Fiscal Deficits, Debt, and Monetary Policy in a Liquidity Trap

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The dramatic policy response to the 2008–09 global economic crisis from many countries has revived some old debates about the use of fiscal and monetary policy in fighting recessions. The central dilemma for policy-makers in Japan, North America, and Europe has been to try to counter a large recession brought on by an unprecedented fall in private consumption and investment spending, despite being constrained by their inability to lower nominal interest rates below their current near-zero level. The end result was an ad hoc series of fiscal and monetary measures: deficit-financed government spending increases, tax cuts, and unconventional monetary policy measures such as open market purchases on long-dated securities, direct increases in the monetary base, and so on. Coming under the catch-all term of "stimulus-packages," the design of these policies was not based on theoretical frameworks or quantitative macroeconomic models of the kind explored within central banks over the past decade, but rather arose from "back-of-the-envelope" style arguments about the size of fiscal multipliers and the impact of liquidity injections on credit flows.

At the same time, economists have vigorously debated whether fiscal and monetary stimulus are useful at all.[1] One fact that has perhaps been less well recognized is that the central dilemma

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1. See, for instance, Krugman (2009) and the response by Cochrane (2009).

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regarding economic policy options in a liquidity trap has been extensively studied within the recent vintage of New Keynesian dynamic stochastic general equilibrium (DSGE) models, in light of Japan's experience in the 1990s. Krugman (1998), Eggertsson and Woodford (2003, 2004), Jung, Teranishi, and Watanabe (2005), Auerbach and Obstfeld (2005), and many other writers explored how to usefully employ monetary and fiscal policy, even when authorities have no further room to reduce short-term nominal interest rates. Recently, a number of authors have revived this literature, given very similar problems now affecting the economies of Western Europe and North America. Papers by Christiano, Eichenbaum, and Rebelo (2009), Eggertsson (2009), and Cogan and others (2010) have explored the possibility of expanding government spending, applying tax cuts, and using monetary policy when the economy is in a liquidity trap.

A key aspect fiscal and monetary policy effects in a liquidity trap that seems to have remained relatively unexplored to date is the role that government deficits and debt issue play, as part of a stimulus package. On the one hand, there has been overwhelming agreement among policy practitioners that to be useful, fiscal stimulus must be financed with debt, rather than compensating tax increases, and also that part of the stimulus could be based on tax cuts rather than spending increases. But in most of the existing classes of New Keynesian DSGE models that examine fiscal and monetary policies in a liquidity trap, the distinction between tax-financed and debt-financed fiscal stimulus is irrelevant (as are tax cuts that leave the present taxation values unchanged), because these models are characterized by Ricardian equivalence, with infinitely lived consumers and infinite planning horizons.

To offer a serious analysis of the role of fiscal stimulus in a liquidity trap, then, it would seem necessary to depart from the benchmark assumption of the infinitely lived Ramsey consumer. This paper takes a first step in this direction. Following several recent papers (such as Annicchiarico, Giammarioli, and Piergallini, 2009), we amend the basic New Keynesian sticky price model of Woodford (2003) and Clarida, Galí, and Gertler (1999), by incorporating finite planning horizons in the manner of Blanchard (1985) and Yaari (1965). This means that debt-financed government spending has different effects than that financed by tax increases; that government debt itself has wealth effects for currently-alive households; that pure lump-sum tax cuts may be expansionary; and moreover, that monetary policy aimed at increasing the outstanding stock of monetary aggregates may have direct real balance effects, independently of its effect (or non-effect) on nominal interest rates.

We explore the impacts of fiscal and monetary policy in this model, contrasting the results with the recent literature on policy in a liquidity trap. We focus on a scenario where a large increase in households' desire to save pushes down the economy's underlying real interest rate and, in an economy with sticky prices, causes a fall in aggregate demand, output, and inflation.

To briefly summarize central results: we find that in an environment where monetary policy rules work "normally"—adjusting interest rates in response to inflation and output gaps—the introduction of finite planning horizons has little to offer in terms of analyzing the impacts of fiscal policy and monetary policy shocks. When the model is calibrated to introduce empirically realistic planning horizons, there is little quantitative impact of the deviation from Ricardian equivalence. In our benchmark model, for instance, the balanced budget government spending multiplier is unity, and the multiplier implied by purely deficit-financed government spending is only slightly larger.

By contrast, when policy is constrained by a liquidity trap, there may be a dramatic difference between the economy's response with an effectively infinite planning horizon and that with a finite horizon. Likewise, the impact of deficit-financing within fiscal policies may be much greater than tax-financed policies. In our benchmark model, the balanced-budget government spending multiplier is also unity, even in a liquidity trap. But the multiplier for a deficit-financed government spending expansion is over 2. Intuitively, the model predicts that in a liquidity trap, government debt issue has substantial wealth effects, which stimulate aggregate demand and private consumption, playing an expansionary macroeconomic role, beyond the direct effects of government spending.

Another perspective is as follows. In an economy with Ricardian equivalence and no capital, a large increase in the desire to save cannot be satisfied in equilibrium. In a flexible price world, we would simply see a fall in real interest rates. In a liquidity trap, where prices are sticky, the adjustment has to take place through a large fall in current output and consumption (see Christiano, Eichenbaum, and Rebelo, 2009 for an explication of this argument). But in a world with finite horizon consumers, government debt issue in effect provides a vehicle for saving, on the part of the private sector. This satisfies part of the increase in their desire to save, and as a result, limits the degree to which aggregate demand and consumption has to fall. Indeed, our results suggest that during a liquidity trap, this macroeconomic role played by government-issued debt can contribute significantly within a fiscal stimulus package.

We also show that the role of government debt issue is essentially equivalent, in our model, to the real balance effect in monetary expansion. As a corollary then, the model implies that this real balance effect may be negligible in normal times, but plays a non-trivial role during a liquidity trap. Again, however, a key requirement for it to work is that Ricardian equivalence fails.

The paper is organized as follows. The next section briefly discusses the nature of fiscal and monetary policy responses to the recent crisis, followed by a section that develops the basic model used throughout this paper. Section 3 discusses the nature of the steady state in the model. Sections 4 and 5 outline the impact of government spending, tax, and debt shocks in the model when the economy is both outside and within a liquidity trap, both qualitatively and quantitatively.

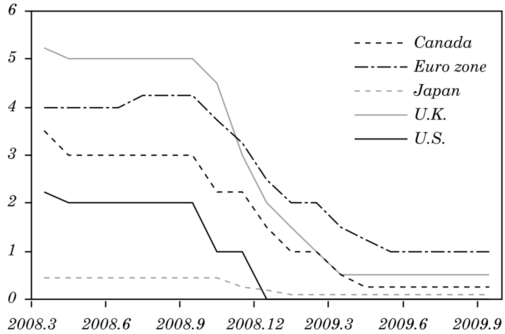
1. Fiscal and Monetary Responses to the Crisis

1.1 The Limits to Monetary Policy

Following the collapse in economic activity across global economies in late 2008, monetary authorities in virtually all countries dramatically reduced interest rates. But by mid-2009, for most central banks, policy rates were close to their minimum feasible levels. Figure 1 describes the path of policy rates from mid-2008 in five major economies. The United States, the United Kingdom, Canada, and the European Central Bank (ECB) all reduced rates in September 2008. By the end of the year, the U.S. Federal Funds rate was near zero. By mid-2009, the other three economies had rates at or below 1 percent. Japan of course, already had a policy rate below 1 percent, but reduced it further in early 2009.

Reaching the limit of monetary policy traction through the interest rate channel, central banks engaged in a range of unconventional monetary policy strategies. The U.S. Federal Reserve for instance, promising to "employ all available tools to promote economic recovery and to preserve price stability," began in late 2008 to widen the range of counterparties it would lend to, and accept a broader range of collateral, based on the assumption that the normal links between interest rates and credit expansion were failing to operate during

Figure 1. Monetary Policy Rates since 2008



Sources: National central banks.

the crisis. Later, the Federal Reserve directly intervened in long-term securities markets, and by mid-2009 had more than doubled the size of its balance sheet (Rudebusch, 2009). Similarly, in March 2009, the Bank of England began a policy of "quantitative easing", involving the purchase of various government and corporate bonds.[2] The ECB has taken a range of similar measures.

There is considerable skepticism about the effectiveness of this unconventional monetary policy, however. Evidence from Japan in the late 1990s provides little support for the idea that increasing available liquidity can stimulate credit flows to consumers and firms and thereby stimulate activity, holding the interest rate constant. Similarly, recent studies in the United States suggest that, to be effective, quantitative easing would have to be much larger than even the recent Federal Reserve balance sheet expansions (Krugman, 2009).

A final channel of monetary policy is communications and the targeting of expectations. Even if interest rates remain at zero for some time, the monetary authority can influence current conditions by announcing its intention to maintain low interest rates even after the recovery is underway. By doing so, the authority influences the private sector's current spending decisions, to the extent that these are based on the projected path of interest rates into the future. Over the past year, this tool has played a key role in central bank communications strategies everywhere.

2. See Céspedes, Chang, and García-Cicco (in this volume) for a discussion of a range of heterodox central bank policies.

