Monetary Policy in the New Neoclassical Synthesis: A Primer

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Great progress was made in the theory of monetary policy in the last quarter century. Theory advanced on both the classical and the Keynesian sides. New classical economists emphasized the importance of intertemporal optimization and rational expectations.[1] Real business cycle (RBC) theorists explored the role of productivity shocks in models where monetary policy has relatively little effect on employment and output.[2] Keynesian economists emphasized the role of monopolistic competition, markups, and costly price adjustment in models where monetary policy is central to macroeconomic fluctuations.[3] The new neoclassical synthesis (NNS) incorporates elements from both the classical and the Keynesian perspectives into a single framework.[4] This "primer" provides an introduction to the benchmark NNS macromodel and its recommendations for monetary policy.

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[1] Lucas (1981) and Ljungqvist and Sargent (2000).

[2] Prescott (1986) and Plosser (1989).

[3] Mankiw and Romer (1991), Mankiw (1990), and Romer (1993).

[4] This primer draws on ideas developed in Goodfriend and King (1997, 2001). See also Brayton, Levin, Tryon, and Williams (1997), Clarida, Gali, and Gertler (1999), and Woodford (2003).

The article begins in Section 1 by presenting a monopolistically competitive core RBC model with perfectly flexible prices. The RBC core emphasizes the role of expected future income prospects, the real wage, and the real interest rate for household consumption and labor supply. And it emphasizes the role of productivity shocks in determining output, the real wage, and the real interest rate.

The NNS model introduced in Section 2 takes costly price adjustment into account within the RBC core. In the NNS model, firms do not adjust their prices flexibly to maintain a constant profit maximizing markup. Instead, firms let the markup fluctuate in response to demand and cost shocks. Markup variability plays a dual role in the new neoclassical synthesis. As a guide to pricing decisions, the markup is central to the evolution of inflation. As a "tax" on production and sales, the markup is central to fluctuations in employment and output.

Section 3 locates the transmission of interest rate policy to employment and inflation in its leverage over the markup. That leverage creates the fundamental credibility problem of monetary policy: the temptation to increase employment by compressing the markup jeopardizes the central bank's credibility for low inflation. The nature of the credibility problem is discussed in Section 3 together with the closely related "inflation scare" problem that confronts monetary policy in practice.

Section 4 traces the effects on employment and inflation of three types of disturbances: optimism or pessimism about future income prospects, a temporary productivity shock, and a shift in trend productivity growth. It then tells how interest rate policy can counteract such shocks. The combination of rational forward-looking price setting by firms, monopolistic competition, and RBC components in the benchmark NNS model provides considerable guidance for interest rate policy. The recommended objectives and operational guidance are developed and presented in Section 5. Section 6 addresses three challenges to these policy recommendations. Section 7 is a summary and conclusion.

1. THE CORE REAL BUSINESS CYCLE MODEL

The core monopolistically competitive real business cycle model is presented in four subsections below: First, the representative household's optimal lifetime consumption plan is derived, given its lifetime income prospects and the real rate of interest. Second, household labor supply is derived. Third, employment and income are determined, taking account of the representative household's choice of labor supply, firm profit maximization, and the economy's production technology. Fourth, the real interest rate is determined, emphasizing its role in clearing the economy-wide credit market and in coordinating aggregate demand and supply.

Household Consumption[5]

The economy is populated by households that live for two periods, the present and the future.[6] Households have lifetime income prospects (y_1, y_2) and access to a credit market where they can borrow and lend at a real rate of interest r. A household chooses its lifetime consumption plan (c_1, c_2) given its income prospects and the real rate of interest to maximize lifetime utility subject to its lifetime budget constraint

$$c_2 = -(1+r)c_1 + (1+r)x \tag{1}$$

where $x = y_1 + \frac{y_2}{1+r}$ is the present (period 1) discounted value of lifetime income prospects.

A household obtains utility from lifetime consumption according to

$$U(c_1, c_2) = u(c_1) + \frac{1}{1+\rho}u(c_2) \tag{2}$$

where $u(c_1)$ is utility from consumption in the present, $u(c_2)$ is utility from future consumption, $U(c_1, c_2)$ is the present discounted value of lifetime utility from consumption, and $\rho > 0$ is a constant psychological rate of time discount. For concreteness we work with log utility: $u(c) = \log c$, so that $u'(c) = 1/c$.

