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The Benefits of Interest Rate Targeting: A Partial and a General Equilibrium Analysis

by Charles T. Carlstrom and Timothy S. Fuerst

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Introduction

One of the oldest debates in monetary economics concerns the appropriate target for monetary policy. Two distinct camps emerge from this debate—those who favor interest rate targets and those who favor money growth targets. Poole (1970) first addressed this question in an aggregate demand framework of the IS-LM type. He showed that an interest rate rule is preferable if money demand shocks are more numerous than IS shocks, while a money growth rule is preferable in the opposite case. Yet, to obtain this answer Poole assumed that the monetary authorities would choose the money supply rule that minimized the variability of output. This assumption, however, begs the question of whether such stabilization is indeed optimal.

This article revisits Poole's original question. It argues that there are clear benefits to interest rate targeting, independent of what types of shocks hit the economy. Furthermore, these benefits arise even though money growth must be procyclical in order to keep interest rates constant, which increases the variability of output. The reason a constant interest rate will be optimal is that interest rates act like a tax on labor, and constant taxes are preferable to variable taxes. This is true whether the alternative to an interest rate target is a constant money growth rule or some general money growth specification. However, this paper places special emphasis on analyzing Poole's original question—the optimality of money growth versus interest rate rules.

We use both a partial equilibrium model and a monetary general equilibrium model with sluggish portfolio adjustments to analyze the benefits of interest rate targets. The general equilibrium analysis shows that an interest rate target will undo the distortion caused by sluggish portfolios. This occurs because, to keep interest rates constant, the monetary authority will supply the reserves that would have been supplied by households in a frictionless environment. Even if private savings cannot respond to current economic conditions, an interest rate target will enable output and employment to respond to them efficiently. Which rule will a benevolent central banker prefer—a constant money growth rate or an interest rate peg? Unlike Poole's analysis, which suggests that the optimality of an interest rate rule depends on the source of the shock affecting the economy, this paper concludes that an interest rate peg

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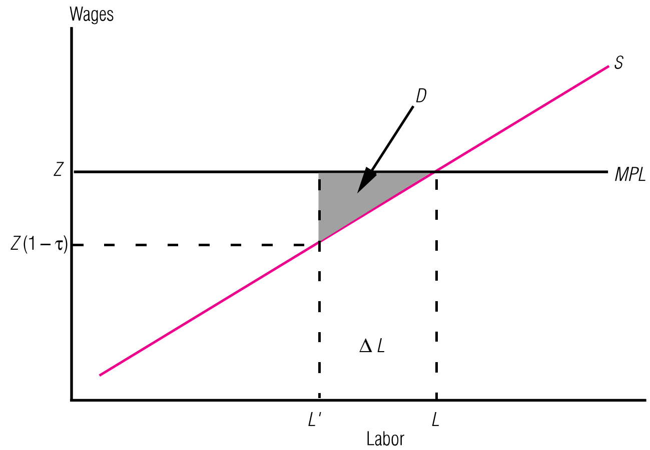
Economic Review 1996 Q2

FIGURE 1

Supply and Demand for Labor



SOURCE: Authors' calculations.

will be the benevolent central banker's choice, whatever one's view about the types of shocks most likely to buffet the economy.

We proceed as follows: Section I sets out a partial equilibrium model of the labor market in order to discuss the benefits of an interest rate peg, and section II does the same for the credit market. Section III integrates these partial equilibrium analyses into a general equilibrium framework. Section IV discusses how the economy will behave with both interest rate targets and money growth targets. It demonstrates that if the economy is buffeted by supply shocks, interest rate rules will dominate any other policy rule. Section V extends this analysis by assuming that the economy is subject to demand shocks. Section VI discusses further possible extensions, and section VII concludes.

I. A Partial Equilibrium Analysis of the Labor Market

This section develops the partial equilibrium analogue of the general equilibrium economy contained in the third section. We investigate a model economy where money is introduced by imposing a cash-in-advance (CIA) constraint on market transactions, so that consumers must hold cash in order to purchase consumption goods. We also assume a CIA constraint on the part of firms, which must hold cash in order to pay their workers. This assumption seems reasonable because there is a lag between the time when workers are paid and when a firm receives payment for its product. This means that firms cannot use cash from sales of their product to pay their workers, but must borrow funds in order to obtain the necessary cash. Sales receipts are then used to repay these loans.

This friction leads to a key distortion in the economy. Since firms must borrow money to pay their wage bill, the nominal interest rate (and hence inflation) acts like a tax on a firm's ability to hire workers. For example, assume that the demand for labor is perfectly elastic, that is, the marginal productivity of labor is constant at the pre-tax market wage, Z. Thus, L hours of work translates into $Z * L$ units of output, where Z can be thought of as a productivity shock term that is assumed to be random over time. A firm that needs cash to pay its workers can borrow $Z * L/R$ dollars (where $R > 1$ is the gross nominal rate of interest) in order to generate $Z * L$ units of output after paying off its loan. Defining $(1-\tau) = 1/R$, we see that a nominal interest rate of R translates into a wage tax of $\tau = 1 - 1/R$.

What are the benefits of a constant interest rate? Such a rate implies that the resulting wage tax, τ, will be constant over time. A constant money growth rule, by contrast, may imply a fluctuating interest rate, and hence a fluctuating wage tax. To understand the conditions under which a constant interest rate—that is, a constant wage tax—is preferred, see figure 1, which plots the supply and demand for labor.[1] Labor supply is standard and is assumed to have a constant elasticity of η. The deadweight loss associated with the CIA constraint is given in figure 1 by triangle D. The average distortion from the inflation (wage) tax is approximately[2]

$$(1) \quad D = \frac{1}{2}\eta E[Z_t L_t (\tau_t)^2].$$

A constant tax rate is usually preferred to a variable tax rate over time.[3] Since positive nominal interest rates act like a wage tax, this suggests that constant interest rates will prove superior to a policy that allows interest rates to

1 It may seem peculiar to look at the inflation-tax distortion in the labor market rather than the money market, but it can be measured in either. However, one cannot count the distortion in both markets, because to do so would be double counting.