1.2 Fiscal Stimulus Policies

Since monetary policy has essentially reached the limit of its effectiveness, virtually all governments, in both advanced and emerging market economies, applied fiscal stimulus packages. Following the G-20 meetings in late 2008, in conjunction with IMF policy recommendations, a rough consensus emerged that fiscal stimulus should equal 2 percent of GDP. There was no direct prescription for distributing this in terms of direct spending and tax cuts, however. Table 1 shows the composition of G-20 economy stimulus packages. Expressed in terms of per capita GDP, after Saudi Arabia, China and the United States provided the largest fiscal stimulus, at 5 and 6 percent of GDP, respectively. But the

Table 1. Stimulus Spending

	2009 stimulus		*Total stimulus*	
Country	*Percent of 2008 GDP*	*Tax cut*	*Percent of 2008 GDP*	*Tax cut*
Argentina	1.3	0	1.3	0
Australia	0.8	47.9	1.8	41.2
Brazil	0.3	100	0.5	100
Canada	1.5	40.4	2.8	45.4
China	2.1	0	4.8	0
France	0.7	6.5	0.7	6.5
Germany	1.5	68	3.4	68
India	0.5	0	0.5	0
Indonesia	1.3	79	2.5	79
Italy	0.2	0	0.3	0
Japan	1.4	30	2.2	30
Mexico	1	0	1	0
Russia	1.7	100	1.7	100
Saudi Arabia	3.3	0	9.4	0
South Africa	1.3	0	2.6	0
South Korea	1.4	17	2.7	17
Spain	1.1	36.7	4.5	36.7
Turkey	0	n.a.	0	n.a.
United Kingdom	1.4	73	1.5	73
United States	1.9	44	5.9	34.8

Source: Prasad and Sorkin (2009).
n.a.: Not available.

composition of these packages varied enormously, with China's stimulus plan having no tax cut component at all, while in the United States about a third of the overall stimulus took the form of tax cuts. Britain's plan consisted mostly of tax cuts, while Russia's and Brazil's contained only tax cuts.

Even without tax cuts, large increases in public sector deficits have financed all stimulus plans. Table 2 illustrates pre-crisis and post-crisis (projected) fiscal balances for G-20 countries. The fiscal positions of many of these advanced economies were already weak in 2007, but over the past year, deficits dramatically increased in most, and are projected to remain well above pre-crisis trends until at least 2014. Emerging economies were generally in a much better fiscal position before the crisis, but most have also seen their fiscal deficits rise significantly.

Table 2. Overall Fiscal Balance as a Percentage of GDP

Country	*2007*	*2009*	*2010*	*2014*
Argentina	−2.1	−3.9	−2.4	−1.7
Australia	1.5	−4.3	−5.3	−1.1
Brazil	−2.8	−3.8	−1.2	−1.0
Canada	1.6	−4.9	−4.1	0.0
China	0.9	−3.9	−3.9	−0.8
France	−2.7	−8.3	−8.6	−5.2
Germany	−0.5	−4.2	−4.2	0.0
India	−1.2	−10.4	−10.0	−0.8
Indonesia	−1.2	−2.6	−2.1	−1.3
Italy	−1.5	−5.6	−5.6	−5.3
Japan	−2.5	−10.5	−10.2	−8.0
Mexico	−1.4	−4.9	−3.7	−3.1
Russia	6.81	−3.6	−3.2	2.2
Saudi Arabia	15.7	5.0	10	14.5
South Africa	1.2	−4.4	−4.7	−2.5
South Korea	3.5	−2.8	−2.7	2.6
Turkey	−2.1	−7.0	−4.3	−4.8
United Kingdom	−2.6	−11.6	−13.2	−6.8
United States	−2.8	−12.5	−10	−6.7

Source: IMF (2009).

While there is significant consensus on the need for fiscal stimulus, the magnitude of this increase in public sector debt, especially among the advanced economies, has raised considerable concerns (IMF, 2009). Table 3 gives the projections for public sector debt for G-20 countries. Higher debt may potentially raise long-term real interest rates, crowding out investment spending and growth, and also potentially raises the prospect of higher inflation rates in the future.

In the analysis below, we only discuss a short-term model, abstracting from the long-run costs of fiscal deficits. The key aim of this paper is to show how deficits may have dramatically different effects in the short run, regardless of whether the economy is in a liquidity trap or not. While we do not dismiss the dangers of increasing public sector debt, at least for the larger economies, these dangers lie more in the future than the present. For now, the path of both long-term interest rates and inflationary expectations in most advanced economies suggest little concern about unsustainable debt levels or high future inflation.

2. The Model of Overlapping Generations

2.1 Demographics and Households

We employ a very standard Blanchard (1985) and Yaari (1965) model of uncertain lifetimes, in an overlapping generation economy. Time is discrete. At any date, a cohort of measure $1 - \gamma$ households is born, where $0 \leq \gamma \leq 1$. An individual household dies with probability $1 - \gamma$ in each period, independent of age, so that γ is the probability of survival from one period to the next. Thus, the total population at any time t is $\Sigma_{s=-\infty}^{t}(1 - \gamma)\gamma^{t-s} = 1$. As in Blanchard's model, we assume a full annuities market, whereby savers get a premium on lending to cover their unintended bequests, and borrowers pay a premium to cover their posthumous debts. Let the utility of a cohort born at date v, evaluated from date 0, be defined as:

$$E_0 \sum_{t=0}^{\infty} (\beta\gamma)^t \left[\log C_{t,v} - v(H_{t,v}) + g(G_t)\right]. \tag{1}$$

Here we define $C_{t,v}$ as the consumption in time t of cohort v, while $H_{t,v}$ is labor supply. Assume that $v'(H_{t,v}) > 0$, $v''(H_{t,v}) \geq 0$. Households supply labor in all periods of life, but real wages decline over an agent's lifetime, as suggested by Blanchard and Fischer (1989). We assume that the composite consumption good represented by $C_{t,v}$ is differentiated across a continuum of individual goods, so that

$$C_{t,v} = \left[\int_{i=0}^{1} C_{t,v}(i)^{1-\frac{1}{\theta}} di \right]^{\frac{1}{1-\frac{1}{\theta}}},$$

where θ is the elasticity of substitution across individual brands. Households also derive utility from aggregate government spending, denoted by G_t. Government spending is taken as given by each household, and utility from government spending is separable from utility of consumption $C_{t,v}$. We assume that $g'(.) > 0$, $g''(.) < 0$.

We focus on a model without capital, to make the comparison with the standard neo-Keynesian DSGE model as clear as possible. Households have only one form of "outside" savings instrument, government bonds. The budget constraint in time t for an agent born in time $v \leq t$ is

$$P_t C_{t,v} + B_{t+1,v} = P_t w_{t,v} H_{t,v} + \Pi_{t,v} - T_{t,v} + \frac{(1+i_t)}{\gamma} B_{t,v}, \tag{2}$$

where $B_{t+1,v}$ represents the nominal bond holdings of cohort v, and $T_{t,v}$ represents their net tax liability to the government.

$$P_t = \left[\int_{i=0}^{1} P_t(i)^{1-\theta} di \right]^{\frac{1}{1-\theta}}$$

is the consumer price index. Real wages in terms of the composite consumption good are denoted $w_{t,v}$, and are cohort specific, as described below. Profits from firms are represented by $\prod_{t,v}$. The presence of full annuity markets implies that rates of return are grossed up to cover the probability of death. To see this, note that in *aggregate*, savers will receive a return of $\gamma \cdot (1+i_t)/\gamma + (1-\gamma)\cdot 0 = (1+i_t)$ on their bond holdings.

Maximizing utility subject to these two constraints gives the conditions:

$$\frac{1}{C_{t,v}} = E_t \frac{\beta\gamma}{C_{t+1,v}} \frac{(1+i_{t+1})P_t}{\gamma P_{t+1}}, \tag{3}$$

$$v'(H_{t,v}) = \frac{w_{t,v}}{C_{t,v}}. \tag{4}$$

Conditions (3)−(4) characterize optimal consumption and labor supply. In addition, the household must choose individual brands to minimize expenditure conditional on a given composite consumption. The familiar condition for the optimal brand choice is given by:

$$C_{t,v}(i) = \left[\frac{P_t(i)}{P(i)}\right]^{-\theta} C_{t,v}.$$

The Euler equation, in conjunction with the household budget constraint, can be represented in the certainty equivalent representation:[3]

$$C_{t,v} = (1-\beta\gamma)\left[\frac{(1+r_t)}{\gamma} b_{t,v} + E_t \sum_{i=0}^{\infty} \alpha_i (w_{t+i,v} H_{t+i,v} + \Pi_{t+i,v} + t_{t+i,v})\right], \tag{5}$$

where $1+r_t = \frac{(1+i_t)P_t}{P_{t+1}}$, $t_{t,v} = \frac{T_{t,v}}{P_t}$, $b_{t,v} = \frac{B_{t,v}}{P_{t-1}}$, and $\alpha_t = \prod_{s=t}(1+r_s)^{-1}\gamma^{s-t}$.

To re-write equation (5) in the form of a dynamic equation in aggregate consumption, it is necessary to be more specific about the way in which wage income evolves over time. Assume that $w_{t,v} = a_{t,v} w_t$ and $a_{t,v} = \overline{a}\phi a_{t-1,v}$ where w_t is the economy-wide average wage, $\overline{a}$ is a constant normalization, and $0 \leq \phi \leq 1$.[4] Thus, relative to the economy-wide average, the wage of each cohort declines over time. This captures, in a crude way, the declining human capital income profile associated with retirement, while still maintaining the ability to aggregate across cohorts, central to the Blanchard-Yaari model. In the description of technology below, we will tie this wage differential to effective labor productivity differences across time. In addition, to

3. This representation ignores complications due to Jensen's inequality, and it is presented simply to give a heuristic account of the aggregation process. The analysis of the model is done by first-order approximation, however, and the solution of the aggregate model is exact at this order. Thus, the error has no consequences for the results below.

4. $\overline{a}$ is chosen so that when the cohort-specific wage is averaged across all currently alive cohorts, it equals the economy wide average wage. This requires that $\overline{a} = \frac{(1-\gamma\phi)}{1-\gamma}$.

allow for easy aggregation to an economy-wide consumption function, we assume that cohort-specific profits and taxes obey the same properties as wage income.

