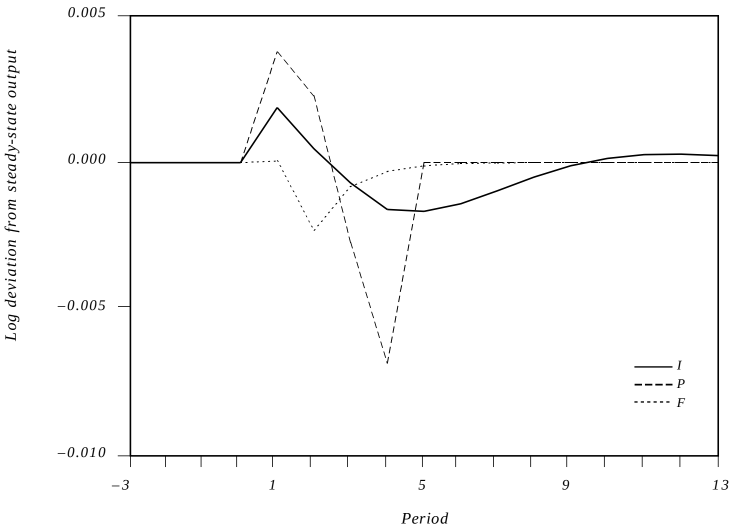


Figure 5. Output during Exchange-Rate-Based Stabilization: Demand Elastic to Real Interest Rate Only



these losses is as above; that is, indexed wage contracts reduce the cost of disinflation relative to preset time-varying wage contracts and increase it relative to short-term fixed wage contracts (second row of table 2). When aggregate demand depends only on the real interest rate, in turn, the net output losses are identical regardless of the type of wage contracts prevailing in the economy (third row of table 2). This implies that wage indexation influences the cost of disinflation only through its effect on the size of the real appreciation of the domestic currency. Inasmuch as the elasticity of the aggregate wage to the expected disinflation is larger when contracts are indexed than when contracts specify preset time-varying wages, it is not surprising that indexed wage contracts reduce the cost of disinflation relative to those contracts. By a similar reasoning, it is not surprising that indexed contracts increase the cost of disinflation relative to short-term fixed wage contracts.

This paper offers no general proof that the above finding should always obtain, but the simulation results reported in table 2 suggest that this finding is robust to alternative parameter specifications. More generally, it seems clear that to the extent that output is adversely affected by a real appreciation of the domestic currency, the basic effect of wage indexation described in the previous paragraph will be preserved. I thus conclude that the qualitative effects of wage indexation on the cost of disinflation under an exchange-rate-based stabilization are likely to be similar to those under a money-based stabilization: indexed wage contracts tend to lower the cost of disinflation relative to preset time-varying wage contracts and raise it relative to short-term fixed wage contracts.

4. Wage Indexation and Output Stability

The previous section examined the consequences of wage indexation in the context of a change in policy regime, characterized by a change in the growth rate of money or in the devaluation rate. Most of the academic literature on wage indexation, however, focuses on the consequences of wage indexation when the economy is hit by exogenous shocks, for a given policy regime. This section reviews the effects of wage indexation to lagged inflation in such a context, focusing on its impact on output stability.

4.1 The Gray-Fischer Proposition Revisited

Despite the sizable literature that has accumulated on the topic, the major academic proposition on wage indexation continues to be that originally stated by Gray (1976) and Fischer (1977): indexing wages stabilizes output when shocks are nominal and destabilizes output when shocks are real. Following Gray, the standard argument in support of this proposition hinges on the assumption that wage indexation is based on current inflation. Fischer's analysis of the lagged indexation rule described by equation 2 also supports this proposition. While Fischer admits that such an indexing formula may be a far cry from the indexing formula used in practice and mentions that indexing to lagged inflation could modify his conclusion that wage indexation stabilizes output in the face of nominal shocks if shocks are transitory, he conjectures that if the nominal shocks are permanent, his basic conclusion should be preserved. He does not address this issue formally.

In Jadresic (2002), I reexamine the effects of wage indexation on output stability in an economy similar to that considered by Gray and Fischer, but using wage equations similar to the ones derived above. Following their analysis, I consider a closed economy in which the exchange rate plays no important role and focus mainly on the case in which the policy regime features a fixed money supply. To solve the problem analytically, I also assume that indexed and preset time-varying wage contracts have a duration of two periods, while fixed-wage contracts have a duration of one period, equal to the indexation period. For comparison, Gray's contracts are one-period contracts, while Fischer's contracts are two-period contracts in the case of nonindexed contracts and an undetermined number of periods in the case of indexed contracts.

The main result stemming from Jadresic (2002) is that in Gray and Fischer's economy, wage indexation to lagged inflation tends to destabilize output regardless of whether shocks are nominal or real. This appears to be true both when indexed wage contracts are compared with short-term fixed wage contracts and, under plausible parameter values, when they are compared with preset time-varying wage contracts.

To illustrate this result, consider an economy in which the rate of change of aggregate output is determined by the rate of change of the real money supply and a nominal shock v_t that is independent and serially uncorrelated, with mean zero and variance σ_v^2. This shock can be interpreted as a permanent, unanticipated shock reduction in money demand. Given the assumption that the monetary authority follows a fixed money supply rule, this specification implies that

$$y_t = -\pi_t + v_t \ . \tag{17}$$

Also assume that inflation is determined by the simple relationship

$$\pi_t = w_t - u_t \ , \tag{18}$$

where u_t is a real shock at period t, assumed to be independent and serially uncorrelated, with mean zero and variance σ_u^2. This shock can be interpreted as an unexpected and permanent increase in the level of productivity.[12]

Equations 17 and 18 can be solved for each type of contract by combining them with the corresponding wage equation, with $N = 2$

12. This is a simplified version of the inflation equation considered in Jadresic (2002), which in addition includes the term $\alpha(y_t - u_t)$ in its right-hand side, where α is the elasticity of prices, given wages. This term is omitted here for simplicity, as the stylized fact seems to be $\alpha \approx 0$ (Blanchard and Fischer, 1989, pp. 464–67). See the discussion below.

and $n = M = 1$, and making the rational expectations assumption that the policy regime of a fixed money supply is well known and that actors know the structure of the economy. The paper's main interest here is the behavior of the output gap (Gap_t), which is defined as the difference between the actual and the frictionless level of output, with the latter being the level of output that would be observed if wages were fully flexible and the current shocks were fully observable.[13] Solving for this variable leads to the following stochastic difference equations:

$$Gap_t^I = \frac{2}{5} Gap_{t-1}^I - \frac{1}{5} Gap_{t-2}^I + \mathrm{v}_t + \frac{1}{5}\mathrm{v}_{t-1} + \frac{2}{5} u_{t-1} \tag{19}$$

$$Gap_t^P = \mathrm{v}_t + \frac{1}{2}\mathrm{v}_{t-1} \ , \quad \text{and} \tag{20}$$

$$Gap_t^F = \mathrm{v}_t \ , \tag{21}$$

where the meaning of the superscripts is obvious.

The behavior of the output gap in response to real and a nominal shocks implied by these equations is depicted in figures 6 and 7. Consider first the case of a nominal shock. The initial impact of such a shock is identical regardless of the type of wage contract. This result arises because, independently of the type of contract considered, wages in any given period are predetermined. Consequently, a positive shock v_t tends to increase real money balances and output identically. Because of the assumption that prices do not respond directly to output, inflation is not modified at the time of the impact and output increases precisely by the amount of the shock.

In subsequent periods, the effects of a nominal shock do depend on the nature of the contracts in the economy. The quickest adjustment of output to equilibrium occurs when short-term fixed wage contracts prevail; in this case the initial expansion of output lasts only for the period of the impact. When preset time-varying wage contracts prevail, one-half of the initial expansion of output persists one period after the impact; thereafter the economy rests in equilibrium. Finally, in the case of indexed contracts, three-fifths of the initial expansion of output persists one period

13. In the model presented here, the frictionless level of output is proportional to the level of productivity. Indeed, with fully adjusting wages and perfect information, wage setters would set $w_t = \pi_t + y_t$; this equation and equation 18 together imply that the rate of change of the frictionless level of output is u_t.

Figure 6. Output Effects of a Nominal Shock in a Closed Economy with a Fixed Money Supply

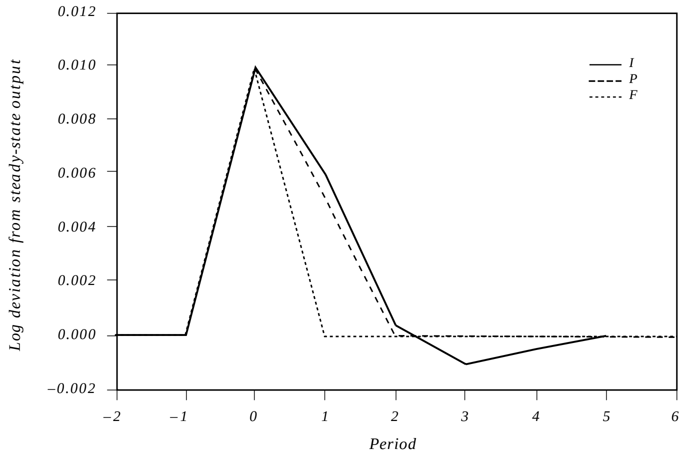
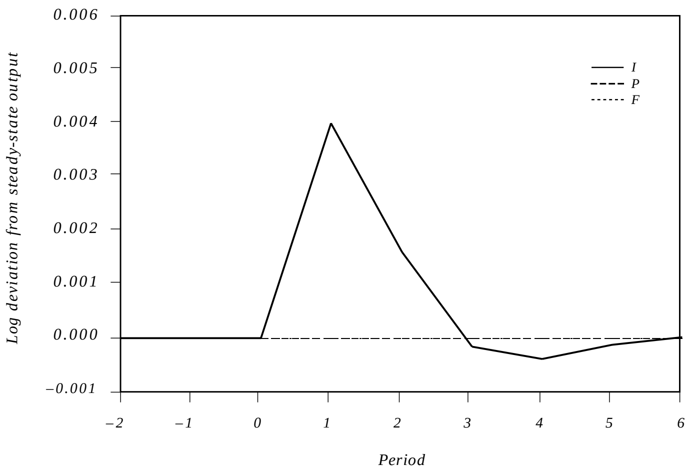


Figure 7. Output Effects of a Real Shock in a Closed Economy with a Fixed Money Supply



after the shock; thereafter output converges to its equilibrium through an oscillatory process that rapidly fades away.[14]

Any reasonable measure of instability demonstrates that these results imply an unambiguous overall effect of wage indexation on the response of output to the nominal shock: wage indexation destabilizes output. What is the intuition? In comparison with short-term fixed wage contracts, indexed wage contracts imply a slower return of output to its equilibrium level; that is, the indexation clauses do not provide a mechanism to compensate for the fact that with longer contracts, a smaller fraction of wages are revised in every period. In comparison with preset time-varying wage contracts, the reason is more subtle: since the indexation clauses automatically transmit part of the increase in wages and inflation from one period to the other, wage setters respond to a positive nominal shock to the economy by anticipating that in subsequent periods inflation will stay temporarily above the trend and that real money balances and output will continue to fall; the anticipation of falling output moderates the adjustment of wages and inflation during the first period after the impact, which slows down the economy's adjustment and causes the initial expansion of output to persist.

Consider now the case of a real shock. As shown in figure 7, such a shock has no impact on the output gap in the period in which it affects the economy. Given that in any single period wages are predetermined, a positive real shock, u_t, reduces prices proportionally and increases real money balances and output exactly by the same magnitude as the size of the shock. Because output and the frictionless level of output increase by the same amount, the output gap remains unaltered. While this result differs from the expansive effect implied by the positive nominal shock considered above, this outcome again does not depend on the type of contract considered.

In subsequent periods, output remains in equilibrium under short-term fixed and preset time-varying wage contracts, but with indexed wage contracts, output is destabilized: there is a boom in the first period after the shock, and thereafter output converges gradually to its equilibrium level. The boom occurs because the reduction in the inflation rate in the period of the shock is transmitted automatically into an inflation rate that is lower than

14. The oscillatory and convergent nature of the evolution of output can be verified by computing the roots of the characteristic equation implied by equation 19, which are imaginary and have the property that the multiplication of their inverses is less than one.

the trend in the next period; this effect raises real money balances and expands output despite the fact that no additional shocks have occurred (in the simple model considered here, the size of the output gap in the period following the shock is two-fifths of the magnitude of the shock). In the next period, upward pressure on wages increases inflation and moves real money balances and output toward their equilibrium levels. Thereafter, output converges to its equilibrium after a sequence of oscillations that gradually fade away.[15]

In the context of Gray and Fischer's specific closed-economy model, Jadresic (2002) shows that the findings that wage indexation to lagged inflation generally destabilizes output tend to be robust to considering a more general inflation equation, which allows for a direct effect of output on prices, given wages. For nominal shocks, the caveat is that if this effect is positive and strong enough, wage contracts indexed to lagged inflation can stabilize output relative to preset time-varying wage contracts—although they would continue to destabilize output relative to short-term fixed wage contracts. In the case of real shocks, wage indexation would always be destabilizing.

These findings are not robust, however, to alternative assumptions about the nature of the economy. As discussed in the following section, considering an open economy can fully reverse these findings. Allowing for alternative monetary policies can also have significant effects. For instance, the analysis in Jadresic (2002) shows that if money supply is indexed to lagged inflation rather than being fixed, the variability of output with indexed wage contracts is reduced to the same level as the variability of output with contracts that specify preset time-varying wages under a fixed money supply. One implication of this result is that even if the economy is hit only by real shocks, wage indexation does not necessarily destabilize output. Of course, the drawback of indexing the money supply is that such a policy dramatically destabilizes inflation.

4.2 Output Stability in the Open Economy

Analyzing the effects of wage indexation on output stability in a closed economy can be useful for academic purposes, and it can be appropriate for understanding the behavior of economies with

15. As in the case of a nominal shock, this process of adjustment can be verified by computing the roots of the characteristic equation associated with equation 19.

a small external sector or with a financial sector that is poorly integrated into the international financial markets and that applies a crawling peg. For most countries today, however, it would be more relevant to discuss the effects of wage indexation in the context of an open economy. I do so in Jadresic (1998), with the help of the simple model presented above for analyzing exchange-rate-based stabilization. This section reviews some of the implications of that analysis. Since the focus now is not only on evaluating the overall effects of wage indexation on output stability, but also on exploring more generally the effects of wage indexation on output behavior, I start by providing some background.

The literature on international macroeconomics demonstrates substantial agreement on the behavior of an open economy hit by aggregate shocks under perfect capital mobility and simple nominal price or wage rigidities. The basic common principles are contained in the Mundell-Fleming results, according to which a monetary shock destabilizes output when the exchange rate floats but does not affect it when the exchange rate is fixed, while a shock on the demand for goods destabilizes output more when the exchange rate is fixed than when it floats. More generally, there is a consensus that in a conventional open economy, the response of output and other macroeconomic variables to aggregate shocks depends crucially on the exchange rate regime in place.[16]

According to the literature on wage indexation, however, indexing wages can cause the behavior of an open economy to be very different from that just described.[17] The sharpest contrast arises under the assumption of full wage indexation, in which case nominal wages are assumed to move proportionally with the current price level and the real wage is thus deemed fixed. In conventional models a fixed real wage makes the level of output independent from nominal variables, and it follows that in this case the Mundell-Fleming results cease to hold: monetary shocks do not affect output even if the exchange rate is flexible, while shocks on the demand for goods affect output identically with a fixed and a floating exchange

16. The seminal references on the behavior of an open economy with nominal rigidities are Fleming (1962), Mundell (1963), and Dornbusch (1976). A useful survey of the related literature can be found in Marston (1985). For an analysis using a representative agent framework, see Obstfeld and Rogoff (1996).

17. On the effects of wage indexation in open economies, in addition to the general surveys on wage indexation mentioned in the introduction, see Genberg (1989), Argy (1990), and Turnovsky (1995).

rate. More generally, full wage indexation would make the exchange rate regime totally irrelevant for output behavior.[18]

Once the lags in actual indexation rules are taken into account, however, it becomes apparent that wage indexation does not have the effects mentioned in the previous paragraph. The analysis in Jadresic (1998) confirms this presumption. By running simulations based on the open economy model and on the wage equations presented in the previous sections, the paper finds that when the lags in actual indexation are considered, wage indexation to lagged inflation affects output behavior substantially less than posited by the previous academic literature. In particular, wage indexation does not appear to invalidate or modify the Mundell-Fleming results or to blur the behavior of output across exchange rate regimes. Rather, the response of output to a variety of shocks appears to be qualitatively similar and of the same order of magnitude regardless of the type of contract prevailing in the economy.

These results are illustrated in figures 8 and 9. These figures show the response of output to a monetary and a demand shock implied by the open economy model of the previous section and the wage equations presented above. The shocks correspond to a permanent, unexpected reduction in the demand for money and a permanent, unexpected increase in aggregate demand for the domestic output, respectively. As before, the simulations assume that the respective policy regime and the structure of the economy are well known by the actors. The floating exchange rate regime corresponds to the assumption $m_t = 0$, and the fixed exchange rate regime to $s_t = 0$. The shocks are equivalent to 0.01 in log terms and the parameter values are those of the base case already defined.

Consider first the case of a monetary shock. The top panel of figure 8 shows the response of output when the exchange rate floats. Output tends to expand temporarily regardless of the type of contract prevailing in the economy. The basic reasons are familiar.

18. When the academic literature refers to partial wage indexation, the contrast with the conventional predictions are less acute, but qualitatively the differences remain. In this case, nominal wages are taken to move less than proportionally with the current price level, but the real wage is still assumed to be more rigid than without wage indexation. In standard models, this increased real wage rigidity lessens the effects of monetary shocks on output when the exchange rate is flexible, and it dampens the effect of shocks in the demand for goods on output when the exchange rate is fixed. The general proposition is that the larger the degree of wage indexation, the smaller are the differences on output behavior across exchange rate regimes (Marston, 1982; Turnovsky, 1983).

First, the monetary shock reduces nominal interest rates and raises expected inflation, cutting down expected real interest rates. Second, the shock depreciates the domestic currency, which increases the competitiveness of the economy given predetermined wages and prices. Both effects tend to boost demand and output.

The top panel of figure 8 clearly shows that wage indexation to lagged inflation does not insulate output from the monetary shock. This result is partly explained by the fact that with wages indexed to lagged inflation, the depreciation of the domestic currency caused by the monetary shock affects future wages but does not affect current wages. Because of this initial predetermination of wages, the temporary rise in the competitiveness of the economy and the temporary reduction in expected real interest rates occur despite the existence of wage indexation. In principle, however, the evolution of indexed and nonindexed wages following the period of the shock could be sufficiently different as to substantially alter the behavior of output, both during and after the shock. In this regard, the top panel of figure 8 shows that, perhaps not surprisingly, the adjustment of output to its steady-state level takes longer with indexed contracts than with short-term fixed wage contracts. Also, output with indexed contracts does not stabilize completely once all contracts have been revised; it converges cyclically to the steady-state level. In all cases, however, the overall response of output to the monetary shock is qualitatively similar, and the effects are comparable in order of magnitude.

Nonetheless, does indexing wages to lagged inflation at least help to reduce its variability? The simulations for alternative parameter values in Jadresic (1998) indicate that the answer is ambiguous and depends crucially on the specific characteristics of the economy. The ambiguity is closely related to the size of the depreciation of the domestic currency due to the monetary shock and its initial impact on prices and inflation. If these effects are large enough, the indexation clauses imply a relatively large adjustment of wages in the period after the shock occurs, and indexed wage contracts can contribute to accelerating the process of adjusting wages, prices, and output. If these effects are small—for instance, because the weight of foreign goods in the CPI is low or because aggregate demand is very sensitive to the real interest rate or the real exchange rate—then indexed contracts can destabilize output. Because indexed wage contracts automatically feed back part of the initial increase in wages and inflation to subsequent periods, they tend to reduce expected real interest rates and thus make the initial expansion of output more persistent. In addition, indexed contracts tend to generate excessive cumulated inflation in later periods, which elevates nominal and real interest rates, reduces competitiveness, and can drive output below its steady-state level. Both effects work to increase the variability of output.