To maximize lifetime utility the household chooses its lifetime consumption plan (c_1, c_2) so that

$$(1+r) = (1+\rho)\frac{c_2}{c_1} \tag{3}$$

where the household's choices for $c_1$and c_2 exhaust its lifetime budget constraint (1).[7] Below we see how lifetime income prospects are determined and how the real interest rate adjusts to reconcile desired aggregate household consumption with aggregate output.

Household Labor Supply

The representative household must also choose how to allocate its time to work and leisure. In deciding how much to work, a household takes the real hourly wage in terms of consumption goods w as given in the labor market.

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[5] Fisher (1930) and Friedman (1957) pioneered the theory of household consumption.

[6] As will become clear below, it is not necessary to specify the length of the two periods in order to explain the mechanics of the forward-looking benchmark NNS model and its implications for monetary policy. The features of the NNS model highlighted here are qualitatively consistent with those of a fully dynamic version of the model specified as a system of difference equations connecting periods of relatively short duration.

[7] To maximize lifetime utility, a household must choose c_1 and c_2 so that what it requires in future consumption to forgo one more unit of current consumption, $(1+\rho)\frac{c_2}{c_1}$, equals the interest rate, $1+r$, at which it can transform a unit of current consumption into future consumption by lending.

The household has a time budget constraint

$$l + n = 1 \tag{4}$$

where l is time allocated to leisure, n is time allocated to work, and the amount of time per period is normalized to 1. A household gets utility directly from leisure. Leisure taken in the present and the future contributes to lifetime utility as does consumption. Again we work with log utility so that utility from leisure is given by $v(l) = \log l$ and $v'(l) = 1/l$.

The allocation of time in a given period that maximizes the household's utility is the one for which the marginal utility earned directly by taking leisure equals the marginal utility earned indirectly by working

$$1/l = w/c. \tag{5}$$

Using time constraint (4) to eliminate leisure l in (5) we can express the household's willingness to supply labor n^s as a function of household consumption c and the real wage w

$$n^s = 1 - \frac{c}{w}. \tag{6}$$

Household labor supply (6) has three important features. First, holding the wage w constant, household labor supply is inversely related to household consumption. This makes sense because if the household is able to consume more goods, say, because its lifetime income prospects have improved, then it will wish to consume more leisure as well. Second, holding consumption fixed, labor supply varies directly with the real wage. This also makes sense because, other things the same, a higher hourly wage increases the opportunity cost of leisure and makes work more attractive. Third, if both consumption and the real wage rise equiproportionally, then the effects on labor supply are exactly offsetting. We see below that this last feature of labor supply is important to account for some aspects of long-run economic growth.

Firms, Employment, and Output

There are a large number of firms in the economy, each producing a different variety of consumption goods. Because their products are somewhat different, firms are monopolistically competitive. Each firm has enough pricing power in the market for its own output that it can sustain a price somewhat above the marginal cost of production. Firms face a constant elastic demand for their products, which means that the profit maximizing markup of price over marginal cost is a constant $\mu^* > 1$, invariant to shifts in demand or in the cost of production.[8] For the remainder of Section 1, we assume that firms adjust their prices flexibly to maintain the constant profit maximizing markup μ^* at

[8] This point can be verified with a little algebra.

all times. The demand for all varieties of goods is symmetric, so consumption is treated as a single composite good.

Firms produce consumption goods c from labor input n according to the production technology

$$c = a \cdot n \tag{7}$$

where a is labor productivity per hour in units of consumption goods. Productivity a fluctuates and grows over time with technological progress.

The markup of price over the marginal cost of production is defined as

$$\mu = \frac{P}{MC} \tag{8}$$

where P is the dollar price of a unit of consumption goods, and MC is the cost in dollars of producing a unit of consumption goods. According to production technology (7), $1/a$ hours of work is needed to produce a unit of c. If the hourly wage is W dollars, then the marginal cost in dollars (unit labor cost) of producing a unit of consumption goods is W/a. Substituting for MC in the definition of the markup and rearranging yields

$$\mu = \frac{a}{W/P} = \frac{a}{w} \tag{9}$$

where w is the real wage.

Note that (9) uses only the production technology and the definition of the markup to express the markup μ in terms of productivity a and the real wage w. We see immediately from (9) that the equilibrium real wage w^* is determined as

$$w^* = a/\mu^*. \tag{10}$$

If firms adjust their product prices to maintain markup constancy, the real wage grows and fluctuates only with productivity a. Since the profit maximizing markup exceeds unity, $\mu^* > 1$, the real wage is less than labor productivity $w^* < a$. Firms are content to stop hiring before bidding the real wage up to the marginal product of labor because they maximize monopoly profit by restricting their own output somewhat.