2.2 Aggregation

To represent economy-wide outcomes, we need to aggregate across cohorts. One immediate aggregation difficulty arises from equation (4). Because (i) households have different consumption levels, and (ii) each cohort has a different value for labor productivity in production of final goods, it will not be possible to aggregate equation (4) across generations in general. To proceed, we then make the following specific functional form assumption:

$$v(H_{t,v}) = \eta H_{t,v}. \tag{6}$$

Thus, we assume that the disutility of work is linear in hours worked. In this case, we can aggregate equation (4) directly across all currently alive cohorts. This restricts the analysis somewhat, but provides a simple prediction for the impacts of monetary and fiscal policy shocks when nominal interest rates are positive, and when full Ricardian equivalence holds. The key question we address is how allowing for both of these features (zero-interest rates and non-Ricardian equivalence) to be relaxed together influences policy effects.

The assumption (6) allows us to write the aggregate labor supply condition as:

$$\eta C_t = w_t. \tag{7}$$

The consumption expression (5) may be aggregated across cohorts to give:

$$C_t = (1-\beta\gamma)\left[(1+r_t)B_t + E_t\sum_{i=0}^{\infty}\tilde{\delta}_i(w_{t+i}H_{t+i} + \Pi_{t+i} - t_{t+i})\right], \tag{8}$$

where now $\tilde{\delta}_i = \prod_{s=t}(1+r_s)^{-1}(\gamma\phi)^{s-t}$.

In aggregate, the budget constraint for all households is:

$$B_{t+1} = (1+r_t)B_t + w_tH_t + \Pi_t - t_t - C_t. \tag{9}$$

Note that in the aggregate there is no γ term in the flow budget constraint, since the risk premium only represents a transfer from one generation to another.

Then, manipulating equations (8) and (9), we can write the aggregate Euler equation as:

$$C_{t+1} = \frac{\beta(1+r_{t+1})}{\phi} C_t - \frac{(1-\gamma\phi)(1+r_{t+1})(1-\beta\gamma)b_{t+1}}{\gamma\phi}. \tag{10}$$

In contrast to the standard Ramsey model, in this model, the growth in aggregate consumption depends on both interest rates and aggregate wealth. When $\phi\gamma < 1$ and aggregate wealth is positive, aggregate consumption growth is lower than in the Ramsey model, because the average household is actually less patient. Equivalently, a rise in the value of government debt generates a wealth effect, which reduces desired aggregate savings.

2.3 Firms

Retail goods firms hire labor and capital to produce their individual brands, using the production function:

$$Y_t(i) = A_t H_t(i)^{1-\alpha}, \tag{11}$$

where $H_t(i) = \int_{j=0}^{1} \sum_{s=t}^{-\infty} a_{t,s} H_t(i,s,j)$ is firm i's composite employment. The expression $H_t(i,s,j)$ represents the employment by firm i of household j in cohort s. Each household in a given cohort s has an identical effective labor productivity $a_{t,s}$, captured by the process described above. The idea is that labor of different vintages has different efficiencies, and since $\phi < 1$, labor income per unit of effort tends to decline over time, for each cohort. This is an important feature of the model, since it gives each generation a downward sloping income profile over their planning horizon. In fact, it allows for a greater desire to save on the part of each cohort, and moves the model closer to the standard overlapping generations (OLG) model, with working and retirement phases of life.

We abstract from capital accumulation, but allow for the presence of a fixed factor of production, so that $0 \leq \alpha \leq 1$. Finally, A_t is a productivity term, common to all firms.

Retail firms are monopolistically competitive, and face an elasticity of demand given by $\theta > 1$ in each period. Firms adjust their prices according to the usual Calvo assumption of a constant probability of price change, $1 - \kappa$, however, the previous price changed long ago. When firms adjust their prices, they maximize discounted expected profits, where per-period profits for each firm i are $\prod_t(i) = P_t(i)Y_t(i) - W_tH_t(i)$. Thus, firm i's expected discounted profit is written as:

$$V_t(i) = E_t\sum_{j=0}^{\infty}\delta_{t+j}\kappa^j\left\{P_{t+j}(i)Y_{t+j}(i) - W_{t+j}(i)\left[\frac{Y_{t+j}(i)}{A_{t+j}}\right]^{\frac{1}{1-\alpha}}\right\},$$

where $W_t = w_tP_t$ is the aggregate nominal wage, and the firm's demand function is $Y_t(i) = \left[P_t(i)/P_t\right]^{-\theta}C_t$. The profit maximizing price for firm i, setting its price at time t is then

$$\tilde{P}_t(i) = \frac{E_t\sum_{j=0}^{\infty}\frac{\theta}{(\theta-1)(1-\alpha)}\delta_{t+j}\kappa^jW_{t+j}(i)\left[\frac{Y_{t+j}(i)}{A_{t+j}}\right]^{\frac{1}{1-\alpha}}}{E_t\sum_{j=0}^{\infty}\delta_{t+j}\kappa^jY_{t+j}(i)}. \tag{12}$$

Each newly price setting firm sets the same price. Then, using the law of large numbers, the price index becomes

$$P_t = [(1-\kappa)\tilde{P}_t^{1-\theta} + \kappa P_{t-1}^{1-\theta}]^{\frac{1}{1-\theta}}.$$

2.4 Fiscal Authority

The fiscal authority has expenditure commitments arising from net transfers to households and direct government spending. For now, we do not separately consider nominal money balances in the model, so there is no direct measure of seigniorage revenues. Thus, the fiscal authority obtains revenue simply from net tax receipts T_t and nominal debt issue. The government budget constraint is given by:

$$P_tG_t - T_t = B_{t+1} - (1 + i_t)B_t. \tag{13}$$

We allow for a number of possible configurations of fiscal policy rules. One such rule is to take the path of government spending as exogenously given to the fiscal authority, and adjust the net transfer to achieve a given target for the debt-to-GDP ratio. Alternatively, net transfers could be adjusted to balance the government's budget in every period, maintaining a constant path of (real or nominal) government debt.

2.5 Monetary Policy

Assume that the monetary authority follows an interest rate rule, given by:

$$i_t^R = (1+\rho_t)(1+\hat{\pi})\left(\frac{P_t}{P_{t-1}}\frac{1}{1+\hat{\pi}}\right)^{\sigma_\pi}\left(\frac{Y_t}{\hat{Y}}\right)^{\sigma_y} - 1, \tag{14}$$

where ρ_t represents a desired path for the equilibrium real interest rate, $\hat{\pi}$ represents a desired path for the inflation rate, and $\hat{Y}$ is the target level of aggregate output. We assume that $\sigma_\pi > 1$ and $\sigma_y > 0$. This rule is somewhat unrealistic in that we do not allow for interest rate "smoothing". This is not critical to results, however.

The monetary authority can follow the rule (14) only when $i_t^R > 0$, however. If the rule stipulates a negative nominal interest rate, then the central bank is constrained by the zero lower bound on nominal interest rates. Thus, the path of nominal interest rates in the model must be governed by:

$$i_t = \max(i_t^R, 0). \tag{15}$$

2.6 Equilibrium Conditions

Now, combining equations (9), (11), and (13) the aggregate resource constraint for the final composite good is:

$$A_t H_t^{1-\alpha} = Y_t = G_t + C_t. \tag{16}$$

The zero lower bound condition (15) is usually thought of as a constraint on the short-run behavior of monetary policy. But this is not necessarily the case. For instance, if the monetary authority has a low enough long-term inflation target, this could force the long-run real interest rate down to the level where the zero bound is a binding constraint. Although this has no long-term consequences for output's path, it does place a condition on the required path of real government debt. We explore this issue briefly in the next section.

3. Long-Run Flexible Price Equilibrium

In a flexible price equilibrium, equations (7) and (12) give the solution for equilibrium aggregate output:

$$\frac{\theta\eta}{\theta-1}(Y-G)=(1-\alpha)A^{\frac{1}{(1-\alpha)}}Y^{\frac{-\alpha}{(1-\alpha)}}. \tag{17}$$

From equation (17), the long-run government spending multiplier is given by

$$\frac{dY}{dG}=\frac{1-\alpha}{1-\alpha+(1-g_y)\alpha}, \tag{18}$$

where $g_y \equiv G/Y < 1$. The multiplier is increasing in the steady state ratio of government spending to GDP, but it must be no greater than unity.

Define $b_y = b/Y$ as the long-run government debt-to-GDP ratio. For a given value of g_y, the long-run real interest rate is determined by the steady state version of (10):

$$\left[\frac{\beta(1+r)}{\phi}-1\right]=\Phi(1+r)b_y, \tag{19}$$

where $\Phi \equiv [(1-\gamma\phi)(1-\beta\gamma)]/\gamma\phi(1-g_y)$. The real interest rate is increasing in the steady state government debt-to-GDP ratio. In this model, without capital, government debt does not crowd out real investment, and has no effect on steady state aggregate output or consumption. But a higher b_y increases real interest rates, and tilts the profile of each generation's consumption toward the future.

The steady state nominal interest rate is obtained from equation (14), taking the desired real interest rate ρ as constant.

$$(1 + i) = (1 + r)(1 + \pi), \quad i > 0, \tag{20}$$

$$(1 + \pi) = (1 + r)^{-1}, \qquad i = 0. \tag{21}$$

For a given target real interest rate, inflation, and output, there may be more than one inflation rate satisfying these conditions, where i is defined by equation (15). For instance, one equilibrium is given by $\pi = \hat{\pi}$, $Y = \hat{Y}$ and $i = \rho$. But another equilibrium is given by:

$$i = 0, \;\; \pi = \left[(1+\rho)(1+\hat{\pi})^{1-\sigma_\pi}\right]^{-\frac{1}{\sigma_\pi}} - 1.$$

Benhabib, Schmitt-Grohé, and Uribe (2002) were the first to demonstrate that Taylor rules will generally be associated with multiple equilibrium rates of inflation when nominal interest rates are bounded below by zero. Here we focus only on equilibria with positive inflation rates, where the steady state inflation rate is equal to the target rate $\hat{\pi}$.[5] In this economy, there is only one such equilibrium consistent with equations (19) and (15). Thus, we may re-write equation (20) as

$$(1 + i) = (1 + r)(1 + \hat{\pi}), \quad i > 0, \tag{22}$$

$$(1 + \hat{\pi}) = (1 + r)^{-1}, \qquad i = 0. \tag{23}$$

The two conditions (19) and (22) have separate interpretations, depending upon whether the nominal interest rate is positive or at the zero lower bound. When $i > 0$, the conditions determine i and r separately, for given $\hat{\pi}$ and b_y. The steady state monetary rule (14) determines $\hat{\pi}$, while b_y is determined by steady state fiscal policy, consistent with equation (13), in conjunction with an appropriate transversality condition. Thus, monetary and fiscal policy can be thought of as independent, in a steady state with $i > 0$. Moreover, there is a recursive structure, such that the fiscal stance, summarized by the value of b_y, determines r, while the inflation target determines i.