Figure 9 shows the case of a shock in the demand for the domestic good. Given the nominal rigidity introduced by the wage

Figure 8. Output Effects of a Monetary Shock in an Open Economy

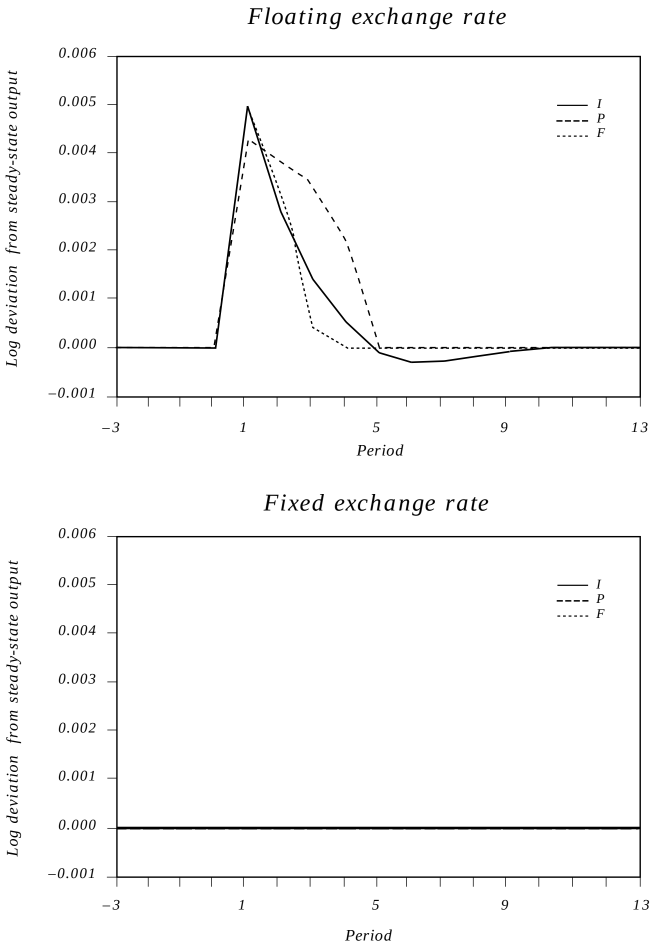
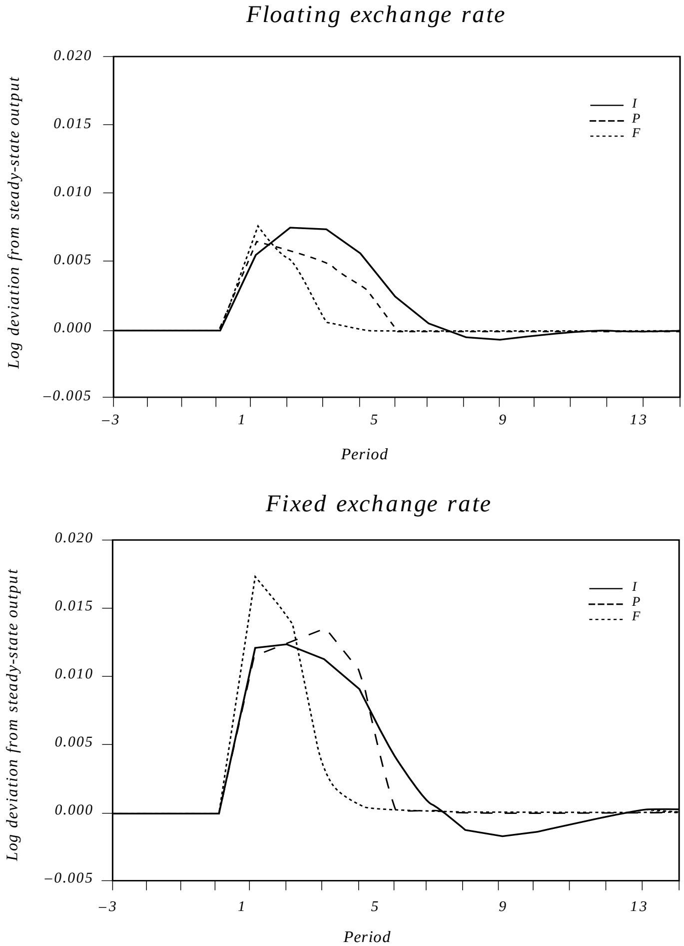


Figure 9. Output Effects of a Demand Shock in an Open Economy



contracts, the increase in demand causes a temporary boom in output. Moreover, in line with the Mundell-Fleming results, the magnitude of this boom is significantly smaller when the exchange rate floats than when the exchange rate is fixed. The reason is that the long-term real appreciation required by the economy in order to accommodate the demand shock is attained differently depending on the exchange rate regime. With a fixed exchange rate, the real appreciation is achieved through an increase in wages and inflation in the periods following the shock. This process temporarily reduces expected real interest rates and achieves the real appreciation only gradually; these effects work to destabilize output during the period of adjustment. With a floating exchange rate, in turn, most of the required real appreciation is attained through a nominal appreciation at the time of the shock. This nominal appreciation helps to stabilize output, both by shifting demand out of the domestic good more quickly and by putting less pressure on wages and inflation as a vehicle for adjustment, which helps to stabilize expected real interest rates.

For this paper, the most important result is that the order of magnitude of the output boom caused by the demand shock does not depend on whether the wages are indexed or not. While the alternative types of wage contract under consideration do imply some differences in the behavior of output during the adjustment process, those differences are relatively minor, and they do not change the fact that a floating exchange rate substantially moderates the response of output to the shock. The relatively small effect of wage indexation on output behavior is again partly due to the fact that, regardless of the type of wage contract prevailing in the economy, wages are predetermined at the time the shock occurs. In addition, the top panel of figure 9 shows that the differences in the behavior of output are minor even when the different dynamics associated with the alternative types of contract are fully considered.

Does wage indexation have any tendency to destabilize the behavior of output in response to a demand shock when the exchange rate floats and to stabilize it when the exchange rate is fixed? In the case of a floating exchange rate, the top panel of figure 8 and the simulations for alternative parameter values in Jadresic (1998) indicate that wage indexation does tend to destabilize output. In this case, and for almost all parameter values considered, the variance of output with indexed wage contracts is larger than with preset time-varying wage contracts and with short-term fixed wage contracts. The reason is that in the periods immediately after the shock occurs, the indexation clauses quickly feed back into wages the lower inflation due to the initial appreciation, which tends to curb or even reduce them. This effect works first to moderate the magnitude of the real appreciation and then to reduce the expected real interest rate, as demanders anticipate that wages and inflation will have to accelerate in the future in order to compensate the unnecessary cutback of current wages. Consequently, with a floating exchange rate, the output boom caused by the demand shock tends to persist longer when contracts are indexed, which destabilizes output.

In the case of a fixed exchange rate, the analysis in Jadresic (1998) indicates that wage indexation has no clear-cut effect on the output response to a demand shock. Two parameters that are especially important in determining whether wage indexation raises or reduces this response are the elasticities of the demand for the domestic good with respect to the expected real interest rate and with respect to the real exchange rate. This is because wage indexation slows down the adjustment of wages and inflation, which tends to moderate the initial fall in expected real interest rates but to reduce the speed of the real appreciation required to reestablish equilibrium. While the former effect is stabilizing, the latter is destabilizing. Depending on the specific elasticities of the demand for the domestic good, wage indexation can either stabilize or destabilize output.

Jadresic (1998) also considers the effects of price shocks and productivity shocks. The analysis confirms that the effects of wage indexation to lagged inflation on output behavior are relatively small. Also, the results indicate that wage indexation is likely to destabilize output when shocks are in prices and that it has an ambiguous effect when shocks are in productivity.

To summarize, once the lags in actual indexation are taken into account, wage indexation in the open economy affects the behavior of output substantially less than posited in the previous literature. Also, the net effects of wage indexation on output stability in this context are ambiguous. For instance, if the economy is hit mainly by price shocks, wage indexation is likely to destabilize output. The same is bound to happen if the economy is hit mostly by shocks in the demand for goods and there is a floating exchange rate. However, if the economy is hit mainly by monetary or productivity shocks, or if it is hit mainly by demand shocks and there is a fixed exchange rate, the net effects of wage indexation are ambiguous and depend on the economy's parameter values. The overall implication is that a definite evaluation of the net effects of wage indexation on output stability in the open economy requires a precise specification of the economy under consideration, an issue which requires further research.

5. Further Macroeconomic Consequences of Wage Indexation

The previous sections focused on the consequences of wage indexation for the behavior of output. The above analysis, however, also has implications on other variables and issues. This section explores some of those implications, comparing them with the implications of the standard approach in the academic literature.

5.1 The Choice of Exchange Rate Regime

Building on models in which wage indexation is based on current inflation, the indexation literature infers that wage indexation would be a powerful reason to prefer a flexible exchange rate regime over a fixed exchange rate regime. This result has come out under the traditional approach in which the policymakers are assumed to be concerned only with output stabilization, as well as under the more modern approach in which the policymakers are assumed to be concerned with maintaining low inflation along with output stability, but in which their preferences are time inconsistent and exhibit an inflation bias. The crux of the argument is that wage indexation helps to protect output from monetary shocks regardless of the exchange rate regime in place. If this effect is true, wage indexation makes a fixed exchange rate unnecessary for dealing with monetary shocks and reduces the incentives to create inflationary surprises.

Consider first the traditional approach that evaluates exchange rate regimes according to the extent to which they help to stabilize output. While it is obviously recognized that anything can happen in the more general case of an arbitrary degree of indexation, the literature shows that with optimal wage indexation, in which the degree of indexation is optimally chosen to minimize the deviations between the actual and the frictionless level of output, a floating exchange rate regime is always better or at least as good as a fixed exchange rate regime.[19] This result hinges on the prediction that

19. This proposition is put forth by Flood and Marion (1982), and Aizenman and Frenkel (1985a, b, 1986). The latter also show that around the optimal degree of wage indexation, a higher degree of indexation raises the optimal degree of exchange rate flexibility. In addition, they show that the concept of optimal wage indexation based on the minimization of the expected squared discrepancy of actual output from its frictionless level is equivalent to a concept of optimal wage indexation based on the minimization of the welfare cost of the distortions existing in the labor market.

wage indexation helps to protect output from monetary shocks regardless of the exchange rate regime in place. If this effect is true, wage indexation clearly weakens the key merit of a fixed exchange rate regime under the criterion of output stabilization.

Wage indexation would also be a strong reason for preferring a flexible exchange rate regime if policymakers are concerned with maintaining low inflation along with output stability. This issue has been examined using a Barro and Gordon (1983) framework in which the policymakers' preferences are time inconsistent and exhibit an inflationary bias. In such a context and in the absence of wage indexation, it is generally accepted that a fixed exchange rate can perform better than a flexible exchange rate; this result requires that the fixed exchange rate increase the credibility of low inflation and that the benefits of this improved credibility outweigh the costs of losing flexibility to adjust to aggregate shocks.[20] In contrast, the indexation literature shows that if the degree of wage indexation is optimal in the sense explained above, a flexible exchange rate regime generally gives better results than a fixed exchange rate regime.[21] As in the previous paragraph, this result also hinges on the prediction that wage indexation helps to protect output from monetary shocks. To the extent that this effect is true, wage indexation obviously reduces the incentives to create inflationary surprises and thus weakens the usefulness of the credibility effect associated with a fixed exchange rate regime.

Despite the faultless logic of the above arguments, the conclusion that wage indexation makes a flexible exchange rate generally preferable over a fixed exchange rate is unwarranted once the lags in actual indexation rules are taken into account. As is clear from the argument, that proposition depends crucially on the premise that wage indexation protects output from monetary shocks even when the exchange rate is flexible. As is also clear from the analysis in the previous sections, such a premise does not conform with the results obtained above, at least as a general or significant proposition.

20. This result can be formally derived by applying Barro and Gordon's (1983) analysis of inflationary bias with discretionary policy in an open economy context. See, for instance, Alogouskofis (1994); Obstfeld and Rogoff (1996).

21. This result is due to Rasmussen (1993). It requires the condition that wage setters care about inflation at least as much as the policymakers do.

What, then, are the general implications of the analysis on the choice of exchange rate regime? The broad similarity of the behavior of output with and without wage indexation suggests that the choice of exchange rate regime in economies with wage indexation depends on the same type of factors that affect the choice of exchange rate regime in economies without wage indexation. For instance, wage indexation seems unlikely to significantly alter the possible tradeoff between credibility of low inflation and flexibility in dealing with aggregate shocks, which part of the literature attributes to the choice between a fixed and flexible exchange rate. Therefore, while considering the existence of wage indexation does not help solve the long-standing problem of which exchange rate regime is optimal, it also does not appear to be a crucial factor in deciding the optimal regime. This suggested implication contrasts sharply with the suggestion of the academic literature that wage indexation generally makes a flexible exchange rate preferable.

A corollary of the above is that the existence of wage indexation is unlikely to be a good reason for implementing an indexed exchange rate regime. This is confirmed in Jadresic (1998), which finds that regardless of the type of contract in the economy, the effects of such a regime on output and real exchange rate stability are broadly similar to those of presetting the path for the exchange rate. In the end, with or without wage indexation, the main distinctive effect of an indexed exchange rate regime seems to be its well-known adverse effect on inflationary stability.

5.2 The Level and Variability of Inflation

The fact that actual indexation is with respect to lagged rather than current inflation also has implications for the determination of the level and variability of inflation. This section explores these implications.

Whether and how wage indexation affects the level of inflation depends on the factors that determine monetary policymaking. The literature typically analyzes this issue in the context of Barro and Gordon's (1983) model, under the assumption that the monetary authority has time-inconsistent preferences and cannot credibly commit to maintaining low inflation. Within this framework, the academic research has been ambiguous regarding the effects of wage indexation on the level of inflation. On the one hand, authors who accept the standard assumption that wage indexation is based on current inflation and that it thus stabilizes output when shocks are nominal generally assume that introducing wage indexation reduces the incentives to create nominal surprises and therefore reduces the level of inflation (for instance, see Fischer and Summers, 1989; Milesi-Ferretti, 1994; Crosby, 1995). On the other hand, while not questioning that wage indexation has this anti-inflationary effect, Ball and Cecchetti (1991) argue that this effect is more than offset by the fact that wage indexation mitigates the cost of inflation, which is inflationary.

Once the lags in actual wage indexation are considered, wage indexation seems relatively more likely to increase the level of inflation. Indeed, the findings discussed above indicate that when cost-of-living adjustments are based on lagged inflation, the standard assumption that wage indexation protects output from nominal shocks is unwarranted: wage indexation to lagged inflation can increase the response of output to a nominal shock, and, more generally, it modifies the shock's effect on output substantially less than is assumed in the literature. Consequently, wage indexation to lagged inflation is not necessarily a deterrent to the creation of nominal surprises, and when it is, it certainly is not as strong as wage indexation to current inflation. Given that wage indexation also diminishes the cost of inflation and reduces the will to fight inflation, then wage indexation seems relatively more likely to raise the inflation level. Of course, this presumption is conditional on the postulate that the monetary authority cannot credibly commit to maintaining low inflation, which is controversial (for instance, see McCallum, 1999).

Regarding the variability of inflation, Gray (1976) and Fischer (1977) argue that wage indexation increases price variability; this result implies larger inflation variability, at least in their basic models. In contrast, Jadresic (1998, 2002) finds that the effects of wage indexation is ambiguous. For instance, in a closed economy with a fixed money supply, wage indexation raises inflation variability when indexed wage contracts are compared to preset time-varying wage contracts, but it can either raise or lower inflation variability when indexed wage contracts are compared to short-term fixed wage contracts. In simulations with an open economy, in turn, it appears that wage indexation can similarly reduce inflation variability, but there is no guarantee that this is always the case.

6. Summary and Concluding Remarks

This paper has reviewed the macroeconomic consequences of wage indexation, drawing on recent research by the author. In line with standard indexation rules, and in contrast to the previous academic literature, this research treats wage indexation explicitly as a clause in long-term contracts that grants periodic wage adjustments according to lagged inflation. To evaluate the consequences of contracts with this type of clauses, the paper models the behavior of the economy in the absence of indexation using two alternative standards of reference, namely, contracts that specify preset time-varying wages and short-term contracts that specify fixed wages.

Table 3 summarizes some of the main consequences of wage indexation to lagged inflation, contrasting the results of this analysis

Table 3. Summary of the Macroeconomic Consequences of Wage Indexation

	Type of wage indexation	
Macroeconomic indicator	*To current inflation*	*To lagged inflation*
Cost of disinflation		
Money-based stabilization	Reduces cost	Reduces cost if nonindexed contracts specify preset time-varying wages; increases cost if nonindexed contracts specify fixed wages
Exchange-rate-based stabilization	Reduces cost	Reduces cost if nonindexed contracts specify preset time-varying wages; increases cost if nonindexed contracts specify fixed wages
Output stability		
Closed economy[a]	Depends on the variance of real and nominal shocks	Reduces stability
Open economy	Ambiguous	Ambiguous
Choice of exchange rate regime	Prefer flexible exchange rate	Choice similar with or without indexation
Level of inflation[b]	Ambiguous	Ambiguous, but relatively more likely to increase inflation
Variability of inflation	Increases	Ambiguous

a. With fixed money supply.
b. If the monetary authority cannot credibly commit to maintaining low inflation.

with the predictions of the standard approach that assumes that wage indexation is based on current inflation. The details that underlie the construction of this table have already been discussed throughout the paper and in the references there provided. For the record, the result that the effects of wage indexation on the cost of disinflation under exchange-rate-based stabilization are likely to be qualitatively similar to those under money-based stabilization is new.

An important lesson that emerges from this summary and comparison is that the standard analysis of wage indexation in the academic literature can provide a very misleading picture of the consequences of the typical type of wage indexation observed in real life. This finding should not be very surprising. As soon as one recognizes that standard wage indexation rules define a nominal rather than a real rigidity, it becomes apparent that the effects of wage indexation can differ considerably from those predicted by the assumption that wage indexation is based on current inflation. The research reviewed in this paper goes beyond this general statement, however, by showing that the assumption that wages are indexed to current inflation is of little usefulness even as a gross approximation of the issue. Table 3 indicates that in most of the issues examined, the macroeconomic consequences of wage indexation to lagged inflation are substantially different from the consequences of wage indexation to current inflation, even at a qualitative level.

The broad picture that emerges from taking into account the lags in actual wage indexation validates the views that most policymakers and applied observers seem to have on the consequences of wage indexation. The analysis indicates that wage indexation to lagged inflation can increase the cost of disinflation, destabilize output regardless of the types of shock in the economy, and matter relatively little for the choice of exchange rate regime. The analysis further suggests that unless policymakers are firmly committed to maintaining low inflation, wage indexation to lagged inflation is relatively more likely to increase average inflation. However, the analysis also indicates that there are important qualifications to be made with respect to these propositions.

In particular, wage indexation to lagged inflation can reduce the cost of disinflation if the alternative to indexed wage contracts are contracts that specify preset time-varying wages. Also, in an open economy and for a given policy regime, wage indexation to lagged inflation can increase or reduce output stability depending on the specific characteristics of the economy under consideration. A definite evaluation of what is the more relevant case in practice requires further research.

References

Adams, C., and D. T. Coe. 1990. "A Systems Approach to Estimating the Natural Rate of Unemployment and Potential Output for the United States." *IMF Staff Papers* 37(2): 232-93.

Aizenman, J. 1987. "Wage Indexation." In *The New Palgrave: A Dictionary of Economics*, edited by J. Eatwell, M. Milgate, and P. Newman, 838-40. London: Macmillan.

Aizenman, J., and J. A. Frenkel. 1985a. "On the Tradeoff between Wage Indexation and Foreign Exchange Intervention." *Weltwirtschaftliches Archiv* 121: 1-17.

———. 1985b. "Optimal Wage Indexation, Foreign Exchange Intervention, and Monetary Policy." *American Economic Review* 75(3): 401-23.

———. 1986. "Wage Indexation, Supply Shocks, and Monetary Policy in a Small, Open Economy." In *Economic Adjustment and Exchange Rates in Developing Countries*, edited by S. Edwards and L. Ahamed, 89-129. University of Chicago Press for the National Bureau of Economic Research.

