Inflation Targeting and the Inflation Process: Lessons from an Open Economy

Guy Debelle
Reserve Bank of Australia

Jenny Wilkinson
Reserve Bank of Australia

Inflation targeting in an open economy involves a number of complexities that do not arise with inflation targeting in a closed economy. One of these is that central banks in open economies have to decide how to respond to changes in the exchange rate. Pitchford (1993), Svensson (1998), and Ball (1998) examine this issue theoretically, and in broad terms, they reach the conclusion that in the presence of exchange rate shocks, central banks should consider targeting a measure of nontraded, or domestic, inflation rather than the aggregate inflation rate. The implication of their analysis is that central banks should respond to developments in the exchange rate, but only to the extent that the shocks to the exchange rate stimulate output growth in the economy or affect aggregate inflation expectations.

In the broader discussion of optimal policymaking under an inflation target, several papers use the Ball-Svensson framework to explore the impact of including nontraded rather than aggregate inflation in the central bank's objective or policy reaction function.[1] Others investigate how the specifics of the exchange rate pass-through process affect the monetary policy decision.[2] In many cases, these issues are discussed in the context of policy reaction functions that are variants of the Taylor rule.

We would like to thank Adam Cagliarini and Ben McLean for superb research assistance.

1. Bharucha and Kent (1998); Ryan and Thompson (2000).
2. Cunningham and Haldane (2002).

Inflation Targeting: Design, Performance, Challenges, edited by Norman Loayza and Raimundo Soto, Santiago, Chile.

In this paper, we summarize the essential features of an economy that affect the choice between targeting aggregate and nontraded inflation, and we examine the issue empirically. The empirical part of the paper has two components. Section 2 uses an empirical model of the Australian economy to illustrate the choice between targeting aggregate inflation rather than a measure of nontraded inflation and outlines some of the aspects of the economy that affect that choice. We examine the tradeoff in the context of both optimal policymaking and policymaking that uses a Taylor-type rule to set interest rates. These results, however, depend on our understanding of the inflation process. Section 3 thus examines the inflation process in Australia over the last two decades, using reduced-form price equations that are often used for forecasting. Specifically, we look at changes in the responsiveness of the inflation rate to exchange rate shocks and deviations of output from potential, and we examine variations in the persistence of the inflation process over time. The results for Australia are compared with those for the United States, the United Kingdom, Canada, and New Zealand.

1. Which Inflation Rate To Target In An Open Economy?

An important issue that confronts an inflation-targeting central bank in an open economy is that changes in the exchange rate can have a significant effect on inflation outcomes via the prices of traded goods. If the central bank is pursuing a strict inflation target, the policy responses required to offset the effects of exchange-rate-induced changes in inflation may be damaging to the nontraded sector of the economy, and they can generate a large degree of volatility in output.

Consequently, Ball (1998) and Svensson (1998) suggest that it may be preferable for a central bank to target a measure of inflation that abstracts from these direct exchange rate effects. This section reviews their arguments and outlines the main considerations that might affect the choice of which inflation rate to target.

These issues can be illustrated by the following simple model, which is similar to that in Ball and Svensson:

$$y_t = \phi y_{t-1} - \beta r_{t-1} - \alpha e_{t-1} + \varepsilon_1 , \quad (1)$$

$$\pi_t = \pi_t^e + \delta y_{t-1} - \gamma \Delta e_t + \varepsilon_2 , \text{ and} \quad (2)$$

$$\Delta e_t = r_t - r^* + \varepsilon_3 , \quad (3)$$

where y is the output gap, r the real policy interest rate, e the real exchange rate, and π inflation.

The first equation is an aggregate demand equation, in which monetary policy is assumed to affect output with a one-period lag. A depreciation of the exchange rate also leads to an expansion in output with a one-period lag, through its effects on net exports. The second equation is an open-economy Phillips curve. Changes in the exchange rate are assumed to be passed through immediately to the prices of imported goods in the consumer price basket. For the moment, inflation expectations are assumed to be backward looking, depending on past values of the aggregate inflation rate; this is discussed further below. Note that exchange rate changes affect inflation more rapidly than they do output. The third equation explains the dynamics of the exchange rate in terms of an interest rate parity condition.

The central bank is assumed to have an objective function of the standard form,

$$\sum_{s=1}^{\infty} \theta^{s-1}\left[(1-\lambda)\left(\pi_{t+s}-\pi^{*}\right)^{2}+\lambda y_{s}^{2}\right], \tag{4}$$

where $0 \leq \lambda < 1$. The central bank sets its policy instrument to minimize deviations of inflation from its target and to minimize the output gap. When λ is zero, the central bank can be characterized as a strict inflation targeter, for which output considerations are always secondary to minimizing inflation variability.

Consider a temporary depreciation of the exchange rate that results from a portfolio realignment lasting only one period (that is, a decline in ε_3). The depreciation will generate an immediate increase in inflation as imported goods prices rise. If a rigid inflation target is in place, the increase in inflation can be counteracted by a rise in interest rates to offset the downward pressure on the exchange rate from the portfolio shift. This policy change is reversed in the following period when the downward pressure on the exchange rate dissipates. The policymaker can thus successfully stabilize the inflation rate, but at the cost of inducing additional volatility in output, as output responds to the shifts in interest rates.

If the policymaker targeted nontraded inflation rather than aggregate inflation, the policy response would be considerably more moderate. A muted response would also occur under a more flexible inflation targeting regime. Output variability would be lower in both of these cases, but at the expense of greater volatility in the aggregate inflation rate (assuming that the effect of interest rate changes on output are more potent than exchange rate changes). Some policy response would still be necessary to reduce the volatility resulting from the effect of the depreciation on output and to offset any effect of the exchange rate movements on nontraded goods prices or inflation expectations.

Hence targeting aggregate inflation instead of nontraded inflation presents a choice between inflation variability and output variability. Responding to exchange-rate-induced fluctuations in inflation increases output variability, while ignoring them increases aggregate inflation variability.

Ball (1998, p. 19) argues that targeting a measure of long-run inflation "purged of the transitory effects of exchange rate fluctuations" is the optimal strategy for a central bank in an open economy. To bolster his argument, he raises the possibility that, in practice, the increased output variability from targeting aggregate inflation may destabilize inflation in the medium term (although such a result is not possible in his simple framework).

To make such an evaluation, however, one needs to assess the relative costs of inflation and output variability. Tradeoff curves can illustrate the various combinations of output and inflation variability that correspond to different objective functions or rules for the central bank, but the paucity of knowledge on the relative costs to society of inflation and output variability prevents an easy comparison of these combinations. The coefficient λ in the objective function (equation 4) is a critical but unknown variable. The general assumption is that some degree of inflation variability should be permitted. The question is, how much?

One also needs to know which measure of inflation enters the objective function. The aggregate consumer price index is designed to be representative of the average consumption basket, so it would appear to be the most obvious measure to use. However, various sectors of the economy, most notably producers in the nontraded sector, may face considerably different price baskets. They would be relatively disadvantaged if an aggregate measure were targeted instead of a nontraded measure.

Nevertheless, curves showing tradeoffs between output variability and the variability of various measures of inflation can be generated and presented as a menu of options to policymakers. The rest of this section discusses some of the key features of the economy that affect the shape and position of these tradeoff curves in an open economy, and hence the relative merits of targeting aggregate versus nontraded inflation.

First, the nature of the shocks hitting the economy is important, in terms of both their source and their persistence. Bharucha and Kent (1998) examine this factor using a calibrated model similar to that presented above. They demonstrate that if the shocks occur primarily to the exchange rate (equation 3), then a nontraded inflation target may be preferable in that it reduces output variability substantially. If, on the other hand, the shocks primarily occur in the nontraded sector of the economy, then a nontraded inflation target will place much of the burden of adjustment on the traded goods sector.

With regard to the persistence of the shocks, temporary changes in the exchange rate that are likely to be unwound within a short period do not necessarily warrant a policy response. The inflationary impulse of an exchange rate temporarily below equilibrium should be offset by the disinflationary effect of the subsequent appreciation back to equilibrium. If changes in the nominal exchange rate are expected to be permanent—reflecting changes in the real exchange rate—then monetary policy needs to ensure that the resulting inflationary pressures do not lead to a permanent increase in the inflation rate. While this principle is easy to state, its practical implementation is particularly problematic. As Ball (2000) notes, it would be useful to find an alternative measure of inflation that simplified this problem in practice. The next section examines whether movements in unit labor costs may serve as a useful proxy.

A second element that affects the nature of the tradeoff is the extent to which aggregate and nontraded inflation are affected by movements in the exchange rate. The aggregate inflation rate will be affected directly according to the degree of import penetration of the consumer goods market. Exchange rate changes may also have a significant direct impact on nontraded inflation, however, if the nontraded sector is dependent on imported inputs in production.

The speed and extent of the pass-through of exchange rate changes to final goods prices is also important. A more protracted pass-through reduces the impact of a given exchange rate movement on the inflation rate and thereby reduces the size of the necessary policy response to it. Some evidence of a change in the pass-through of exchange rate movements in the 1990s is discussed in section 3.

Third, inflation expectations play a critical role. An important function of inflation targeting is to maintain stability in inflation expectations and thereby anchor ongoing inflation. The appropriate inflation targeting strategy thus depends on how inflation expectations are formed, the degree to which they are forward looking, and how well they are anchored. If inflation expectations are primarily backward looking and are dependent on movements in the aggregate inflation rate, then exchange rate movements will tend to have a larger and more persistent impact on both aggregate and nontraded inflation, as they get built into expectations. If, on the other hand, inflation expectations are forward looking, then temporary exchange rate changes will not lead to much movement in inflation expectations, since wage and price-setters recognize them as temporary. This is a key part of the process that affects the extent to which exchange rate changes lead to a temporary boost to inflation rather than a permanent pickup.