2 By definition, $\Delta L = \eta \frac{\Delta W}{W}$ and $L_t = \eta \tau_t L_t$. Therefore, $D \approx \frac{1}{2} \Delta L \tau_t Z = \frac{1}{2} L_t Z(\tau_t)^2$.

3 See Sandmo (1974) and Barro (1979, footnote 7).

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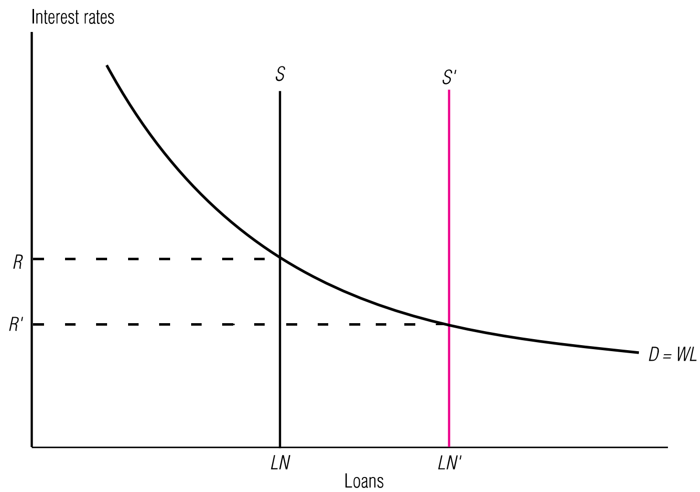
Economic Review 1996 Q2

FIGURE 2

Supply and Demand for Loans



SOURCE: Authors' calculations.

vary. Why one might suspect that constant tax rates and interest rates are preferable to variable ones is apparent in figure 1 and equation (1). The distortion from a tax is triangle *D* in figure 1 and is thus proportional to the square of the tax. Therefore, a tax that stays at 15 percent over time will usually be better than one that fluctuates from zero to 30 percent. With a constant 15 percent tax, the associated loss is proportional to 15 squared, or 225; however, the loss with a tax that is either zero or 30 percent is proportional to either zero (zero squared) or 900 (30 squared). If both of these are equally likely, the average loss associated with a time-varying tax rate is 450 (versus 225 for a constant tax).

II. A Partial Equilibrium Analysis of the Credit Market

Although intuitive, this partial equilibrium analysis is incomplete. It ignores the general equilibrium effects that the labor market has on other markets—and vice versa. For example, the distortion in the labor market spills over into the credit market because a higher interest rate lowers a firm's demand for labor, which in turn decreases the firm's demand for loans. Thus, these two markets become intimately linked. The general equilibrium section shows that this link is crucial if we are to understand the costs and benefits of interest rate rules.

Before developing this general equilibrium model, it is useful to discuss the market for loans, because it is so closely connected with the labor market. Besides the wage-tax distortion caused by the CIA constraint, another important friction in the economy is that households can adjust their consumption and savings decisions only sluggishly in response to new conditions. This is the so-called "sluggish portfolio adjustment" or "limited participation" assumption, first proposed by Lucas (1990) and further analyzed by Fuerst (1992).[4] This friction affects the loan market directly, but, as we will show, it also spills over into the labor market.

We employ this assumption because it predicts that monetary surprises will increase output *and* lower nominal interest rates.[5] Both of these predictions are crucial to understanding how the Federal Reserve operates. For example, if the Fed wishes to lower interest rates and stimulate economic activity, it increases money growth. Despite the nearly universal agreement that faster money growth lowers nominal interest rates in the short term, very few economic models generate this prediction.[6]

However, models with sluggish portfolio adjustments (households' inability to immediately adjust their consumption and savings decisions to shocks) can cause a liquidity effect. In these models, the key assumption is that households adjust their portfolios more slowly than firms do. Christiano, Eichenbaum, and Evans (1996) present evidence that there is a liquidity effect and that households do indeed adjust their portfolios more slowly than firms.

By plotting the supply and demand for loans (equilibrium in the credit market), figure 2 helps illustrate why sluggish portfolios may produce a liquidity effect. The demand for loans slopes downward, meaning that as interest rates decrease, the quantity demand for loans increases. This occurs because a rise in the nominal interest rate is equivalent to an increase in the wage tax; its result is less employment and thus a reduction in the demand for loans. However, the supply of loans is perfectly inelastic because sluggish portfolio adjustments imply that the

4 For an eminently readable paper that provides a detailed discussion of this economy, see Christiano (1991).

5 The ability of surprise monetary injections to lower nominal interest rates is called the liquidity effect. For empirical evidence of a liquidity effect, see Christiano, Eichenbaum, and Evans (1996).

6 Even dynamic optimizing versions of sticky-price models cannot generate the liquidity effect. While real interest rates may decrease with monetary expansions, this decline is not large enough to undo the increase in the expected inflation component of the nominal interest rate.

supply of credit (savings by households) is predetermined. That is, households cannot adjust their savings decisions in response to changes in either money growth (interest rates) or productivity.

When the Fed increases the money supply, it injects reserves into the financial system, thereby shifting the supply of loans outward. With sluggish portfolios, this results in lower interest rates, which in turn induce firms to expand employment and boost output.[7] If portfolios were not sluggish, this increase would be completely offset because households would save less, thereby shifting the supply of loans inward.

To understand the distortion caused by sluggish portfolios, consider the effects of a positive productivity shock. A productivity increase (in figure 1, an increase in Z) induces firms to hire more workers. The greater demand for workers in turn shifts out the demand for loans in figure 2. In an economy without portfolio rigidities, households respond to a productivity shock by saving more. Their extra savings increase the cash that intermediaries have on hand to loan out to firms, thereby shifting out the supply of credit (loans) as well.