Alogouskofis, G. 1994. "On Inflation, Unemployment, and the Optimal Exchange Rate Regime." In *The Handbook of International Macroeconomics*, edited by F. Van der Ploeg, 192-223. Cambridge, Mass.: Basil Blackwell.

Argy, V. 1990. "Choice of Exchange Rate Regime for a Smaller Economy: A Survey of Some Key Issues." In *Choosing an Exchange Rate Regime: The Challenge for Smaller Industrial Countries*, edited by V. Argy and P. De Grauwe, 6-81. Washington: International Monetary Fund.

Ball, L. 1990. "Credible Disinflation with Staggered Price Setting." NBER Working Paper 3555. Cambridge, Mass.: National Bureau of Economic Research.

Ball, L., and S. Cecchetti. 1991. "Wage Indexation and Discretionary Monetary Policy." *American Economic Review* 81(5): 1310-19.

Barro, R. J., and D. B. Gordon. 1983. "A Positive Theory of Monetary Policy in a Natural Rate Model." *Journal of Political Economy* 91 (April): 589-610.

Blanchard, O. J., and S. Fischer. 1989. *Lectures on Macroeconomics*. MIT Press.

Blanchard, O. J., and L. F. Katz. 1997. "What We Know and Do Not Know about the Natural Rate of Unemployment." *Journal of Economic Perspectives* 11(1): 51-72.

Blanchflower, D. G., and A. J. Oswald. 1995. “An Introduction to the Wage Curve.” *Journal of Economic Perspectives* 9(3): 153-67.

Bonomo, M., and R. García. 1994. “Indexation, Staggering and Disinflation.” *Journal of Development Economics* 43: 39-58.

Carmichael, J., J. Fahrer, and J. Hawkins. 1986. “Some Macroeconomic Implications of Wage Indexation: A Survey.” In *Inflation and Unemployment: Theory, Experience, and Policy-Making*, edited by V. E. Argy and J. W. Nevile, 78-102. London: G. Allen and Unwin.

Crosby, M. 1995. “Wage Indexation and the Time Consistency of Government Policy.” *Scandinavian Journal of Economics* 97(1): 105-21.

Devereux, M. 1994. “Wage Indexation, Adjustment, and Inflation.” In *Labor Market in an Era of Adjustment*, edited by S. Horton, R. S. M. Ravi, and D. Mazumdar, vol. 1, 195-236. Washington: World Bank.

Dornbusch, R. 1976. “Expectations and Exchange Rate Dynamics.” *Journal of Political Economy* 84 (December): 1161-76.

————. 1982. “Stabilization Policy in Developing Countries: What Have We Learned?” *World Development* 10(9): 701-8.

Edwards, S. 1996. “A Tale of Two Crises: Chile and Mexico.” NBER Working Paper 5794. Cambridge, Mass.: National Bureau of Economic Research.

Fischer, S. 1977. “Wage Indexation and Macroeconomic Stability.” *Carnegie-Rochester Conference Series on Public Policy* 5: 107-48.

————. 1985. “Contracts, Credibility, and Disinflation.” In *Inflation and Unemployment: Theory, Experience, and Policy-Making*, edited by V. E. Argy and J. W. Nevile. London: George Allen and Unwin.

————. 1988. “Real Balances, the Exchange Rate and Indexation: Real Variables in a Disinflation.” *Quarterly Journal of Economics* 103(1): 27-49.

Fischer, S., and L. Summers. 1989. “Should Governments Learn to Live with Inflation?” *American Economic Review* 79(2): 382-87.

Fleming, J. M. 1962. “Domestic Financial Policies under Fixed and under Floating Exchange Rates.” *IMF Staff Papers* 9 (November): 369-79.

Flood, R. P., and N. P. Marion. 1982. “The Transmission of Disturbances under Alternative Exchange Rate Regimes with Optimal Indexing.” *Quarterly Journal of Economics* 97(1): 43-66.

Friedman, M. 1974. "Monetary Correction." In *Essays on Inflation and Indexation*, edited by H. Giersh and others. Washington, D.C.: American Enterprise Institute for Public Policy Research.

García, P. S. 1995. "Mercado laboral y crecimiento: Chile 1980-1994 y proyecciones de mediano plazo." *Colección Estudios CIEPLAN* 40: 39-70. Santiago.

Genberg, H. 1989. "Exchange Rate Management and Macroeconomic Policy: A National Perspective." *Scandinavian Journal of Economics* 91(2): 439-69.

Gray, J. A. 1976. "Wage Indexation—A Macroeconomic Approach." *Journal of Monetary Economics* 2(2): 221-35.

Henderson, D.W., and W. J. McKibbin. 1993. "A Comparison of Some Basic Monetary Policy Regimes for Open Economies: Implications of Different Degrees of Instrument Adjustment and Wage Persistence." *Carnegie-Rochester Conference Series on Public Policy* 39 (December): 221-317.

Hendricks, W. E., and L. M. Kahn. 1985. *Wage Indexation in the United States: Cola or Uncola*. Cambridge, Mass.: Ballinger.

Kaufman, R. T., and G. Woglom. 1986. "The Degree of Indexation in Major U.S. Union Contracts." *Industrial and Labor Relations Review* 39(3): 439-48.

Jadresic, E. 1991. *Wages, Indexation, and Aggregate Supply*. Ph.D. dissertation, Harvard University.

———. 1992. "Dinámica de salarios y contratos en Chile." *Colección Estudios CIEPLAN* 34 (June): 5-30. Santiago. For English version, see "What Type of Contracts Underlie Aggregate Wage Dynamics?" IMF Working Paper 67. Washington: International Monetary Fund.

———. 1995. "Inflación, nivel de actividad y contratos salariales en Chile." In *Análisis empírico de la inflación en Chile*, edited by F. Morandé and F. Rosende. Santiago: Andros Productora Gráfica.

———. 1996. "Wage Indexation and the Cost of Disinflation." *IMF Staff Papers* 43(4): 796-825.

———. 1998. "Macroeconomic Performance under Alternative Exchange Rate Regimes: Does Wage Indexation Matter?" IMF Working Paper 118. Washington: International Monetary Fund.

———. 2002. "Wage Indexation and Output Stability Revisited." *Journal of Credit, Money and Banking* (forthcoming).

Landerretche, O., F. Lefort, and R. Valdés. 2002. "Causes and Consequences of Indexation: A Review of the Literature." This volume.

Marston, R. C. 1982. "Wages, Relative Prices and the Choice between Fixed and Flexible Exchange Rates." *Canadian Journal of Economics* 15(1): 87-103.

———. 1985. "Stabilization Policies in Open Economies." In *Handbook of International Economics*, edited by R. W. Jones and P. B. Kenen, vol. 2, 859-916. Amsterdam: North-Holland.

Maturana, V. 1992. "Los acuerdos salariales bajo negociaciones colectivas y la situación macroeconómica." Thesis, Pontificia Universidad Católica de Chile. Santiago.

McCallum, B. T. 1999. "Issues in the Design of Monetary Policy Rules." *Handbook of Macroeconomics*, edited by J. B. Taylor and M. Woodford. Amsterdam: North-Holland.

Milesi-Ferretti, G. M. 1994. "Wage Indexation and Time Consistency." *Journal of Money, Credit and Banking* 26(4): 941-50.

Mundell, R. A. 1963. "Capital Mobility and Stabilization Policy under Fixed and Flexible Exchange Rates." *Canadian Journal of Economics and Political Science* 29 (November): 475-85.

Morandé, F. G. 1985. "A Note on Wage Indexation in a Model with Staggered Wage Setting." *Economics Letters* 17: 19-22.

Obstfeld, M., and K. Rogoff. 1996. *Foundations of International Macroeconomics*. MIT Press.

Rasmussen, B. S. 1993. "Exchange Rate Policy, Union Wage Indexation, and Credibility." *Journal of International Economics* 35: 151-67.

Rebelo, S., and C. A. Végh. 1995. "Real Effects of Exchange Rate-Based Stabilization: An Analysis of Competing Theories." NBER Working Paper 5197. Cambridge, Mass.: National Bureau of Economic Research.

Riveros, L. A. 1996. "Adjustment, Inflation and Equity Effect: A Literature Survey on Wage Indexation." Unpublished paper. University of Chile. Santiago.

Rodriguez, C. A. 1982. "The Argentine Stabilization Plan of December 20th." *World Development* 10: 801-11.

Simonsen, M. H. 1983. "Indexation: Current Theory and the Brazilian Experience." In *Inflation, Debt and Indexation*, edited by R. Dornbusch and M. H. Simonsen, 99-132. MIT Press.

Taylor, J. B. 1980. "Aggregate Dynamics and Staggered Contracts." *Journal of Political Economy* 88(1): 1-23.

Turnovsky, S. J. 1983. "Wage Indexation and Exchange Market Intervention in a Small Open Economy." *Canadian Journal of Economics* 16(4): 574-92.

———. 1995. “Macroeconomic Stabilization Policy under Rational Expectations.” In *Methods of Macroeconomic Dynamics*, 201-30. MIT Press.

Van Gompel, J. 1994. “Stabilization with Wage Indexation and Exchange Rate Flexibility.” *Journal of Economic Surveys* 8(3): 251-81.

Williamson, J. 1985. “Concluding Appraisal.” In *Inflation and Indexation: Argentina, Brazil and Israel*, edited by J. Williamson, 167-78. Washington: Institute for International Economics.

THE CHILEAN EXPERIENCE IN COMPLETING MARKETS WITH FINANCIAL INDEXATION

Eduardo Walker
Pontificia Universidad Católica de Chile

For a Chilean capital market participant, it may be hard to imagine a world without the indexation unit, the *Unidad de Fomento* (UF). Most market participants would probably agree that the UF played a central role in the creation of a local capital market and also that it has had a positive impact on growth and welfare. The trouble, of course, is proving it, which is precisely what this paper aims to do.

From an investor's perspective, financial indexation may have quite a different role than the one presumably assigned to it by economic authorities. For the latter, indexation may represent an efficient mechanism for signaling to the market a commitment to keeping inflation under control. This, in turn, has to be weighed against the possibility of smoothing taxes by letting inflation dilute the value of the outstanding nominal government debt, although this creates certain time inconsistencies.[1] From this perspective, then, completing the financial market is not directly relevant, even though it may be important for determining the financial costs of government debt. The optimal government debt structure could take into account its implications on welfare, efficiency, and the completeness of the financial markets.

The idea of market completeness comes from Arrow and Debreu, who analyze a case in which there is a finite number of possible future states of the world (namely, peace, war, recession, and prosperity).[2] Completing the market consists in generating patterns of payments in the different states that did not previously exist, such that investors can either hedge against or bet on the occurrence of certain states in a way that could not be done before. In practice, a given financial

1. See, for example, Landerretche, Lefort, and Valdés (in this volume).
2. Arrow (1964); Debreu (1959).

Indexation, Inflation, and Monetary Policy, edited by Fernando Lefort and Klaus Schmidt-Hebbel, Santiago, Chile.

instrument can be said to complete the market if it generates relevant patterns of return that cannot be replicated by the existing securities in the national or international financial markets.[3] In addition, if given markets or instruments are developed as a byproduct of a certain financial innovation, then the innovation has helped to complete the markets.

At the same time, indexation may have the perverse effect of allowing market participants to feel comfortable with certain, seemingly reasonable levels of inflation, which may eventually make it harder for economic policymakers to reduce inflation. Perhaps private discomfort with inflation facilitates the implementation of policies to reduce inflation, but in any case, aside from sending letters to the newspapers, the role of the private sector in reducing endemic inflation rates is not clear.

I argue that indexation in Chile (together with several other structural reforms that have taken place) has helped to complete and develop the financial markets at least in the following senses: it has allowed the existence of medium- and long-term bond (and loan) markets that otherwise would not exist; long-term UF indexed bonds create relevant patterns of returns that are not available either internationally or locally via short-term nominal or indexed bonds or dollar-denominated bonds; and long-term UF indexed bonds generate relevant patterns in that they are useful for hedging against adverse changes in capital good prices. I further argue that had it not been for the rules that made the Chilean indexed unit mandatory for many financial transactions, as well as for the UF-denominated government (Central Bank) debt, the fixed-income market would have developed toward shorter-term, dollar-denominated securities, as the international evidence from the other developing countries suggests. This, in turn, would have had a significant impact on the potential bankruptcy costs of the Chilean economy.

1. Capital Markets and Inflation

The problem of how to develop a capital market under high and volatile inflation rates has been a subject of analysis for quite some time.[4] In this context, Chile is an interesting case study.

3. It has to be relevant in the sense that, in equilibrium, the pattern would not be diversified away. For instance, in a capital asset pricing model (CAPM), only one risky mutual fund is needed, and no particular premium would be paid for new patterns.

4. See, for example, Aspe Arnella, Dornbusch, and Obstfeld (1983).

1.1 A Brief History

Before 1972, upper limits on interest rates and credit rationing coexisted. Starting in 1974, nominal and real (UF-based) interest rates became progressively liberalized and quantitative restrictions on credit began to disappear. In 1974 a new tax law introduced monetary correction mechanisms, with the idea of neutralizing the impact of inflation on the balance sheets and also on the tax obligations by firms and individuals. Nevertheless, as documented in Valdés (1988), the monitoring of asset and liability structures of financial intermediaries probably failed, first with the SINAP (national system of savings and loans), then with the so-called *financieras*, and later with other episodes.[5]

This early experience with the liberalization of financial markets ended with the devaluation of the local currency and the well-studied debt crisis of 1982, with most of the financial sector back in the hands of the Sate (see, for example, Mizala, 1991, and the references therein). This crisis may be at least partly attributed to poor practices in the risk management of the bank's assets, corresponding to a mismatching problem.[6] Dollar-denominated debt predominated over other kinds of debt because of its apparently lower cost at the time, but it usually did not have dollar-denominated assets as a counterpart. It is reasonable to expect that this lack of matching increases expected bankruptcy costs after a devaluation.[7]

In any case, indexation clearly is not a sufficient condition for creating a successful, stable capital market. Nevertheless, it does seem useful and probably even necessary in a context of moderately high and volatile inflation rates, especially considering that these variables usually are linked to other unstable macroeconomic indicators.

The Chilean experience suggests that the following steps are necessary for a capital market to develop in an inflationary context: end financial repression by deregulating institutions and liberalizing interest rates; create an indexed unit and allow for indexed financial instruments;[8] reform the tax code to achieve inflation neutrality; and

5. See Valdés (1988) for a good description of the liberalization process and several bankruptcy cases.

6. See Mendoza (1991).

7. The debt crisis might have had a smaller impact on the real economy if banks had issued indexed debt instead of dollar-denominated debt. There are two simple reasons for this. First, UF-based loans seemed more expensive, such that total debt levels presumably would have been smaller. Second, the inflation-adjusted value of the exchange rate increased 60 percent between June and December of 1982 and 53 percent toward the end of 1983. Thus indexed levels would have been much lower.

8. The *Unidad de Fomento* (UF) was introduced in Chile in 1967, although daily adjustments only began in 1977. For example, see Mendoza (1991).

create regulatory institutions to monitor, among other things, the matching of the asset and liability structure of financial intermediaries. The first three conclusions are present, for example, in De Pablo, Mancera, and Henrique (1983).[9] The last conclusion arises from the Chilean experience and also from the application of well-known principles in asset and liability management.

1.2 A Market for Indexed Securities

An important question that needs to be answered is the following. What are the necessary conditions for ensuring the success of a market of indexed financial instruments? This section opens the discussion on this issue, while section 2.4 (below) uses empirical evidence for Chile to illustrate what is meant by success.

The widespread acceptance for the UF as the de facto local currency unit in most financial transactions is probably attributable to four factors. First, the unit has credibility, in that it will not be manipulated by the authorities and is based on the Chilean consumer price index (CPI), which is computed by an independent entity, the National Institute of Statistics (INE).[10] Second, the laws themselves accept the UF as a valid alternative currency unit. For example, most loans and time deposits are legally required to be indexed; in the case of life insurance companies, assets and liabilities are measured in UFs. Third, there is a deep, liquid market for Central Bank indexed bonds. This provides a riskless real interest rate for many different maturities, which serves as a reference for private transactions. Finally, Chile's tax regulations are consistent with a generalized indexation of the economy. An additional benefit is that the UF significantly reduces the cost of recontracting and allows price adjustments to occur almost instantaneously in an inflationary environment.

It is likely that these conditions are necessary and sufficient for ensuring the success of an indexed bond market. Points two, three, and four deserve special attention. First, if the laws do not explicitly consider the index as a valid currency unit, it is less likely that private contracts will generally use it. For example, if life insurance companies do not issue indexed contracts, then buying indexed assets may not be suitable for linking loans to the CPI, if companies cannot raise funds in

9. See also CEP (1992, pp. 112-13).

10. By contrast, the *dólar acuerdo* has no credibility. The Central Bank has outstanding debt denominated in that unit, whose value is supposedly determined by a crawling peg rule. In at least three opportunities, however, the Central Bank has revalued the *dólar acuerdo* or changed the rule, automatically reducing the market value of the outstanding debt.

the same unit. Second, trading indexed government bonds is also important, since it reduces the uncertainty surrounding the expected costs and benefits of buying or selling indexed securities. The costs of creating a new market and informing investors may be large enough to inhibit the spontaneous creation of indexed securities by private investors.[11] Finally, tax considerations are also important. If unexpected inflation is neutral in terms of tax consequences, it is likely that more issuers and investors will be interested in such instruments. Since the issue at hand is the market for bonds with a fixed real income, the tax advantages of debt are important, too. In Chile between 1974 and 1984, the use of debt carried a considerable tax advantage that was eliminated with the 1984 tax reform.[12] In combination with other factors, this would probably lead to lower debt levels (indexed or otherwise) in Chile than in other countries.

In January 1997 the United States Treasury issued Treasury inflation-protected securities (TIPS), which provide an interesting case study. Soon after the issue of these ten-years bonds, the Federal Home Loan Bank and the Tennessee Valley Authority announced that they would do the same.[13] Given the current 3.3 percent rate of inflation and compared with the 6.4 percent interest rate on the equivalent nominal bonds, the resulting 3.45 percent real interest rate was debatably large. This may be due to the illiquidity of the new instrument, as well as to uncertainty over the status of the current CPI index, which is said to overstate inflation.[14] Shortly after the introduction of this new security, the pension fund manager TIAA-CREF created a new inflation-protected account that is considered to be a long-term, low- to medium-volatility alternative. Nevertheless, the tax treatment of this security may also partly explain the relatively large yield. Cohen, Hassett, and Hubbard (1997) argue that inflation continues to be relevant for the determination of the user cost of capital. The use of debts still has a tax advantage, but in the particular case of indexed bonds, both the real component and the nominal adjustment to the value of the bond (the nominal capital gain) are taxed. This means that if the inflation rate becomes high enough, the cash flows paid by the bonds could be insufficient to pay the tax liability they create.[15]

11. Campbell and Shiller (1996) also present the money illusion and balkanization arguments.

12. This may be an additional explanation for the debt crisis. See Hernández and Walker (1993) (or see Walker and Hernández [1992] for an English version of the same paper).

13. See, for example, www.morevalue.com/themes/i-bond2.html.

14. For a simple discussion see the Financial Pipeline website (www.finpipe.com/tips.html).

15. This and other potential problem are noticed by Campbell and Shiller (1996).

In this discussion, the four elements considered necessary for a successful indexed market are present, including the credibility of the unit; its validity as an alternative currency unit for certain financial products; tax considerations; and a central authority taking the first step to create a new, liquid instrument. The private sector must now continue to develop the market.

Other important reforms that have directly or indirectly contributed to deepening the Chilean financial markets include the pension fund reform and privatizations. Pension funds originally invested only in indexed, fixed-income securities, and they still invest a large fraction of their portfolios in that way. Privatized firms have also frequently used the capital markets to finance their operations. In the end, it is not possible to isolate the effects of the UF on the development of the local capital markets.