Similarly, if the inflation target is perceived as credible, inflation expectations will be well anchored on the target inflation rate and again will not respond strongly to temporary deviations in the actual inflation rate. In such circumstances, the credibility of the inflation target is somewhat self-fulfilling. Shocks to the inflation rate, from changes in the exchange rate for example, would not be expected to lead to a prolonged deviation of inflation from target. Because of this belief, expectations are not adjusted, and the inflation rate is more stable.

2. Evidence from a Small Empirical Macroeconomic Model

The discussion in the previous section implies that the choice of the appropriate inflation target is largely an empirical issue that depends on the structure of the economy and the specification of the welfare function. In this section, we use a small model of the Australian economy to illustrate the tradeoff curves and their sensitivity to the structure of the economy. We then draw some conclusions on the relative merits of targeting aggregate and nontraded inflation.

This analysis extends the work of Bharucha and Kent (1998), who examine the choice of inflation target in a simple calibrated version of the Ball and Svensson model, focusing on the influence of different shocks. Ryan and Thompson (2000) also examine this issue, using a model of the Australian economy and assuming the use of simple policy rules. The analysis here focuses primarily on optimal policy, although some policy rules are considered to provide a basis of comparison with Ryan and Thompson.

2.1 Methodology

The tradeoff curves are generated using a simple empirical model of the Australian economy similar to that in Beechey and others (2000).[3] The model is a relatively complex version of the simple Ball-Svensson framework, but the central features are the same, namely, an equation for output, an equation for aggregate inflation, and an objective function for the central bank[4]. As in the Ball-Svensson model, monetary policy is transmitted to output through two channels: directly through changes in the real interest rate (with a six-quarter lag) and indirectly through changes in the real exchange rate (with a four-quarter lag). The real exchange rate is explained by movements in the terms of trade and real interest rate differentials.

Aggregate inflation is measured by changes in the consumer price index. It depends on contemporaneous and lagged changes in import prices, lagged growth in unit labor costs and its own lags (which serve as a proxy for backward-looking expectations). There is no forward-looking component of inflation expectations.[5] The majority of the effect of exchange rate changes on import prices is assumed to occur contemporaneously, consistent with estimates of first-stage pass-through (Dwyer, Kent, and Pease, 1994). Exchange rate changes are thus transmitted immediately to aggregate inflation (although the initial impact is relatively small). Monetary policy affects aggregate inflation through its impact on the output gap in the unit labor cost equation and through its effect on import prices via the exchange rate.

For specifying an appropriate inflation target variable in an open economy, Ball (2000) advocates a measure of long-run inflation that filters out the transitory effects of exchange rate fluctuations. We initially tried a measure of inflation based on the prices of nontraded goods in the consumer price index. This proved to be dependent on exchange rate fluctuations, however, because of the importance of imported inputs in the production of nontraded goods and also because of govern-

3. The model is described in detail in Appendix A. Beechey and others (2000) also provide a summary of macroeconomic developments in the Australian economy over the past two decades, and further details are provided in Gruen and Shrestha (2000).

4. We assume the central bank doesn't discount outcomes in future periods. In equation 4, θ is assumed to be unity throughout the simulations.

5. This primarily reflects the lack of a useful measure of inflation expectations in Australia. Historically, however, backward-looking expectations have accurately characterized the inflation expectations process in Australia (Brischetto and de Brouwer, 1999).

ment-determined prices.[6] Instead we chose unit labor costs as a measure of inflation in the nontraded sector. (Hereafter we use the terms unit labor costs and nontraded inflation interchangeably.) Unit labor costs are modeled using a Phillips curve specification, with expectations modeled as a weighted average of aggregate and nontraded inflation. Hence while the exchange rate has no direct effect on unit labor costs, it does have indirect effects through the influence on inflation expectations and the output gap.

The policymaker is assumed to have an objective function as described in equation 4. Two forms of the objective function are considered: one with aggregate inflation, the other with growth in unit labor costs. To generate the tradeoff curves, the relative weight on output variability (λ) is varied between 0 and 1. The instrument of monetary policy is the nominal cash rate.

The model of the economy is then simulated by taking draws of the error terms in each equation for both exogenous and endogenous variables, using a distribution based on the estimated variance-covariance matrix. The policymaker is assumed to know the full structure of the economy but assumes the value of all future shocks are zero. Each period the policymaker chooses the optimal level and future path for interest rates either with the aim of minimizing the objective function or according to a Taylor rule. The model is simulated for 100 periods for each value of λ, and the variability of output, aggregate and nontraded inflation are calculated in each simulation.

2.2 Optimal Policy Results

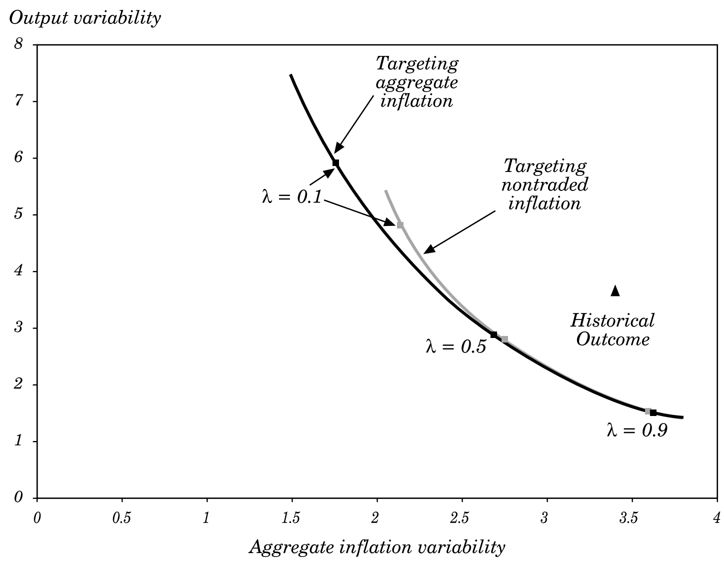
The top panel of figure 1 shows the tradeoff between output variability and aggregate inflation variability when aggregate inflation is the objective and when nontraded inflation is the objective. Similarly, the bottom panel shows the tradeoff between output variability and nontraded inflation variability for the two different objective functions. For comparison, the actual historical outcomes are also shown (for the first quarter of 1985 to the fourth quarter of 1999).

The figure illustrates the obvious conclusion that the best way to minimize the variability of a particular measure of inflation is to directly target that measure by placing it in the objective function. The upper

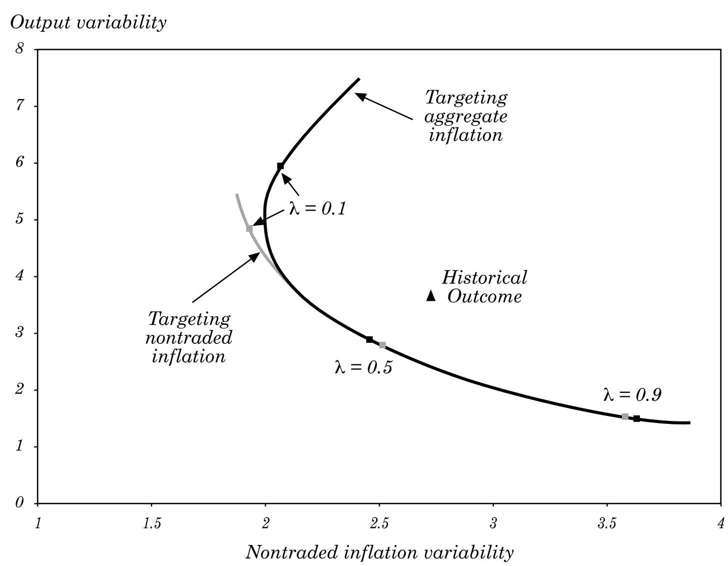
6. Ryan and Thompson (2000) also find that nontraded inflation was sensitive to exchange rate movements, and they examine a policy rule that targets unit labor costs in the nontraded sector.

Figure 1. Optimal Policy

Tradeoff Curve: Aggregate inflation



Tradeoff Curve: Nontraded inflation



panel of the figure, however, shows that the variability of aggregate inflation is not significantly higher when nontraded inflation is targeted. Only a small difference emerges as relatively more weight is placed on inflation variability (as λ declines). This result is not surprising, because nontraded inflation is an important determinant of aggregate inflation. Therefore, in minimizing the variability of nontraded inflation, the policymaker also reduces the variability of aggregate inflation.

The converse is also generally true, except when a relatively large weight is placed on inflation variability (when λ is less than about 0.25). Strict inflation targeting then generates considerably more variability in nontraded inflation. Consequently, those parts of the economy for which nontraded inflation is more important will be worse off under a strict aggregate-inflation-targeting regime.

Output variability is also considerably higher under a strict aggregate inflation target than under a strict nontraded inflation target. These results are similar to those in Svensson (1998), who finds that strict inflation targeting regimes generate a large amount of volatility in domestic inflation and output.

These simulations assume that the policymaker is able to distinguish exactly between temporary and permanent shocks to the exchange rate and to respond appropriately. Making this distinction is considerably more difficult in practice. These results suggest that there may not be much cost in focusing on a nontraded measure of inflation. That is, policymakers may only need to respond to exchange rate changes to the extent that they expect them to be reflected in movements in nontraded inflation.