5. This requires that the authority have a steady-state target real interest rate equal to the real interest rate implied by equation (19), and a steady-state target for output equal to that implied by equation (17).

But equations (19) and (22) may also be associated with an equilibrium where $i = 0$, and the nominal interest rate is at the zero lower bound. From equation (22), this can occur only if $r < 0$—that is, if the economy is dynamically inefficient. From equation (19), dynamic inefficiency can occur, even when $b_y > 0$ and $\phi < 1$. If each cohort has a declining wage profile over time, the economy may be dynamically inefficient, even if government debt-to-GDP is positive.

The behavior of the steady state under the zero lower bound is fundamentally different from that occurring when $i > 0$. Putting equations (19) and (22) together when $i = 0$, we obtain the single relationship:

$$\pi^T = \frac{\beta}{\phi} - \Phi \frac{b_y}{1 - g_y} - 1. \tag{24}$$

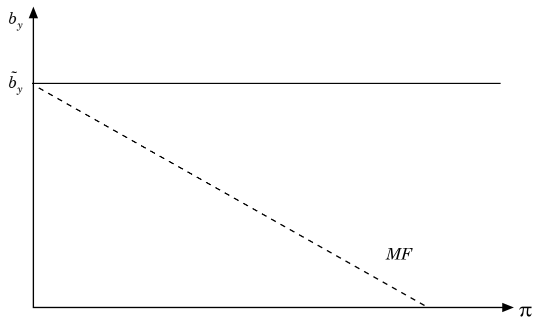
Condition (24) defines the sense in which monetary and fiscal policy are interdependent in an economy at the zero lower bound.[6] If the government debt-to-GDP ratio is such that the equilibrium real interest rate is negative, then the target rate of inflation must be uniquely determined. Conversely, if the target rate of inflation is taken as given, then the debt-to-GDP ratio must be adjusted to achieve the equilibrium real interest implied by this target. Moreover, at the zero lower bound on the nominal interest rate, the steady state is no longer recursive. A higher value of π^T implies a lower (more negative) real interest rate, and must be accompanied by a fall in b_y, holding g_y and all the other variables constant.

Figure 2 illustrates the trade-off implied by condition (24). In the figure, $\tilde{b}_y$ represents the value of the debt ratio for which $r = 0$, implied by (19). For $b_y < \tilde{b}_y$, the real interest rate is negative. Whether the economy is stuck at the zero lower bound depends on the inflation target. The schedule MF illustrates condition (24). For a given $b_y < \tilde{b}_y$, the lower the inflation target, the more likely the economy will be at the zero lower bound. MF describes the required values of b_y for each value of the inflation target, when the economy is stuck at the zero lower bound. Thus, in a steady state, there must be a negative relationship between government debt and the inflation rate, when

6. Leeper (in this volume) provides an alternative view of the interaction between monetary and fiscal policy, even when nominal interest rates are positive, based on the interdependence implied by the public sector budget constraint.

the economy is at the zero lower bound.[7] Intuitively, the condition says that, in the long run, if monetary authorities are committed to low inflation targets, then low real interest rate episodes are likely to push them to the zero bound. If they remain committed by a low inflation target at the zero bound, then this really means that they are preventing the real interest rate from falling any further. This can only be done through giving up control of the outstanding stock of government debt. Equivalently, if the fiscal authority insists on reducing the stock of real debt in an environment where the real interest rate is pushed below zero, then the monetary authorities must accommodate this with a higher rate of inflation. In either case, with a permanent zero nominal interest rate, there must be a negative relationship between government debt and inflation.

Figure 2. The Trade-off Implied by Equation (24)



Sources: Author's drawing.

4. Monetary and Fiscal Policy in the Short Run under a Zero Lower Bound

We now analyze the model in the short run, when prices adjust as per equation (12). Like Christiano, Eichenbaum, and Rebelo (2009),

7. Beaudry, Devereux, and Siu (2009) examine this restriction in a more complete dynamic growth model. Condition (24) abstracts from the possibility of bubble equilibria. When the real interest rate is negative, it is possible that other non-fundamental assets may be valued in equilibrium, so that total wealth would include both the value of government debt and the bubble asset.

Eggertsson and Woodford (2003, 2004), and Eggertsson (2009), we wish to explore the usefulness of monetary and fiscal policy in responding to an environment where the economy has been pushed to a zero lower bound; that is, where the nominal interest rate is stuck at zero for some time. Initially, we will just compare the differential effects of policy in the two environments: the first, when the nominal interest rate operates according to a standard Taylor rule, and the second, when the nominal interest rate is zero. This gives us the basic contrasting results of this section. We later provide a quantitative comparison of the usefulness of monetary and fiscal policy alternatives in response to the zero lower bound constraint.

Under what circumstances should the policymaker face a zero interest rate constraint? As in the previous literature, we may think of this situation as generated by a large increase in the representative agents' discount factor, raising desired savings and pushing down the flexible price equilibrium real interest rate. If the policymaker follows a Taylor rule, as in equation (14), then the nominal interest rate may be pushed down to its lower bound. The increase in desired savings leads to a fall in aggregate demand and a fall in the output gap. In normal times, the optimal response to this shock would be to reduce nominal interest rates to facilitate the required real interest rate adjustment. But when nominal interest rates are zero, they cannot be reduced further. How should policy respond? Two main answers have been offered in the literature. Krugman (1998), Jung, Teranishi, and Watanabe (2005), and Eggertsson and Woodford (2003) discuss a range of alternative monetary policy rules that may be applied, despite the fact that the interest rate remains at or near zero for some time. The common feature of these proposals is that the policymaker should make an announcement about the conduct of monetary policy once the economy has left the zero bound region. If the authority announces that policy will remain loose even after the zero bound no longer binds, it does so to lessen the deflationary impact of the current shock. The obvious difficulty with using monetary policy in this way is that the announcement must be credible for it to have any effect on current output and inflation. The policymaker must follow a history-dependent rule, and continue to pursue monetary easing even after the conditions that warrant such easing have faded. Eggertsson and Woodford (2003) discuss a range of targets for monetary authorities that would replicate the optimal history dependent rule, but may be easier to communicate to the public.

The second main response to a zero lower bound trap is the use of fiscal policy. Fiscal policy may directly influence aggregate demand in the traditional Keynesian manner, even when the monetary authority cannot reduce interest rates any further. Fiscal policy options for the zero lower bound trap are discussed by Christiano, Eichenbaum, and Rebelo (2009), Eggertsson (2009), and Cogan and others (2010).

One common characteristic of previous literature analyzing the role of policy at the zero lower bound is that models display Ricardian equivalence. Hence, the financing of government spending expansion has no role to play, and the real balance effects of monetary policy are not operative. In the recent policy discussion, summarized in section 1, however, the need to run government deficits, generated either by tax cuts or bond-financed government spending increases, is seen as paramount to the stimulus package in all countries. The notion that large fiscal expansion occurring in many countries could just as easily be financed with tax increases as with government deficits seems completely at variance with all policy discussion. It is therefore important to be able to analyze the impact of fiscal deficits when interest rates are stuck at the zero lower bound, and to compare this with the case where interest rates are part of regular monetary policy. The advantage of the current model is that we can analyze the role played by tax cuts and spending increases separately, and distinguish between debt-financed and tax-financed fiscal expansion. Moreover, we can analyze separately the real balance effects of monetary policy, which can operate even at zero interest rates.[8]

4.1 Approximating the Model under a Taylor Rule

In the case where nominal interest rates are positive and adjust according to equation (14), we have a standard New Keynesian model, save for the presence of government debt in the Euler equation (10). Using equations (10) and (16), we may approximate equation (10) as follows:

$$\hat{Y}_{t+1} = \hat{Y}_t + \left[(i_{t+1} - E_t \pi_{t+1}) + \hat{\nu}_{t+1}\right] - \Phi \hat{b}_{t+1} - E_t(\hat{G}_{t+1} - \hat{G}_t), \tag{25}$$

8. Ireland (2005) emphasizes the real balance effect of monetary policy, which can operate even when the nominal interest rate is zero. He does so in a purely flexible price model though, similar to the case described in section 2, above.

where $\hat{Y}_t = \log(\frac{Y_t}{\bar{Y}})$, $\hat{G}_t = \frac{G_t - \bar{G}}{\bar{Y}}$, $\hat{\pi}_t = \log(\frac{P_t}{P_{t-1}})$, $\hat{b}_t = \frac{b_t - \bar{b}}{\bar{Y}}$,

and $\Phi \equiv [(1-\beta\phi)(1-\gamma\phi)]/\gamma\phi(1-g_y)$. The linear approximation is taken around an initial debt-to-GDP ratio equal to zero, so that $\bar{b} = 0$.[9] The government spending shock represents a deviation of government spending from the steady state level, relative to GDP. We are assuming that there is an optimal (flexible price equilibrium) level of government spending given by $\bar{G}$, and movements in government spending here represent deviations from the optimum. The variable $\hat{\nu}_t$ represents a temporary shock to the discount factor, where we assume that the discount factor can be represented as $\beta_t = \exp(\nu_t)$ and the steady state value of ν is set at zero, $\bar{\nu}_t = 0$. The departure from full Ricardian equivalence is governed by the composite coefficient Φ, which depends on the steady state discount rate, the probability of survival, and the time path of labor income within each cohort.