However, when savings behavior is sluggish, the supply of credit does not increase. It can do so only if the monetary authority steps in and supplies extra reserves, which by assumption would not be forthcoming if money growth were constant. The effective supply curve with an interest rate peg is therefore perfectly elastic (horizontal) at R. With constant money growth, however, the supply curve is completely inelastic, so that interest rates must increase substantially with productivity shocks in order to clear the loan market. With sluggish portfolios, keeping money growth constant is especially costly, because it implies that interest rates must be quite variable in order to clear the loan market.

With an interest rate peg, the credit for loans to firms is supplied by the monetary authority rather than by the private sector. That is, in order to keep interest rates from rising, the monetary authority supplies reserves to the banking sector, enabling firms to borrow more and thereby increase their employment. This allows the economy to respond more efficiently and quickly to potential economywide shocks, like productivity shocks. Analogous to revenues and losses in the labor market, the same variables can be measured in the loan market instead. One can calculate the deadweight loss from the CIA constraint in either the labor market or the loan market, but not in both.

The next section combines the major features of the partial equilibrium models discussed above into a general equilibrium model where firms must borrow cash to pay their workers, and households can adjust their savings decisions only sluggishly. The first of these distortions, which arises from the firm's CIA constraint, implies that if the nominal interest rate is positive, there will be too little labor supplied (or, equivalently, too little savings or loans demanded) in equilibrium. The second distortion results from the sluggish portfolio assumption, which implies that interest rates will vary too much and that this variability is bad precisely because the interest rate is acting like a wage tax (or a tax on the demand for loans).

We show that the benefit of an interest rate peg is that it essentially eliminates the distortion caused by sluggish portfolios. The real sides of two economies—one with portfolio rigidities and an interest rate peg, the other with an interest rate peg and instantaneous portfolio adjustments—will be identical. However, there will also be a cost associated with pegging interest rates. Because of the precautionary demand for savings, variability in interest rates will tend to increase savings. This increase spills over into the labor market, mitigating the distortion caused by the CIA constraint. Despite these costs and benefits, we show that a constant interest rate will still be preferable to a policy that allows interest rates to vary.

III. The General Equilibrium Analysis

The model economy consists of four different types of agents: households, firms, financial intermediaries, and the government. At the beginning of each period, all money in the economy is in the hands of households, which accumulated it in the previous period from labor, dividend, and interest earnings. Households decide how much of this money they wish to save (loan to the financial intermediary) for future consumption, and how much they wish to pay to firms in order to consume today. We assume that households must hold money in order to purchase consumption goods.

As discussed earlier, portfolio adjustments are assumed to take time. The simplest way of

7 This is a partial equilibrium story, so we have obviously ignored the roles of price adjustments and expected inflation, which are crucial to understanding the whole story. Readers interested in the conditions under which a liquidity effect arises in a general equilibrium model with sluggish portfolios are encouraged to see Christiano (1991).

modeling this sluggishness is by positing that households make consumption and savings decisions before they identify the various shocks that buffet the economy. This less-than-perfect flexibility is meant to reflect that continually changing one's behavior with every bit of new information would be prohibitively costly. We first consider the case of productivity shocks (supply shocks). We then examine the case where there are shocks to government spending (demand shocks).

After households make their consumption and savings decisions, the productivity shock, Z, occurs and is costlessly observed by everyone.[8] Under an interest rate peg, the monetary authority then injects money into the economy through the financial intermediary, so that the productivity shock does not change nominal interest rates. Therefore, money growth will be endogenous, responding as necessary to keep the nominal interest rate from changing. With a constant money growth regime, there will be a fixed injection to the financial intermediary, and interest rates will respond endogenously.

The model's details are spelled out below. Since the purpose of this paper is to provide a simple example of the benefits of an interest rate peg, we abstract from capital accumulation and assume particular functional forms for utility and production. In addition, the productivity shock is assumed to be independently identically distributed (i.i.d.) over time. As Carlstrom and Fuerst (1995) show, none of these abstractions affects our results.

Households

Preferences are standard in that households derive utility from consumption, c_t, and disutility over labor, L_t, to maximize discounted expected utility subject to the CIA constraint and the resource constraint:[9]

$$\max E_0 \sum_{t=0}^{\infty} \beta^t [\ln(c_t) - AL_t^s], \text{ subject to}$$

$$\text{(i)} \quad P_t C_t \leq M_t - N_t + W_t L_t^s$$

$$\text{(ii)} \quad M_{t+1} \leq R_t N_t + D_t + F_t + (M_t - N_t + W_t L_t^s - P_t C_t).$$

The variables M_t, P_t, C_t, W_t, and L_t^s are the time t money holdings, nominal price level, consumption, nominal wage, and labor supply (or hours worked). The first constraint is the CIA constraint, which says that consumers must have enough cash on hand to finance consumption expenditures. This cash consists of the worker's wage earnings (which are paid in cash) and the fraction of period t money holdings left after the saving partner visits the financial intermediary to deposit N_t dollars.

The second constraint states that the cash sources the household carries into $t+1$ include interest on savings, dividends that the household receives from the firm F_t, and dividends it receives from the intermediary D_t. Since the household is an atomistic part of the economy, dividend payments are outside its control and are equivalent to lump-sum payments. Financial intermediaries' profits arise because of the monetary injection they receive. Firms' profits arise because a worker's average productivity is greater than his marginal productivity. The sum in parentheses is the cash that is not spent when the consumption market closes. In equilibrium, this will be zero.

Firms

The economy consists of one representative firm owned by a representative household. The firm produces one consumption good according to the production function

$$(2) \quad y_t = \bar{K} + Z_t L_t^D.$$

The variable L_t^D is labor demand at time t, while Z_t is the productivity shock, which we assume to be i.i.d. over time. The unusual aspect of this production function is $\bar{K}$, which measures the contribution of capital to production and is assumed to be fixed. We have fixed capital entering additively in the production function because we wish to capture the observed phenomenon that labor increases with positive productivity shocks.[10] This feature arises in more complicated models with capital accumulation, where capital affects the marginal productivity of labor.