To determine equilibrium employment n^*, use (7) and (10) to substitute for c and w in labor supply function (6)

$$n^s = 1 - \frac{a \cdot n}{a/\mu^*} \tag{11}$$

and equate desired labor supply n^s to labor utilized by firms n to find equilibrium employment n^*

$$n^* = \frac{1}{1+\mu^*}. \tag{12}$$

Notice that equilibrium employment n^* depends only on the profit maximizing markup μ^* and not on productivity a. The reason is that productivity a affects consumption c and the real wage w proportionally given hours worked n, so that the productivity effects operating through consumption and the real wage in labor supply function (6) are exactly offsetting. This feature of the core RBC model is necessary to account for some fundamental facts about long-run economic growth. For instance, labor productivity in the U.S. economy has grown by more than 2 percent per year for over 100 years; and output and the real wage have both grown at roughly the same rate. Yet the fraction of time allocated to work has changed relatively little during that same period.[9]

Equilibrium output c^* is determined from production technology (7) and equilibrium employment (12) as

$$c^* = a \cdot \frac{1}{1+\mu^*} \tag{13}$$

where output c^* grows and fluctuates proportionally with productivity a.

The Real Interest Rate: Coordinating Demand with Supply[10]

To complete our understanding of the core RBC model, we must check that households have sufficient income to purchase all the consumption goods that firms produce each period *and* that households can be induced to choose a lifetime consumption plan that matches the current and future production of consumption goods. The real interest rate plays the central role in aligning the demand and supply of consumption goods over time.

Households have two sources of income. First, there is wage income which equals the real wage multiplied by hours worked, wn. Second, there is profit income which equals firms' revenue from sales minus the wage bill, $an - wn$. Profits are positive because $w < a$. Since households own the firms, total household income each period is the sum of wage income and profit income $wn + (an - wn) = an$, which is exactly the value of consumption goods produced and sold each period. Thus, households do indeed earn enough income each period to buy the goods produced in each period. It follows that the lifetime consumption plan (c_1, c_2) that matches the current and future supply of consumption goods given by (13), $c_1^* = a_1 \cdot \frac{1}{1+\mu^*}$ and $c_2^* = a_2 \cdot \frac{1}{1+\mu^*}$, also satisfies the lifetime budget constraint (1).

The real interest rate r^* that makes desired lifetime consumption match the intertemporal supply of consumption goods is found by substituting the

[9] Romer (1989).
[10] Fisher (1930).

current and future supply of consumption goods (c_1^*, c_2^*) into condition (3)

$$(1 + r^*) = (1 + \rho)\frac{a_2 \cdot \frac{1}{1+\mu^*}}{a_1 \cdot \frac{1}{1+\mu^*}} = (1 + \rho)\frac{a_2}{a_1} \tag{14}$$

where we see that the equilibrium real interest rate r^* varies directly with the growth of labor productivity, $\frac{a_2}{a_1}$.

One can understand the determination of the real interest rate as follows: When productivity is stagnant ($a_1 = a_2$), households are satisfied with a flat lifetime consumption plan as long as the real interest rate equals the psychological rate of time preference ($r^* = \rho$). In that case, the return to lending exactly offsets the preference for consuming in the present. On the other hand, if future productivity is expected to be higher than current productivity ($a_1 < a_2$), then households want to borrow against their brighter future income prospects to bring some consumption forward in time. In the aggregate, however, households cannot do so because the future productivity has not yet arrived. As households try to borrow against the future, they drive the real interest rate up to the point where they are satisfied with the steeply sloped consumption plan that matches the growth of productivity. The equilibrium real interest rate clears the economy-wide credit market by making the representative household neither a borrower nor a lender. In so doing, the equilibrium real interest rate also clears the economy-wide goods market by inducing the representative household to spend its current income exactly.