The variability of interest rates associated with these tradeoff curves is considerably larger than that observed in practice. The standard deviation of the interest rate changes ranges between 2.5 and 5.5. The objective function was therefore amended in the normal way to include a term for smoothing the interest rate by penalizing interest rate variability. A weight on the smoothing term that was sufficient to reduce the volatility in interest rates to the historically observed level did not have a significant impact on the tradeoff curves: the variability in output and aggregate inflation only increased marginally. This result is similar to that in Lowe and Ellis (1997), who also find that reducing the volatility of policy interest rates does not greatly affect the variability of the other target variables. When a smoothing objective is included, however, the increase in the variability of nontraded inflation under a strict aggregate inflation target is even greater.

The model was altered in a number of ways to test the sensitivity of the results to the structure of the economy. First, we doubled the variability of the exchange rate shocks.[7] This naturally shifted the variability frontiers up and to the right, but it did not materially alter the conclusion that the choice of inflation target does not have much impact except in the case of strict inflation targeting.

Second, we changed the process for the real exchange rate. In the model, long-run movements in the real exchange rate are driven by the terms of trade, which are assumed to be stationary. When we modeled the terms of trade as a nonstationary process, allowing for permanent shifts in the real, and thus also the nominal, exchange rate, the effect was to steepen the tradeoff curves. That is, increasing the weight on output in the objective function led to a larger reduction in output variability and a smaller increase in inflation variability than in the baseline case. However, there was very little difference in outcomes for the two different inflation objectives.

Third, we altered the expectations process in the nontraded sector to allow for some credibility in the inflation target. A positive weight was placed on a constant term set equal to the inflation target, thereby anchoring unit labor costs in the long run. Inflation expectations retained some backward-looking element, however. This change to the expectations process naturally shifted the tradeoff curves towards the origin, as the expectations process was less volatile. In other words, establishing credibility in the inflation target allows the policymaker to choose from a superior set of economic outcomes. The choice of inflation target did not result in any significant differences in the variability of either measure of inflation. However, a strict aggregate inflation target generated even more variability in output (relative to a strict nontraded inflation target) than in the baseline case.

2.3 Policy Rule Results

The simulations above analyzed the tradeoff between targeting aggregate and nontraded inflation assuming policy is set optimally in every period to minimize the central bank's objective function. Ball (1998), Svensson (1998), and Ryan and Thompson (2000), however, all examine the choice of the appropriate inflation target in the context of policy being set according to a Taylor-type rule. In the simple Ball-Svensson framework, the Taylor rule, or a Taylor rule that includes the exchange rate, is an optimal policy reaction function. In more complicated models like that

7. It is assumed that this change in the variability does not alter any other aspect of the model.

used above, however, such rules are only rough approximations of optimal policy. Optimal policy in these models takes account of changes in all the variables in the economy, rather than only the variables in the policy rule. The simple rules, however, may still be useful to the extent that aggregate output and inflation are summary statistics for developments in the economy, or that tractable and transparent policy rules are desirable.

To investigate the tradeoff that applies when the central bank follows a policy rule, the model is simulated in the same way as in the previous section except that the central bank is assumed to follow a rule rather than optimizing an objective function every period. We examine two policy rules, one with weights on output and aggregate inflation and the other with weights on output and nontraded inflation. In the first set of simulations, these policy rules are contemporaneous, including only current-dated measures of inflation and output. Simulations are then conducted using forward-looking rules that incorporate the forecast of output and inflation three quarters ahead.[8] In each case, a number of simulations are conducted for different sets of weights on output and inflation in the policy rule. An efficient frontier for each rule traces out the lowest combinations of inflation and output variability as these weights are varied.

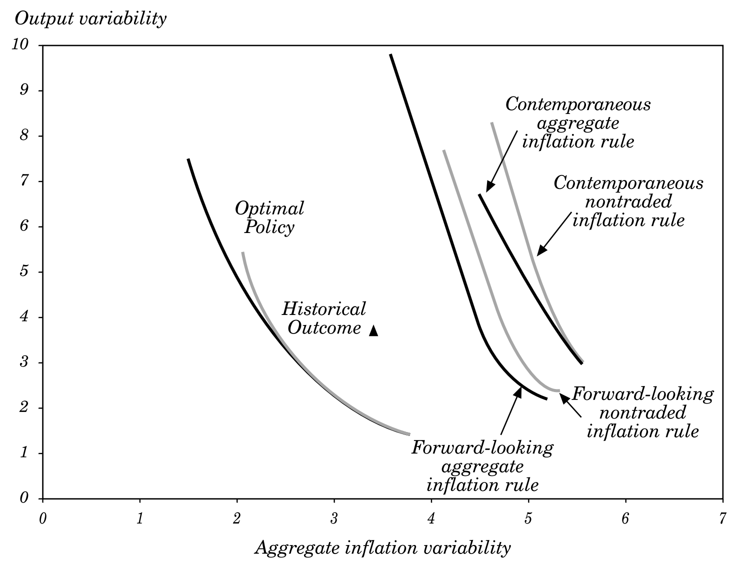
Figure 2 shows the efficient frontiers from rules that respond to contemporaneous movements in output and aggregate inflation and rules that respond to forecasts for these variables. For comparison, it also shows the optimal policy frontiers derived earlier. The frontiers for the policy rules result in significantly more variability in inflation and output than was the case for optimal policy—and more than that which was actually observed in practice. These simulations also confirm two results in Ryan and Thompson (2000). First, an aggregate inflation rule generates a more preferable tradeoff than a nontraded inflation rule, although the differences between the two rules are not stark. Second, a forward-looking rule leads to lower output and inflation volatility than a contemporaneous rule.

2.4 Summary

The results of these simulations suggest that in a representative model of the Australian economy, targeting aggregate inflation and targeting nontraded inflation deliver similar economic outcomes. This occurs because exchange rate changes have a muted effect on aggregate inflation. The only exception to this conclusion is that having a

8. Ryan and Thompson (2000) indicate that three quarters is the most efficient horizon for a Taylor rule in a model similar to that used here.

Figure 2. Taylor Rule Tradeoff Curves



strict aggregate inflation target significantly increases the variability of nontraded inflation and output, as greater reliance is placed on the faster-acting exchange rate channel of monetary transmission.

An important caveat to this conclusion is that the simulations assume the policymaker is able to distinguish between temporary and permanent movements in the exchange rate. These results are also very sensitive to the nature of the inflation process. The next section examines how this has changed over the past two decades.

3. Evidence of Changes in the Inflation Process

To operate an inflation-targeting regime and to assess the range of options facing policymakers, it is crucial to have a reasonable understanding of the inflation process. As well as understanding the behavior of inflation expectations, an important factor with which small open economies have to contend is that shocks to the exchange rate, which occur frequently and are often large, can have a significant direct effect on the inflation rate. Understanding the link between changes in the exchange rate and inflation is thus particularly important.

The inflation process in many industrialized countries may have changed over the last decade, however. Reports on monetary policy, or inflation, by inflation-targeting central banks, for example, allude to a fall in the extent of pass-through of exchange rate shocks to domestic retail prices in several different countries over several different episodes:

> Exchange rate pass-through continues to be more muted and diffuse than historical experience would suggest.[9]
> Staff analysis suggested that import prices had fallen by less than was expected given the rise in the exchange rate.… In other words, the pass-through from exchange rate appreciation had been unexpectedly weak. [Members concluded that] since the pass-through from the earlier, much larger appreciation seemed to be incomplete, there was a good chance that the recent depreciation would have little effect.[10]
> The exchange rate normally affects inflation through import prices… In practice, however, the weak krona has not affected either import or consumer prices as much as the Riksbank had anticipated.[11]
> Import prices have for some time exerted a restraining influence on consumer price inflation. The extent of this effect was unexpected. Historical experience suggested that, given the exchange rate depreciation between mid-1997 and late 1998… some eventual impact in the form of higher import prices at the retail level could be expected.[12]

This possibility has been raised and explored in a number of papers in recent years.[13] There have also been suggestions that the inflation process more generally may have changed in recent years. Taylor (2000) examines data for the United States and finds a reduction in the persistence of inflation shocks. That is, he finds that the inflation process in the United States was less highly autocorrelated in the 1980s and 1990s than in the previous two decades. Taylor argues that the low inflation outcomes of the last two decades may have caused this reduction in persistence. Kuttner and Posen (1999) also present evidence of a reduction

9. Reserve Bank of New Zealand, *Monetary Policy Statement,* March 1999, p. 13.

10. Bank of England, *Minutes of Monetary Policy Committee Meeting,* 8 and 9 October 1997, p. 4.

11. Speech by Sweden's First Deputy Governor Lars Heikensten, "Monetary Policy and the Exchange Rate," given in Stockholm, 19 April 1999. Available at www.riksbank.com.

12. Reserve Bank of Australia, "The Economy and Financial Markets," *Reserve Bank of Australia Bulletin,* August 1999, p. 32.

13. See, for example Cunningham and Haldane (2002); Dwyer and Leong (2000), McCarthy (1999). McCarthy (1999) finds that for the nine OECD countries he examines, pass-through is considerably lower over 1983–98 than it was over the full sample period (1976–98), although he claims that these differences are probably statistically insignificant.

in the persistence of inflation in Canada, New Zealand, and the United Kingdom in the period since each country has been inflation targeting. They argue that this reduction in persistence may reflect the success of the inflation-targeting regime in "enhancing public trust of the central bank's long-run target commitment" (Kuttner and Posen, 1999, p. 34).