8 The modeling fiction used is that households consist of a "worker–shopper" and a "saver" to conduct financial transactions. The assumption of sluggish portfolios implies either that the saver does not observe the shock contemporaneously, or that he leaves for the bank before Z is realized. After Z is realized, the worker–shopper leaves for work and then purchases consumption goods on the way home.

9 The assumption that the disutility of working is linear in labor supply is equivalent to assuming that labor supply is indivisible. See Rogerson (1988) or Hansen (1985) for details.

10 Without this assumption, the income and substitution effects of a productivity shock will cancel one another out, so that labor supply will be constant in equilibrium. Interest rates will also be constant, with or without portfolio rigidities.

Because firms are also subject to a CIA constraint, at the beginning of period t they borrow enough from the financial intermediary to finance their nominal labor costs, $W_t L_t^D$. Every firm then uses the proceeds from selling its consumption goods to pay off the labor loan that it took out when the period began, $R_t W_t L_t^D$. Since the firm is owned by the representative household, it maximizes

$$E\left\{\sum_{t=0}^{\infty}\left[\beta^{t+1}\frac{U_{c,\,t+1}}{P_{t+1}}\right]D_t\right\} \text{ subject to (2),}$$

where $D_t = P_t y_t - R_t W_t L_t^D$.

The term in the square brackets above is a shareholder's marginal utility of a dollar received at the end of period t. Therefore, a dollar of a dividend received in period t can be transformed into $1/P_{t+1}$ units of consumption in period $t+1$, where $U_{c,\,t+1}$ reflects the household's marginal valuation of each additional unit of consumption.

The Financial Intermediary

There is also a representative but competitive financial intermediary, owned by the representative household, that is completely passive in our analysis. It accepts deposits from households, N_t, and receives lump-sum transfers from the government equal to the seigniorage the government receives from money creation, $M_{t+1} - M_t$, then loans these funds out to firms. Therefore, in equilibrium, the supply of loans must equal the demand for loans: $W_t H_t = N_t + (M_{t+1} - M_t)$. Because governments distribute their seigniorage to intermediaries, intermediaries make a profit, which is distributed to households as a lump-sum payment.[11] This dividend payment is given by

(3) $F_t = R_t(M_{t+1} - M_t)$.

The Monetary Authority

For most of this section, we consider two different operating procedures for the monetary authority. The first is pursuit of an interest rate target, where reserves are supplied to the banking sector in such a way that the interest rate in the economy is constant at $\bar{R}$. Note that money growth, $G_t = M_{t+1}/M_t$, is not constant under this procedure and responds endogenously to support the interest rate target. The second operating procedure that we analyze, money growth, $G_t = \bar{G}$, is constant. In this case, the interest rate R_t is not constant and will respond endogenously to productivity shocks.

Equilibrium

In equilibrium, the labor (4), loan (5), and goods (6) markets must all clear and the CIA constraint (7) must be satisfied.

(4) $L_t^s = L_t^D = L_t$

(5) $n_t + G_t - 1 = w_t L_t^D$

(6) $Y_t = \bar{K} + Z_t L_t = C_t$

(7) $p_t C_t \leq 1 - n_t + w_t L_t$,

where $w_t = \dfrac{W_t}{M_t}$, $p_t = \dfrac{P_t}{M_t}$, and $n_t = \dfrac{N_t}{M_t}$.[12]

Since this model does not include capital, equation (6) states that the goods market clears when consumption equals output. Equation (7) is the household's CIA constraint which, when combined with (5), states that, in equilibrium, tomorrow's money stock must equal the value of consumption today.

Equilibrium also consists of households maximizing utility[13]

(8) $A = \dfrac{w_t}{p_t C_t}$

and firms maximizing profits

(9) $\dfrac{w_t}{p_t} = \dfrac{Z_t}{R_t}$.

This last condition says that the equilibrium real wage rate will equal the marginal productivity of labor deflated by the gross nominal

■ **11** Therefore, revenues from money creation are essentially redistributed to households in a lump-sum manner instead of being used by the government to help finance deficit spending. This assumption is made for simplicity and does not affect the results of our analysis.

■ **12** As long as nominal interest rates are strictly positive, that is, $R > 1$, (7) will be satisfied with equality. All equations with nominal variables are divided by the beginning-of-period money supply so that they are stationary.

■ **13** There is actually one more equation that is necessary in equilibrium. This is the household's intertemporal first-order condition, which determines its choice of n_t. After simplification, this first-order condition is $E_s(\frac{1}{G_t}) = \beta E_s(\frac{R_t}{G_t G_{t+1}})$. For the sluggish portfolio model, $s = t-1$, since savings n_t are chosen at time $t-1$. With fixed capital and independent technology shocks, this implies that savings will be constant, $n_t = \bar{n}$. With flexible portfolios $s = t$, indicating that n_t can be chosen conditional on time t innovations.

interest rate; that is, the real wage equals the after-tax marginal productivity of labor. This equation also gives the demand curve for labor.

Combining (5), (6), (7), and (9) implies the following expression for equilibrium consumption:

$$(10) \qquad C_t = \frac{\bar{K}}{1 - R_t s_t}\,,$$

where $s_t = \frac{n_t + G_t - 1}{G_t}$, $R_t = \bar{R}$ for an interest rate peg, and $s_t = \bar{s}$ when money growth rates are pegged.

The variable s_t is interpreted as the share of the money stock held by the intermediary. As the next equation indicates, this share will determine equilibrium labor, and thus output, for the economy. Using (5) and (8) gives the following expression for labor in equilibrium:

$$(11) \qquad L_t = \frac{s_t}{A}.$$

The disadvantage of letting money growth be constant is apparent in (11). With sluggish portfolios and i.i.d. technology shocks, n is constant (see footnote 7). Therefore, when money growth rates are pegged, the share of money in the hands of the intermediary will also be constant, $s_t = \bar{s}$. This implies that with constant money growth, labor will also be constant.