2. THE NEW NEOCLASSICAL SYNTHESIS

The new neoclassical synthesis (NNS) builds on the core real business cycle (RBC) model to provide an understanding of fluctuations in employment and inflation and a framework for thinking about monetary policy. The main departure is that firms do not adjust their product prices flexibly in the NNS model to maintain a constant profit maximizing markup. Consequently, the markup fluctuates in response to shocks to aggregate demand and productivity. The remainder of Section 2 explains why markup variability is central to fluctuations in inflation and employment in the benchmark NNS model. Section 3 discusses how monetary policy exerts its leverage over employment and inflation through the markup. Section 4 considers various shocks in the NNS model and explains how interest rate policy actions can counteract them. The recommendations for monetary policy implied by the benchmark NNS model are spelled out in Section 5.

Firm Pricing Practices, Inflation, and the Markup

It is costly for a firm producing a differentiated product to determine the price that maximizes its profits at each point in time. Pricing requires information

on a firm's own demand and cost conditions that is costly to obtain. Moreover, that information needs to be assessed and processed collectively by top management. Management must prioritize pricing decisions relative to other pressing concerns, so pricing decisions get the attention of management only every so often.[11] Hence, a firm considers whether to change its product price only when demand or cost conditions are expected to move the actual markup significantly and persistently away from the profit maximizing markup. For instance, if higher nominal wages W, or lower productivity a were expected to compress the markup significantly and persistently, then it would be in the firm's interest to consider raising its product price to restore the profit maximizing markup.

These points can be summarized in four pricing principles:

1) Firms would like to keep their actual markup μ as close to the profit maximizing markup μ^* as they can over time, subject to the cost of changing their product prices.

2) Firms must balance the one-time cost of changing prices against the benefit of staying close to the profit maximizing markup over time.

3) A firm is more apt to change its product price to restore the profit maximizing markup the larger and more persistent it expects a deviation of its actual markup from the profit maximizing markup to be.

4) Firms move their prices with expected inflation on average over time.

The implications of these pricing principles for the economy-wide rate of inflation π may be summarized as follows:

$$\pi = INF(\mu_1, E\mu_2) + E\pi \tag{15}$$

where $E\pi$ is the expected trend rate of inflation, and $INF(\mu_1, \mu_2)$ is a function indicating the effect of the current and expected future markup on inflation.[12] When the current and expected future markup both equal the profit maximizing markup, then firms move their prices in accordance with expected trend inflation $E\pi$, i.e., $INF(\mu^*, \mu^*) = 0$. Markup compression ($\mu < \mu^*$) moves actual inflation above trend inflation, and markup expansion ($\mu > \mu^*$) moves actual inflation below trend inflation.

We characterize increasingly inflationary situations as follows:

A) Absolute Price Stability: $\mu_1 = E\mu_2 = \mu^*, E\pi = 0$. Current and expected future markups equal the profit maximizing markup, and expected trend inflation is zero.

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[11] Calvo (1983) models price stickiness by assuming that a firm gets opportunities to change its price on a stochastic basis; this accords with the description of price-setting given here.

[12] Calvo's (1983) pricing model yields a forward-looking inflation process approximately like (15). See the discussions and derivations in Clarida, Gali, and Gertler (1999), Gali and Gertler (1999), Goodfriend and King (1997, 2001), and Taylor (1999).

B) Low Inflation Potential: $\mu_1 < \mu^*, E\mu_2 = \mu^*, E\pi = 0$. Current markup is compressed relative to the profit maximizing markup, but the expected future markup is not, and expected trend inflation is still zero.

C) Modest Inflation Potential: $\mu_1 < \mu^*, E\mu_2 < \mu^*, E\pi = 0$. Markup compression is expected to persist, but expected trend inflation is still zero.

D) Persistent Trend Inflation: $\mu_1 = E\mu_2 = \mu^*, \pi = E\pi > 0$. Current and expected future markups are at their profit maximizing levels, but expected trend inflation is positive.

Employment Fluctuations and the Markup

Inflation today is reasonably low and stable in the United States and around the developed world. Hence, we consider the nature of employment fluctuations in the NNS model in terms of situations A and B above. In other words, we suppose that the current markup may be compressed or elevated relative to the profit maximizing markup, but firms do not expect that gap to persist for very long. And firms expect zero inflation. The central bank is said to have "credibility for zero inflation" in these situations. When the central bank has credibility for zero inflation, firms are disinclined to raise or lower their product prices in response to a shock to their current markup because they expect the markup shock to be temporary.[13] In such circumstances, the current price level P is nearly invariant to current shocks or current monetary policy actions.[14]

In this case current employment and output are determined by the aggregate demand for goods. The reason is two-fold. First, each firm faces a downward sloping demand for its particular variety of consumption good, and a firm can sell only as much as households wish to purchase at the going price. Second, firms are happy to produce and sell as much as households are willing to buy because labor productivity exceeds the real wage. Hence, holding product price constant, profits rise with employment, production, and sales. Since firms can't sell more than demand will allow and firms are happy to accommodate demand, aggregate demand governs output in the short run, and output governs employment given labor productivity.[15]

We can understand the determination of employment in the benchmark NNS model from either a Keynesian or a classical perspective. The Keynesian

[13] Markup shocks are expected to be transitory because monetary policy is expected to make them so. See Sections 4 and 5 below.