Andersen and Wascher (2000) take a different perspective. They show that there was a systematic positive bias in the inflation forecasts of the Organization for Economic Cooperation and Development (OECD) in the 1990s, and they examine whether particular shocks, which have been common across countries, can explain this outcome. The paper also explores whether structural changes in the inflation process can be identified. The authors conclude that there is no systematic explanation across countries for the lower-than-expected inflation outcomes, and the structural changes they find are neither common across countries nor statistically significant.[14]

The Australian experience has been similar to that of many other OECD countries. During the 1990s, inflation was both lower and considerably less variable than would have been predicted at the beginning of the decade. The response of inflation to exchange rate shocks, in particular, was considerably more muted than expected. Dwyer and Leong (2000) examine the Australian experience, looking for evidence of a structural change in both the inflation process and the process that drives each of the major determinants of inflation. Using recursive estimation techniques, they provide tentative evidence that the speed with which exchange rate changes are passed through to consumer prices has fallen. This change is not statistically significant, but the authors emphasize that the magnitude of the change is economically significant. They also discuss changes to the wage-setting process in Australia over the last two decades, arguing that these are likely to have dampened the transmission of price shocks to wages and hence reduced the potential for wage-price spirals to develop.

This section of the paper further explores these issues. First, we estimate a simple, reduced-form price equation for Australia in an attempt to summarize the dynamics of the combined price and wage-setting processes.[15] Similar equations are estimated for Canada, New Zealand, the

14. Their paper examines forecasts and developments in eight OECD countries: Australia, Canada, Japan, Spain, Sweden, Switzerland, the United Kingdom, and the United States. It compares the behavior of inflation during the 1990s with that of the previous three decades.

15. These equations are similar to those estimated in Andersen and Wascher (2000).

United Kingdom, and the United States for comparison. Unlike earlier studies, however, we then use rolling regressions with a ten-year window to gauge the changes that are taking place in these processes. Although rolling regressions provide less efficient coefficient estimates than recursive regressions, they provide a clearer indication of structural changes as they are occurring. Our focus is as much on whether these changes would be of economic significance as on whether we can reject the statistical hypothesis of no structural change at conventional levels of significance.

We derive the equation we estimate from the following two reduced-form relationships:

$$\pi_t = \pi_t^e + \alpha_1\left(\pi_{t-i}^m - \pi_{t-1}\right) + \alpha_2\left(gap_{t-i}\right) + \alpha_3\left(\Delta gap_{t-i}\right) + u_t \text{, and} \tag{5}$$

$$\pi_t^e = \left(1 - \Sigma\beta_k\right)\pi^* + \Sigma\beta_k\pi_{t-k}, \tag{6}$$

where π is the log difference of the aggregate price level, π^e is expected inflation, π^m is the log difference of import prices, and *gap* is the log of output relative to potential. π^* is discussed below.

The first equation is a Phillips curve, where inflation outcomes depend on expected inflation, growth in real import prices (a measure of the real exchange rate), the output gap, and the change in the output gap. The last term reflects the fact that in the Australian data, the speed at which the output gap is being closed, as well as its level, is typically important.

The second equation describes the process by which inflation expectations are formed. Some proportion ($\Sigma\beta_k$) of inflation expectations is formed in a backward-looking manner, and the rest ($1 - \Sigma\beta_k$) is anchored at some constant rate of inflation, π^*, which we call the perceived inflation target. Over time it is therefore possible that both the perceived inflation target (π^*) and the extent to which inflation expectations are linked to the target rate ($1 - \Sigma\beta_k$) may change, and movements in these two can be distinguished from each other. If $\Sigma\beta_k = 1$, inflation expectations are entirely backward looking, while if $\Sigma\beta_k = 0$, they are completely anchored to the target, π^*.[16]

Substituting equation 6 into equation 5, and assuming $k = 2$, generates the equation we estimate:

$$\pi_t = \delta_0 + \delta_1\pi_{t-1} + \delta_2\pi_{t-2} + \delta_3\pi_{t-i}^m + \delta_4 gap_{t-i} + \delta_5\Delta gap_{t-i} + u_t, \tag{7}$$

16. These two equations imply that in the short run there is a tradeoff between output and inflation, but there will be no tradeoff in the long run, provided that inflation expectations eventually adjust one-for-one with actual inflation. If $\Sigma\beta_k = 1$ this will always be the case; if $\Sigma\beta_k < 1$, it requires that π^* eventually converges on the actual inflation rate.

from which individual parameter estimates of the short-run elasticities of inflation with respect to import prices and the output gap can be calculated, together with the extent to which expectations are backward looking ($\sum\beta_k = \delta_1 + \delta_2 + \delta_3$) and the perceived inflation target ($\pi^* = \delta_0/(1 - \delta_1 - \delta_2 - \delta_3)$).

Before we proceed to examining the results, a couple of caveats. First, the model we are using to capture inflation expectations includes a backward-looking part and an anchored part. This is incomplete, since it does not explicitly include an alternative forward-looking indicator of inflation expectations. One justification for using such a simple model is that in the case of Australia, at least, inflation expectations seem to be quite well explained by an anchor and historical inflation outcomes.[17] Second, the constant term in the above equation (δ_0), and the way it changes over time, could reflect several factors in addition to those outlined above. Mismeasurement of the true output gap, for example, would affect the estimate of the constant: if the true level of the economy's potential output were underestimated, the constant (and the implied estimates of the perceived inflation target) would be biased downward. If the degree of mismeasurement of the output gap were to change over time, this could thus explain variations over time in the estimates of the constant. The existence of other sources of structural change that are not captured in this very simple model could also affect the constant term, as would misspecification more generally. We are thus inclined to interpret any of the results pertaining to the constant term, and hence the estimates of the perceived target rate of inflation, as indicative of the changes that may be taking place, rather than as definitive evidence for them.

We now turn to the estimation results. Equation 7 is estimated for each country over the period from the first quarter of 1983 to the third quarter of 2000, using quarterly data. The dependent variable is underlying inflation in Australia's case, and either a measure of core inflation or the first difference of the private consumption deflator for each of the other countries.[18] The lag length of the output gap and import price terms were chosen for each country to best fit the data over the full sample period. The full sample estimates of these regressions are presented in table 1.

17. Brischetto and De Brouwer (1999) find that households' inflation expectations are quite well explained by a constant and lagged inflation, although the real interest rate (lagged six months) is also significant.

18. See appendix B for further details.

Table 1. Estimated Price Equations[a]

	Coefficient estimates									
Country	*Constant*	π_{t-1}	π_{t-2}	π^m_{t-i}	gap_{t-j}	Δgap_{t-k}	*Adjusted* R^2	*Standard error*	*LM test (1st to 4th)*	*Chow test*[b]
Australia	0.001 (1.6)	0.41 (3.8)	0.46 (4.6)	0.03 (2.4)	0.05 (2.6)	0.14 (3.2)	0.84	0.003	0.27	0.03
Canada	0.003 (2.9)	0.33 (2.9)	0.30 (2.8)	0.01 (0.3)	0.06 (1.7)	0.21 (2.6)	0.33	0.004	0.51	0.02
New Zealand	0.001 (1.1)	0.42 (3.4)	0.40 (3.3)	0.06 (2.2)	0.08 (1.4)	0.30 (3.3)	0.64	0.007	0.21	0.001
United Kingdom	0.004 (3.2)	0.33 (2.9)	0.28 (2.6)	0.04 (2.2)	0.10 (2.9)	0.14 (1.9)	0.52	0.003	0.05	0.003
United States	0.002 (2.4)	0.46 (3.1)	0.25 (2.0)	-0.01 (-0.6)	0.03 (1.1)	0.07 (1.0)	0.35	0.003	0.01	0.07

Source: Authors' calculations.

a. Dependent variable is the quarterly log difference of the price level. The estimation period is 1983:1 to 2000:2. The equations were estimated using the following specifications:

Australia: $\pi_t = \delta_0 + \delta_1\pi_{t-1} + \delta_2\pi_{t-2} + \delta_3\pi^m_{t-1} + \delta_4 \text{gap}_{t-2} + \delta_5\Delta\text{gap}_t + \mu_t$

Canada: $\pi_t = \delta_0 + \delta_1\pi_{t-1} + \delta_2\pi_{t-2} + \delta_3\pi^m_{t-1} + \delta_4 \text{gap}_{t-4} + \delta_5\Delta\text{gap}_{t-1} + \mu_t$

New Zealand: $\pi_t = \delta_0 + \delta_1\pi_{t-1} + \delta_2\pi_{t-2} + \delta_3\pi^m_{t-1} + \delta_4 \text{gap}_{t-3} + \delta_5\Delta\text{gap}_{t-1} + \mu_t$

United Kingdom: $\pi_t = \delta_0 + \delta_1\pi_{t-1} + \delta_2\pi_{t-2} + \delta_3\pi^m_{t-3} + \delta_4 \text{gap}_{t-4} + \delta_5\Delta\text{gap}_{t-2} + \mu_t$

United States: $\pi_t = \delta_0 + \delta_1\pi_{t-1} + \delta_2\pi_{t-2} + \delta_3\pi^m_{t-1} + \delta_4 \text{gap}_{t-4} + \delta_5\Delta\text{gap}_{t-1} + \mu_t$

Figures in parentheses are t statistics. Chow and Lagrangian multiplier (LM) test results reported as p values.

b. Chow breakpoint test for structural change at 1992:1.