However, with an interest rate peg, money growth is endogenous, so that the share of money held by intermediaries is not constant. The next section analyzes how money growth must respond in order to keep interest rates constant.

IV. Interest Rate Targets versus Money Growth Targets

The Benefit of an Interest Rate Peg

In order to understand how money growth will behave to support an interest rate peg, combine (6), (10), and (11) to obtain the relationship between the share of cash held by intermediaries, s_t, and productivity:

$$(12) \qquad s_t = \frac{Z_t - A\bar{K}\bar{R}}{Z_t \bar{R}}.$$

To keep nominal interest rates constant, the share of cash held by financial intermediaries must increase as productivity rises. Then, from the definition of s_t, money growth must also increase with productivity (since $n_t = \bar{n}$).

Equation (12), however, will hold regardless of whether portfolios are rigid. The only difference between an economy with portfolio rigidities and one without them is how the increase in s_t is achieved. With sluggish portfolios, since savings n are predetermined, the private sector cannot supply the credit necessary to make this occur. Therefore, in order to keep interest rates constant, the monetary authority must step in and supply reserves to the banking system, which lowers the real rate of interest. In appendix 1, we show that with portfolio rigidities, money growth (G_t^{pr}) and savings will be of the following form:

$$\frac{1}{G_t^{pr}} = a + \frac{b}{Z_t}\,,$$

where $a, b > 0$ and $n_t^{pr} = n_{ss}$.

Without portfolio rigidities, private savings are not fixed; that is, they can respond to current economic conditions. This reverses the role of private savings versus government credit creation. When there are no portfolio rigidities (npr), money growth G_t^{npr} is constant, while private savings respond to productivity increases:

$$G_t^{npr} = G_{ss} \text{ and } n_t^{npr} = c - \frac{d}{Z_t}\,,$$

where $c, d > 0$. The relationship between the two economies is $E(n_t^{npr}) = n_{ss}$, $E(\frac{1}{G_t^{pr}}) = \frac{1}{G_{ss}}$.[14]

The important variable governing the economy's behavior is s_t, the share of cash held by financial intermediaries. With an interest rate peg, this share is the same regardless of whether portfolios are sluggish. Therefore, from equation (11) we know that hours worked will also be the same. Since the share of cash held by intermediaries increases with positive productivity shocks, equilibrium labor will respond quickly and efficiently to technology shocks whether or not portfolios are sluggish. The only difference between the two economies is whether the private sector or the government is supplying the

■ 14 With flexible portfolios, there are many possible money growth rules that support an interest rate peg (see footnote 13). Another rule that will support an interest rate peg is i.i.d. money growth shocks.

credit.[15] Without portfolio rigidities, a constant money growth rule can support an interest rate peg. Households are now supplying the intermediary with the savings that the monetary authority supplied when portfolios were rigid.

The advantage of an interest rate peg is that it eliminates the distortion caused by sluggish portfolios. However, it does not eliminate the distortion caused by the CIA constraint, which persists as long as nominal interest rates are positive. With a constant money growth rule, both distortions will be present. Despite this, however, we are in a second-best environment and cannot conclude that an interest rate peg will necessarily dominate a constant money growth rule. The reason is that sometimes two distortions are preferable to one (for example, if one distortion mitigated the other). Indeed, we will show that this occurs to a limited extent: Variable interest rates increase savings, partially mitigating the distortion caused by the CIA constraint.

We do know, however, that the Friedman rule of setting the nominal interest rate to zero, $R = 1$, will be unambiguously better than a money growth rule or any other rule that achieves a zero nominal interest rate on average. This is because all distortions in the economy are eliminated when the nominal interest rate is pegged to zero.

Sluggish Portfolios: Constant Money Growth versus Constant Interest Rates

When money growth is constant, equilibrium will still be characterized by equations (10) and (11) above. The difference is that in equation (12), s_t, the share of cash in the hands of financial intermediaries, will be constant, while the nominal interest rate will vary. With constant money growth and sluggish portfolios, this share is also constant, since neither money growth nor private savings can change:

$$(12') \qquad R_t = \frac{Z_t}{\bar{s}Z_t + A\bar{K}}.$$

This equation shows that with constant money growth, interest rates and technology shocks covary positively with one another. A rise in productivity increases loan demand, which in turn increases interest rates, because credit is fixed. Equation (11) tells us that interest rates will increase until equilibrium labor does not change. Labor's inability to respond to technology shocks will prove especially costly. An equivalent way to look at this cost is through the sharp interest rate movements required to ensure that the loan market always clears.

Under an interest rate peg, labor can respond to productivity changes because money growth is procyclical. However, for the same reason, many economists and policymakers believe that an interest rate peg would be counterproductive. They reason that if money growth were procyclical, output (and hence consumption) would also be more variable. They consider this undesirable because, holding everything else constant, consumers prefer a less variable consumption stream.

Yet everything else is not held constant. Allowing labor to respond efficiently to productivity shocks may increase the variability of consumption, but it also increases average consumption. To see this, assume that the average distortion is the same for an interest rate peg as it is for a money growth peg. That is, we assume that $1/\bar{R} = E(1/R_t)$ or, equivalently, that $E(s_t) = \bar{s}$ (from equation [12′]).

From (10) and (12′), the standard deviation of consumption when interest rates are pegged equals

$$(13) \qquad \sigma_R = \frac{\sigma_Z}{A\bar{R}}.$$

From the goods-market-clearing condition, the standard deviation of consumption when money growth is constant equals

$$(14) \qquad \sigma_G = \frac{\bar{s}\sigma_Z}{A}.$$

Since $\bar{s} < 1/\bar{R}$, it is easy to see that consumption is more variable under an interest rate peg.[16] This occurs because money growth is allowed to move with output when interest rates are constant, thus increasing the variability of both output and consumption. Why is an interest rate peg beneficial under these circumstances? Mean consumption will also be higher under an interest rate peg than it is with constant money growth.