[14] The price level is nearly invariant to current economic conditions because firms *choose* not to adjust their product prices to maintain markup constancy. Firms *would* adjust their prices to restore markup constancy if they expected that *otherwise* their markups would deviate persistently and significantly from the profit maximizing markup. Prices are less flexible in the NNS model the more confident are firms that monetary policy will manage nominal cost conditions so as to maintain their profit maximizing markup without any price adjustments. Hence, credibility for low inflation reinforces price stickiness in the NNS model.

[15] Blanchard and Kiyotaki (1987).

transmission mechanism runs from aggregate demand to employment. The production technology $c = an$ shows how employment n depends on aggregate demand c and labor productivity a. Firms attract enough labor to meet demand given labor productivity by offering a nominal wage W sufficient to induce households to supply the required labor input. Since the price level P is nearly invariant to current economic conditions, the higher nominal wage raises the real wage w. According to labor supply function (6) given aggregate demand c, a higher real wage increases labor supply by raising the opportunity cost of leisure. When demand falls and firms need less labor, wages fall since enough labor supply is forthcoming at a lower real wage.

The classical perspective takes the view that actual employment n must equal labor willingly supplied by households n^s *regardless of the strength of aggregate demand*. Working in this direction, substitute $c = an$ and $w = a/\mu$ into labor supply function (6), equate n and n^s, and solve for employment to arrive at

$$n = \frac{1}{1+\mu}. \tag{16}$$

From the classical perspective, employment in the NNS model is determined inversely with the markup, exactly as in the core RBC model.[16] The only difference is that firms adjust their prices continually to maintain a constant profit maximizing markup μ^* in the flexible price RBC model and markup constancy stabilizes aggregate employment in that case. When circumstances are such that the price level P is sticky in the NNS model, however, the markup fluctuates with the real wage and labor productivity according to (9), and employment fluctuates as well according to (16).

Employment varies inversely with the markup in (16) because the markup drives a wedge between the price of consumption goods and the marginal cost of production. In effect, the markup is a percentage sales tax administered by firms, the proceeds of which are distributed as profits to households. As is the case for any tax, a higher tax rate reduces the supply of the good being taxed, and a lower tax rate expands the supply of that good. Hence, a compressed markup expands (and a higher markup contracts) the production and sale of consumption goods. Alternatively, recall from (9) that a higher markup means a lower real wage relative to labor productivity; so the markup also acts like a tax on labor supply because it drives the real wage below the marginal product of labor. Thus, the labor market perspective provides another way of understanding why employment fluctuates inversely with the markup. The classical perspective is compatible with the Keynesian perspective because the markup shrinks when the wage rises to attract more labor in order to accommodate an increase in aggregate demand.

[16] Rotemberg and Woodford (1999).

It is useful to sum up this way: In the flexible price RBC model firms neutralize the effect of aggregate demand and productivity shocks on aggregate employment by adjusting their prices to maintain markup constancy. The flexible price RBC model is classical in the sense that aggregate output is determined independently of aggregate demand. We saw in Section 1 that the real interest rate adjusts in the flexible price RBC model to make household demand for aggregate consumption *conform* to the aggregate supply of consumer goods. In the NNS model, fluctuations in aggregate demand can *induce* fluctuations in employment and output. In that sense the NNS model is Keynesian. But since the NNS model has the classical RBC model at its core, we call it the new neoclassical synthesis, recalling Paul Samuelson's designation for the original attempt to synthesize classical and Keynesian economics in the 1950s. Since firms maintain the profit maximizing markup on average over time in the NNS model, the NNS model behaves like the flexible price RBC model on average but with leeway for monetary policy to influence aggregate demand and stabilize employment and inflation.