2. Indexation and the Long-Term Fixed-Income Markets

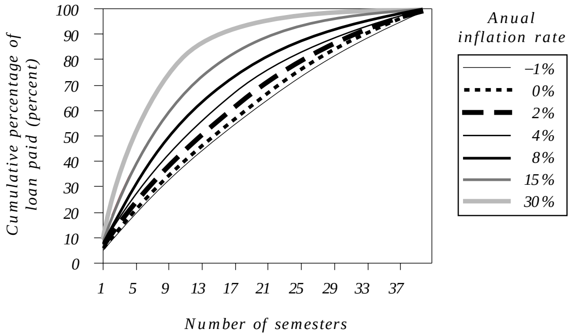
This section presents arguments justifying the idea that generalized indexation contributes to the existence of a long-term market in countries with a history of high, volatile inflation rates.

2.1 Inflation and the Shortening of Effective Maturity

Higher interest rates imply a shortening of the effective maturity (or duration) of a fixed-income security. Naturally, for a given real interest rate, higher expected inflation rates imply that a larger fraction of the value of a given fixed-income (nominal) security has to be paid at the beginning of its life.

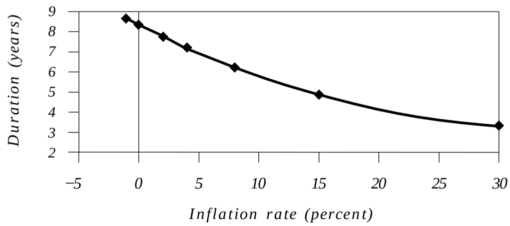
Figure 1 shows the percentage of the total present value of a twenty-year annuity bond that is paid during the first and following semesters. For example, with a 30 percent annual inflation rate, 80 percent of the real value of the loan is paid after the tenth semester. With a 0 percent inflation rate, the same 80 percent is paid after twenty-seven semesters. Another way to look at this is through the Macaulay duration corresponding to the bond's price elasticity to changes in its discount rate. The response of a pure discount bond to the inflation rate, for a fixed real interest level, can be used as a point of reference. Increasing the inflation rate from 0 percent to 15 percent reduces the duration of the bond from about eight and a half years to about five years. With 30 percent inflation, the number drops to slightly above three years. Therefore, high levels of expected inflation concentrate the inflation-adjusted (real) payments in the first few years of the life of the bond, and thus little incentives remain for extending the maturity of the bonds from the perspective of either borrowers or lenders. For example, under the same assumptions, extending the life of a loan from ten to fifteen years increases its present value by 32 percent under zero inflation, but by only 10 percent under a 15 percent inflation rate.

Figure 1. Inflation and the Total Present Value of a Twenty-Year Annuity Bond[a]



Source: Author's calculations.
a. Equal payments; forty semesters; various inflation rates; 6 percent real rate.

Figure 2. Inflation and the Effective Duration of a Twenty-Year Annuity Bond[a]



Source: Author's calculations.
a. Equal payments; forty semesters; various inflation rates; 6 percent real rate.

The problem, of course, is that under high inflation, nominal payments that are far off have little real value. Keeping the real value of payments relatively constant would require increasing nominal payments. This is exactly what indexation does (in addition to its more important feature of providing protection for unexpected changes in the inflation rate), and the above arguments clearly make a case for the practice. Without some kind of indexation, high inflation rates make long-term markets disappear.

2.2 The Nature of the Inflation Risk Premium in Nominal Rates

Campbell and Shiller (1996) estimate the inflation risk premium for a five-year U.S. pure discount bond to fall in the neighborhood of 50 to 100 basis points. Their estimation methodologies include sample averages and the covariance between consumption growth and stock index returns (based on the capital asset pricing model, or CAPM, and the C-CAPM). They also cite evidence for the United Kingdom indicating an average premium of only 0.5 percent.

The actual risk premium could be even lower if the nature of the inflation risk premium resembled that of a sleeping monster.[16] In this case, the normal covariance and other sample statistics would not reflect the true risk premium, unless the number and magnitude of the high inflation episodes in the sample coincide with what was expected, on average, by the markets participants.[17]

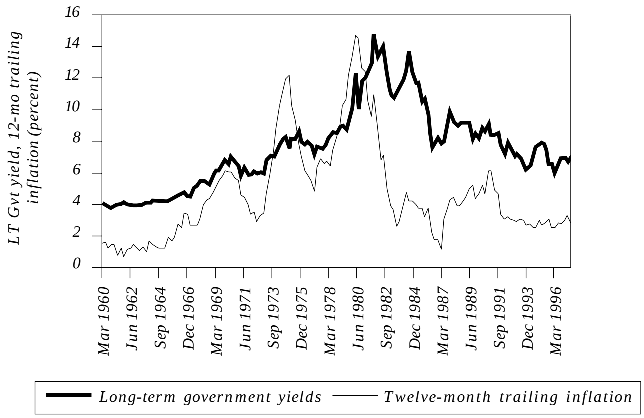
Figure 3 shows long-term U.S. government yields and trailing twelve-month inflation rates. Judging from valley to valley, four high inflation episodes seem to have occurred. A comparison of the left and right extremes of the graph indicates that real yields are higher toward the end, giving nearly a 4 percent real rate of return as opposed to about 2 percent at the beginning of the periods. Comparing that with the 3.5 percent of the TIPS rate gives a 0.5 percent premium, assuming that the term structure for real rates is flat.[18]

16. Haugen (1995) explains that if the higher expected return on value stocks is due to risk, then the risk must correspond to a sleeping monster.

17. This so-called peso problem argument has also been used to explain the equity premium puzzle (Goetzmann and Jorion, 1997). It is the kind of risk reflected in the increase in the value of out-of-the-money put options after the stock market crash of 1987 (Bates, 1997).

18. See Barro (1995).

Figure 3. Inflation and Long-Term U.S. Government Yields



Source: Ibbotson Associates.

In the case of a country like Chile, where the inflation episodes have been significantly more acute, it is only possible to speculate on how large the premiums on long-term nominal bonds would have to be in order to induce investors to buy them. Mendoza (1991) finds evidence of a liquidity premium (a higher return) for ninety-day UF-denominated deposits over nominal thirty-day deposits. This is like a negative inflation premium. These are very short-term instruments, however, and the conclusions cannot be extended to longer-term securities. The large historical levels and the high volatility of the inflation rate together should imply that the inflation premium would be larger than in the United States. Nevertheless, the exercise presented in the appendix shows that large inflation volatility might have counter-intuitive implications. Given a credible inflation target, a higher historical volatility would imply (ceteris paribus) lower nominal rates on long-term bonds by a convexity effect: the present value is a convex function of its discount rate. For a given long-term expected value, therefore, higher volatility in the inflation rates implies lower nominal rates. This effect may be more than offset by a higher required risk premium stemming precisely from the high volatility. Nevertheless, the point is that using the Fisher equation to estimate the inflation risk premium may lead to underestimating it. It may thus be difficult to estimate the inflation premium because of its sleeping monster nature and the impact of its volatility on the implementation of the Fisher equation.

To estimate what the long-term nominal rates would look like in Chile, I start by assuming twice the U.S. inflation risk premium.

The rate for the Central Bank's twenty-year adjustable bond (the PRC 20, or Pagaré Reajustable del Banco Central) is set at the level prevailing at the end of July 1997 (6.5 percent), and the long-term expected inflation rate is assumed to be 4 percent. Using the Vasicek model, this gives a nominal yield for the equivalent (annuity) nominal bond of between 11 and 12 percent (using inflation risk premiums of 1 and 2 percent, respectively) and a duration of seven years (about one year less than that of the corresponding UF bond).

2.3 Implications of not Having an Indexed Unit of Account

In the particular case of Chile, a forced elimination of the UF would likely have large negative social costs—apart from welfare redistribution effects—given that most financial transactions use the UF as a reference and that most financial instruments are expressed in this unit. Any manipulation of the UF is likely to have a considerable negative impact, because when a widely accepted unit loses its credibility, it casts doubt on the true value of a very large fraction of the financial assets held by investors. Affiliates of the pension fund system would be especially affected.

In the case of other countries with a history of high, volatile inflation rates, I hypothesize that the lack of a widely accepted indexed monetary unit would have two implications. First, the capital markets would begin to rely on a different inflation protection unit such as a foreign currency—probably the U.S. dollar, given its widespread acceptance.[19] Second, the maturities of most financial instruments (in local nominal currency or denominated in dollars) would be relatively short.

The reasons to expect a relatively short-term market in local nominal currency, which were discussed above, have to do with the shortening of the effective maturities of the fixed-income nominal securities. On the other hand, the purchase or sale of dollar-denominated instruments usually entails important risks. From an investor's perspective, the principal risk of investing in a foreign currency-denominated asset is an unexpected appreciation of the local currency. This happened, for example, in 1994, when the UF appreciated 12.5 percent against the dollar, which affected the few Chilean pension funds with investments abroad. Given the arbitrage that exists between short-term UF- and

19. In addition, the inflation tax would become smaller because the demand for local money balances would decrease.

peso-denominated deposits (Mendoza, 1991), this means that the latter also had an additional real return of approximately 12.5 percent above their counterpart in dollars. It is perhaps because of these risks and the relatively high local interest rates that a very small percentage of institutional investments are denominated in dollars. Investors should consider the trade-off between this currency risk and interest rate risks. If only foreign currency-denominated bonds were available for longer term investing, it could be convenient to invest a certain fraction of the portfolio in such instruments.

From the perspective of a productive firm, issuing dollar-denominated debt has different degrees of risk, depending on the nature of the firm's activities. A firm in the productive tradables sector should probably issue long-term dollar-denominated debt to match the currency denomination of assets and liabilities and reduce bankruptcy risks. Bankruptcy risk is here understood as a second moment risk that has to do with the residual variance of net income, which depends on the covariance between income and expense flows. It needs to be measured ex ante, before the trend of the exchange rate is known, for example. In this sense, firms in the nontradables sector would increase their bankruptcy risk by issuing dollar-denominated debt. If this is the only way to obtain relatively long-term financing, firms will face a trade-off between the possibilities of matching the currency and maturity structures of assets and liabilities. Compared to the alternative of issuing long-term indexed debt, firms will probably end up with a larger-than-optimal fraction of dollar-denominated debt and a shorter-than-optimal maturity for it. Thus while there is room for some foreign currency-denominated debt, the maturities will be generally shorter than with matching debt given the inevitable degree of mismatching in the asset and liability structure.

Taken together, these two effects imply that a long-term fixed-income market would probably be less developed than in an indexed market. By the same token, under high inflation rates, if a foreign currency replaces the local currency as the preferred denomination for local securities, the economy is likely to face higher potential bankruptcy costs than in the case of a generalized use of indexed debt. Firms in the tradables sector should be similar with or without indexing their debt structure, whereas firms in the nontradables sector will increase their potential for bankruptcy by issuing dollar-denominated debt instead of indexed debt.

Table 1 presents evidence for Colombia, Mexico, and Venezuela with regard to which securities are more frequently traded. As expected, most of the fixed-income securities that are traded are short-term, but little evidence was available for dollar-denominated bonds.

Table 1. Volumes Traded in Mexico, Venezuela, and Colombia

Billions of U.S. dollars

	Mexico[a]				Venezuela[b]	Colombia[c]
Type of instrument	*1993*	*1994*	*1995*	*1996*	*1996*	*1996*
Equity	83.37	81.35	28.33	41.31	1.42	1.50
Fixed-income securities	30.95	10.63	5.68	2.66	...	...
Money market	4,184.42	5,262.55	598.86	869.90	...	...
Brady bonds	...	...	...	...	1.95	1.95
Long-term bonds	...	...	...	...	0.21[d]	13.45
Short-term securities	...	...	...	...	...	20.73
Total	4,298.73	5,354.52	632.87	913.88	3.58	37.63

Source: For Mexico, Larraín Vial; for Venezuela and Colombia, Santander Investment.
a. Bolsa Mexicana de Valores.
b. Bolsa de Valores de Caracas; most transactions are over the counter.
c. Number of U.S. dollar transactions in local markets.
d. Bolivar-denominated.

The relative composition of short- and long-term bond trading volumes is heavily biased toward the short term in all cases, notably more than in the case of Chile (see table 2). Nonetheless, a large fraction of what appears as long-term fixed-income securities in local currency actually corresponds to floating-rate notes. This is the case for almost all long-term fixed-income securities in Mexico, for example. Thus these would also be short term. The relative sizes with respect to the Chilean market are also interesting. The Mexican economy is roughly six times the Chilean one, but the so-called fixed-income category is even smaller than the Chilean mortgage bond subsector.

2.4 The Chilean Fixed-Income Market

Table 2 shows the trading volume of the Santiago stock exchange, which corresponds to the principal trading center in the country. In 1996, the total amount traded was roughly three times the Chilean gross domestic product (GDP), and in this sense it is relatively large. The largest fraction of the total amount traded in 1996 corresponds to financial intermediation (53 percent of the total); this category actually corresponds to a market that provides short-term liquidity, in which very short-term securities such as time deposits are traded. The longer-term fixed-income market is smaller, but it still represents a large volume relative to GDP. Such instruments totaled US$79 billion, of which nearly US$59 billion correspond to securities issued by the Central Bank and the government. The bonds issued by the private sector represent US$20 billion, more than half of which corresponds to mortgage bonds. Mortgage bonds are thus by far the most important privately issued fixed-income security.

Table 2. Volumes Traded on the Santiago Stock Exchange

Billions of U.S. dollars[a]

Instrument	*1994*	*1995*	*1996*
A. Dollars (bills and checks)	5.87	11.33	12.48
B. Government, state-owned firm, and Central Bank bonds			
Bono Reconocimiento (BR)	0.90	1.06	1.11
Pagarés Compra Cartera (PCC)	1.96	1.30	0.24
Pagarés Capítulo XVIII-XIX (PCD)	2.24	2.91	3.24
Pagarés Dólar Preferencial (PDP)	3.42	2.09	0.08
Pagarés Reajustables del Banco Central con Cupones (PRC)	35.36	59.71	54.23
Pagarés Reajustables Tesorería (PRT)	0.03	0.00	0.00
Pagarés Tasa Flotante (PTF)	0.17	0.02	0.00
Pagaré Portador Banco Central (PPBC)	0.28	0.30	0.01
Bonds issued by state-owned firms	0.00	0.00	0.00
Bonos Cora (COR)	0.00	0.00	0.00
Subtotal	44.36	67.39	58.90
C. Private fixed-income bonds			
Mortgage bonds	5.61	11.29	12.94
Leasing bonds	0.76	0.98	2.59
Bank bonds	2.93	2.42	2.63
Bonds issued by nonfinancial firms	0.95	1.39	2.32
Subtotal	10.25	16.07	20.48
Subtotal fixed-income bonds (B + C)	54.61	83.45	79.38
D. Short-term financial intermediation			
Nonindexed IOUs	16.22	21.20	28.00
Indexed IOUs	22.64	40.52	83.32
Subtotal	38.86	61.72	111.33
E. Stocks	6.18	11.37	8.47
F. Investment fund shares	0.09	0.33	0.08
Total	105.61	168.20	211.74

Source: Bolsa de Comercio de Santiago, *Memoria Anual*, 1994-96.
a. Numbers adjusted to December 1996 using the Chilean CPI and then transformed into dollars at the exchange rate 424.75 pesos to the U.S. dollar.

Table 3 decomposes the volumes traded in 1996. The UF (and other very similar units) is the most important denomination for both short- and long-term securities. The dollar-denominated short-term securities that are traded are not really financial instruments; these corresponds more properly to a foreign exchange market. The vast majority of the securities issued by the private and public sectors are denominated in indexed units.

Table 3. Estimated Decomposition of Transactions on the Santiago Stock Exchange, 1996

Billions of U.S. dollars

Type of instrument	*Short Term*	*Long Term*	*Total*
Peso-denominated debt	28.00	0.00	28.00
Private sector	28.00[a]	0.00	28.00
Public sector	0.00	0.00	0.00
Dollar-denominated debt	12.48	3.54	16.02
Private sector	12.48[b]	0.30[c]	12.78
Public sector	...	3.24[d]	3.24
Indexed debt	83.32	75.84	159.16
Private sector	83.32[e]	20.18[f]	103.50
Public sector	0.00	55.66[g]	55.66
Total	123.81	79.38	203.19

Source: Superintendencia de Valores y Seguros.
a. Corresponds to nonindexed IOUs in table 7 (section D).
b. Corresponds to dollars (bills and checks) in table 7 (section A).
c. Assumes that 13 percent of the amount of traded bonds issued by nonfinancial firms (estimated at US$2.3 billion) corresponds to U.S. dollars (the same proportion of their outstanding debt).
d. Corresponds to Pagarés Capítulo XVIII-XIX (PCD) in table 7.
e. Corresponds to indexed IOUs in table 7 (section D).
f. Subtotal of private fixed-income bonds (table 7) minus private sector dollar-denominated debt.
g. Subtotal of government, state-owned firm, and Central Bank bonds (table 7) minus public sector dollar denominated debt.

Dollar-denominated bonds are rather scarce. As of December 1996, the firms that had outstanding debt in dollars actually did belong to the tradables sector.[20] The one exception was CTC, the largest local telephone company, but in this case a large fraction of its costs are dollar denominated. Of its total outstanding debt (estimated at US$564 million), 36 percent was dollar denominated.[21] Other recent dollar-denominated bond issues, not registered with the securities commission, have been sold abroad, but they correspond to firms that do business overseas.

Table 4 shows the asset holdings of the principal institutional investors in Chile. After the bank loans, the major holdings again correspond to Central Bank and government debt (US$20.5 billion) and mortgage bonds (US$8 billion). Looking at the totals, the first three columns are almost entirely indexed and long term.

20. These are Soquimich (mining); Celarauco (pulp); Cocar (coal); CTC (telephone); Viña Santa Rita (wine); and Industrias Tricolor (paints).

21. Debt estimates sourced from the *Boletín Mensual* (December 1996) published by the Superintendencia de Valores y Seguros (SVS).

Table 4. Asset Classes Held by Major Institutional Investors, 1996

Millions of U.S. dollars

Investor	*Central Bank and government bonds*	*Mortgage bonds*	*Nonfinancial bonds*	*Deposits and bank bonds*	*Stocks*	*Investment fund shares*	*Foreign investments*	*Other*	*Total*
Pension funds	11,591	4,919	1,285	1,591	7,159	834	149	0	27,527
Life insurance companies	2,605	2,957[a]	n.a.	n.a.	577	n.a.	n.a.	1,053[b]	7,192
Mutual funds	604	212	65	1,721	198	0	0	11	2,810
Short-term fixed-income	484	31	1	1,347	0	0	0	3[c]	1,866
Long-term fixed-income	97	169	63	329	0	0	0	1[c]	658
Equity	24	13	1	45	198	0	n.a.	7[c]	287
Banks	5,785	0	0	0	0	0	1,2	38,585[d]	44,371
Total	20,584	8,088	1,350	3,312	7,934	834	149	39,649	81,900

Source: Authors calculations based on data from Superintendencia de Valores y Seguros de Chile (SVS), *Boletín Mensual*, several issues; Superintendencia de Bancos e Instituciones Financieras de Chile (SBIF); Superintendencia de Administradoras de Fondos de Pensiones de Chile (SAFP); Central Bank of Chile.

a. Assumes that all privately issued bonds held are mortgage bonds; also includes bonds issued by banks.

b. Corresponds to other real estate investments. Includes *mutuos hipotecarios*, another type of mortgage bond.

c. Cash plus others.

d. Excludes mortgage loans; includes all other loans and cash, principally *colocaciones efectivas*.

It is difficult to decompose deposits and bank bonds, but an analysis of the composition of the pension funds' assets indicates that 93 percent of it is indexed, 27 percent is truly long term (bank bonds), and 8 percent is indexed deposits with a maturity of over one year. Finally, the bank loans can be decomposed as 15 percent U.S. dollar denominated, 37 percent peso denominated, and 48 percent indexed. Thus out of the US$82 billion represented in the table, US$51.6 billion (63 percent) is indexed.

This analysis indicates that the overall evidence shows a successful indexed market. Most productive and financial firms have chosen UF-denominated debt. For the purposes of matching assets and liabilities, therefore, the UF dominates other feasible alternatives such as dollar-denominated debt, which gives credibility to the hypothesis that without the UF, the overall bankruptcy risks of the economy would increase. The relatively large mortgage bond market can also be interpreted as evidence of success. In this case, it implies lower expected distress costs for individuals and firms that have purchased real estate property with indexed loans, compared with the alternatives of either short-term nominal or long-term dollar-denominated debt.