■ **15** If all real variables are the same, the real rate of interest will also be the same. Since nominal interest rates are the same by assumption, the expected rate of inflation is also the same for an economy with and without portfolio rigidities. Yet with portfolio rigidities, money growth increases with productivity shocks. However, this increase leads to a one-time rise in the price level and does not affect "expected" inflation, since with portfolio rigidities, the expectation is formed prior to realization of the productivity shock.

■ **16** From (12), we know that $\bar{s} = 1/\bar{R} - AKE(1/Z_t)$. This implies that $\bar{s} < 1/\bar{R}$.

From equation (6), the goods-market-clearing condition, we obtain

$$(15)\quad E_tC_t^R - E_tC_t^G = \text{cov}(L_t^R, Z_t).$$

Average consumption is higher under an interest rate peg precisely because labor responds optimally to technology shocks. Therefore, the same economic force that increases output's variability when interest rates are pegged also increases average consumption. With constant money growth, however, labor supply is constant. Variable labor is preferred because it allows workers to truncate the effect of bad shocks by working less and to accentuate the effect of good shocks by working more.

Despite increased variability in consumption, households would gladly trade off this extra variability for the extra consumption it provides on average. Using (13) we have

$$(16)\quad EU^R - EU^G = \ln\left(\frac{1}{\bar{R}}\right) - E\ln\left(\frac{1}{R_t}\right) > 0.$$[17]

This expression is positive, since utility is concave and, by assumption, $E(1/R_t) = 1/\bar{R}$. Recalling that $1/R_t = (1 - \tau_t)$, this expression is the general equilibrium equivalent of the result that a constant tax rate is preferred to a variable one.

To compare an interest rate peg with a constant money growth rule, something must be held constant across the two regimes. The analysis above assumes that the average distortion is the same for both economies. An alternative variable that could be held constant across both regimes is the amount of seigniorage collected under each. Although $1 - 1/R$ measures the distortion in the economy, the effective rate at which taxes are collected is $1 - 1/G$.[18] These two differ because, even if inflation is zero, there still exists the distortion caused by workers' inability or unwillingness to obtain direct payment in real goods after production. Therefore, an alternative way to compare constant money growth rates and constant interest rates is to choose money growth so that $\frac{1}{\bar{G}} = \frac{1}{\beta E(R_{t-1})} = E(\frac{1}{G_t}) = \frac{1}{\beta\bar{R}}$. This is equivalent to setting interest rates in the two economies to be equal on average. In appendix 2, we show that for any two policies in which average seigniorage is the same, a constant interest rate will be preferred to a variable one.[19] As a special case, this implies that an interest rate rule is preferred to a constant money growth rule.

The intuition about the advantages and disadvantages of a constant money growth rule versus a constant interest rate rule is this: The cost of a money growth rule is that with sluggish portfolios, it greatly increases interest rate variability and thus the variability of the equivalent wage tax. However, there is also a benefit to having a constant money growth rate, that is, letting interest rates be variable: Since interest rates are the same on average, the inverses of the interest rates are not the same; in particular, $1/\bar{R} > E(1/R_t)$. Therefore, to obtain equal revenue, the average distortion is greater with an interest rate peg. Variable interest rates help mitigate the distortion caused by the CIA constraint, because they increase savings. From equation (12), we derive $E(s_t) > \bar{s}$ or $n^G > n^R$. This increase in savings spills over into the labor market, implying more employment, thus mitigating the distortion caused by the CIA constraint. Unless this distortion is extremely large ($R > 2$), the gains from reducing it are less than the potential gains from stabilizing interest rates and hence wage taxes.

V. Interest Rate Rules and Government Spending Shocks

Up to this point, our analysis has assumed that all shocks to the economy are productivity shocks. Poole's original study suggested that an interest rate rule is preferred when money demand shocks are more numerous than IS shocks, while a money growth rule is preferred when IS shocks are more numerous. The meaning of IS and LM shocks is ambiguous in general equilibrium models. Nonetheless, one might expect an interest rate rule to be desirable, because we assume that all shocks to the economy are supply shocks.

17 Since $E(s_t) = \bar{s}$, equilibrium labor is the same on average. Therefore, given the assumption that utility is linear in leisure, we are simply left with the difference in the utility from consumption, which from (13) simplifies to (16).

18 We define seigniorage for the two policies in terms of how many labor units the government can hire with the revenue. This is because we think of the government as using seigniorage to hire labor in order to produce a public good. Therefore, seigniorage (in labor units) equals $(M_{t+1} - M_t)/W_t = (G_t - 1)/(A{*}p_t{*}C_t) = (G_t - 1)/(A{*}G_t)$. If government production is not subject to the same high-frequency technology shocks as the private sector, the average amount of public goods produced will be the same for any two policies where $E(1/G_t)$ is the same for both policies. For simplicity, however, the actual model in the text continues to assume that these revenues are given right back to the households as a lump-sum transfer. That is, the government robs Peter to pay Peter.

19 Actually, an interest rate target will be preferred only if $\bar{R} < 2$. That is, the nominal interest rate must be less than 100 percent annually.

To analyze the effect of demand shocks, we introduce government spending shocks into our framework.[20] The question now is whether a benevolent monetary authority should accommodate government spending shocks to support an interest rate peg. The answer is yes.

Government spending that is financed with lump-sum taxes can be introduced quite simply by redefining output and consumption as follows:

$$y_t = (\bar{K} + e_{ss}) + \bar{Z}L_t$$

$$C_t = K_t + \bar{Z}L_t,$$

where $K_t = (\bar{K} + e_{ss}) - e_t$.

The only difference in the definition of consumption is that K is no longer constant but can vary randomly over time. In particular, we assume that K_t is i.i.d. over time, which corresponds to the assumption that government spending shocks are i.i.d. A large value of K is equivalent to government spending below its mean ($e_t < e_{ss}$), while small values of K represent government spending shocks above its mean ($e_t > e_{ss}$).