3. INTEREST RATE POLICY, CREDIBILITY, AND INFLATION SCARES

As is common practice, assume that the central bank implements monetary policy in the NNS model with a short-term nominal interest rate policy instrument R. By definition, the real interest rate r is $R - E\pi$, the money interest rate paid or earned on a loan above and beyond the compensation for expected inflation. In practice, a central bank's influence over the real interest rate is limited for two reasons. It exercises direct control of only the nominal rate. Expected inflation is variable, possibly highly variable if the central bank has little credibility for low inflation, so control of the nominal interest rate translates loosely into control of the real interest rate. Moreover, longer-term interest rates are what matter for economic activity, and a central bank influences long-term interest rates only indirectly via the management of its short-term nominal interest rate policy instrument. We ignore these important complications to focus on the essence of interest rate policy in what follows.

In order to understand the mechanism through which interest rate policy actions are transmitted to the economy, we must first specify the *context* in which policy is acting. Continue to assume that the central bank has credibility for zero inflation so that $E\pi = 0$ and the price level P is nearly invariant to current shocks and interest rate policy actions. In this case the central bank's choice of nominal interest rate target $\overline{R}$ translates into a target for the real interest rate $\overline{r}$. Moreover, in this case the public expects the future markup to be at its profit maximizing level $E\mu_2 = \mu^*$. Recall that current and future productivity (a_1, a_2) are given by technology, independently of interest rate

policy. In this context, (13) says that expected future household consumption is *anchored by future income prospects* at $c_2^* = a_2 \frac{1}{1+\mu^*}$.

In order to trace the effect of an interest rate policy action on current macroeconomic variables, use (3) to express current desired consumption c_1 in terms of expected future consumption $c_2^* = a_2 \frac{1}{1+\mu^*}$ and the real interest rate target $\bar{r}$

$$c_1 = \frac{1+\rho}{1+\bar{r}} \cdot a_2 \frac{1}{1+\mu^*}. \tag{17}$$

Expression (17) reveals the nature of the leverage that interest rate policy exerts on aggregate demand: Current consumption c_1 is inversely related to the real interest rate target $\bar{r}$ when expected future consumption is anchored at $a_2 \frac{1}{1+\mu^*}$. An increase in the real interest rate target depresses current aggregate demand by raising the opportunity cost of current consumption in terms of future consumption. The contraction in aggregate demand is reflected in reduced current employment n_1, a low current real wage w_1, and an elevated current markup μ_1. Conversely, a cut in the real interest rate target expands current aggregate demand, raises the real wage, and compresses the markup. The transmission mechanism can be understood from either the Keynesian or the classical point of view. From the Keynesian perspective, interest rate policy exerts leverage over employment and output because production is demand determined in the short run. From the classical perspective, that leverage derives from the fact that aggregate demand influences wages, which in turn influence the markup, which behaves like a variable tax rate in the RBC setting.

The leverage that interest rate policy actions exert on employment creates the *fundamental credibility problem of monetary policy*. The credibility problem arises from a basic tension in the new neoclassical synthesis. On one hand, firms set their prices so as to maintain a profit maximizing markup on average over time. From the household's point of view, however, the markup acts like a tax on consumption and labor supply that reduces welfare. Therefore, the central bank has an incentive to pursue expansionary monetary policy on behalf of households to undo the markup tax. That temptation is greatest when the central bank's credibility for low inflation is *most* secure, since then employment can be expanded with little immediate increase in inflation or inflation expectations. The problem is that by giving in to this temptation the central bank undercuts its own credibility. If firms come to expect the markup to be compressed persistently, they will raise prices to restore the profit maximizing markup. Inflation and inflation expectations will rise, and the central bank will lose credibility for low inflation. In short, credibility for low inflation is fundamentally fragile in the new neoclassical synthesis because the public recognizes the central bank's temptation to pursue expansionary monetary policy to depress the markup and expand employment.[17]

[17] Barro and Gordon (1983), Chari, Kehoe, and Prescott (1989), and Sargent (1986) discuss credibility issues in models other than those of the new neoclassical synthesis.

From time to time the public comes to doubt the central bank's commitment to low inflation. The history of monetary policy in the United States contains numerous "inflation scares" marked by sharply rising long-term bond rates reflecting increased expected inflation premia.[18] Inflation scares create a fundamental dilemma for monetary policy. At the initial nominal interest rate target $\overline{R}$, expected higher inflation lowers the implied real interest rate target $\overline{r} = \overline{R} - E\pi$ and exacerbates the inflation scare by stimulating current demand and compressing the markup. The central bank could raise $\overline{R}$ just enough to offset the effect of expected higher inflation on the real rate. However, neutralizing the effect of higher inflation expectations on the real interest rate target does nothing to fight the collapse of credibility itself.