2.5 Possible Links between Markets

Tables 2, 3, and 4 show that the most important long-term bond issues are mortgages. Most of the outstanding stock issued is in the hands of the pension funds and the life insurance companies. The longer maturity of these instruments gives these investors the possibility of matching their assets and (defined or undefined) liabilities. Such instruments have thus been useful for the development of these two industries. The funds raised in this manner are essentially used in the construction sector, fostering development in the medium- to high-income residential sector, in particular.

The lack of indexed bonds issued by nonfinancial firms could be used as an argument against their attractiveness or even their usefulness from a social welfare perspective. I argue, however, that other factors explain the relatively low volumes issued.

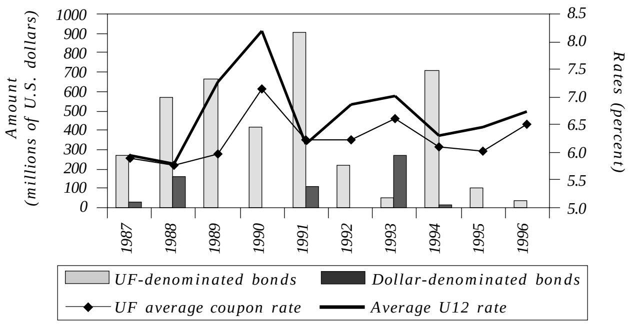
Figure 4 shows the bond issues registered with the Chilean securities commission (the Superintendencia de Valores y Seguros, or SVS). Registration represents the purpose of issuing and selling a bond, but it is possible for a bond issue to fail. The amounts listed represent the aggregate face value of debt, such that the ex post proceeds from bond sales may be different. The figure shows a downward trend (with the exception of 1994, when the failed Pangue issue made up 25 percent of the total). The figure also indicates an inverse relation between the interest rate level in a particular year and the amount registered.

In addition, the year with the highest dollar issues was 1993, when UF-based interest rates were high. This leads to the hypothesis that one of the reasons for the small amount of bonds issued by nonfinancial firms is that, on average, UF-based interest rates have been high. The Central Bank has kept local interest rates high by means of a special reserve requirement on foreign capital flows into Chile, which has segmented the fixed-income market from the rest of the world.

A simple exercise illustrates the extent to which local UF rates are higher than their equilibrium levels:

U.S. real interest rate (TIPS):	3.5 percent
Country dollar risk premium:[22]	1.1 percent
Purchasing power parity (PPP) rule followed by the Central Bank for the *dólar acuerdo* (expected depreciation of the UF):	–4 percent
UF/U.S. dollar currency risk premium:	X
Theoretical rate:	X + 0.6 percent
PRC 10 rate (22 July 1997):	6.7 percent

Figure 4. Nonfinancial-Firm Bond Issues Registered with the Chilean Securities Commission[a]



Source: Superintendencia de Valores y Seguros (SVS), *Boletín Mensual*, various issues.
a. Numbers in UF changed into dollars at the December 1996 rate of UF/US$ = 31.27. Avgerage U12 rate corresponds to a market-determined interest rate offered by the Banco del Estado mortgage bonds.

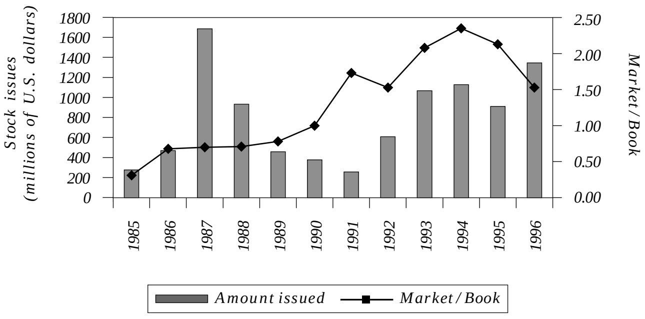
22. Estimated by CB Capitales as the difference between the dollar rates obtained by local companies abroad and the corresponding U.S. Treasury Rate. *Informe Económico* 6, May 1997. For Mexico, Domowitz, Glen, and Madhavan (1996) find an equivalent premium of 2.0 to 2.7 percent.

This exercise shows a very large spread that helps explain why issuing UF-denominated bonds may not be attractive. The currency risk premium would have to be extremely large to make the current rate an equilibrium one.

A second reason why bond issues are scarce in Chile relative to other countries is the Chilean tax structure, which is virtually neutral with respect to the incentives for the use of debt or equity.[23]

Third, although the fixed-income market is segmented, the stock market is likely to be integrated with the rest of the world because of the foreign investors that operate in Chile and the massive use of American depository receipts (ADRs) by the largest firms. Figure 5 shows the intentions of issuing stock, valued at subscription prices (which are likely to differ from the final prices obtained), as well as the market-to-book ratio for the aggregate stock market. Excluding 1987 and 1988 (years in which privatizations were significant), the figure shows an upward trend. The market-to-book ratios increased considerably (tripling since 1990) as a result of the alignment process of the local stock market with the rest of the world.[24] Relative to presumable equilibrium levels, then, debt financing may be expensive in comparison with equity financing. This may have tilted the financial structure toward the use of equity.

Figure 5. Subscription Price and Market (Book) Value of Stock Issues[a]



Source: Bolsa de Comercio de Santiago, Reseña 1996.
a. Exchange rate used: 424.75 pesos to the dollar.

23. See Hernández and Walker (1993) or Walker and Hernández [1992] (English version).

24. Walker (1998) estimates a 6 percent drop in the real discount rate for stocks after 1991.

Finally, the early bond issues may have contributed to the development of the stock market as well. The pecking-order theory outlined in Myers (1984) suggests that information asymmetry and its associated costs leads to the establishment of a sequence of preferred financing sources: first, retained earnings, followed by debt (presumably supplier's credit, then banks, and finally the public) and then new equity. The sequence can be interpreted either as a list of preferred financing sources (given a certain level of information asymmetry between a firm and its stakeholders) or as a chronological sequence (as a function of the accumulation of information by investors about firms' activities). Figures 4 and 5 show evidence that is roughly consistent with the latter vision. Figure 4 shows relatively large public issues of debt until 1991. Hernández and Walker (1993) conclude that during the same period the use of bank debt was significantly reduced. This is also consistent with a new step in the pecking-order theory, in the sense that as potential investors become informed about the nature of traded firms and their businesses, issuing traded securities becomes less costly since the information asymmetry is smaller. The new bond issues required firms to provide orderly information to the securities commission and to the official risk rating committee. Issuing firms later used the same institutional arrangements to get approval for selling new stock issues to the pension funds.

The long-term indexed bond market has thus been important for the development of the entire capital market.

3. The Unique Return Patterns of Indexed Bonds

The idea of completing a market with financial indexation from the perspective of a local investor is rather intuitive: in the absence of indexation, unexpected inflation risks are essentially nondiversifiable, but this risk is totally eliminated with the aid of indexation. For example, long-term investors who hold indexed annuity bonds for the purposes of their pension are essentially holding a riskless security. At the same time, a firm whose income and expense streams are tied to the price index would view moderate levels of indexed debt as riskless. Indexation can therefore serve as a welfare-improving device that completes the market.

To go a step further, if all security returns are measured in terms of indexed units (as is usually done in Chile), then a riskless asset can be defined as one with zero variance measured in this unit. In this context, an indexed bond issued by the government would be riskless by definition (for a matched investment horizon). Therefore, analyzing whether there are other assets besides indexed bonds whose combinations provide a riskless portfolio amounts to finding two perfectly negatively correlated assets. It is hard to imagine two of such assets. Any attempt to identify the degree to which indexed bonds differ from other local assets (for example, how successfully they can be replicated) makes little sense from this perspective. No combination of stocks, cash, and real estate, for example, can be expected to provide a riskless indexed return. The return patterns of indexed bonds are thus analyzed by themselves.

Figure 6 and table 5 both present results for Chilean indexed bonds. The indexes are the following:

• INPRC10. The PRC 10 is a Central Bank UF-denominated bond with semiannual constant coupons over ten years. The index assumes a simple trading strategy that consists in buying a newly issued PRC 10 at the end of each month, using the proceeds from the sale of the previous one. The interest rate used for the calculations corresponds to the yield of the bond on the last day of each month. In the early years, before the existence of the PRC, the equivalent PDP series was used. The calculation is based on data provided by AFP Habitat and the Bolsa de Comercio de Santiago.

• INU12. This index corresponds to a twelve-year mortgage bond issued by the Banco del Estado de Chile. The bond is based on a different indexation mechanism, which may make it behave slightly differently from UF-indexed instruments.[25] It is calculated using the same methodology and the same data sources as the INPRC10.

• INUF90. This index corresponds to the ninety-day UF-denominated deposit rate offered by prime banks to large pension funds. The methodology and sources are the same as for the INPRC10.

• CB YIELD. The CB Yield corresponds to a fixed-income, UF-based, long-term government bond index calculated by CB Capitales. Data are provided by CB Capitales.

The U12 and the CB Yield are used only for control purposes, given that the longest series correspond to the other two indexes. The correlations between INPRC10 returns and the returns on the INU12 and CB Yield are quite high, and in this sense the PRC 10 may be representative. It is also interesting to note that in the common period, the

25. The mechanism used is the average value index (the Índice de Valor Promedio, or IVP), which is similar to a lagged UF.

observed returns are very similar among the longer-term indexes as well as with the short term deposit, although there would seem to be a premium of between 6 and 10 basis points per month in the PRC 10 returns. Not surprisingly, the short-term security has the lowest volatility, followed by the CB Yield (a portfolio), PRC 10, and U12. Since the U12 has a longer duration, these results are to be expected. The small differences among the different volatilities and correlations suggest that there is little room for diversification in the fixed-income markets. This, in addition to the similarity of the observed returns, gives credibility to the idea of a well-arbitraged market.

Figure 6 supports the results in the table, showing a very similar behavior for the long-term indexes, while the behavior of the short-term index is obviously different and, in particular, significantly smoother, given its short maturity. It is precisely the volatility of the longer-term indexes that gives protection to the long-term investors, jointly with their long-term negative serial correlation, which is apparent in the graph.[26] This is due to the effects of a mean-reverting changing yield through time. Short- and long-term UF investing thus provides very different patterns of returns that are not equivalent from the perspective of a local investor.

Table 5. Representative Fixed-Income Indexes

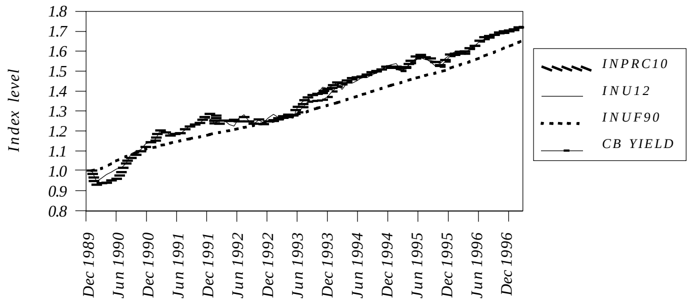
Percent

	Index[a]			
UF-based statistic	*INPRC10*	*INU12*	*INUF90*	*CB YIELD*
Period covered	Jan 1990 to Mar 1997	Jan 1990 to Mar 1996	Jan 1990 to Mar 1997	Jan 1993 to Feb 1997
Average monthly return	0.63	0.63	0.57	0.63
Monthly standard deviation	1.47	1.59	0.18	0.78
Common period (Jan 1993 to Mar 1996)				
Average monthly return	0.64	0.59	0.54	0.62
Monthly standard deviation	0.90	1.28	0.07	0.86
Correlations				
INPRC10	1.00	0.64	0.52	0.78
INU12	...	1.00	0.15	0.43
INUF90	...	...	1.00	0.47

Source: Author's calculations, based on data provided by AFP Habitat, the Bolsa de Comercio de Santiago, and CB Capitales.
a. Indexes defined in text.

26. For overlapping annual PRC 10 returns, the one-year serial correlation is –0.42. For nonoverlapping yearly returns, it is –0.82 (with only 6 data points).

Figure 6. Cumulative Wealth of UF-Based Indexes[a]



Source: Author's calculations.
a. See text for definition of indexes.

4. The Unique Return Patterns of Indexed Bonds: An International Perspective

The idea of completing the market with indexed bonds is analyzed here from the perspective of an investor who looks to world markets for alternatives that are similar to indexed Chilean fixed-income securities. The results show that replicating portfolios of foreign securities generally will not do a very good job. These findings can be useful in several ways:

• For the Chilean Central Bank, which has to invest in foreign assets and which maintains UF-denominated short- and long-term liabilities. It is interesting to consider the kind of portfolio that minimizes the tracking variance with respect to the Central Bank's liabilities, that is, the kind of portfolio that minimizes the variability of the difference between asset and liability returns.

• For Chilean investors who wish to invest abroad. In the case of long-term local investors, a riskless investment opportunity is represented by a long-term UF denominated bond; in the case of short-term local investors, the riskless asset would be a UF short-term instrument. In both cases, the results indicate the foreign portfolio that most closely resembles the local riskless asset. These results also indicate why pension funds and insurance companies have invested so little in foreign securities;

• For government authorities, who need to better understand why foreign investors are interested in investing in local fixed-income securities despite the reserve requirements.

The analysis is developed based on software and data from Ibbotson Associates.[27] It treats two fixed-income, UF-based wealth indexes as if they were two separate fund managers. I conduct a performance attribution analysis of the indexes (see Sharpe, 1992) and also analyze the out-of-sample rolling portfolios that would have most closely resembled the indexes. The algorithm implements a Markowitz-style optimization model, searching for the nonnegative portfolio weights that minimize both the tracking variance, var $(r_I - r_R)$, where I and R represent the replicated index and the replicating portfolio, respectively, for the entire period and also the series of weights that would minimize it on a thirty-six-month moving-average basis. The latter is used to calculate out-of-sample replicating portfolio returns.

To find foreign replicating portfolios, INPRC10 and INUF90 were transformed into dollars, at the observed exchange rate and the corresponding value in pesos for the UF.[28]

All the international data used were provided by Ibbotson Associates. The data indexes chosen are the Salomon Brothers (SB) three-month U.S. Treasury bill index; the intermediate-term U.S. government bond index; the long-term U.S. government bond index; the long-term U.S. corporate bond index; the Salomon Brothers (SB) broad investment-grade (BIG) bond index; the Standard and Poor's 500 index; the Morgan Stanley (MS) capital international EAFE index; the Morgan Stanley (MS) capital international Latin America free index; and the International Finance Corporation (IFC) emerging composite index. The criterion employed was to seek world coverage with bond and stock portfolios, giving additional emphasis to the U.S. indexes.

Figure 7 shows the cumulative dollar return for the indexes and their overall replicating portfolios. Only the in-sample results are shown (for example, when a single set of portfolio weights is used for the entire period) because the out-of-sample results were similar. The replicating portfolio barely obtains half of the wealth accumulated by the local indexes, as a result of the high local interest rates and the UF-dollar appreciation.

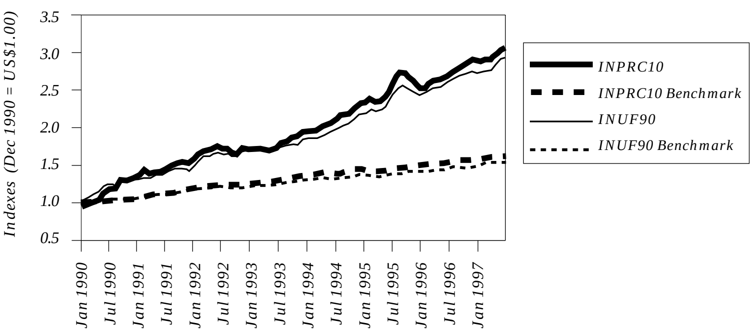
Table 6 lists the asset class weights that turned out to be different from zero, and it also presents the parameters of a simple one-variable linear regression that correlates the index returns with their corresponding replicating portfolios. The portfolio weights are heavily

27. Used by permission. The software is called ENCORR ATTRIBUTION.
28. Data provided by the Central Bank of Chile.

concentrated in short-term U.S. Treasury bills (or T-bills), because if no single asset class has a significant correlation with the indexes, then the tracking variance is minimized with the smallest variance asset. Nonetheless, the replicating portfolios of the two indexes display certain differences. The longer-term index includes long-term U.S. government bonds (whereas the short-term index does not) and also has larger percentages in emerging markets. The regression statistics indicate that the out-of-sample methodology provides insignificant results, except for the constant (alpha). This contrasts with the overall period results, which appear statistically significant despite their low explanatory power. This implies that the optimal portfolio weights may not be stable through time. The serial correlation of the rolling portfolio implies that it may be possible to use this information to better calculate portfolio weights.

Both UF-based indexes thus provide patterns of return that are not available in the international markets. This is true in the following two senses. First, the large alphas indicate that with respect to their replicating portfolios, the UF-based indexes provided additional dollar returns of between 0.7 and 1.0 percent per month. Second, the low correlations indicate that the alternatives behave very differently through time and do not entail the hedging properties that may be required by a local investor.

Figure 7. Dollar-Based Indexes and their Replicating Portfolios[a]



Source: Author's calculations.
a. See text for definition of indexes.

Table 6. Average Composition of Replicating Portfolios, January 1990 to March 1997[a]

	Overall		*Rolling*	
Data index	*INPRC10*	*INUF90*	*INPRC10*	*INUF90*
SB three-month T-bill	78.4300	90.7500	...	...
Long-term U.S. government	8.0900	0.0000	...	...
IFC emerging composite	12.2300	7.3200	...	...
MS Latin America free	1.2500	1.9200	...	...
Summary statistic				
Alpha	0.0072	0.0069	0.0104	0.0103
Alpha *t* statistic	2.4035	2.3864	3.3677	3.7981
Beta	1.0737	1.1254	0.1628	0.0269
Beta *t* statistic	3.5094	2.9070	0.6166	0.0886
R^2	0.1266	0.0904	0.0077	0.0002
F statistic	12.3159	8.4507	0.3802	0.0078
No. observations	87	87	51	51
Serial correlation	0.0991	0.1069	0.2682	0.3140

Source: Author's calculations, based on Ibboston Associates data and software.
a. Data indexes and replicating portfolios defined in text.

Other lessons that can be drawn from this exercise are that the Central Bank should consider, for hedging purposes, including long-term U.S. government bonds and a small proportion of emerging market equity in its portfolio. Finally, investing in foreign fixed-income seems to make little sense for a Chilean investor whose investment horizons are represented by either index, given that local indexed bonds outperform them.

5. Relevance of the Return Patterns Provided by UF Bonds

The results of the previous section indicate that UF-denominated short- and long-term bonds provide patterns of returns that are not available in the international markets. This section assesses whether these patterns are relevant and if so, in what sense.

The analysis includes three different perspectives. The state-variable perspective addresses the idea that the short- and long-term UF-based indexes may represent relevant states of nature. From the perspective of an optimal leverage composition (or hedging against changes in capital asset prices), the issue is whether firms that belong to the nontradables sector would find it convenient to use more

UF-denominated debt. Finally, the third perspective encompasses whether UF-denominated bonds provide useful protection against adverse changes in nontradable goods prices.

5.1 States of Nature

If short- and long-term UF-denominated bonds are indeed useful indicators of the state of the economy, news about them should have a significant impact on the prices of financial instruments. In particular, investors might want to either hedge against or bet on the movements of these variables, and this risk should be priced. Therefore, if the returns of these bonds are correlated with those of the stock market, for example, significant relationships should emerge.[29]

To test this simple idea, I performed a regression analysis with the four industry stock market indexes of the Bolsa Electrónica de Santiago. These are value-weighted indexes that represent buy-and-hold strategies. The four sectors represented are electricity, services, manufacturing, and natural resources. The returns on these indexes are first expressed in dollars and calculated in excess of the ninety-day U.S. T-bill returns. This procedure is also carried out for the explanatory variables, namely, the excess dollar return of the short- and long-term UF-based indexes and of the long-term U.S. government bond index.[30] The next section explains the reason for working with excess returns; here, it is interesting to note that the resulting numbers are almost unit-free, since the variation of the dollar exchange rate is implicitly subtracted on both sides.