The forward-looking inflation equation follows in standard fashion from the first-order approximation of equation (12) and the definition of the price index.

$$\pi_t = \lambda\left(\frac{\hat{Y}_t - \hat{G}_t}{1-g_y} + \frac{\alpha}{1-\alpha}\hat{Y}_t\right) + \beta E_t \pi_{t+1}, \tag{26}$$

where $\lambda = [(1-\kappa\beta)(1-\kappa)(1-\alpha)]/\kappa\left[(1-\alpha)+\alpha\theta\right]$. The term in brackets represents the deviation of real marginal cost from its steady state level, given the assumptions on the disutility of labor for each generation.

The linear approximation of the interest rate rule is written as:

$$i_t^R = \rho + \bar{\pi} + \sigma_\pi(\pi_t - \bar{\pi}) + \sigma_y \hat{Y}_t. \tag{27}$$

In this section, we assume that $i_t^R > 0$, so that the interest rate always follows equation (27).

9. This facilitates the exposition. Allowing for non-zero debt ratios requires the interest rate to be an additional state variable, which makes the algebra more complicated, but does not substantially change the results so long as b_y is not too large.

Finally, we take a linear approximation of the government budget constraint as follows:

$$\hat{b}_{t+1} = (1+r)\hat{b}_t + \hat{G}_t - \hat{T}_t, \tag{28}$$

where $\hat{T}_t = (T_t - \bar{T})/\bar{Y}$. Since we are approximating around an initial steady state with a zero debt-to-GDP ratio, this approximation does not depend on the first-order dynamics of the real interest rate. On its own, however, equation (28) will involve non-stationary dynamics in the government debt ratio. To avoid this, we assume that the fiscal authority chooses a tax rule so that the dynamics of aggregate government debt to GDP are stationary, for given government spending movements. In particular, we assume that net taxes have a discretionary and an automatic component, such that:

$$\hat{T}_t = \hat{T}_{1t} + t\hat{b}_t, \tag{29}$$

where t is constant, and is chosen such that $\omega = 1 + r - t < 1$. This ensures that following a temporary shock to government spending or the discretionary component of taxes which leaves the long-run real primary deficit unchanged, the debt level will return to its steady state.

4.2 Shocks to the Discount Factor

A natural way to think about policy being constrained by the lower bound on interest rates is that an increase in the desire to save drives down the equilibrium flexible price real interest rate. Under an inflation targeting monetary rule, this requires a fall in the nominal interest rate. The variable $\hat{\nu}_t$, representing a shock to the discount factor, increases the ex-ante savings rate of all generations. Assume that $\hat{\nu}_t$ is governed by the process:

$$\hat{\nu}_{t+1} = \mu\hat{\nu}_t + \varepsilon_{t+1},$$

where $E_t(\varepsilon_{t+1}) = 0$. An increase in the discount factor leads to a persistent fall in the equilibrium real interest rate. Using the interest rate rule (27), the impact of the shock can be obtained from the solution to equations (25)−(29). The increase in the discount factor increases the desire to save, reducing aggregate demand, and causing a fall in both output and inflation. The responses of output and inflation are given by:

$$\hat{Y}_t = -\frac{(1-\alpha)(1-\beta\mu)}{\Delta_\mu}\hat{\nu}_{t+1}, \tag{30}$$

$$\hat{\pi}_t = -\frac{z\kappa}{\Delta_\mu}\hat{\nu}_{t+1}, \tag{31}$$

where $z = (1 - \alpha g_y)/(1 - g_y)$, and $\Delta_\mu = (1 - \alpha)(1 - \beta\mu)(1 - \mu + \sigma_y) + \kappa(\sigma_\pi - \mu)z > 0$.

The impact of a discount factor shock is cushioned by interest rates' endogenous response. The higher the interest rate response to inflation and the output gap, the smaller the effect of the shock. In the optimal monetary policy framework presented in Woodford (2003), an optimal monetary response that goes beyond the interest rate rule can fully accommodate a discount factor shock, reducing nominal interest rates by the extent of the shock itself, and fully stabilizing output and inflation. But this requires that authorities have sufficient leeway to reduce the nominal interest rate. For large enough shocks, the zero bound on the interest rate may apply, and some alternative monetary or fiscal policy must be used to respond to the shock. Before we analyze the economy's response under a zero bound, however, we investigate the impact of fiscal policy shocks when the nominal interest rate is positive, and the economy operates under the monetary rule (27).

4.3 Government Spending, Debt, and Tax Shocks under a Taylor Rule

Previous papers have analyzed the effects of government spending shocks in this type of model. The only difference here from the previous literature is the failure of Ricardian equivalence, and the effects of government debt accumulation. To highlight this difference, we first examine the impact of a one-off shock to government debt. It is easy to solve equations (25)−(29) to show that the effect of an increase in b_t on output and inflation is as follows:

$$\hat{Y}_t = \frac{(1-\alpha)(1-\beta\omega)\omega\Phi}{\Delta_\omega}\hat{b}_t, \tag{32}$$

$$\hat{\pi}_t = \frac{z\kappa\omega\Phi}{\Delta_\omega}\hat{b}_t, \tag{33}$$

where $\Delta_\omega = (1-\alpha)(1-\beta\omega)(1-\omega+\sigma_y) + \kappa(\sigma_\pi - \omega)z > 0$. An increase in government debt is perceived as an increase in wealth for currently alive cohorts. This leads to an increase in consumption and a fall in desired saving. Current aggregate demand rises, pushing up inflation. The rise in inflation increases the real interest rate via the interest rate rule, partly offsetting the impact of the higher debt on current output. The greater the response to inflation or the output gap in the interest rate rule, the greater the increase in the real interest rate, and the smaller the impact on output and inflation. Note also that the impact of a debt shock depends on the persistence in government debt generated by the government budget constraint. If the debt-sensitive tax rule is such that an initial debt shock is very transitory (that is, ω very low), the impact on output or inflation is small.

We can now focus on the effects of government spending and taxes. To provide a benchmark comparison with the Ricardian equivalence case, we focus first on a government spending expansion financed by a tax increase, that is, we calculate the balanced budget multiplier.

Assume that both discretionary taxes and government spending increase by the same amount. In both cases, assume that after the initial increase, both discretionary taxes and spending converge back to their steady state levels at the rate μ. Then, from equations (25)–(29), we may compute that:

$$\hat{Y}_t = \frac{(1-\alpha)\left[(1-\mu)(1-\beta\mu) + \kappa(\sigma_\pi - \mu)/(1-g_y)\right]}{\Delta_\mu}\hat{G}_t, \tag{34}$$

$$\hat{\pi}_t = \frac{\alpha\kappa(1-\mu) - (1-\alpha)\sigma_y/(1-g_y)}{\Delta_\mu}\hat{G}_t. \tag{35}$$

The first thing to note about equation (34) is that it is independent of Φ, the coefficient on government debt in the aggregate Euler equation. The balanced budget multiplier is the same as that of the standard Ricardian equivalence model, because the policy has no consequences for government debt. In addition, the multiplier is clearly less than unity. That is:

$$\mathrm{Sign}\left(\frac{\hat{Y}_t}{\hat{G}_t}-1\right) = -\mathrm{Sign}\left[(1-\beta\mu)(1-\alpha)\sigma_y + \alpha\kappa(\sigma_\pi-\mu)\right] < 0.$$

Even though prices are sticky and adjust slowly to changes in aggregate demand, the balanced budget multiplier is actually less than that of the purely flexible price equilibrium multiplier. The key reason is that under the monetary policy rule (27), the real interest rate increases so much in response to a rise in fiscal spending (financed by taxation) that aggregate private consumption falls. Only in the special case of constant returns in production ($\alpha = 0$) and no output gap in the interest rate rule ($\sigma_y = 0$) will the multiplier be exactly unity, that is, equal to that of the flexible price equilibrium.

This suggests that if the nominal interest rate is free to adjust and follows a standard rule (27), government spending is a particularly inefficient way to stimulate the economy. The most that a fiscal expansion can do is to leave aggregate private consumption unchanged, and in general consumption will fall. Equivalently, we can say that government spending expansion increases output, but output actually falls below the level it would attain in a flexible price equilibrium, in the face of the same balanced budget government spending increase.

The impact of a balanced budget government expansion on inflation is given by equation (35). If $\sigma_y = 0$ and $\alpha = 0$, the inflation rate is unchanged, because output responds exactly as in a flexible price equilibrium. With constant returns ($\alpha = 0$) and $\sigma_y > 0$, inflation will *fall*, since output is below the flexible price equilibrium.

We now turn to the analysis of a tax cut in the model with an interest rate rule. A temporary discretionary tax cut will increase the primary government deficit and cause a persistent increase in government debt. How will this affect GDP? From equations (25)–(29) we can establish that:

$$\hat{Y}_t = -\Phi\frac{(1-\alpha)^2(1-\beta\omega)(1-\beta\mu)(1+\sigma_y)-(1-\alpha)\kappa z\left[\beta\omega(\sigma_\pi-\mu)-\sigma_\pi(1-\beta\mu)\right]}{\Delta_\mu\Delta_\omega}\hat{T}_t. \quad (36)$$

Note that with Ricardian equivalence, where $\Phi = 0$, this is negative by definition. For $\Phi > 0$, we would anticipate that the expression on the right hand side of expression (36) is negative (tax increases are contractionary). Interestingly however, this is not necessarily true in this model. Take the case where μ and ω are very close to unity (tax cuts are highly persistent, and the deficit is very slow to fall). Then expression (36) is positive for $\sigma_\pi > 1$, and therefore a cut in taxes will reduce GDP in the economy where the interest rate follows a Taylor rule.