Over the full sample, this very parsimonious model does quite a good job of capturing the inflation process. In the case of Australia, the equation explains 85 percent of the variation in quarterly inflation, which is very close to the explanatory power of more fully elaborated models of inflation estimated on the Australian data.[19] For Australia, each of the coefficients on the explanatory variables have the expected sign and are significant. They imply that a 10 percent shock to import prices would lead to a 0.6 percent increase in the price level over the following year and a 1 percent increase after two years. A 1 percentage point fall in the output gap for one year would lead to a 0.5 percent fall in inflation over the first year and a 0.3 percent fall over the second year.

For the other countries, these equations also perform quite well, explaining between 35 and 65 percent of the variation in quarterly inflation over the full sample. For the Canadian, New Zealand, and United Kingdom data, the coefficient estimates are generally of the expected sign and significant. In the case of the United States, both the import price term and the output gap term are insignificant. Across all equations, the coefficient estimates are of similar orders of magnitude.

Figures 3 through 7 show rolling regression estimates using the above specifications for each country. In each case, the window is ten years. For example, the first point on each of these graphs illustrates the coefficient estimates from the equations that were estimated using data from March 1983 to December 1992, and the last point illustrates estimates from regressions taken from September 1990 to June 2000. One standard error bands around each estimate are also presented.

For Australia (figure 3), the results point to quite a substantial change in the inflation process over the last two decades. We discuss each of the coefficient estimates in turn. First, we focus on the response of inflation to import price shocks. Panel C shows rolling regression estimates of the coefficient on import prices in these inflation equations. It shows that import prices had a significant effect on inflation in the early part of the sample, but they had no systematic effect on inflation outcomes after around 1987. In other words, once the large depreciation of the exchange rate in the mid-1980s was excluded from the estimation period, inflation was much less sensitive to exchange rate developments. This could reflect a change in the

19. Beechey and others (2000) estimate an error correction model for quarterly changes in the acquisitions consumer price index (CPI); it explains around 90 percent of the variation in quarterly inflation. This model has a richer dynamic structure, and it incorporates unit labor costs and oil prices as well as the explanatory variables included above.

price-setting process of either importers or retailers, or it could reflect a nonlinearity in the effect of exchange rate developments on inflation outcomes. It could also reflect the fact that the depreciation of the mid-1980s as well as being large, was also widely perceived to be permanent, because it coincided with a period in which commodity prices fell sharply and the current account deficit increased markedly. The depreciation was thus widely interpreted as being necessary to help the Australian economy adjust to these developments. In most other episodes, in contrast, it has been much less clear whether exchange rate changes were likely to be permanent or temporary.

The models we are estimating are designed primarily to capture the short-run dynamics of the inflation process. It would thus be unwise to use them to draw conclusions about changes in the extent of exchange rate pass-through over a long horizon. It is possible, for example, that the long-run relationship between imported prices and consumer prices has changed little, but pass-through has become more protracted. In an inflation-targeting framework, however, this change still implies that a given shock to the exchange rate would require less of a policy adjustment.

The lack of response of inflation to exchange rate developments is also evident in the New Zealand data (see panel C of figure 4, especially in the later years of the sample). In the United Kingdom (panel C of figure 5) and Canada (panel C of figure 6), these coefficient estimates have stayed roughly stable over the sample period. Thus while the recent experience in Australia and New Zealand would suggest that inflation has become less sensitive to exchange rate movements, this has not occurred in other open, inflation-targeting countries, all of which have recorded low inflation outcomes in recent periods.

The coefficient on the output gap in the Australian equation varied over the sample period (panel D of figure 3), and it was both higher and statistically more significant in the second half of the sample. On the other hand, the coefficient on the change in the output gap (panel E of figure 3) (that is, the indication that there are speed limits on growth) drifted down over the period and was insignificant in regressions starting from around 1987. The latter trend is consistent with the increasing flexibility of both product and labor markets in Australia.

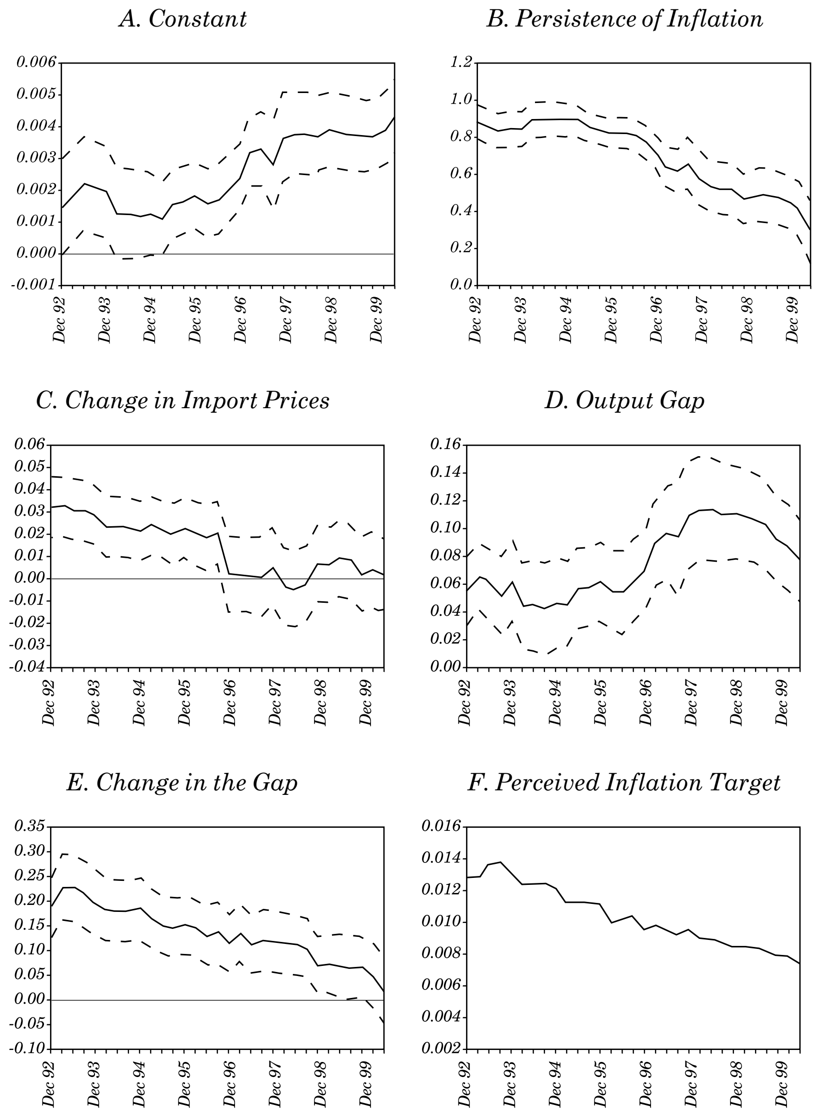
For the other countries, estimates of the coefficient on the change in the output gap also varied quite a lot over the sample period. In the case of New Zealand, for example, as in Australia, the change in the output gap appears to have been a much more significant explanator of inflation developments earlier in the sample than it has been more recently. The estimated coefficients on the level of the output gap were roughly stable in Canada and the United Kingdom, while for the United States, the coefficient drifted toward zero over the sample period.

We now turn to estimates of the degree of autocorrelation, or persistence, in the inflation process. In the model outlined above, these estimates correspond to estimates of the degree to which inflation expectations can be characterized as being backward looking. For Australia, panel B of figure 3 suggests that the inflation process has become markedly less autocorrelated over the last two decades. These estimates could be interpreted as implying that during the 1980s, inflation expectations were based almost exclusively on past inflation developments, while during the 1990s, close to seventy percent of inflation expectations were tied to a target rate of inflation. This result supports the Kuttner and Posen (1999) hypothesis that the adoption of inflation targeting has increased the capacity of the central bank to manage inflation, by reducing the propagation of inflation shocks. The results could also be interpreted, however, as providing support for Taylor's (2000) hypothesis that the persistence of inflation shocks decreases in a low inflation environment.

The results for the other countries qualifies these conclusions, however (see panel B in figures 4, 5, 6, and 7). Only the Australian and New Zealand data show a clear decline in the persistence of inflation over the period, although in both of these cases the decline was quite sharp. In the United Kingdom and the United States, by contrast, the degree of persistence appeared to increase quite markedly and monotonically from the 1980s to the 1990s, while in Canada it remained roughly unchanged. The results for the United States are counter to those presented in Taylor (2000); these rolling regression estimates suggest that conclusions about persistence are quite sensitive to the time period chosen.