Tables 7 and 8 show the results of this exercise. A seemingly unrelated regression (SUR) analysis was performed, including equations for the short- and long-term index excess returns. Table 7 shows the results of estimating an autoregressive equation for the short-term index return, while table 8 shows the results for the long-term bond and stock indexes.

In table 7 the lags were set ex post at three to minimize the number of degrees of freedom lost in the SUR analysis for the rest of the equations, given that higher lags were not significant. Results show a relatively weak positive AR(1) behavior.

29. Strictly speaking, the first step in testing this is to estimate the sensitivity of different asset prices to these state variables and then to verify whether this risk is priced in a cross-section.

30. Same sources as before.

Table 7. Influence of UF-Based Indexes on Stock Returns: The State Variable[a]

Explanatory variable	*EINUF90*	
Constant	0.0061	(2.7731)
EINUF90 (t – 1)	0.2650	(2.0925)
EINUF90 (t – 2)	–0.0500	(–0.3823)
EINUF90 (t – 3)	–0.1350	(–1.1896)
Summary statistic		
No. observations	60	
d. f.	56	
Adjusted R^2	0.0339	
SSR	0.0126	
DW	1.9677	

Source: Author's calculations.
a. Dependent variable is the ninety-day UF-based index excess returns (measured in dollar excess returns above the ninety-day T-bill monthly return). Estimation model is a seemingly unrelated regression (SUR); *t* statistics in parentheses.

Table 8. Influence of UF-Based Indexes on Stock Returns: Stock, UF, and U.S. Dollar Portfolio Returns[a]

Explanatory variable	*EINPRC10*	*ERELECT*	*ERSERVI*	*ERINDUS*	*ERNATUR*
EINUF90	1.1571	–0.3356	–1.0352	–0.4501	–1.6159
	(17.6062)	(–0.2564)	(–0.7610)	(–0.3409)	(–1.1868)
EINPRC10	…	2.2766	2.4900	1.5870	2.7715
	…	(2.2227)	(2.3385)	(1.5356)	(2.6006)
EUSLTGVT	0.0490	–0.0838	0.7331	0.7990	0.0379
	(1.1169)	(–0.2384)	(2.0065)	(2.2534)	(0.1038)
Summary statistic					
No. observations	60	60	60	60	60
d.f.	58	57	57	57	57
Adjusted R^2	0.8222	0.2447	0.2400	0.1909	0.1916
SSR	0.0042	0.2636	0.2845	0.2692	0.2854
DW[b]	1.9681	1.8903	1.7390	1.7716	1.7715
Hypothesis					
UF coefficients > U.S. dollar (*p* values)	…	0.0089	0.0952	0.2516	0.2524
Equal UF coefficients (*p* values)					
0.0973	…	x	…	x	…
0.1376	…	x	…	…	x
0.4076	…	…	x	x	…
0.5880	…	…	x	…	x

Source: Author's calculations.
a. All dependent and explanatory variables are measured in dollar excess returns above the ninety-day T-bill monthly return. EINUF90 corresponds to the ninety-day UF-based index excess returns; EINPRC10 corresponds to the ten-year UF-denominated bond excess returns; EUSLTGVT corresponds to the long-term government bond excess returns; ERELECT, ERSERVI, ERINDUS, ERNATUR correspond to the four industry indexes calculated by Bolsa Electrónica and respectively represent the electrical, services, manufacturing, and natural resources sectors. Estimation model is a seemingly unrelated regression (SUR); *t* statistics in parentheses.
b. The DW statistics do not change if we include a constant in the equations.

Table 8 starts with an analysis of the long-term UF-based index in the first column of numbers. This is a very well behaved equation in which the only significant explanatory variable is the excess return on the short-term UF-denominated bond. In the other equations, the coefficient on the short-term bond is negative and insignificant, and in three out of the four equations the coefficient on the long-term bond is very significant. The joint hypothesis that the coefficients on the UF-denominated bonds are zero at any significance level can thus be rejected.

The analysis indicates that UF-denominated bonds are useful indicators of the state of the economy. This is especially true in the case of the long-term bond, even though it is greatly influenced by the short-term rate.

5.2 Optimal Debt Composition or Hedging against Capital Asset Price Changes

All the regressions in table 8 exclude a constant and are expressed as returns in excess of the T-bill returns, because one minus the sum of the regression coefficients represents what should be invested in the T-bill. To see this, assume three assets (*A*, *B*, and *C*) and suppose that the aim is to find the unrestricted portfolio composed of *B* and *C* that best replicates *A*. If we run the regression

$$r_A - r_B = \mathrm{b}\left(r_C - r_B\right) + \nu \ ,$$

then estimated b will represent the fraction of the portfolio invested in *C* and 1 – b the fraction invested in *B*. The regression analysis finds the portfolio weights that minimize the tracking variance.

Consequently, the coefficients of the regressions without constants can be interpreted as the portfolio weights of the short-term UF-denominated bond, the long-term UF-denominated bond, the long-term U.S. government bond and the T-bill (computed as one minus the sum of the other coefficients).

The results obtained have two alternative (but complementary) interpretations. First, they could represent hedging portfolios made up of the low-risk, fixed-income portfolios that most closely resemble the returns of the industry portfolio. The idea is to identify the portfolio that investors would choose if they could not invest directly in a given industry. Which portfolio, for example, allows us to hedge best against adverse price changes in housing (the nontradables sector)? The second interpretation is that of the optimal leverage composition, in which the evolution of the industry portfolios represents those of the firms that compose them. The portfolios would reflect the market's assessment of changes in the value of assets. In this case it makes sense to look for the composition of the total liability (represented by government bonds)—in terms of maturity and currency denomination—that most closely follows the market value of assets, because this minimizes bankruptcy risks.[31]

The hypothesis that can be tested (and that is consistent with both of the above perspectives) is that the nontradables sectors (electricity and services) should have a higher optimal percentage of the total composition (either as a hedging portfolio or as a liability) in UF-denominated bonds. The opposite should be true for the tradables sector (manufacturing and natural resources). The test should also verify whether the former is greater than the latter, as expected. In this case, since the variables involve the market value of equity rather than of assets, results are likely to be biased against the hypothesis. For example, if a firm already has an optimal debt composition, the value of equity would be less affected by adverse changes in the exchange or interest rates.

The results in table 8 can now be reinterpreted. First, the replicating portfolio of the long-term indexed bond consists of a long position in the short-term UF-denominated bond (1.16), a long but insignificant position in the long-term U.S. government bond (0.05), and a short position in the T-bill (–0.21). This means that historically the UF-denominated bond has provided a pattern of returns that is similar to buying a short-term indexed bond with dollar-denominated debt.

The last four columns in table 8 show the results for the stock portfolios. In general, these are well-behaved regressions, and the results are in line with what can be expected considering the usual explanatory power for stock portfolio returns based on a few explanatory variables. Moreover, results are generally significant, although the coefficients could be biased if the omitted variables are correlated with the regressors. Nonetheless, the portfolio perspective given above is still valid.

To interpret the results for the stock portfolios, the central procedure is to test whether the total amount in UF-denominated bonds (the sum of the first two coefficients) is greater than the amount

31. Government bonds are considered representative because from the perspective of an issuing firm, the bond issued is free of default risk.

in dollar-denominated bonds. In other words, it is sufficient to test whether the sum of the first two coefficients is greater than 0.5. The role of separate coefficients for the short- and long-term bonds (both UF-denominated and dollar-denominated) is to allow for the adjustment of the portfolio duration. Results indicate that for the electrical and services portfolios (in the nontradables sector), the UF coefficients are indeed larger than the dollar coefficients at significance levels of 1 percent and 10 percent, respectively. For manufacturing and natural resources (in the tradables sector), they are not. This is consistent with what is to be expected. At the same time, only the electrical sector gives some indication of having coefficients that are larger than those of the industries in the tradables sector.

The evidence is thus mixed, and it only partially supports the hypothesis that the optimal composition is biased toward the indexed unit.

5.3 Indexed Bonds and Goods Prices

Table 9 presents the results of performing simple bivariate Granger causality tests between tradable and nontradable goods price returns and the short- and long-term indexed bond returns. The idea is to verify to what extent investing in these assets would provide protection to an investor who wishes to hedge against adverse changes in goods prices. This requires a measurement unit for returns and price changes, and since the U.S. dollar has had a significant downward trend, I decided to measure everything in units of the tradable good. Therefore, the price returns actually correspond to the change in the relative prices of the tradable and nontradable goods. The index returns are also measured in terms of the tradable good.

Table 9. Bivariate Granger Causality Tests[a]

Causality test	*Adjusted R^2*	*Observed significance for AR(1) test*[b]	*Lagged variable*[c]	*Sum of coefficients*	*t statistic*
NT causes UF90	0.1652	0.4787	CPI-NT	1.0951	1.3917
UF90 causes NT	0.0694	0.7515	INUF90	−1.0385	−0.7721
NT causes PRC10[d]	0.2612	0.1644	CPI-NT	0.5501	0.7264
PRC10 causes NT[d]	0.2552	0.0881	INPRC10	0.0034	0.0186

Source: Author's calculations, based on data from the Chilean Instituto Nacional de Estadística (INE).
a. Variables measured in terms of tradable goods units. Sample period is 1992:1 to 1997:3. NT means nontradable; CPI-NT corresponds to the consumer price index of the nontradables sector; INUF90 corresponds to the ninety-day indexed bond returns; INPRC10 corresponds to the ten-year indexed bond returns.
b. Test suggested by Godfrey (1978) and Breusch (1978).
c. Tested twelve lags in each case.
d. Modeled with an AR(1) error

Results show that the correlation between lagged price returns and bond returns are positive, but not significant. There is thus no direct evidence that UF-based investing alone provides a good hedge against increases in the relative prices of nontradable goods. More importantly, indexed bond returns do not feed back into prices, which helps to mitigate the eventual concern of the economic authorities that financial indexation perpetuates inflation.

6. Conclusions and Final Comments

This paper has provided sufficient evidence to prove that financial indexation has been an important factor in the development of the Chilean capital market. This is likely to have had a positive impact on welfare and growth through better resource allocation. The paper analyzed the issue from several perspectives to justify the conclusion.

The Chilean experience with the liberalization of financial markets leads to the conclusion that in addition to liberalizing interest rates and credit restrictions and establishing an inflation-neutral tax system, the UF constitutes a central piece of the technology developed for protecting capital market participants from inflation. This technology includes the credibility of the unit, compatible laws, and the precedent established by the central authorities in issuing indexed bonds.

Without an inflation-protection unit, high expected inflation rates and nominal financial instruments imply that the effective maturity of a long-term nominal bond is short. The implications of not having an index unit are that longer-term debt is likely to be issued in a foreign currency (such as the U.S. dollar) and that the overall size and average maturity of the fixed-income markets are likely to be reduced. This, in turn, implies a larger degree of mismatching in firms' asset-liability structures, which increases the expected bankruptcy costs.

The paper describes the Chilean fixed-income market and its generalized indexation as successful. An estimated 63 percent (US$82 billion) of the assets held by institutional investors, including banks, pension funds, life insurance companies, and mutual funds, are indexed. Excluding banks from the sample increases the number to 80 percent. Excluding equity investment as well further increases the percentage to 99 percent.

The paper also identifies links with other markets, especially the equity market, concluding that the development of a fixed-income indexed market was a necessary step toward the development of the equity market. Similar arguments apply in the financial sector with regard to the development of mortgages, pension funds, and life insurance companies. In the real sector, the development of the construction sector through the market for mortgages was probably one of the greatest benefits of indexation. On the other hand, nonfinancial firms have issued small amounts of debt, partly as a result of the distortion between the required returns on debt and equity.

It is not possible to successfully replicate the short- and long-term indexed bond return patterns in international markets, and in this sense they are unique. This uniqueness is relevant for local investors, considering the following evidence. First, short- and long-term indexed bonds represent states of nature that significantly impact asset prices. Second, different debt structures (hedge portfolios) would be optimal for firms in the tradables and nontradables sectors, with the latter being tilted toward UF-denominated securities. These results also indicate that the Central Bank's optimal asset composition should include long-term U.S. government bonds and a small fraction of emerging market equity. Finally, from the perspective of local investors, investing in foreign fixed-income securities seems to make little sense, which may explain why this process has been so slow.

The economic authorities have probably played an important role in the development of the local capital market. In addition to establishing the set of regulations, the issuance of indexed bonds with diverse maturities has provided an important stimulus. The liquidity and benchmarking that these bonds provide are necessary signals for the private sector. In this sense, other government initiatives, such as issuing nominal and dollar-denominated long-term bonds in addition to indexed bonds, would probably help to continue completing the financial markets. For example, long-term nominal bonds could have a social role not only in terms of clarifying private sector expectations about future inflation rates, but also in terms of modifying or creating certain forms of industrial organization. With these instruments providing clear reference rates and with minor legal changes, the market for nominal funds is likely to experience increased competition, which could lower nominal interest rates on consumption loans, for example.

APPENDIX

The Convexity Effect

Consider the Vasicek (1977) model for the term structure of interest rates. It assumes that the changes in the nominal interest rates follow a mean-reverting diffusion process with constant parameters of the following type:

$$\mathrm{d}r = a\left(b - r\right)\mathrm{d}t + \sigma \mathrm{d}z \ ,$$

where a is the "pull", b the level toward which the rates revert, σ the volatility parameter, and dz the Wiener process. This equation has a closed form solution that depends on the above parameters and also on the current level of the short rates.

To study the impact of the volatility of the inflation rate, the real U.S. rates are assumed to be constant, and the current and equilibrium rates are assumed to correspond to the TIPS rate plus a 3 percent long term inflation rate (which gives a log nominal rate of 6.396 percent). We estimate the parameters a and σ from a simple regression of changes in the annual inflation rate against its lagged value from 1960 on. This yields the corresponding estimates of 0.26 and 2.15 percent, respectively. Calculating the Vasicek formula with these parameters generates a downward-sloping nominal yield curve. Using the Fisher equation to estimate the expected inflation rate (that is assumed constant) would therefore underestimate it by 17 basis points in the ten-year bond and 25 basis points in the twenty-year bond. For Chile, using a current and long-term real rate of 6 percent, a constant expected inflation rate of 4 percent, a parameter a equal to 0.201,[32] and twice the volatility of the United States (4 percent), the ten- and twenty-year nominal discount bonds appear to have interest rates that are 78 basis points and 130 basis points below the value given by the Fisher equation. In this case, the inflation risk works in a way that is opposite to what can be expected. Increasing the inflation volatilities reduces the resulting nominal rates. The present value is a convex function of its discount rate. Therefore, for a given long-term expected value, higher volatility in the inflation rates implies lower nominal rates.

32. Corresponds to the coefficient of the error correction model in Rojas, Rosende, and Vergara (1995, table V.10).

References

Aspe Arnella, P., R. Dornbusch, and M. Obstfeld, eds. 1983. *Financial Policies and the World Capital Market: The Problem of Latin American Countries.* University of Chicago Press for the National Bureau of Economic Research.

Arrow, K. J. 1964. "The Role of Securities in the Optimal Allocation of Risk-Bearing." *Review of Economic Studies* 31(2): 91-96.

Barro, R. J. 1995. "Optimal Debt Management." NBER Working Paper 5327. Cambridge, Mass.: National Bureau of Economic Research.

Bates, D. S. 1997. "Post-'87 Fears in S&P 500 Futures Options." NBER Working Paper 5894. Cambridge, Mass.: National Bureau of Economic Research.

Breusch, T. S. 1978. "Testing for Autocorrelation in Dynamic Linear Models." *Australian Economics Papers* 17: 334-55.

Campbell, J. Y., and R. J. Shiller. 1996. "A Scorecard for Indexed Government Debt." NBER Working Paper 5587. Cambridge, Mass.: National Bureau of Economic Research.

CEP. 1992. *El ladrillo: bases de la política económica del gobierno militar chileno,* 2nd ed. Santiago.

Cohen, D., K. A. Hassett, and R. G. Hubbard. 1997. "Inflation and the User Cost of Capital: Does Inflation Still Matter?" NBER Working Paper 6046. Cambridge, Mass.: National Bureau of Economic Research.

Debreu, G. 1959. *Theory of Value: An Axiomatic Analysis of Economic Equilibrium*. Yale University, Cowles Foundation for Research in Economics.

De Pablo, J. C., M. Mancera, and M. Henrique, 1983. "The Capital Market under Conditions of High and Volatile Inflation." In *Financial Policies and the World Capital Market: The Problem of Latin Amercian Countries,* edited by P. Aspe Arnella, R. Dornbusch, and M. Obstfeld. University of Chicago Press for the National Bureau of Economic Research.

Domowitz, I., J. Glen, and A. Madhavan. 1996. "Identification and Testing of a Term Structure Relationship for Country and Currency Risk Premia." Mimeographed (August).

Godfrey, L. G. 1978. "Testing against General Autoregressive and Moving Average Error Models When the Regressors Include Lagged Dependent Variables." *Econometrica* 46: 1293-302.

Goetzmann, W. N., and P. Jorion. 1997. "A Century of Global Stock Markets." NBER Working Paper 5901. Cambridge, Mass.: National Bureau of Economic Research.

Haugen, R. A. 1995. *The New Finance: The Case against Efficient Markets*. New York: Prentice Hall.

Hernández, L., and E. Walker. 1993. "Estructuras de financiamiento corporativo en Chile (1978-1990)." *Estudios Públicos* 6 (Winter).

Landerretche, O., F. Lefort, and R. Valdés. 2002. "Causes and Consequences of Indexation: A Review of the Literature." This volume.

Mendoza, E. 1991. "Efficient Arbitrage under Financial Indexation: The Case of Chile." IMF Working Paper 49. Washington: International Monetary Fund.

Mizala Salces, A. 1991. *Financial Market Liberalization in Chile, 1973-1982*. New York and London: Garland Publishing.

Myers, S. 1984. "The Capital Structure Puzzle." *Journal of Finance* 39 (July): 187-221.

Rojas, P., F. Rosende, and R. Vergara. 1995. "Dinámica de la inflación en Chile: elementos para el análisis." In *Análisis empírico de la inflación en Chile*, edited by F. Morandé and F. Rosende, 155-204. IEUC and ILADES/Georgetown University.

Sharpe, W., 1992. "Asset Allocation: Management and Performance Measurement." *Journal of Portfolio Management* (Winter): 7-19.

Valdés, S. 1988. "Ajuste estructural en el mercado de capitales: la evidencia chilena." Unpublished paper. Santiago: Central Bank of Chile.

Vasicek, O. A. 1977. "An Equilibrium Characterization of the Term Structure." *Journal of Financial Economics* 5: 177-88.

Walker, E., and L. Hernández. 1992. "Financial Corporate Structure in Chile: Evidence From Times Series Accounting Data (1978-1990)." Working Paper 192-01. Santiago: Pontificia Universidad Católica de Chile, Escuela de Administración.

Walker, 1998. "Mercado accionario, crecimiento económico y rentabilidad esperada: Evidencia chilena." *Cuadernos de Economía* 35 (104): 49-72.

Indexation of Public Debt: Analytical Considerations and an Application to the Case of Brazil

Ilan Goldfajn
Central Bank of Brazil and
Pontificia Universidad Católica do Rio de Janeiro

Since the implementation of the Real Plan of 1994, the Brazilian economy has been in the process of reducing its degree of indexation. For more than three decades, Brazilian wages, rents, financial securities, and other contracts were indexed to the price level. The frequency of adjustment sometimes reached monthly or even daily intervals, as in the case of some financial securities.

Brazilian indexation was inseparably associated with high rates of inflation, which averaged 20 percent per month over the last three decades. Inflation peaked at 82 percent per month during the hyperinflation (or megainflation) episode that occurred just before the Collor Plan went into effect. The association between inflation and indexation has always provoked the debate about whether high and variable inflation induces the indexation of the economy through the breakdown of nominal contracts or whether indexation perpetuates the inflationary process as argued by the inertial theory of inflation.[1]

Brazilian indexation has relied mainly on price-level indexation as opposed to exchange rate indexation, which is common in several

A similar version of this article was published in the *Journal of International Finance and Economics* 5(1): 43-56, 2000.

At the time of writing, Ilan Goldfajn was affiliated with the International Monetary Fund.