What is the explanation for this? The reason is that, for σ_π greater than unity, and sufficiently large, a tax cut causes a large offsetting increase in interest rates due to its inflationary effects. The impact of a tax cut on current inflation is always positive, and given by:

$$\hat{\pi}_t = -\kappa z \Phi \frac{(1-\alpha)(1+\sigma_y - \beta\omega\mu) + \kappa z \sigma_\pi}{\Delta_\mu \Delta_\omega} \hat{T}_t. \tag{37}$$

A very persistent tax cut signals a persistent increase in future government debt, which causes the forecast of future inflation to rise, increasing current inflation, and pushing current interest rates upward. This secondary effect can be large enough to reduce aggregate demand and lead to a fall in output. Thus, again, we may conclude that during "normal times," when the nominal interest rate follows a conventional rule of the type given by equation (14), tax cuts are unlikely to be an effective stabilization tool.

Note that we have not yet given a quantitative analysis of the effects of tax cuts and government spending policies in this model. In the discussion of the calibrated model below, we show that for both policies, the multiplier effects of government spending and tax cuts (even if the latter are positive) are likely to be quite low.

4.4 Fiscal Policies under a Zero Lower Bound

Now assume that the shock to the discount factor is large enough to push the economy into a liquidity trap: thus, the nominal interest rate is constrained by the zero lower bound.[10] In this case, the economy's dynamics are fundamentally different. The effects of the

10. To ensure that the approximations remain accurate at the zero lower bound, it is necessary to restrict the size of the discount factor shock placing the economy at the bound. See Eggertsson and Woodford (2003).

initial shock and policy measures to counter the shock on inflation and the output gap operate through substantially different channels when the policy interest rate cannot respond.

In section 2 above, we analyzed the properties of a steady state in which the nominal interest rate is at the zero lower bound. By contrast, here we will focus on a situation where the lower bound constraint is temporary, the rise in the discount factor dissipates over time, and the economy's real interest rate returns to its steady state. In a crude way, this captures the impact of an aggregate demand shock coming from an unanticipated temporary rise in the savings rate.[11]

To make the analysis concrete, we follow Eggertsson and Woodford (2003, 2004) and Eggertsson (2009) in assuming that the discount factor shock drives the economy to the zero lower bound for an uncertain number of periods. We assume a one-time shock to the discount factor that continues with probability μ per period. So in each future period, the discount factor reverts to the steady state with probability $1 - \mu$. In the intervening time, the discount factor is at its post-shock level, and is sufficiently high that the policy implied by the original interest rate rule would require a zero interest rate. As in Eggertsson and Woodford (2003, 2004), Eggertsson (2009), and Christiano, Eichenbaum, and Rebelo (2009), we investigate both the impact of the original shock, and the impact of an alternative series of monetary and fiscal policies, when the economy operates at the zero interest rate bound.

Solving the model given by equations (25)–(29) when $i_t^R = 0$, under the assumption that the shock reverts back to steady state with probability $1 - \mu$, we obtain the impact of the discount rate shock on the output gap and inflation as:

$$\hat{Y}_t = -\frac{(1-\alpha)(1-\beta\rho)}{\Delta_\mu^z}\hat{\nu}_{t+1}, \tag{38}$$

11. In the case of a permanent zero lower bound, the conditions for a unique stable path of adjustment of inflation, output, and government debt are not always met. In particular, in the Ricardian equivalence version of this model (when $\Phi = 0$), the conditions for uniqueness in the zero interest rate case are not met for familiar reasons (for example, Clarida and others, 1999). But with $\Phi > 0$ and allowing for a non-zero initial nominal government debt, there is a real balance effect that may be sufficient to restore uniqueness (Ireland, 2005), even if the nominal interest rate is stuck at zero forever. Nevertheless, because we are primarily concerned with the analysis of short-run stabilization policies, we follow the recent literature and analyze the (somewhat more realistic) case of a temporary liquidity trap.

$$\hat{\pi}_t = -\frac{z\kappa}{\Delta_\mu^z}\hat{\nu}_{t+1}. \tag{39}$$

where $\Delta_\mu^z = (1-\alpha)(1-\beta\mu)(1-\mu) - \kappa\mu z$. A condition for stability is that $\Delta_\mu^z > 0$.[12] Note however that $\Delta_\mu - \Delta_\mu^z = (1-\alpha)(1-\beta\mu)\sigma_y + \sigma_\pi\kappa\mu z > 0$. Hence, in comparing equations (30) and (38), a rise in the discount factor will affect both inflation and the output gap more in an economy constrained by the zero lower bound. This is not surprising, and follows as a converse argument to the logic presented above, regarding the response of inflation and the output gap under an interest rate rule. Since the nominal interest rate cannot respond, the fall in demand reduces output, which reduces inflation and—given the shock's persistence—the fall in anticipated inflation pushes up the real interest rate, pushes demand down further, and reduces output even more. So long as $\Delta_\mu^z > 0$, this process converges, but to a much lower level of output than would occur under a positive interest rate rule.

How do monetary and fiscal policies operate when the interest rate is zero? Again, we focus on the importance of debt- and deficit-related policies, given that the failure of Ricardian equivalence is the key in this analysis. To simplify our analysis and make comparison with the previous section easier, we initially make the special assumption that fiscal policies enacted while the economy is constrained by the zero lower bound are completely eliminated when the constraint is no longer binding, and the economy then reverts immediately to its steady state. This involves the assumption that at the period of the return to positive interest rates, taxes are raised to completely eliminate the accumulated government debt resulting from fiscal policy expansions.

Thus, government debt built up over and above its initial steady state (or zero) is wiped out, and debt reverts to zero after the return to positive interest rates. This allows the economy to return to a steady state. This assumption makes the algebraic comparison with the previous section very simple, but it is not a critical feature of the argument. We explore an alternative case below, where the accumulated debt is eliminated gradually after the return to positive nominal interest rates. We can see that all the points made in this section remain valid. In fact, because the cohorts holding

12. See Eggertsson (2009).

the accumulated debt continue to treat it as net wealth after the return to positive interest rates, this alternative path of convergence reinforces the impact of current fiscal policies.

First, we can analyze the impact of an arbitrary rise in government debt, in a manner similar to equations (32) and (33) above.

$$\hat{Y}_t = \frac{(1-\alpha)(1-\beta\omega\mu)\omega\Phi}{\Delta^z_{\omega\mu}}\hat{b}_t, \tag{40}$$

$$\hat{\pi}_t = \frac{z\kappa\omega\Phi}{\Delta^z_{\omega\mu}}\hat{b}_t, \tag{41}$$

where $\Delta^z_{\omega\mu} = (1 - \alpha)(1 - \beta\mu\omega)(1 - \omega\mu) - \kappa\mu\omega z$. Again, for stability, it is necessary that $\Delta^z_{\omega\mu} > 0$.

As in the case of a positive nominal rate, an increase in government debt leads to a rise in the output gap and the inflation rate, so long as Ricardian equivalence fails ($\Phi > 0$). The quantitative impact may be greater or less than equations (32) and (33). On the one hand, the nominal interest rate does not respond here, leading to a larger impact on both inflation and the output gap. However, in this experiment, the interest rate rule reverts back to equation (14) with probability $1 - \mu$. The quantitative analysis below shows that the effects of increasing government debt may be greater or lesser during a liquidity trap than under a positive interest rate rule.

If a rise in the discount factor affects the output gap more negatively in a liquidity trap, it is reasonable to think that compensating fiscal policies could prove more able to stabilize the economy, since in this environment an expansion in government spending or a tax cut does not elicit automatic interest rate responses that limit fiscal instruments. In this vein, Christiano, Eichenbaum, and Rebelo (2009) and Eggertsson (2009) show that government spending policies may have significantly higher multiplier effects in a liquidity trap than during normal times. But again, their analysis was confined to the situation of full Ricardian equivalence, where a balanced budget expansion in government spending is identical to a debt-financed expansion. We now wish to revisit this question, allowing for debt versus tax-financed spending policies to have different effects. As a corollary, we can investigate the effect of tax cuts compared to government spending expansions, as we did above for the case outside the liquidity trap.

Using equations (25)−(29) we can establish that a *balanced budget* increase in government spending has the following impacts on the output gap and inflation:

$$\hat{Y}_t = \frac{(1-\alpha)\left[(1-\mu)(1-\beta\mu) - \mu\kappa/(1-g_y)\right]}{\Delta_\mu^z}\hat{G}_t, \tag{42}$$

$$\hat{\pi}_t = \frac{\alpha\kappa(1-\mu)}{\Delta_\mu^z}\hat{G}_t, \tag{43}$$

where $\Delta_\mu^z = (1-\alpha)(1-\beta\mu)(1-\mu) - \kappa\mu z$. From equation (42) we see that the multiplier effect on output exceeds unity whenever $\alpha(1-g_y) > 0$. Hence, the balanced budget government spending multiplier is always greater in a liquidity trap than when the nominal interest rate is positive and responds according to a Taylor rule. But the multiplier is not necessarily large. When $\alpha = 0$, the multiplier is exactly unity: a balanced budget expansion has no impact whatsoever on private consumption. Moreover, the inflationary effects of a balanced budget increase in spending also exceed those under the Taylor rule. This is for two reasons: first, because in the absence of endogenous interest rate adjustment to the output gap (that is, $\sigma_y = 0$), the multiplier impacts of shocks are greater in the zero lower bound economy, since$\Delta_\mu^z < \Delta_\mu$. Moreover, when $\sigma_y < 0$, as we saw in expression (34) above, the interest rate response to a government spending increase in the Taylor rule economy will mitigate the impact on inflation, something that does not happen in the zero lower bound economy.

In the economy with the Taylor rule, we saw, paradoxically, that a tax-financed spending increase could be more or less expansionary than the equivalent deficit-financed increase. In the recent rounds of stimulus packages applied in many countries, an important feature of spending policies was that they were financed by debt issue rather than tax increases. In fact, the essential rationale behind this intervention was to combine spending increases with tax cuts, to stimulate overall spending. The perception was that when nominal interest rates cannot be lowered, this becomes the last possible channel for stabilization policy. Again however, in the context of our framework, this only makes sense if Ricardian equivalence fails. To examine this argument, we now focus on the effects of tax cuts in the model constrained by the zero lower bound.