There is no obvious explanation for the diversity of outcomes across countries. All of the countries considered (other than the United States) became inflation targeters in the early 1990s, and all achieved very low inflation outcomes in that decade. In Australia and New Zealand, other structural changes in the economy, in particular the deregulation of the labor market, could be responsible for a large part of the reduction in the degree of persistence in the inflation process. As pointed out by Dwyer and Leong (2000), around 80 percent of wages in Australia were indexed in 1985; by 1990 this proportion had fallen to less than 10 percent. Similar—and even more far-reaching—changes to the industrial relations system occurred in New Zealand. This cannot, however,

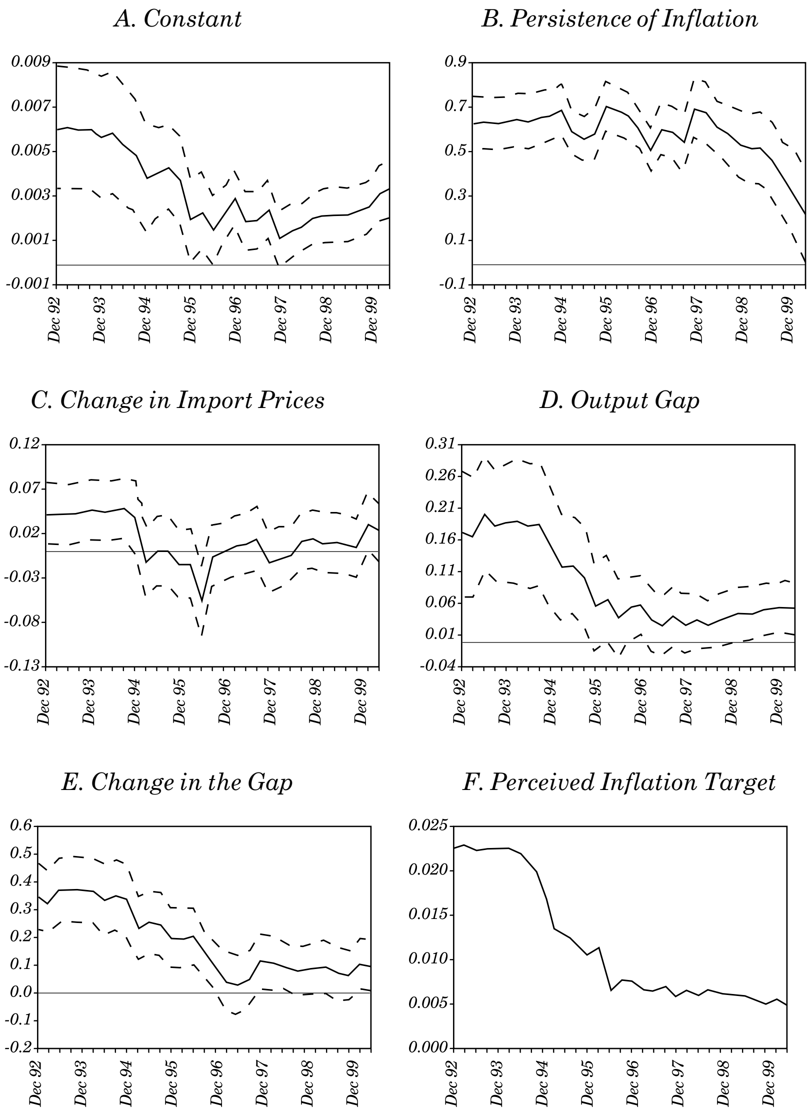
Figure 3. Coefficient Estimates from Ten-Year Rolling Regressions for Australia, 1983:1 to 2000:2[a]



Source: Authors' calculations.

a. Specification as in Table 1. Dashed lines are 1 standard error bands. Persistence of inflation is $(\delta_1 + \delta_2 + \delta_3)$. Perceived inflation target is $\delta_0 / [1 - (\delta_1 + \delta_2 + \delta_3)]$.

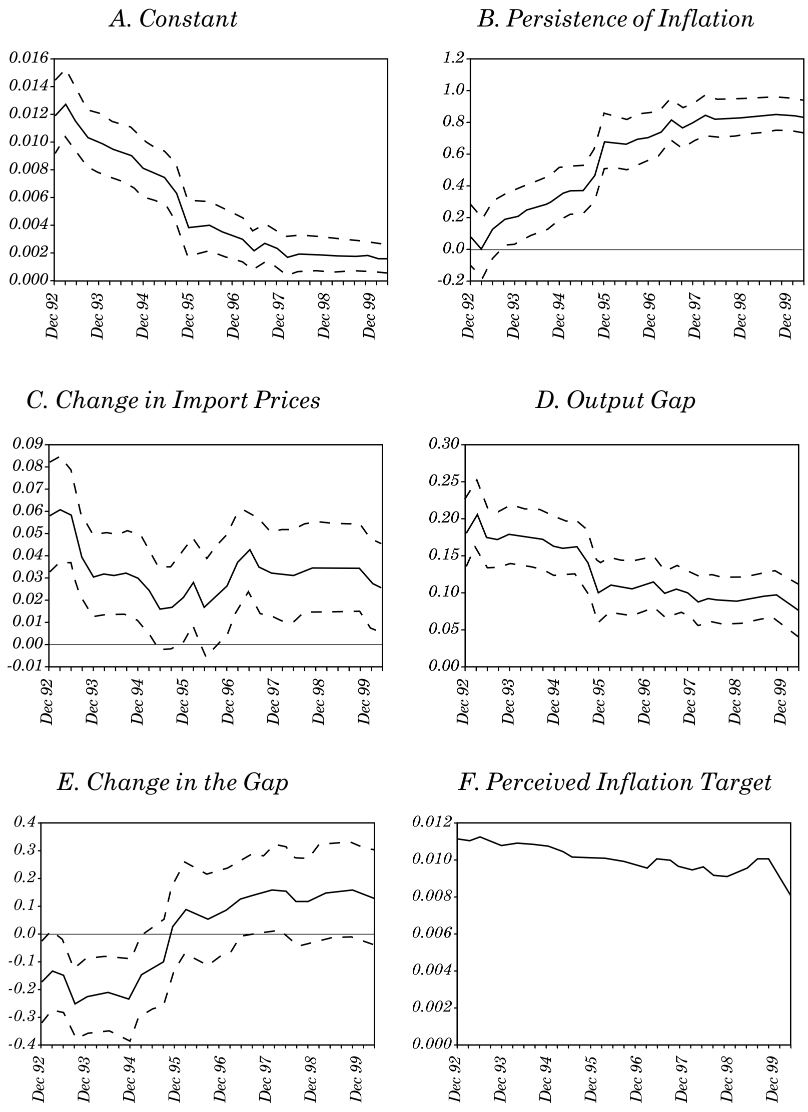
Figure 4. Coefficient Estimates from Ten-Year Rolling Regressions for New Zealand, 1983:1 to 2000:2[a]



Source: Authors' calculations.

a. Specification as in Table 1. Dashed lines are 1 standard error bands. Persistence of inflation is $(\delta_1 + \delta_2 + \delta_3)$. Perceived inflation target is $\delta_0 / [1 - (\delta_1 + \delta_2 + \delta_3)]$.

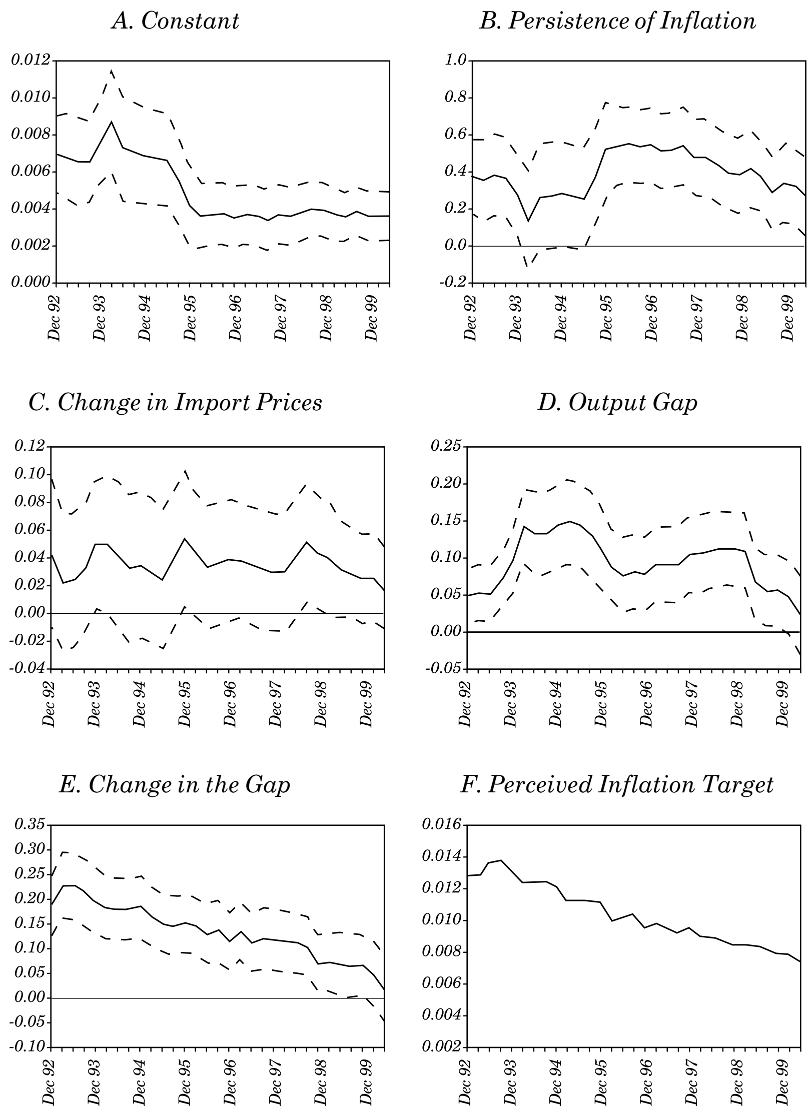
Figure 5. Coefficient Estimates from Ten-Year Rolling Regressions for United Kingdom, 1983:1 to 2000:2[a]



Source: Authors' calculations.

a. Specification as in Table 1. Dashed lines are 1 standard error bands. Persistence of inflation is $(\delta_1 + \delta_2 + \delta_3)$. Perceived inflation target is $\delta_0 / [1 - (\delta_1 + \delta_2 + \delta_3)]$.