I would like to thank Trevor Alleyne, Márcio Garcia, Fernando Lefort, Klaus Schmidt-Hebbel, and Andrés Velasco for very useful comments, and Ugo Fasano, Patricia Menandro (Andima), Mário Mesquita, Áureo de Paula, and Evan Tanner for kindly providing me with the data.

1. For this debate and the inertial inflation theory, see Arida and Resende (1985); Simonsen (1983). See also Fischer and Summers (1989), who show how better protection may end up causing more inflation.

Indexation, Inflation, and Monetary Policy, edited by Fernando Lefort and Klaus Schmidt-Hebbel, Santiago, Chile.

other inflationary experiences. This peculiar feature has often been justified by the institutionality of Brazilian indexation mechanisms.

These mechanisms, which date back to 1964, concentrated on price-level indexation well before the country began to experience the high inflation of the late 1980s and early 1990s.

This paper investigates Brazilian indexation in the financial sector over the last few decades, focusing, in particular, on indexation of the public debt. Not only were government indexed securities a sizable portion of total securities, but they also took a central role (as reference values and even as a unit of account) in spreading indexation mechanisms to other contracts in the economy, such as wages, rents, taxes, and other private financial contracts. Important government indexed securities include the Obrigações Reajustáveis do Tesouro Nacional (ORTN, later OTN) in 1964-89 and the Bonus do Tesouro Nacional (BTN) in 1989-91.

This paper examines the composition of public debt among price-level-indexed, nominal, and foreign-denominated securities. It argues that the volatility of inflation, the level of total debt, the volatility of the real exchange rate, and the correlation between expenditures and inflation are important determinants of the composition of public debt. To illustrate the main government incentives for issuing different public debt securities, the paper derives a simplified model of debt indexation and denomination. It models a government that wants to minimize both the fluctuation of the government budget and inflation. The smoothing of the budget allows for smaller changes in the tax rate, which implies higher utility for a representative consumer, given convex distortion costs. The main trade-off can be summarized as follows. On the one hand, issuing indexed securities allows the government to minimize fluctuations of the real value of its debt as a result of inflation variability, and it eliminates the temptation of inflating away the debt, which, in equilibrium, would lead to costly higher inflation. On the other hand, if expenditure shocks are positively correlated to inflation shocks, nominal securities serve as implicit contingent debt, thus reducing the value of debt when it is most needed.

The paper also investigates when it is preferable to issue foreign-denominated securities. These are a better option when the real exchange rate does not fluctuate substantially and the correlation between the real exchange rate shocks and government expenditures is negative.

The paper is organized as follows. The next section summarizes Brazilian experience with indexation. Section 2 presents the model and section 3 looks at the composition of public debt in Brazil. Finally, section 4 concludes.

1. INDEXATION IN BRAZIL

Most of Brazil's institutionalization of indexation dates back to 1964 during the first military government of President Castelo Branco.[2] Before that date, two laws inhibited the emergence of automatic adjustments of contracts. The 1933 law passed by President Vargas simply prohibited contracts from being stipulated in currencies other than the milreis, the Brazilian currency at that time. Besides being a nationalistic reaction in favour of the Brazilian sovereign monetary unit, the law attempted to curb the established practice of foreign companies indexing their prices to the exchange rate in order to neutralize the effect of the devaluation of milreis on their receipts measured in foreign currency. From an economic point of view, the law was based on the fact that exchange rate indexation significantly impaired the correction of balance-of-payments imbalances.

The second law, the Lei da Usura, established a nominal interest rate ceiling of 12 percent. Since inflation generally exceeded this ceiling, implying negative real rates, several mechanisms were established to bypass the law. Long-term contracts were nonexistent, however, since they required explicit indexation mechanisms to deal with uncertainty regarding future inflation rates.

In 1964, the military government decided to reduce the distortions in the economy resulting from these two laws. It therefore introduced the *correção monetária*, a sophisticated indexation mechanism that adjusted taxes, tariffs, and some financial contracts, but not the exchange rate, wages, or bank deposits. The government wanted to avoid the negative effects that the absence of indexation had on public receipts and some financial contracts. The absence of indexation on the exchange rate and wages was justified to allow corrections of external imbalances and to avoid the inflationary consequences of wage indexation.

The government also issued the Obrigações Reajustáveis do Tesouro Nacional (ORTN). These were public debt securities that had maturities ranging from one to twenty years and that were adjusted automatically for past inflation plus interest rates of 6 percent per year. The objective was to avoid financing the deficit through inflationary monetary expansion. The government believed that indexing the debt would increase the demand for long-term securities with fixed real rates and also allow for lower debt service, since it

2. This section draws on Simonsen (1995).

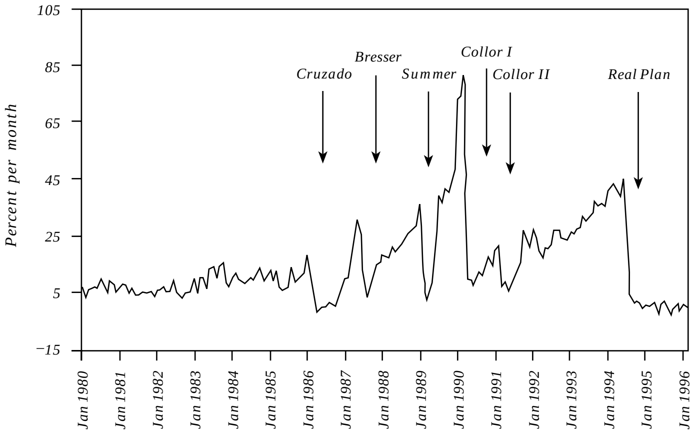
expected inflation to decline below market expectations embedded in nominal interest rates paid on nominal securities.

The ORTN rapidly became an important reference value for other contracts. Starting in 1964, mortgage contracts were adjusted by the quarterly variation of the ORTN. This adjustment became known as the UPC (the unit of reference of capital). Indexation spread to almost all areas of the economy beginning in 1967, during the Costa e Silva administration. Wages could no longer be denied automatic indexation. The exchange rate policy was based on purchasing power parity, and rents were adjusted every six months. In short, the Brazilian economy became highly indexed.

Both indexation and inflation continued to increase under the next two governments, from 1974 to 1985. The Mexican default and the resulting crisis led to higher inflation and renewed efforts to implement restrictive monetary and fiscal policies. With the economy highly indexed to past inflation, all attempts to reduce inflation through traditional policy instruments proved inappropriate.

The inflation process was thought to be inertial and its reduction to require measures that eliminate widespread indexation in the economy. In March 1986, the Cruzado Plan was implemented; this was the first in a long series of stabilization plans. This first attempt was unsuccessful, as were the following four plans (namely, the Bresser, Summer, Collor I, and Collor II plans) (see figure 1). The widespread indexation of contracts persisted, and inflation continued to increase.

Figure 1. Inflation and Stabilization Plans



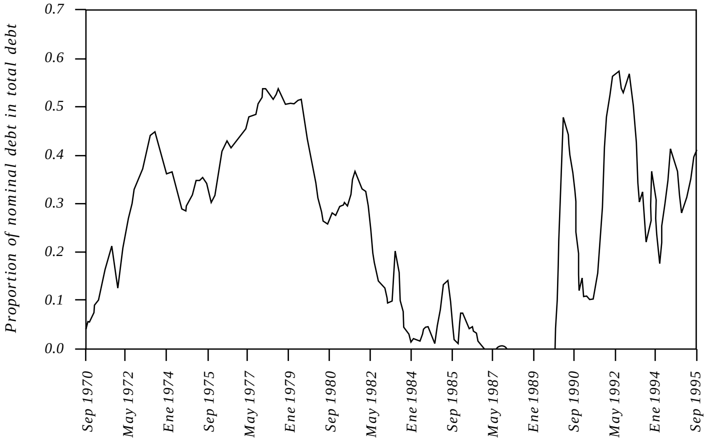
Source: Conjuntura Economica (IPA/DI).

Given the high levels of uncertainty with respect to inflation, nominal contracts could not survive. The proportion of nominal public debt reached zero during the megainflation process that preceded the Collor plan. Figure 2 shows the proportion of nominal debt in the hands of the public.

The Real Plan of July 1994 succeeded in reducing inflation. It was an ingenious scheme of changing numeraires. In March 1994 nominal prices, wages, and other contracts were allowed to be quoted in a unified reference value (URV) that would be replaced by a new currency, the real, in July 1994. Given that prices were already indexed to several different references, the innovation of the URV was to coordinate a unified unit of account that would substitute for all other indexation mechanism. In the interim period after the introduction of the URV and before its replacement by the real, it was expected that relative prices would converge to their equilibrium value. This was important for the second phase of the conversion, when the URV would be transformed into real on a one-to-one basis and then pegged to the dollar. This pegging, in fact, caused inflation to plunge from 46 percent in June 1994 to 1.5 percent in September 1994.

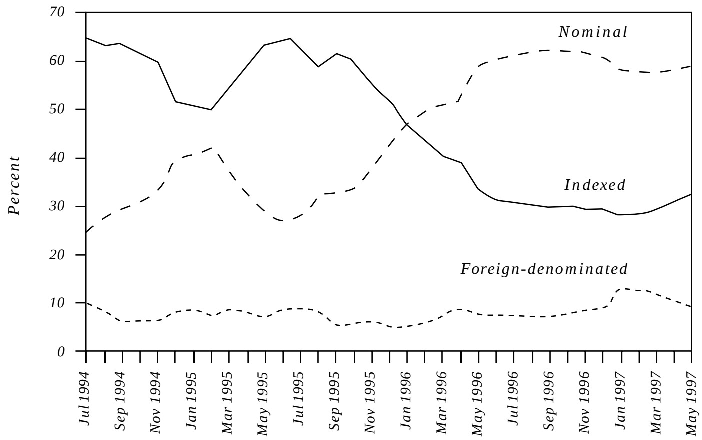
Lower inflation and deliberate government legislation to eliminate the indexing of the economy together reduced the indexation of short-term contracts substantially. In particular, the proportion of indexed public debt diminished considerably. Figure 3 shows the composition of public debt after the Real Plan. The most striking fact is that the proportion of nominal debt has increased significantly, as one should expect from the increasingly stable inflation environment.

Figure 2. Nominal Debt in Brazil



Source: Associação Nacional das Instituições do Mercado Aberto (Andima).

Figure 3. Composition of Public Debt



Source: Central Bank of Brazil.

2. THE MODEL

The government decision to manage its public debt hinges on the trade-off between time-consistency problems and tax-smoothing motives. The former generate higher inflation than is optimal; credibly committing to low inflation therefore requires a structure based on securities indexed to either foreign or domestic inflation. Tax smoothing calls for issuing securities whose returns are negatively correlated with the tax needs of the government. This may be the case of both nominal debt and debt linked to a foreign currency.

The model uses a two-period example to derive the optimal composition of debt, including nominal, indexed, and foreign-denominated liabilities. The objective is to highlight the effects of both tax smoothing and time-consistency considerations on the optimal composition in the simplest possible framework.[3]

The government's objective is to minimize distortions from taxes (τ) and inflation (π), both of which are assumed to be quadratic. There are three sources of uncertainty: government spending, the real exchange rate, and the money demand are assumed to be stochastic.

3. A multiperiod model is developed in Goldfajn (1996). For a related model of public debt indexation, see Calvo and Guidotti (1990).

The latter introduces uncertainty with respect to the inflation rate:

$$\text{Min}\ \ \mathrm{E}\left(A\frac{\tau^2}{2}+\frac{\pi^2}{2} \right). \tag{1}$$

In the first period, the government chooses the composition of the debt that it sells to the public, which will mature at the end of period two. Three financial instruments are available: nominal bonds that are sold at a nominal interest rate (i) and have a realized rate of return of

$$\frac{(1+i)}{(1+\pi)},$$

indexed bonds that pay a real rate of r plus the realized rate of inflation (π); and foreign-denominated bonds that pay the foreign interest rate (i^*) plus the rate of depreciation (e) and have a realized real rate of return in domestic currency equal to

$$\frac{(1+i^*)(1+e)}{(1+\pi)}.$$

No shocks or other financing decisions take place in the first period.

In the second period, the government decides about the optimal money growth, given the level of debt and its composition. Subsequently, the shocks are realized and taxes are levied to balance the budget.[4] Consumers are in the background; they enter the model as risk-neutral debt holders who demand a nominal interest rate that includes a fixed real interest rate (r) plus the expected rate of inflation (π^e):[5]

$$1+i=(1+\pi^e)(1+r). \tag{2}$$

The assumption of risk neutrality on the part of the investors is not restrictive and is made for simplicity. Had I assumed risk-averse investors, they would have demanded an extra premium to hold nominal debt, but the main results would still hold.[6]

4. The budget has to balance since this is the last period. In the multiperiod model, taxes and money growth are decided simultaneously, and the amount of debt financing is adjusted for the shocks.

5. It is assumed that the real interest rate r is equivalent to that demanded on indexed bonds. Even with risk neutrality, equation 2 is an approximation.

6. The results depend on the fact that the government wants to minimize the fluctuations on the real value of its debt, since they generate costly changes in the tax rates. The investors' degree of risk aversion does not change this fact.

The paper assumes uncovered interest rate parity:

$$1 + i = \left(1 + e^e\right)\left(1 + i^*\right) . \tag{3}$$

The money market equation determines the equilibrium inflation rate:

$$\pi = \hat{m} + \tilde{v} , \tag{4}$$

where $\hat{m}$ is money supply growth created by the government and $\tilde{v}$ represents velocity shocks that are assumed to be white noise. Here the paper assumes that the government sets the money supply and allows the nominal exchange rate to be determined endogenously.[7]

In equilibrium, rational investors will anticipate the government's decision on money supply growth. In the model, this implies that investors anticipate the average inflation generated by the government:

$$. \tag{5}$$

The government's budget constraint in the second period is that taxes have to be equal to spending plus the real value of debt.[8] Using equations 2 and 3 and linearizing the budget constraint, I obtain

$$\tilde{\tau} = \tilde{G} + \left(1 + r\right)B\left[1 - \theta\left(\tilde{\pi} - \pi^e\right) - \theta^*\left(\tilde{q} - q^e\right)\right] , \tag{6}$$

where θ and θ^* are the proportions of nominal and foreign-denominated debt, respectively, B is the level of total debt, and

$$\tilde{q} = \tilde{\pi} - \tilde{e} . \tag{7}$$

Unexpected increases in inflation reduce nominal debt, and unexpected real appreciations reduce foreign-denominated debt. (Assume for simplicity that foreign inflation is zero.)

2.1 The Commitment Solution

The commitment solution is derived first. It is assumed that the government can credibly commit in the first period to the decisions

7. An alternative and equivalent assumption is to allow the government to set the rate of depreciation and let money be determined endogenously.

8. For simplicity, revenues from cash balance holdings are ignored.

taken in the second period. In the first period, therefore, the government will choose both the composition, θ and θ*, and the way it will finance itself between taxes and money growth in the second period. Minimizing equation 1 subject to equations 5 and 6, I obtain the solution

$$\hat{m}^* = 0 \,, \tag{8}$$

and the optimal proportions are

$$\theta = \frac{\sigma_{g\pi}\,\sigma_q^2 - \sigma_{gq}\sigma_{\pi q}}{B\left[\sigma_\pi^2\,\sigma_q^2 + \left(\sigma_{\pi q}\right)^2\right]} \quad \text{and} \tag{9}$$

$$\theta^* = \frac{\sigma_{gq}}{B\,\sigma_q^2} - \frac{\sigma_{\pi q}\,\theta}{\sigma_q^2} \,, \tag{10}$$

where σ denotes variance or covariance. It is assumed, for simplicity, that r = 0.

The optimal money supply growth is zero because there are no benefits from announcing a higher money path: nominal interest rates will increase proportionally to higher inflation rates. Moreover, higher inflation rates imply higher distortion costs, such that governments will optimally commit to a zero inflation path.

The optimal proportion of the debt in nominal terms increases with the covariance of inflation with spending but diminishes with the variance of inflation. The intuition is that shocks to the other components of the budget should be optimally hedged. On the one hand, nominal debt is a good hedging device for the government whenever shocks to spending (or any other component of the primary deficit) are positively correlated to inflation shocks and, therefore, negatively correlated to the debt value. This avoids having to raise taxes in bad states of the world. On the other hand, pure inflation variance only introduces noise to the budget and induces the use of more indexed debt. This will be the case in countries that face large nominal shocks relative to real movements. The real value of the their debt would fluctuate without a corresponding change in other budgetary components. This induces the use of a high proportion of indexed debt. The empirical section of the paper demonstrates that this is precisely the case of Brazil.

Having liabilities in foreign currency introduces another instrument for hedging, provided the correlation between the real exchange rate and other domestic budget components (in this case spending) are not zero. The trade-off with foreign-denominated liabilities is that they may introduce more noise to the budget. If the value of foreign currency used to peg part of the debt is not very stable, that is, if there is a high variance of the real exchange rate, taxes will fluctuate more to compensate the movements in the real value of foreign-denominated debt.

The optimal proportions of nominal and foreign-denominated debt derived above imply a specific relationship between them. A larger share of nominal debt is associated with a larger share of foreign-denominated debt depending on whether the covariance between inflation and the real exchange rate is positive or negative. If the returns covary negatively, the two bonds are complements in the government's portfolio and they should increase proportionally.

2.2 Absence of Commitment

In this section, the assumption of commitment is relaxed. If the government cannot commit its future behavior, it will face time-consistency problems arising from the fact that it controls the average inflation rate. Optimal behavior in the second period will be to inflate some of the existing nominal debt. Ex ante, rational investors will anticipate the future temptation to inflate, adjust expected inflation, and demand a higher nominal interest rate. The inflation rate will be higher in this equilibrium than in the previous one, in which the government could commit itself.[9]

It is interesting to calculate the effect of future incentives to inflate on the debt composition chosen in the first period. Solving backwards, the government minimizes taxes and inflation costs in period two, but takes as given the level of debt (B), its composition (θ and θ^*), and the nominal interest rate (i). Minimizing equation 1 subject to equations 5 and 6 in the second period, I obtain the following solution:

$$m^* = A\,B\,\theta\,\Omega \quad \text{and} \tag{11}$$

$$\Omega = \left(\overline{G} + B\right), \tag{12}$$

9. The government here cannot systematically affect the real exchange rate, q.

where $\overline{G}$ is expected spending. The first-order condition of equation 11 uses equation 5. It says that in the second period the government equates the expected marginal costs of raising taxes and inflation. The equilibrium values of taxes and inflation, after shocks are realized, are

$$\tilde{\tau} = \tilde{G} + B\left(1 - \theta\hat{\pi} - \theta^{*}\hat{q}\right) \quad \text{and} \tag{13}$$

$$\pi = m^{*} + \tilde{v}, \tag{14}$$

where $\hat{\pi}$ and $\hat{q}$ are the unexpected shocks to inflation and the real exchange rate.

In comparison with the previous case, the absence of commitment increases the average rate of inflation, creating expected distortion costs. The incentive to inflate and the resulting equilibrium inflation depend on the proportion of nominal debt outstanding, θ. The government in period one would therefore need to adjust its optimal θ to reduce the incentive to inflate. Thus it will deviate from the optimal proportion of nominal debt for hedging purposes. In other words, the absence of other commitment technologies forces the government to use indexation to satisfy two objectives, hedging and commitment, leaving it worse off.

The government in period one minimizes the loss function in period two by choosing the appropriate indexation of debt. For this purpose, it is possible to explicitly derive the loss function that the government faces in the first period (dropping irrelevant terms and using the values from equations 11 through 14):

$$\begin{aligned} \text{Loss} = \; & A^{2} B^{2} \theta^{2} \Omega^{2} - 2\theta B \sigma_{g\pi} - 2\theta^{*} B \sigma_{gq} \\ & + B^{2}\left(\theta^{2}\sigma_{\pi}^{2} + \theta^{*2}\sigma_{q}^{2} + 2\theta\theta^{*}\sigma_{\pi q}\right). \end{aligned} \tag{15}$$

The first term on the right-hand side of the equation is the price of not being able to commit to not inflating the nominal debt. It is the traditional inflationary bias of time-consistent solutions. Indexing the debt is one of the commitment technologies. The government will now take into account this term when choosing its optimal proportion of nominal debt. It is clear that setting $\theta = 0$ will completely avoid this type of cost. The second and third terms are the hedging role of nominal debt and foreign-denominated debt, respectively. If inflation (or the real exchange rate) and government spending are positively correlated, tax rates will fluctuate less and governments can reduce distortions in the economy. It is thus optimal to have contingent debt that reduces the real value of debt when financing needs are higher. Nominal and foreign-denominated debt are implicitly contingent debt. The last term on the right-hand side of the equation works against issuing both nominal and foreign-denominated debt. If the variance of inflation or the real exchange rate is high, it will imply large changes in the real value of debt, which will increase the variance of tax rates. Setting $\theta = 0$ and $\theta^* = 0$, completely indexing the debt, eliminates this last effect.