Again, using equations (25)−(29), we can derive the responses of the output gap and inflation as:

$$\hat{Y}_t = \frac{-\Phi(1-\alpha)\left[(1-\alpha)(1-\omega\mu)(1-\beta\omega\mu)+\beta\omega\mu^2 z\right]}{\Delta_{\mu}^{z}\Delta_{\omega\mu}^{z}}\hat{T}_t, \tag{44}$$

$$\hat{\pi}_t = -\kappa\Phi\frac{z(1-\alpha)(1-\beta\omega\mu^2)}{\Delta_{\mu}^{z}\Delta_{\omega\mu}^{z}}\hat{T}_t. \tag{45}$$

The expression in (44) is always negative. Hence, in contrast to the case with positive interest rates, tax cuts are always expansionary at the zero lower bound, so long as Ricardian equivalence fails. Tax cuts increase private sector wealth, leading to a fall in private saving and an increase in aggregate demand and output. Tax cuts also make government debt grow more. At the same time, tax cuts are inflationary, as the output gap increases in response to the increase in aggregate demand, as confirmed by equation (45). Unlike the case where the Taylor rule applies, however, there is no compensating increase in the policy interest rate resulting from the increase in inflation. This raises the possibility that tax cuts may be substantially more expansionary in an economy stuck at the zero lower bound. To assess the validity of the arguments for deficit financing as an important stabilization tool, then, we must turn to a quantitative assessment of the strength of these effects.

4.5 Quantitative Comparison of Policies

How big are the effects of fiscal policy in the economy within a liquidity trap? We take the calibration presented in table 4. The parameter values are quite standard and follow the assumptions made in the recent literature in this area, save for the particular assumptions we have made to allow for aggregation in the OLG model (log utility, and linear disutility of leisure). We look at two versions of each model, one with constant returns to scale and another with decreasing returns to labor, assuming that $\alpha = 0.3$. In the first model, we follow Christiano, Eichenbaum, and Rebelo (2009) in setting the discount factor at 0.99, while the Calvo price adjustment is parameter κ at 0.85, so that $\lambda = 0.028$. In the second version, with $\alpha = 0.3$, the definition of λ is different, so we choose κ at a different value (0.7), and $\theta = 10$, so as to reproduce $\lambda = 0.025$. We initially set the parameters of the interest rate rule at $\sigma_\pi = 1.5$ and $\sigma_y = 0$, but we also look at variations on these settings. In addition we set the steady state government spending ratio equal to 0.15, approximately the relevant value for the U.S. economy.

Table 4. Parameter Values

Parameter	*Value*
β	0.985
Φ	0.011
λ	0.028; 0.025
α	0; 0.3
σ_π	1.5
σ_y	0; 0.25
g_y	0.15
μ	0.8

The parameters governing the cohort time-horizon are very important in assessing the degree to which government deficits have any affect on real allocations. It is well known that if the household planning horizon in the Blanchard-Yaari model is too great, then the results are quantitatively equivalent to a model with an infinite horizon (for example, Evans, 1991). As a result, the quantitative literature on the impacts of deficits using the Blanchard-Yaari model usually interprets the probability of death in a broader manner than that implied by straightforward demographic data. Bayoumi and Sgherri (2008) directly estimate the Blanchard-Yaari parameters from a reduced form consumption function from the model, and find estimates of γ below 0.8 at an annual frequency. This implies a five-year horizon for consumers in their planning decision. We choose γ to match this at the quarterly frequency. On parameter ϕ, governing the rate of earnings decline over the lifetime, we have little direct evidence to match this. We simply make a rough estimate based on the fact that agents spend about two-thirds of their adult lives working and one-third retired, so we set $\phi = 0.6$. In combination with the assumption for β, these assumptions imply that Φ is about 0.011 at the quarterly frequency. We should note that this calibration is not guaranteed to enlarge the impact of government deficits. Even with these assumptions about the planning horizon and wage distribution, we show that the effects of deficits under a Taylor rule are very slight.

The parameter μ, governing the number of periods for which it is anticipated that the zero lower bound on the interest rate will apply, is a critical feature of the dynamics. If this is too large, then the stability condition is not satisfied. We set $\mu = 0.8$, so that nominal interest rates are anticipated to be zero for five quarters.[13] To compare with the economy under the Taylor rule, we assume that all shocks in that case have persistence equal to 0.8.

Table 5 presents quantitative results comparing the effects of policies under the Taylor rule with the economy constrained by the zero lower bound on interest rates. In the baseline calibration, we see that the impact of a discount factor shock in the economy at the zero lower bound is orders of magnitude more than in an economy operating under a Taylor rule. This shock increases the desire to save, reducing current demand, output and inflation. In the economy operating under a Taylor rule, the nominal interest rate will fall, pushing down the real interest rate and reducing the incentive to save. The equilibrium real interest rate falls. In contrast, when the nominal interest rate cannot respond, the way the increased desired savings is satisfied in equilibrium is for current output to fall relative to expected future output. But the fall in current output leads to a fall in current inflation, which raises the real interest rate, increasing the desire to save. When $\mu < 1$, and the stability conditions on the model under the zero lower bound are satisfied, this process has an eventual equilibrium leading to a very large fall in current output.

The second panel of table 5 illustrates the impact of fiscal policies in both interest rate scenarios, under the baseline calibration with $\alpha = 0$ (constant returns to scale). In both cases, the balanced budget multiplier is unity. Even though the impact of demand shocks is potentially much greater in the zero lower bound economy, in which the real interest rate may respond pathologically, in this case a demand shock requires no real interest rate responses at all. When the government spending expansion is financed by current taxation,

13. This is not a necessary feature of the solution. We could allow the zero lower bound to be operative for a finite but known number of periods, after which the economy converges back to steady state. In this case, the duration of the zero interest rate phase could be arbitrarily extended.

Table 5. Simulation Results

Model and variable	$\hat{v}$	$\hat{b}$	$\hat{G}$	$\hat{G}-\hat{T}$	$\hat{T}$
Taylor rule model					
$\hat{Y}$	−3.20	0.04	1.07	1.00	−0.07
$\hat{\pi}$	−0.05	0.01	0.07	0.00	−0.07
$\hat{R}$	−0.36	0.01	0.03	0.00	−0.03
Zero lower bound model					
$\hat{Y}$	−13.8	0.05	2.01	1.00	−1.01
$\hat{\pi}$	−2.68	0.01	0.23	0.00	−0.23
$\hat{R}$	2.15	0.00	−0.19	0.00	0.19

Source: Author's computations.

there is no consequence at all for government debt. Output responds one for one to the expansion in both the current period and all future periods in which expansion continues. Consumption is unaffected. As a result, there is no need for real interest to move. Thus, under this calibration, the zero lower bound has no implications at all for the effects of balanced budget fiscal expansions (although as we see below, this conclusion may be substantially altered under different monetary rules or decreasing returns to scale).

Now, take the same calibration, but assume that the government spending expansion is deficit-financed. Both government spending and government debt increase simultaneously. This rise in government debt leads to a wealth-induced increase in private consumption, and—as in the aggregate—households save less. As a result, the government spending multiplier exceeds unity in the economy with both positive and zero interest rates. But the scale of the responses differs dramatically between the Taylor rule economy and the zero lower bound economy. In the Taylor rule case, growth in aggregate demand pushes up inflation, which in turn leads to a rise in the real interest rate. This substantially reduces the impact of government debt on private consumption. The government spending multiplier rises from unity under a balanced budget expansion to only 1.07 in the economy with deficit financing.

In the economy constrained by the zero lower bound, the inflation generated by the increased government spending leads to a fall in the real interest rate. This substantially increases the government spending multiplier. In the baseline case, the multiplier rises from unity under a balanced budget expansion to approximately 2 under deficit financing of government spending. Thus, while tax-financed government spending has no additional expansionary effects in a liquidity trap, deficit-financed spending is far more expansionary. When the economy is constrained by the zero lower bound, there is a very large difference in the predicted effects of fiscal expansions depending on whether they are financed with debt or with taxes. Deficit spending has a much greater impact on output than tax-financed spending.

An immediate corollary of these results is that the impact of pure tax cuts, holding the path of government spending fixed, is substantially different in the Taylor rule economy to that constrained by the zero lower bound. In the first case, tax cuts generate expansion by increasing private wealth and raising aggregate household saving. Although the economy does not exhibit Ricardian equivalence under the Taylor rule, the scale of the response to tax cuts is very small. With a tax cut of 1 percent of GDP, output rises just 0.08 percent of GDP. Hence as a first approximation, the economy with a Taylor rule has negligible departures from Ricardian equivalence, and tax reductions have little stimulatory effect.

In contrast, at the zero lower bound, tax cuts have a major effect. A tax cut of 1 percent of GDP increases output by about 1 percent of GDP: the tax multiplier is unity. Although they leave the present discounted value of government tax revenues unchanged, tax cuts increase perceived lifetime wealth for currently alive generations. This increases current demand and output. But this in turn boosts inflation, causing real interest rates to fall, and further increasing present aggregate demand.

One aspect of the model that seems somewhat counterfactual is inflation's response in a zero lower bound. Since inflation is purely forward looking in the model, fiscal policies significantly influence inflation, even in a liquidity trap. In fact, fiscal policies influence inflation more with zero interest rates than under a Taylor rule. We could improve the model's performance in this respect by introducing some backward looking elements into the inflation process.