The first-order conditions are the same as before, except that in equations (10)–(12), Z_t is assumed to be constant while K is allowed to vary:

$$(17) \quad C_t = \frac{K_t}{1 - R_t s_t},$$

where $s_t = \dfrac{n_t + G_t - 1}{G_t}$, $R_t = \bar{R}$ for an interest rate peg, and $s_t = \bar{s}$ when money growth rates are pegged.

$$(18) \quad L_t = \frac{s_t}{A}$$

$$(19) \quad R_t = \frac{\bar{Z}}{\bar{s}\bar{Z} + AK_t} \text{ (money growth rule)}$$

$$(19') \quad s_t = \frac{\bar{Z} - A\bar{R}K_t}{\bar{Z}\bar{R}} \text{ (interest rate rule).}$$

With a money growth rule, interest rates increase to clear the loan market so that equilibrium labor is constant once again. When interest rates are pegged, however, labor will increase with positive government spending shocks (K is small). This increase is brought about as the money supply increases in order to keep the interest rate from rising. An interest rate peg will still undo the distortion caused by sluggish portfolio adjustments.

To understand the dynamics of the model, it is useful to look at the labor market again. The demand curve for labor, given by equation (9), is completely elastic at the marginal productivity of labor deflated by the nominal interest rate, $\bar{Z}/R_t$. Labor supply is obtained by combining (8) and (6). For a money growth peg, labor supply equals

$$(20) \quad L_t^s = \frac{1}{A\bar{s}}\left(\frac{w_t}{p_t}\right) - \frac{K_t}{\bar{s}}.$$

A positive shock to government spending (small K) has the immediate impact of reducing today's private consumption relative to tomorrow's. As the marginal utility of consumption rises, workers want to increase the number of hours worked in order to boost their consumption. Thus, labor supply (20) shifts outward. This increases firms' demand for both labor and loans. In order to clear the loan market, interest rates are driven up, thereby shifting labor demand (9) down. In equilibrium, the nominal interest rate increases until the real wage in (20) declines, so that equilibrium labor does not change.

Therefore, with a money growth rule, output (private consumption plus government spending) is constant, implying that private consumption is crowded out completely. With an interest rate peg, however, money growth increases in order to prevent the nominal rate from rising (19′), thereby allowing both labor and output to increase. Combining (2) and (19), private consumption is constant ($C_t^R = \frac{\bar{Z}}{A\bar{R}}$), so that equilibrium output rises by the amount of the increase in government spending.

If we choose an interest rate target such that $Es_t = \bar{s}$, it is easy to see that mean consumption is the same with either operating target. But an interest rate target is preferred, since private consumption is less variable (that is, constant). However, equation (16) will still hold, implying that an interest rate target will be preferred to any other rule where $1/\bar{R} = E(1/R_t)$. As with productivity shocks, seigniorage is higher for a money growth peg if $1/\bar{R} = E(1/R_t)$. However, as appendix 2 makes clear, if $1/\bar{G} = E(1/G_t)$, an interest rate rule will be preferred to a money growth peg.

20 In some ways, it is misleading to call government spending shocks "demand shocks," since they act like a drain on resources.

VI. Extensions

The foregoing analysis illustrates an important implication of an interest rate target: It completely eliminates the distortion caused by households' inability to readjust portfolio holdings quickly following either technology or government spending shocks. But there is nothing special about these shocks. The result of this analysis would be true for any type of shock, including preference shocks. For example, the same arguments would apply if A or even β were allowed to vary over time.

We also assume that these shocks are i.i.d. over time. In an earlier paper (Carlstrom and Fuerst [1995]), we show that this assumption is also unnecessary. Under a money growth rule, consumption and labor will depend on last period's shocks and not on today's innovations. In contrast, an interest rate rule will once again allow labor and consumption to respond to today's information. As before, this option value will be welfare-improving.

The other assumption used in our model—that portfolios are rigid for exactly one period—is also nonessential. Suppose that households adjust their portfolios slowly because of convex adjustment costs, as in Christiano and Eichenbaum (1992). Equation (12′) will still determine the share of cash held by intermediaries. Therefore, labor and output will also be the same. The only difference will be how fast money must grow in response to various shocks in order to support the interest rate target. Besides allowing the economy to respond efficiently to current shocks, the interest rate rule also has the advantage of enabling households to avoid the costs associated with adjusting their nominal portfolio holdings.

Yet monetary authorities typically do not keep interest rates constant over the course of a business cycle. One reason often given is that procyclical money growth may make output more variable, but it has already been refuted in this paper: It is efficient to allow the economy to respond to shocks, although output variability increases. A second reason is fear of the long-run inflationary consequences of an interest rate peg. In the model presented here, long-term inflation is pinned down by the nominal interest rate, but short-term inflation can be quite variable under an interest rate peg. The long-run inflation rate will be pinned down by Fisher's equation. The real federal funds rate has averaged approximately 2 percent per year since the beginning of the century; thus, if one wants inflation to average zero over time, one should choose a funds rate peg of 2 percent. Similarly, if one wants inflation to average 3 percent, the nominal interest rate peg should be 5 percent. As for increased short-run inflation variability, it is far from clear why this is costly.[21]

According to one argument, there are costs to changing prices, so stable prices would be beneficial. If these costs result simply from having to reprogram price scanners and change price tags on products, it is uncertain that prices will change more frequently with variable inflation, given that inflation is positive. In addition, similar savings are associated with an interest rate target, since it has the advantage of allowing households to avoid the costs associated with adjusting their nominal portfolio holdings.

VII. Conclusions

This paper explores some of the benefits of interest rate targeting. An interest rate peg is desirable because such a policy eliminates any distortion caused by sluggish portfolios. That is, an interest rate peg allows labor—and thus output and consumption—to respond optimally to economic shocks. An equivalent way to think about the benefits of an interest rate peg is that it minimizes the "inflation tax" distortion. Nominal interest rates are a tax on non-interest-bearing assets and mimic the effect of wage taxes. With sluggish portfolios and constant money growth, interest rates can be quite variable. Eliminating this variability is welfare-improving.