The government minimizes the loss function in the first period and obtains the optimal proportion of debt in nominal and foreign currency:

$$\theta = \frac{\sigma_{g\pi}\,\sigma_q^2 - \sigma_{gq}\,\sigma_{\pi q}}{B\left[\left(A^2\,\Omega^2 + \sigma_\pi^2\right)\sigma_q^2 + \sigma_{\pi q}^2\right]} \quad \text{and} \tag{16}$$

$$\theta^* = \frac{\sigma_{gq}}{B\,\sigma_q^2} - \frac{\sigma_{\pi q}\,\theta}{\sigma_q^2} \ . \tag{17}$$

This optimal value has an additional term, $\Omega^2 A$, when compared to the commitment case. The government now has to take into account the marginal cost, in terms of higher average inflation, of not indexing one extra unit of debt. This additional cost will reduce the optimal proportion of nominal debt. The higher the term $\Omega^2 A$, the more tempted the government appears to be to inflate the debt. To credibly commit itself to not inflate, the government will thus use a higher proportion of indexed debt. This will reduce the amount of nominal debt available for hedging purposes, deviating further from the commitment solution. The $\Omega^2 A$ term depends on both the level of total debt and average spending. If the total debt, B, is larger, the government is more tempted to inflate the debt. The higher the debt, therefore, the lower the optimal proportion of nominal debt. This effect is similar to the one derived in Blanchard and Missale (1994).

The effect of the debt level on foreign-denominated debt is more ambiguous. First, there is the direct effect of the level of debt on the composition through the hedging mechanisms. For given variances and covariances and a given level of shocks to spending, the higher the total debt, the lower is the proportion of foreign-denominated debt needed to obtain the same amount of hedging. Second, the impact of the term $\Omega^2 A$ (through θ in equation 17) depends on whether the covariance between inflation and the real exchange rate is positive or negative. The latter also defines whether foreign-denominated debt and nominal debt are complements or substitutes in the government's portfolio.

I could restrict the values of θ and θ^* to between 0 and 1, which means that there is no negative debt in any component of the debt, that is, governments do not hold net positive claims with the private sector. In this case corner solutions may arise.

Two relevant issues on debt management are not stressed in the model. First, governments frequently claim that they manage debt to minimize borrowing costs. However, if markets work efficiently and there is no free lunch, any gains from shifting to cheaper securities should imply higher risks to the government.[10] Since higher risks to the government ultimately imply higher risks to society (for example, through a higher probability of raising taxes to close the budget), it is not clear that anyone gains from this strategy. In the model, I have omitted this aspect by assuming risk-neutral investors and equivalent real returns for all the securities. Second, governments can, in principle, smooth shocks intertemporally by raising debt in bad moments and repaying debt in good times. The nature of the shock then becomes irrelevant, and debt composition is indeterminate. In a previous paper, I show that even if governments smooth taxes through time, there is a role for smoothing taxes through states of nature; this is the hedging argument described above (see Goldfajn, 1996). The relative importance of the hedging argument is an empirical matter. The following section evaluates the importance of hedging and credibility arguments in the case of Brazil.

3. Empirical Analysis

The implications of the model can be summarized as follows:

• The proportion of nominal debt should decrease with the level of total debt.

• Nominal debt should be negatively related to the variance of inflation.

10. This occurred, for example, when the Mexican central bank shifted from domestically denominated CETES to dollar-denominated *Tesobonos* and implicitly assumed the exchange rate risk.

- Nominal debt should increase when the covariance of inflation and spending is larger, whereas foreign-denominated debt should increase when the covariance between the real exchange rate and spending is larger.
- Foreign-denominated debt should be negatively related to the variance of the real exchange rate.

This section tests the main determinants of public debt indexation and denomination. The analysis focuses on the joint behavior of the macroeconomic series that determines the budget constraint of the government (that is, government spending and inflation), the level of the debt, and its composition for Brazil.

3.1 Data

The paper uses monthly public debt data for the period 1980-97, obtained directly from the Central Bank of Brazil and from the historical series published in Andima (1992). The data set incorporates disaggregated data on the composition of public debt between indexed and nominal debt held by the public (net of the holdings of the Central Bank).

The paper also uses monthly data on the real exchange rate, inflation, and spending. Inflation is measured by changes in the wholesale price index, and spending is the total disbursment of the government net of interest rate payments. The original source of the series is the Central Bank of Brazil. The series of real exchange rate values is multilateral, based on the wholesale price index; it is calculated in Goldfajn and Valdés (1996).

3.2 First Stage: Obtaining the Variance and Covariance Series

The paper first obtains the four variance and covariance series for Brazil: the variance of inflation, the covariance of inflation with government spending, the variance of the real exchange rate, and the covariance of the real exchange rate with spending. The variance-covariance structure of innovations in government spending, real exchange rate, and inflation was obtained for Brazil by performing a vector autoregression (VAR) of these variables. The variances were obtained from the residuals of the VAR. In the same manner, the covariances were obtained from the off-diagonal-terms covariance matrix of the residuals.

The variance and covariance series were estimated with a series of rolling VAR estimations. A new VAR was estimated for each year, with a different data set available to estimate the covariance matrix. For each estimation, the last forty observations and two lags were used. In this way a time series of estimates of the four relevant variances and covariances were obtained. The series start in January 1980 and end in December 1997.

Three series of correlations are relevant to the discussion. First, the correlation between spending and real exchange rate innovations in Brazil tends to be positive in most of the sample, giving a hedging role to the foreign-denominated debt. This is an expected result, since higher spending increases the demand for nontradables, which appreciates the currency. Second, the correlation between spending and inflation is positive at the beginning of the sample and at the very end (1980-85 and 1994-96), but it becomes negative in the late 1980s when inflation reached hiperinflationary levels. The reason is that for low and medium levels of inflation, either government spending created pressures on prices or, in the reverse causality, increases in prices generated more government spending. In this case, nominal debt played a role as a hedging device. When inflation rates became very high, however, shocks to inflation tended to reduce government spending, since wages and payments in the public sector were not perfectly indexed to the price level. Finally, the correlation between inflation and the real exchange rate is positive in the whole sample. Because prices and exchange rates were not perfectly flexible, positive shocks to inflation did not always translate into proportional shocks to the nominal devaluation rates, which led to real appreciations of the currency. Nominal and foreign-denominated debt were therefore substitutes in the government portfolio.

3.3 Second Stage: OLS Regressions

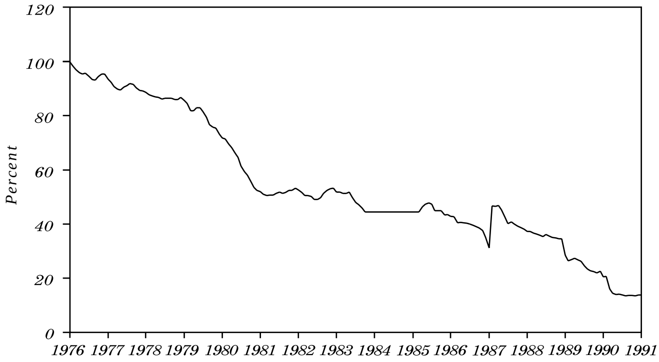
The second stage uses the estimated variances and covariances obtained in the first stage to estimate their influence on the choice of θ and θ^*, in an ordinary least squares (OLS) regression. The period of estimation is 1980-95, and the frequency is monthly.

The proportion of nominal debt is regressed against the variance of inflation, the covariance of spending and inflation, the level of public debt as a proportion of gross domestic product (GDP), a constant, a time trend, and dummy variables to control for both the Collor and

Real plans.[11] The dummies are included because both plans caused important structural breaks with a potentially important influence on the composition of public debt. The Collor Plan of March 1990 froze a good part of the financial securities available, including public debt securities. The Real Plan represented a structural break from the previous inflationary environment; it therefore had potentially important effects on the composition of public debt.

Indexed debt in Brazil was not a guaranteed positive real return to its holders. Figure 4 shows the real value of an indexed bond from 1976 to 1991. It is clear from the figure that indexation in Brazilian indexed securities was far from perfect. The indexation mechanism lagged behind actual inflation and did not protect the real value of this type of debt. An interesting way to test the effect of imperfect indexation is to observe the behavior of the average maturity of all public debt, including indexed debt. If indexation is imperfect, agents will require shorter maturities, even in indexed debt, to avoid large fluctuations in the real value of debt. I can therefore repeat the OLS regressions above using the average maturity as the dependent variable, since the predictions of the model can be equally applied to the average maturity of debt. The effects of the variance of inflation, the level of public debt, and the covariance of inflation and spending on the real value of debt should be correlated to the average maturity of debt.

Figure 4. Real Value of Government Indexed Bond (January 1976 =100)



Source: E. Tanner, "Intertemporal Solvency and Indexed Debt: Evidence from Brazil", *Journal of International Money and Finance* 14(4): 549-73, 1995

11. Neto (1996) runs similar regressions to test the model outlined in Goldfajn (1996). His specification and results differ somewhat from those obtained below, however.

Finally, the proportion of foreign-denominated debt is regressed against the variance of the real exchange rate, the covariance of spending and the real exchange rate, the level of public debt as a proportion of GDP, a constant, a time trend, and dummy variables to control for both the Collor and Real plans.

3.4 Results

The results of the regression are presented in tables 1 through 3. The expected signs are listed in the bottom row.

In table 1, the level of debt seems to have a significant effect and in the direction predicted by the model. A higher level of debt reduces the long nominal proportion of debt. This supports the model, since having a higher total debt affects the incentives to inflate and influences the decision on whether to issue nominal debt.

The variance of inflation has a negative effect on the proportion of nominal debt, as uncertainty with regard to inflation tends to reduce maturities. As predicted by the model, a high variance of inflation should reduce the amount of nominal debt. This phenomenon was an important feature of the Brazilian economy, in which the deepening of financial indexation was positively correlated to the uncertainties that accompanied high inflation rates.

Table 1. Determinants of Debt Indexation in Brazil, 1980–95[a]

Explanatory variable	*D/Y*	*Trend*	σ_π	*Collor I Plan dummy*	*Real Plan dummy*	$\sigma_{\pi g}$	R^2
Inflation	–0.05	0.26	–0.14	...	...	...	0.30
	(–3.8)	(4.93)	(–2.38)	...	...	...	...
Inflation and spending	–0.06	0.27	–0.21	20.3	...	...	0.34
	(–3.86)	(5.01)	(–3.39)	(1.7)	...	...	...
Real exchange rate	–0.07	0.24	–0.20	20.1	19.1	...	0.40
	(–4.93)	(3.48)	(–3.09)	(1.7)	(2.85)	...	...
Real exchange rate and spending	–0.06	0.23	–0.11	18.5	20.85	1.04	0.44
	(–4.78)	(3.41)	(–1.54)	(1.56)	(2.9)	(2.64)	...
Expected sign	–	...	–	+	+	+	...

Source: Author's calculations.
a. The dependent variable is the proportion of nominal debt. A constant was included in each regression; *t* statistics were corrected by the Newey-West consistent matrix and are shown in parentheses.

The covariance with spending also fit the predictions of the model. The coefficient on the covariance of inflation and spending have the correct sign: it is positive and significant at the 5 percent level. This confirms the prediction of the model that the higher this covariance, the higher the proportion of nominal debt.

The results further show that both the Collor and Real plans increased the proportion of nominal public debt, the former through a compulsory freezing of financial assets and the latter through a structural change in the inflationary regime.

Table 2 presents the regressions with the average maturity of public debt. The coefficients on debt-to-GDP ratio, variance of inflation, the covariance of inflation with spending, and the Collor plan have the same signs as predicted by the model and are equivalent to the ones obtained in the regressions presented in table 1.

Table 3 contains the results of the regressions with foreign-denominated debt. The coefficients on the variance of the real exchange rate and the covariance of the real exchange rate with spending have the right signs but are insignificant. The level of debt has a negative effect on the proportion of foreign denominated debt. Credibility arguments should imply a positive sign.[12]

To take into account the covariance between the residuals of the regressions that underlie the results in tables 1 and 3, a seemingly unrelated regression (SUR) system was estimated. The results are similar to those obtained in the previous tables (see table 4).

Table 2. Determinants of Debt Maturity in Brazil, 1986–95[a]

Explanatory variable	*D/Y*	*Trend*	σ_π	*Collor I Plan dummy*	*Real Plan dummy*	$\sigma_{\pi g}$	R^2
Inflation	–0.03	0.12	–0.07	...	...	...	0.62
	(–6.6)	(6.99)	(–5.02)	...	...	...	...
Inflation and spending	–0.03	0.12	–0.09	5.43	...	...	0.65
	(–6.9)	(7.14)	(–5.73)	(3.79)	...	...	...
Real exchange rate	–0.03	0.13	–0.09	5.46	–1.94	...	0.65
	(–5.83)	(4.41)	(–6.34)	(3.88)	(–0.59)	...	...
Real exchange rate and spending	–0.03	0.11	–0.06	4.98	0.18	0.27	0.65
	(–6.17)	(3.94)	(–4.43)	(3.59)	(0.06)	(2.57)	...
Expected sign	–	...	–	+	+	+	...

Source: Author's calculations.
a. The dependent variable is the average maturity of debt. A constant was included in each regression; *t* statistics were corrected by the Newey-West consistent matrix and are shown in parentheses.

12. The regressions in tables 1 and 3 were repeated using the amount of nominal or foreign-denominated debt as the independent variable. This isolates the direct negative effect of total debt from the credibility effect that I want to stress. The results are qualitatively identical.

Table 3. Determinants of Foreign Denominated Debt in Brazil, 1980–95[a]

Explanatory variable	*D/Y*	*Trend*	σ_{RER}	*Collor I Plan dummy*	*Real Plan dummy*	σ_{RERg}	R^2
Inflation	–0.01	0.05	...	...	...	...	0.38
	(–2.87)	(4.81)	...	...	...	...	...
Inflation and spending	–0.02	0.10	–0.27	...	...	...	0.52
	(–2.42)	(5.13)	(–1.12)	...	...	...	...
Real exchange rate	–0.02	0.10	–0.23	–2.34	1.72	...	0.52
	(–2.96)	(4.12)	(–0.88)	(–0.87)	(0.84)	...	...
Real exchange rate and spending	–0.02	0.10	–0.21	–2.36	1.66	0.11	0.44
	(–2.95)	(4.16)	(–0.84)	(–0.87)	(0.80)	(0.88)	...
Expected sign	+	...	–	...	...	+	...

Source: Author's calculations.
a. The dependent variable is the proportion of foreign-denominated debt. A constant was included in each regression; *t* statistics were corrected by the Newey-West consistent matrix and are shown in parentheses.

Table 4. Determinants of Debt Composition, Seemingly Unrelated Regression (SUR) System Estimation[a]

Variable	*Nominal debt*	*Foreign-denominated debt*
D/Y	–0.05	–0.01
	(–6.7)	(–6.2)
Trend	0.25	0.11
	(8.9)	(7.8)
σ_{π}	–0.09	0.001
	(–2.04)	(0.07)
$\sigma_{\pi g}$	1.4	0.36
	(2.87)	(3.68)
σ_{RER}	0.13	–0.10
	(0.42)	(–0.97)
σ_{RERg}	–1.57	–0.02
	(–3.63)	(–0.11)
Collor I Plan dummy	16.9	–0.64
	(3.22)	(–0.38)
Real Plan dummy	21.6	1.81
	(5.27)	(1.36)
R^2	0.47	0.57

Source: Author's calculations.
a. A constant was included in the regressions; *t* statistics in parentheses.

4. Conclusions

Since the implementation of the Real Plan, the share of public indexed debt has dropped from 70 to 30 percent of total debt, while the shares of both nominal and foreign-denominated debt have increased. This paper offers a simple model and preliminary evidence to explain these facts.

The paper develops a model of public debt management that concentrates on hedging and credibility motives. The model demonstrates that indexed debt should be issued to enhance the credibility of the government or to avoid unnecessary fluctuations in the real value of debt as a result of variable inflation rates. In contrast, nominal debt serves the purpose of hedging shocks to the budget when inflation is positively correlated to spending. Foreign-denominated debt may also serve as a hedging device if the real exchange rate is positively correlated with spending and does not fluctuate substantially.

The evidence from OLS regressions confirms that the variance of inflation, the size of the public debt, and the correlations of inflation with spending are important determinants of public debt indexation in Brazil.

References

Andima (Associação Nacional das Instituições do Mercado Aberto). 1992. *Séries históricas: dívida pública*. Rio de Janeiro.

Arida, P., and A. L. Resende. 1985. "Inertial Inflation and Monetary Reform in Brazil." In *Inflation and Indexation*, edited by J. Williamson. Washington: Institute for International Economics (IIE).

Blanchard, O., and A. Missale. 1994. "The Debt Burden and Debt Maturity." *American Economic Review* 84(1): 309-19.

Calvo, G. A., and P. Guidotti. 1990. "Indexation and Maturity of the Government Bonds: An Exploratory Model." In *Public Debt Management: Theory and History*, edited by R. Dornbusch and M. Draghi, 52-93. Cambridge University Press.

Fischer, S., and L. Summers. 1989. "Should Governments Learn to Live with Inflation?" *American Economic Review* 79: 382-87.

Goldfjan, I. 1996. "On Public Debt Indexation and Denomination." Working Paper 345. Brandeis University.

Goldfjan, I., and R. Valdés. 1996. "The Aftermath of Appreciations." NBER Working Paper 5650. Cambridge, Mass.: National Bureau of Economic Research.

Neto, A. P. 1996. "Considerações sobre a gestão de dívida pública no Brasil." Unpublished paper. Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio).

Simonsen, M. H. 1983. "Indexation: Current Theory and the Brazilian Experience." In *Inflation, Debt, and Indexation*, edited by R. Dornbusch and M. H. Simonsen. MIT Press.

———. 1995. *30 Anos de indexação*. Rio de Janeiro: Fundação Getulio Vargas.

Tanner, E. 1995. "Intertemporal Solvency and Indexed Debt: Evidence from Brazil." *Journal of International Money and Finance* 14(4): 549-73.

Indexation, Inflation, and Monetary Policy

"This volume presents the current state of knowledge about the classic issues of indexation and inflation. It brings together work by top economists in both academia and central banks. The papers strike just the right balance between intellectual rigor and policy relevance. Any scholar or practitioner of monetary policy can learn a lot from this book."

Laurence Ball, Johns Hopkins University.

"Indexation is a central issue for economies with incomplete markets and credibility problems. Indexation may facilitate and sometimes impede good macroeconomic management. This book provides a fresh look at this and related issues from the perspectives of theory and empirical analysis, taking advantage of the extensive indexation experience in Brazil and Chile. Since market incompleteness and low credibility are common features of emerging-market economies, this book meets the additional criterion of being highly relevant and topical. Moreover, the array of authors is impressive, running from the field's big-hitters to seasoned central bankers with close-range experience on the topic. I am prepared to bet that this book will become indispensable reading for anybody interested in the role of indexation or the macroeconomics of emerging-market economies."

Guillermo A. Calvo, University of Maryland and Inter–American Development Bank.

"Indexation of wages, exchange rates, tax brackets, bonds, mortgages, rents—Chile has had it all. Building on this rich experience, the volume edited by Lefort and Schmidt-Hebbel provides a state-of-the-art analysis of the macroeconomic causes and consequences of indexation. Inflation-targeting central bankers will want to read the chapters on how to carry out policy in an indexed environment. A very useful book."

Andrés Velasco, Harvard University.

BANCO CENTRAL DE CHILE