Table 6 also provides some alternative calibrations. In particular, if the interest rate rule is extended to allow for the output gap, setting $\sigma_y = 0.25$, a value close to empirical estimates, then the multiplier impact of all shocks on the output gap is scaled down in the economy governed by the interest rate rule, but the results under the zero lower bound are completely unaffected. The impact of a discount factor shock on output is smaller, because nominal and real interest rates respond more to the shock. The government spending multiplier is also reduced, because real interest rates rise more in response to the shock. Interestingly, the government spending shock is now deflationary, because the decline in household consumption causes real marginal costs to fall. Moreover, tax cuts become even less expansionary in this case than in the baseline calibration.

Table 6. Simulation Results for the Taylor Rule Model
($\sigma_y = 0.25$)

	$\hat{\upsilon}$	$\hat{b}$	$\hat{G}$	$\hat{G}-\hat{T}$	$\hat{T}$
$\hat{Y}$	−1.75	0.02	0.59	0.56	−0.03
$\hat{\pi}$	−0.30	0.01	−0.04	0.00	−0.035
$\hat{R}$	−0.36	0.01	0.035	0.00	−0.035

Source: Author's computations.

Table 7 illustrates the case with decreasing returns to scale, setting $\alpha = 0.3$—approximately the measure of capital income share—with an alternative calibration for κ. Shocks' impact on output changes significantly under both interest rate scenarios. Under a Taylor rule, both discount factor shocks and fiscal shocks affect the output gap less. This is because with decreasing returns to scale, the output gap's influence on inflation is greater. This triggers greater compensating

Table 7. Simulation Results

	$\hat{\upsilon}$	$\hat{b}$	$\hat{G}$	$\hat{G}-\hat{T}$	$\hat{T}$
Taylor rule model ($\alpha = 0.3$)					
$\hat{Y}$	−3.00	0.032	0.94	0.89	−0.05
$\hat{\pi}$	−0.57	0.01	0.10	0.03	−0.07
$\hat{R}$	−0.72	0.01	0.027	0.00	−0.027
Zero lower bound model					
$\hat{Y}$	−21.0	0.06	3.62	1.86	−1.76
$\hat{\pi}$	−4.00	0.01	0.58	0.215	−0.36
$\hat{R}$	4.14	−0.01	−0.60	−0.21	0.39

Source: Author's computations.

responses from nominal and real interest rates, reducing the real effects of shocks. Again, the government deficit spending multiplier is less than unity, and the impact of tax cuts is only half that of the baseline case.

In contrast, introducing decreasing returns dramatically magnifies the effects of government spending policies in the economy with a zero lower bound. The balanced budget multiplier now increases to 1.9. The deficit spending multiplier is 3.6, and the tax cut multiplier is 1.8. In this case, fiscal expansions affect inflation more, as marginal cost is more responsive to output movements. This increases the negative impact on real interest rates, generating a much larger expansion in equilibrium output.

To some extent, the very substantial responses of real variables under the zero lower bound arise from the model's lack of capital. It would be interesting to extend the model to allow for endogenous capital accumulation. The results of Christiano, Eichenbaum, and Rebelo (2009), however, suggest that this would not alter the main message of this paper: that there is likely to be a very big difference between tax-financed spending and debt-financed spending in an economy where the nominal interest rate is stuck at zero.

We have assumed that all the debt accumulated during the zero lower bound phase is immediately retired, following a return to positive interest rates. This makes comparing the two cases of positive and zero interest rates simple to present. What if we make the alternative assumption that debt is retired gradually according to the rule described by equation (29)? In that case, the multiplier effects of debt are larger than under the baseline case above, as shown in table 8. While the balanced budget multiplier is still unity, the deficit financing multiplier is over 3, and the tax cut multiplier is over 2. Because debt is expansionary, even in an economy with positive interest rates, the expectation of higher

Table 8. Simulation Results for Zero Lower Bound Model with Gradual Debt Elimination

	$\hat{\upsilon}$	$\hat{b}$	$\hat{G}$	$\hat{G}-\hat{T}$	$\hat{T}$
$\hat{Y}$	−13.7	0.12	3.72	1.00	−2.72
$\hat{\pi}$	−2.68	0.02	0.635	0.00	−0.635
$\hat{R}$	2.15	0.02	−0.533	0.00	0.533

Source: Author's computations.

debt in the future is even more expansionary. Note, however, that unlike the previous case, where the impacts of fiscal policy under the zero lower bound do not depend on the parameters of the interest rate rule at all, these effects will be influenced by the rule. The more sensitive the interest rate to the inflation rate or the output gap in the future, after the Taylor rule has been restored, the smaller will be the multiplier effects of current debt-financed government spending or tax cuts.

4.6 Monetary Policy Options

In the standard New Keynesian model discussed by Christiano, Eichenbaum, and Rebelo (2009), Eggertsson and Woodford (2003, 2004), and Eggertsson (2009), monetary policy has no direct leverage once the economy is at the zero lower bound, since monetary policy is described completely by the use of an interest rate rule. In this case, the only way monetary policy can be used in a liquidity trap is by the announcement of an expansionary monetary policy to follow after the economy returns to positive nominal interest rates. These policies have been explored extensively by Eggertsson and Woodford (2003) and by Jung, Teranishi, and Watanabe (2005). In the current model however, monetary policy can exercise additional leverage, thanks to a real balance effect.[14] The monetary authority can print currency or increase bank reserves, and thereby increase public sector liabilities. At the zero lower bound, this is equivalent to issuing debt. Since the experiment we examined above involved issuing debt to finance tax cuts (or spending expansion), a condition that is retired once the economy returns to a positive nominal interest rate, it turns out that the impact of a debt-financed tax cut described above is equivalent to increasing the money base to finance fiscal transfers to the private sector, and then having this operation reversed once the economy returns to a positive nominal interest rate. Thus, to the extent that deficit financing of tax cuts is an effective macroeconomic tool in dealing with a zero interest rate environment, this is also true of monetary policy expansion, as described.[15]

14. See Ireland (2005) for an analysis of this lever of monetary policy in an OLG model with flexible prices.

15. Note that this is not equivalent to an "unconventional" monetary policy, whereby the central bank purchases private sector obligations with government debt. Our model does not have enough heterogeneity or the presence of risk premia to allow for a complete analysis of such an operation.

Quantitatively, however, it is immediately obvious that the real balance effect cannot significantly affect real GDP. For instance, take a monetary policy operation which directly increases M1, by augmenting the money base. In the United States, money base has more than doubled in the past two years as a result of the emergency procedures implemented by the Federal Reserve. But the total net wealth effects of this have been negligible since even after recent operations, M1 and money base represent very small fractions of total U.S. private sector net wealth. Thus, the impact of monetary operations via direct real balance effects alone would account for small fractions of the debt multipliers reported in tables 4 through 8. As a result, while in principle the model allows for a real balance effect of monetary policy, practically speaking, even in a liquidity trap, increasing monetary aggregates alone would have very small effects, as measured by the present model.

5. Conclusions

This paper has analyzed the impact of government spending, tax cuts, and government deficits in an economy where monetary policy is constrained by the zero lower bound on policy interest rates. We show that deficit-financed government spending may be far more expansionary than tax-financed, under these conditions, even if the difference between the two is small during "normal" times, when the policy rate is governed by a Taylor rule. From a different perspective, this paper makes the case that tax cuts alone may be highly expansionary in a liquidity trap, even if they have almost no impact on aggregate demand during normal times. The results have some substantial implications for the recent debate about the design of fiscal stimulus programs to respond to the 2008–09 global financial crisis. It has been argued that successful fiscal stimulus requires direct government spending rather than tax cuts. The results here suggest that deficit-financed tax cuts alone can be quite successful in targeting aggregate demand. To the extent that a large part of the downturn in the real economy came from a substantial increase in the savings rate, pushing the equilibrium real interest rate below zero, the increase in government debt provided by tax cuts may provide a direct vehicle for private sector saving. This staunches deflationary forces and prevents the perverse response of real interest rates following the initial shock.

One important issue not analyzed here is the welfare consequences of fiscal policy. There are a number of subtle and difficult features associated with welfare evaluation in the present model. First, the model allows for dynamic inefficiency, which in this context implies that the steady state net real interest rate may be negative. In that case, it is well known that an increase in government debt can be Pareto improving. But this argument is not relevant for the analysis of section 4, since the fall in real interest rates in our experiment is a temporary phenomenon. Secondly, an analysis of welfare in the present model would be limited, because the model does not incorporate capital accumulation. Thus, this analysis does not consider the standard crowding out effect of government debt on the long-run capital stock. As discussed in section 3 above, government debt has no impact on steady state output or consumption, but simply increases the steady state real interest rate, tilting the time profile of spending for each generation. Thus, it is likely that this analysis would also miss any first-order effects of government debt on steady state welfare.

Nevertheless, welfare may still be increased using several fiscal policy instruments, even when the economy is in a liquidity trap. In particular, Christiano, Eichenbaum, and Rebelo (2009) show that in a liquidity trap, an increase in direct government spending above the flexible price optimum value of spending can increase welfare. Pursuing this analysis in our model is more difficult, because we do not have a natural social welfare function with which to compare utilities across generations. Calvo and Obstfeld (1988) demonstrate that if a government in the Blanchard-Yaari economy has access to a full menu of redistributional fiscal instruments, the social welfare function in the economy becomes equivalent to that of the Cass-Koopmans neoclassical growth model. In that case, we can directly apply the results of Christiano, Eichenbaum, and Rebelo (2009) to establish that government spending expansion could increase welfare in our model, when the economy is in a liquidity trap. But in such an environment (that is, using the results of Calvo and Obstfeld, 1988), there is no longer a deviation from Ricardian equivalence, so the main focus of interest in the present paper would be lost. Analysis of the impact of short-run stabilization policy on welfare while incorporating departures from Ricardian equivalence would require both a social welfare function, which takes into account intergenerational heterogeneity, and a means of approximating this function, along the lines of Eggertsson and Woodford (2003). Clearly the full exploration of short-run welfare trade-offs in the present model represents an interesting research question. Nevertheless, we defer such an analysis to future research.

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