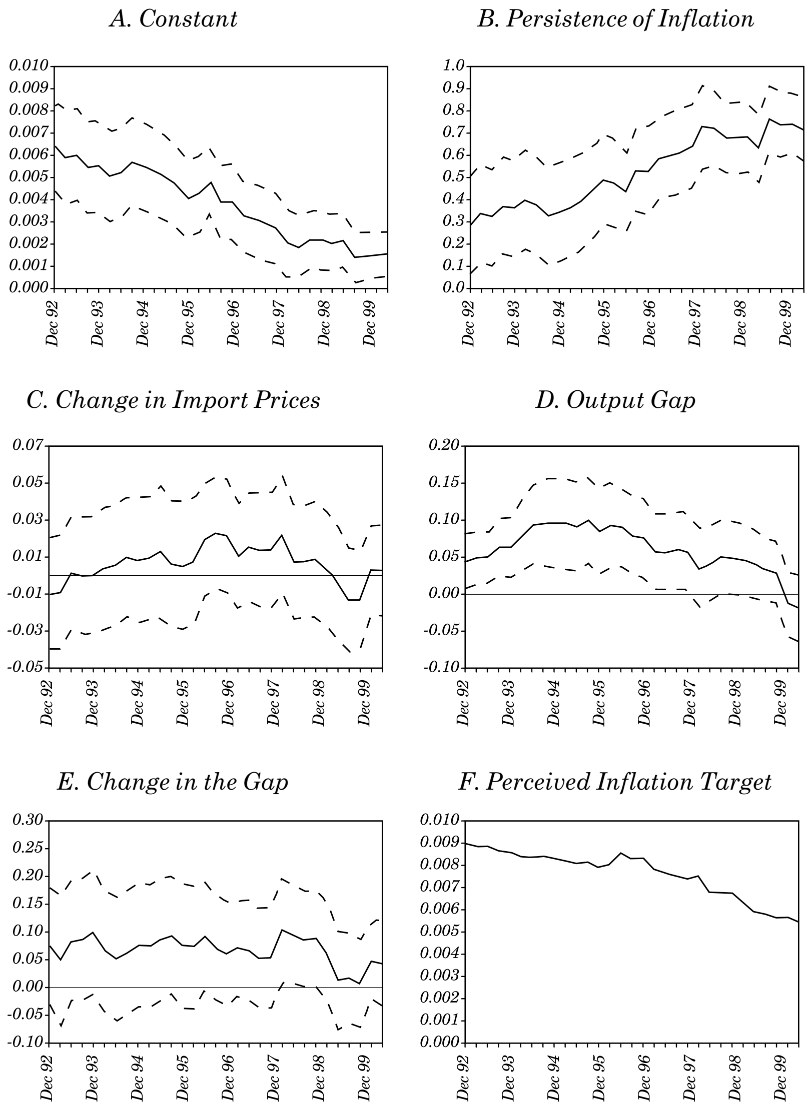
Figure 6. Coefficient Estimates from Ten-Year Rolling Regressions for Canada, 1983:1 to 2000:2[a]



Source: Authors' calculations.

a. Specification as in Table 1. Dashed lines are 1 standard error bands. Persistence of inflation is $(\delta_1 + \delta_2 + \delta_3)$. Perceived inflation target is $\delta_0 / [1 - (\delta_1 + \delta_2 + \delta_3)]$.

Figure 7. Coefficient Estimates from Ten-Year Rolling Regressions for United States, 1983:1 to 2000:2[a]



Source: Authors' calculations.

a. Specification as in Table 1. Dashed lines are 1 standard error bands. Persistence of inflation is $(\delta_1 + \delta_2 + \delta_3)$. Perceived inflation target is $\delta_0 / [1 - (\delta_1 + \delta_2 + \delta_3)]$.

explain why the persistence of inflation was so much lower in Australia and New Zealand during the 1990s than in the United States and the United Kingdom, given the flexibility of the latter countries' product and labor markets. More generally, the wide variation in these estimates over time and across countries suggests that any conclusions drawn from this sort of reduced-form price equation may not be particularly robust.

Overall, the results in this section of the paper suggest that structural changes in the inflation process may well have taken place in each of these countries between the 1980s and the 1990s. Chow tests of structural change, presented in table 1, support this conclusion at a 10 percent level for the United States and at a 5 percent level for each of the other countries.[20] Like Andersen and Wascher (2000), however, we find that the structural changes that have occurred in the inflation processes have differed quite a lot across the countries considered, and it is hard to attribute these changes to any specific global phenomenon. In particular, it seems unlikely that increased credibility can convincingly be argued to have driven the reduction in inflation persistence in Australia and New Zealand given the other countries' results.

4. Conclusion

Whether an open economy should target aggregate or nontraded inflation depends on the objective function of the policymaker, the nature of the shocks to which the economy is exposed, and the structural relationships in the economy. In the end, this is an empirical issue. The results in this paper suggest that for the Australian economy, the choice of inflation target does not generally make much difference to the extent of inflation or output variability. In part, this stems from

20. Table 1 reports tests for a structural break at March 1992, but the results were not particularly sensitive to the break point. For simplicity, a common break point was chosen across countries at a time that coincided roughly with the beginning of the low inflation episode for most of these countries. These results contrast those presented in Andersen and Wascher (2000), although the aim of that paper is to test whether the inflation process in the whole of the 1990s (including the disinflationary period at the beginning of the decade) was significantly different from the behavior of inflation in the previous three decades. Beechey and others (2000) similarly do not find statistically significant evidence of a structural break in the inflation process in the error correction model they estimate. That equation, however, includes unit labor costs as an explanatory variable, whereas the equation estimated above is a reduced-form price equation. Our tests for structural change are thus implicitly tests for structural change in either the price- or wage-setting process

the fact that the estimated pass-through of exchange rate changes to aggregate inflation is found to be protracted.

Changes in the structure of the economy, and particularly the inflation process, however, will affect this conclusion. This paper has shown that the inflation process has undergone significant changes over the past two decades. In Australia's case, the effect of exchange rate changes on inflation has become noticeably more moderate. The inflation process overall also appears to have become considerably better anchored. Both of these developments provide further support for the above conclusion and imply that the Australian economy has become more resilient to temporary price-level shocks.

Evidence from other countries, however, suggests a need for caution. The inflation process varies considerably both across countries and over time, in ways that seem difficult to explain. In particular, it is possible that the economy's response to specific shocks may vary from the average responses implied by reduced-form regression analysis, because of changing perceptions about the nature and likely permanence of shocks. Policymakers will always need to be mindful of the fact that such changes can have significant effects on inflation and growth outcomes, and they must therefore exercise judgement and flexibility in assessing the economic outlook.

Appendix A
A Small Macroeconomic Model of Australia

This model is similar in structure to that presented in Beechey and others (2000). The primary difference is that aggregate inflation is not modeled in an error correction framework. The model is estimated and calibrated over the period 1985:1 to 1999:4. All the inflation processes in the model are calibrated to deliver 2.5 percent inflation in steady state, which is the assumed value of the inflation target in the central bank's objective function.

Output gap

$$y_t = \underset{(0.052)}{0.852}\, y_{t-1} + \underset{(0.061)}{0.159}\, y^f_{t-1} - \underset{(0.027)}{0.137}\left(r_{t-6} - 3.5\right) - \underset{(0.008)}{0.025}\left(rer_{t-3} - \underset{(1.83)}{464.701}\right), \tag{8}$$

where y is the domestic output gap, measured using detrended real nonfarm output; y^f is the foreign output gap, measured as deviations of the U.S. gross domestic product (GDP) from trend; r is the real cash rate (the instrument of monetary policy less aggregate inflation); and rer is the real exchange rate.

Aggregate prices

$$\Delta p_t = \underset{(0.112)}{0.246}\Delta p_{t-1} + \underset{(0.102)}{0.399}\Delta p_{t-2} + \underset{(0.108)}{0.223}\Delta p_{t-3} + \underset{(0.049)}{0.084}\Delta ulc_{t-5} + \underset{(0.015)}{0.040}\Delta pm_t + \underset{(0.016)}{0.008}\Delta pm_{t-1}, \tag{9}$$

where p is the level of the consumer price index (CPI), ulc is a measure of unit labor costs, and pm is import prices. The restriction that the coefficients on prices, unit labor costs, and import prices sum to one was imposed.

Unit labor costs

$$\Delta_4 ulc_t = \underset{(0.088)}{0.513}\Delta_4 p_{t-1} + \underset{(0.088)}{0.487}\Delta_4 ulc_{t-1} + \underset{(0.065)}{0.187 y_{t-1}}. \tag{10}$$

The unit labor cost equation is a linear Phillips curve incorporating adaptive expectations. The assumption of adaptive expectations has historically provided the best fit for Australian data. The equation was estimated with the restriction that the coefficients on lagged inflation sum to one.

Import prices

$$\begin{aligned}\Delta pm_t = &-\underset{(0.023)}{0.748}\Delta e_t - \underset{(0.022)}{0.197}\Delta e_{t-1} + \underset{(0.022)}{0.005}\Delta e_{t-2} - \underset{(0.023)}{0.060}\Delta e_{t-3} \\ &+ \underset{(0.117)}{0.430}\Delta wp_t + \underset{(0.117)}{0.570}\Delta wp_{t-1},\end{aligned} \tag{11}$$

where e is the nominal exchange rate and wp represents world export prices. We assume unitary pass-through of movements in the exchange rate and world prices.