Our analysis also suggests that, in order to achieve an interest rate peg, money growth should be procyclical. This implies that the variability of output will also be higher when interest rates are pegged. Despite popular wisdom to the contrary, this increase in variability is optimal. With productivity shocks, this is so because mean consumption is higher. With government spending shocks, it is so because, although output is more variable, private consumption is less variable.

21 It is obvious why increased inflation uncertainty would be costly. However, inflation would not be more uncertain, since money growth, and hence inflation, would respond to publicly observed shocks. If nominal wage contracts had been made prior to these shocks, this variability would have real costs.

Appendix 1

Portfolio Rigidities and an Interest Rate Rule

With portfolio rigidities, money growth (G_t^{pr}) and savings will be of the form

$$\frac{1}{G_t^{pr}} = a + \frac{b}{Z_t},$$

where a, $b > 0$ and $n_t^{pr} = n_{ss}$.

Given that money growth is of this form, using the first-order condition for n_t (footnote 13), we obtain

$$E_{t-1}\left(\frac{1}{G_{t+1}}\right) = E_{t-1}\left(a + \frac{b}{Z_{t+1}}\right) = \frac{1}{\beta \bar{R}}.$$

This expression uses the assumption that technology shocks are i.i.d. Taking a second-order approximation, we obtain

$$\text{(A1)} \quad a + \frac{b}{\bar{Z}} + \frac{b}{2}\sigma_Z^2 = \frac{1}{\beta \bar{R}},$$

where $\bar{Z}$ and σ_Z^2 are the mean and variance of Z_t, respectively.

From equation (15), the definition of s_t, and our assumed form for money growth, we obtain

$$\text{(A2)} \quad 1 + (n_{ss} - 1)a + \frac{(n_{ss} - 1)b}{Z_t} = \frac{1}{\bar{R}} - \frac{A\bar{K}}{Z_t}.$$

Using the method of undetermined coefficients, we have

$$a = \frac{(\bar{R} - 1)}{\beta \bar{R}\,[(\bar{R} - 1) + \bar{R}A\bar{K}\,(1 + \sigma_Z^2)]}$$

$$b = \frac{AK}{\beta[(\bar{R} - 1) + \bar{R}A\bar{K}\,(1 + \sigma_Z^2)]}$$

$$n_{ss} = 1 + \beta(1 - \bar{R}) - \beta \bar{R}A\bar{K}\,(1 + \sigma_Z^2).$$

No Portfolio Rigidities and an Interest Rate Rule

If portfolios are not fixed, we assume that money growth and savings have the following form:

$$G_t^{npr} = G_{ss} \text{ and } n_t^{npr} = c - \frac{d}{Z_t},$$

where c, $d > 0$, $E(n_t^{npr}) = n_{ss}$, and $E\left(\frac{1}{G_t^{pr}}\right) = \frac{1}{G_{ss}}$.

From footnote 13, we obtain

$$\text{(A3)} \quad \frac{1}{G_{ss}} = \frac{1}{\beta \bar{R}}.$$

Using the definitions of n_t, s_t, and equation (12) yields

$$\text{(A4)} \quad 1 + \frac{(c-1)}{G_{ss}} - \frac{d}{G_{ss}}\left(\frac{1}{Z_t}\right) = \frac{1}{\bar{R}} - \frac{A\bar{K}}{Z_t}.$$

Using the method of undetermined coefficients, we have

$$c = 1 + \beta(1 + \bar{R})$$

$$d = -\beta \bar{R}A\bar{K}$$

$$G_{ss} = \beta \bar{R}.$$

Therefore, $E(n_t^{npr}) = n_{ss}$, and $E\left(\frac{1}{G_t^{pr}}\right) = \frac{1}{G_{ss}}$, as the text of this paper asserts.

Appendix 2

The Desirability of an Interest Rate Peg

This appendix shows that if seigniorage is on average equal, interest rate rules will dominate a money growth rule. Equal revenues imply

$$E\left(\frac{1}{G_t^R}\right) = \frac{1}{G_{ss}}, \text{ or } E(R_t) = \bar{R}.$$

Money Growth Rule:

$$\bar{s} = \frac{1}{R_t} - \frac{AK}{Z_t}$$

$$\bar{s} \approx \frac{1}{\bar{R}} + \frac{\sigma^2_{Rr}}{\bar{R}^3} - \frac{AK}{\bar{Z}} - \left(\frac{AK}{\bar{Z}^3}\right)\sigma^2_Z .$$

Interest Rate Peg:

$$s_t = \frac{1}{\bar{R}} - \frac{AK}{Z_t}$$

$$E(s_t) \approx \frac{1}{\bar{R}} - \frac{AK}{\bar{Z}} - \left(\frac{AK}{\bar{Z}^3}\right)\sigma^2_Z .$$

We know that consumption is equal to

$$C_t^R = \frac{Z_t}{A\bar{R}}$$

$$C_t^G = \frac{Z_t}{AR_t}$$

and labor is $L_t = \frac{s_t}{A}$.

The difference in utility is therefore

$$EU_t^R - EU_t^G = E\ln(R_t) - \ln(\bar{R}) + \bar{s} - E(s_t)$$

$$\approx \frac{1}{\bar{R}^3} - \left(\frac{1}{2\bar{R}^2}\right)\sigma^2_R > 0.$$

If $\bar{R} < 2$, that is, if the nominal interest rate is less than 100 percent, then an interest rate peg is preferred to a money growth peg. Actually, a stronger result holds. Nothing in the proof assumes that money growth is constant. The proof compares an interest rate peg to a policy where the interest rate varies (with average revenues in labor units equal). An interest rate peg will be preferred to any other policy unless the distortion caused by the CIA constraint is extremely large.

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