Real exchange rate

$$\begin{aligned}\Delta rer_t = &-\underset{(0.108)}{0.331}\left(rer_{t-1} - \underset{(1.83)}{464.701}\right) + \underset{(0.102)}{0.423}\left(tot_{t-1} - \underset{(1.05)}{463.516}\right) \\ &+ \underset{(0.233)}{0.589}\left(r_{t-1} - r^f_{t-1} - 1.5\right) + \underset{(0.162)}{1.382}\Delta tot_t - \underset{(0.082)}{0.228}\Delta rer_{t-1} \\ &- \underset{(0.082)}{0.088}\Delta rer_{t-2} - \underset{(0.081)}{0.228}\Delta rer_{t-3},\end{aligned} \tag{12}$$

where rer is the real exchange rate, measured using the real trade weighted index, tot is the terms of trade, and r^f is the Group of Three (G3) real interest rate.

Nominal exchange rate

$$\Delta ner = \Delta rer + \Delta p^f_{t-1} - \Delta p_{t-1}, \tag{13}$$

where p^f is the foreign price level, measured using Group of Seven (G7) core inflation.

Foreign output gap

$$y^f_t = \underset{(0.047)}{1.104}\, y^f_{t-1} - \underset{(0.120)}{0.405}\left(r^f_{t-1} - 2.0\right). \tag{14}$$

Terms of trade

$$\begin{aligned}\Delta tot_t = &-\underset{(0.047)}{0.193}\left(tot_{t-1} - \underset{(1.05)}{463.516}\right) + \underset{(0.100)}{0.217}\Delta tot_{t-1} + \underset{(0.103)}{0.215}\Delta tot_{t-2} \\ &+ \underset{(0.106)}{0.173}\Delta tot_{t-3} + \underset{(0.109)}{0.091}\Delta tot_{t-4} + \underset{(0.111)}{0.249}\Delta tot_{t-5}.\end{aligned} \tag{15}$$

World export prices

$$\Delta wp_t = 0.625 + \underset{(0.092)}{0.462}\left(\Delta wp_{t-1} - 0.625\right) - \underset{(0.098)}{0.118}\left(\Delta wp_{t-2} - 0.625\right) + \underset{(0.091)}{0.320}\left(\Delta wp_{t-3} - 0.625\right). \quad (16)$$

Group of Seven (G7) core inflation

$$\Delta p_t^f = 0.625 + \underset{(0.107)}{0.344}\left(\Delta p_{t-1}^f - 0.625\right) + \underset{(0.106)}{0.332}\left(\Delta p_{t-2}^f - 0.625\right) + \underset{(0.113)}{0.327}\left(\Delta p_{t-3}^f - 0.625\right) - \underset{(0.110)}{0.103}\left(\Delta p_{t-4}^f - 0.625\right) + \underset{(0.113)}{0.327}\,\Delta y_{t-4}^f. \quad (17)$$

Group of Three (G3) real interest rate

The following reaction function was assumed:

$$r_t^f = 2 + 0.3 y_{t-2}^f + 0.1\left(\Delta p_{t-2}^f - 0.625\right), \quad (18)$$

where the equilibrium real interest rate is 2 percent and the equilibrium world inflation rate is 2.5 percent.

Appendix B
Data Sources

Australia

Inflation. Defined as the median inflation index, excluding mortgage interest charges and consumer credit charges. Source: Calculated by the Reserve Bank of Australia, based on data in *Consumer Price Index*, ABS Catalog No. 6401.0.

Output Gap. Defined as the adjusted deviation of nonfarm GDP from HP filtered series ($\lambda = 1600$) Source: Beechey and others (2000).

Import Prices. Defined as the implicit price deflator for imports, excluding fuels and lubricants, civil aircraft, and Reserve Bank of Australia gold imports. Tariff adjusted. Source: Australian Customs Service, *National Income, Expenditure and Product*, ABS Catalog No. 5206.0.

Canada

Inflation. Defined as the chain-linked price index of personal consumption expenditures, seasonally adjusted and adjusted for the introduction of the goods and services tax (GST) in the first quarter of 1991. Source: Statistics Canada, Datastream code CN15614.

Output Gap. Defined as the deviation of GDP from HP filtered series ($\lambda = 1600$), mean-adjusted assuming a sacrifice ratio of 3 percent. Source: Statistics Canada, Datastream code CNGDP…D.

Import Prices. Defined as the import price index, seasonally adjusted. Source: Statistics Canada, Datastream code CNB1226.

New Zealand

Inflation. Defined as the implicit price deflator for private final consumption, adjusted for indirect tax changes in the fourth quarter of 1986 and the third quarter of 1989. Source: New Zealand Department of Statistics, Datastream codes NZCONEXPA and NZCONEXPC.

Output Gap. Defined as the deviation of GDP from HP filtered series ($\lambda = 1600$), mean-adjusted assuming a sacrifice ratio of 3 percent. Source: New Zealand Department of Statistics, Datastream code NZGD….D.

Import Prices. Defined as the import price index. Source: New Zealand Department of Statistics, Datastream code NZIMPPRCF.

United Kingdom

Inflation. Defined as the retail price index, excluding mortgage interest (RPI-X), seasonally adjusted and adjusted for the change in the value-added tax (VAT) in the second quarter of 1991. Source: United Kingdom Office for National Statistics, Datastream code UKRPAXMIF.

Output Gap. Defined as the deviation of GDP from HP filtered series ($\lambda = 1600$), mean-adjusted assuming a sacrifice ratio of 3 percent. Source: United Kingdom Office for National Statistics, Datastream code UKABMI.

Import Prices. Defined as the import price index. Source: United Kingdom Office for National Statistics, Datastream code UKBQKS.

United States

Inflation. Defined as the index of personal consumption expenditures, seasonally adjusted. Source: United States Bureau of Economic Analysis, Datastream code USCE..CE.

Output Gap. Defined as the deviation of GDP from HP filtered series ($\lambda = 1600$), mean-adjusted assuming a sacrifice ratio of 3 percent. Source: United States Bureau of Economic Analysis, Datastream code USGDP…D.

Import Prices. Defined as the chain-type price index for imports, seasonally adjusted. Source: United States Bureau of Economic Analysis, Datastream code USIMN..CE.

References

Andersen, P., and W. Wascher. 2000. "Understanding the Recent Behaviour of Inflation: An Empirical Study of Wage and Price Developments in Eight Countries." Paper prepared for the conference on Empirical Studies of Structural Changes and Inflation. Bank for International Settlements (BIS), Basel, 31 October 2000.

Ball, L. 1998. "Policy Rules for Open Economies." Research Discussion Paper 9806. Sydney: Reserve Bank of Australia.

————. 2000. "Policy Rules and External Shocks." Working Paper 7910. Cambridge, Mass.: National Bureau of Economic Research.

Bharucha, N., and C. Kent. 1998. "Inflation Targeting in a Small Open Economy." Research Discussion Paper 9807. Sydney: Reserve Bank of Australia.

Beechey, M., and others. 2000. "A Small Model of the Australian Macroeconomy." Research Discussion Paper 2000-05. Sydney: Reserve Bank of Australia.

Brischetto, A., and G. de Brouwer. 1999. "Households' Inflation Expectations." Research Discussion Paper 1999-03. Sydney: Reserve Bank of Australia.

Cunningham, A., and A. Haldane. 2002. "The Monetary Transmission Mechanism in the United Kingdom: Pass-through and Policy Rules." In *Monetary Policy: Rules and Transmission Mechanisms*, edited by N. Loayza and K. Schmidt-Hebbel. Santiago: Central Bank of Chile.

Dwyer, J., C. Kent, and A. Pease. 1994. "Exchange Rate Pass-through: Testing the Small Country Assumption for Australia." *Economic Record* 70 (December): 408–23.

Dwyer, J., and K. Leong. 2000. "Changes in the Determinants of Inflation in Australia." Paper prepared for the conference on Empirical Studies of Structural Changes and Inflation. Bank for International Settlements (BIS) , Basel, 31 October 2000.

Gruen, D., and S. Shrestha, eds. 2000. *The Australian Economy in the 1990s: Conference Proceedings*. Sydney: Reserve Bank of Australia.

Kuttner, K., and A. Posen. 1999. "Does Talk Matter after All? Inflation Targeting and Central Bank Behavior." Staff Report 88. Federal Reserve Bank of New York.

Lowe, P., and L. Ellis. 1997. "The Smoothing of Official Interest Rates." In *Monetary Policy and Inflation Targeting*, edited by P. Lowe, 286–312. Sydney: Reserve Bank of Australia.

McCarthy, J. 1999. "Pass-through of Exchange Rates and Import Prices to Domestic Inflation in Some Industrialized Countries." Working Paper 79. Basel: Bank for International Settlements (BIS).

Pitchford, John. 1993. "The Exchange Rate and Macroeconomic Policy in Australia." In *The Exchange Rate, International Trade and the Balance of Payments*, edited by A. Blundell-Wignall. Sydney: Reserve Bank of Australia.

Ryan, Christopher, and Christopher Thompson. 2000. "Inflation Targeting and Exchange Rate Fluctuations in Australia." Research Discussion Paper 2000-06. Sydney: Reserve Bank of Australia.

Svensson, Lars. 1998. "Open Economy Inflation Targeting." Working Paper 6545. Cambridge, Mass.: National Bureau of Economic Research.

Taylor, John B. 2000. "Low Inflation, Pass-through, and the Pricing Power of Firms." *European Economic Review* 44(7): 1389–408.