If the inflation scare persists, a central bank must react by raising its real interest rate target. That is, the central bank must raise $\overline{R}$ by *more* than the increase in $E\pi$. A higher real interest rate target counteracts the inflation scare by contracting current aggregate demand, reducing employment, lowering real wages, and widening the markup. According to (15), tight monetary policy works by elevating the current and expected future markup significantly above the profit maximizing markup. In the contractionary environment, firms move prices up more slowly than expected inflation, and expected inflation comes down as credibility for low inflation is restored.

Inflation scares are costly because ignoring them or raising $\overline{R}$ only enough to cover the increase in $E\pi$ can encourage even more doubt about the central bank's commitment to low inflation. But raising $\overline{r}$ to restore credibility for low inflation only works by contracting employment, output, and consumption to widen the markup significantly and persistently enough to encourage firms to slow the rate of inflation. For this reason, central banks have been reluctant to react promptly to inflation scares. In the past such hesitation led to "stagflation," when rising inflation encouraged by insufficiently preemptive policy would eventually be accompanied by a period of rising unemployment after the central bank set out to restore its credibility for low inflation.

4. FLUCTUATIONS AND STABILIZATION POLICY

In this section we consider three shocks that cause fluctuations in employment and output because firms choose not to adjust prices to maintain markup constancy. Again we assume that the central bank has credibility for low inflation. Inflationary situations A or B prevail, there are no inflation scares, and the current price level P is nearly invariant to current economic shocks and interest rate policy actions. We consider the effects of optimism or pessimism about future income prospects, a temporary productivity shock, and a shift in trend

[18] See Goodfriend (1993) and Chari, Christiano, and Eichenbaum (1998).

productivity growth. In each case we trace the effect of the shock holding the central bank's real interest rate target fixed, then we consider how interest rate policy might react to stabilize employment and inflation.

Optimism and Pessimism about Future Income Prospects

According to the analysis of consumption in Section 1, a household plans lifetime consumption to satisfy (3) and to exhaust its lifetime budget constraint (1). Using these two conditions, we can write current aggregate demand c_1 in terms of lifetime income prospects (y_1, y_2) and the central bank's real interest rate setting $\bar{r}$

$$c_1 = \frac{1+\rho}{2+\rho}(y_1 + \frac{y_2}{1+\bar{r}}). \tag{18}$$

Since current output and income are demand determined when the price level P is nearly invariant to current shocks and policy actions, we can set $y_1 = c_1$ in (18) and solve for c_1 in terms of y_2 and $\bar{r}$

$$c_1 = \frac{1+\rho}{1+\bar{r}} \cdot y_2. \tag{19}$$

According to (19), households transmit increased *optimism or pessimism* about future income prospects y_2 (whether in future wage or profit income) to current consumption, employment, and output. The reason is that households want to allocate any expected change in lifetime resources to both current and future consumption. Moreover, because current income is demand determined, there is a secondary (multiplier) effect on current income that amplifies the initial impact of increased optimism or pessimism about the future. Both the primary and secondary effects are captured in (19).

Although households react to increased optimism or pessimism by attempting to borrow or lend in the credit market, ultimately any change in current aggregate demand must be reflected in an equal change in current production. Collectively, households cannot borrow from the future to consume more in the present because it is impossible to bring goods forward in time. Nor is it possible to store goods for future consumption in this benchmark NNS model. However, the real interest rate does not react to conditions in the credit market because the central bank intervenes by injecting or draining cash to maintain its nominal interest rate target $\bar{R}$. In so doing, interest rate policy actually facilitates the transmission of optimism or pessimism about the future to current employment and output.

In principle, interest rate policy can counteract the effect on current employment and output of increased optimism or pessimism about the future. For instance, according to (19), a lower real interest rate target $\bar{r}$ can stabilize current consumption, employment, and output against increased pessimism about future income prospects. At best, however, stabilization policy can only

be partially effective because it is difficult to recognize shocks promptly and because policy actions affect spending with a lag.

A Temporary Productivity Shock

Aggregate productivity grows on average over time as a result of technological progress. However, productivity growth fluctuates over time because the invention and implementation of technological improvements do not occur smoothly. We can think of a temporary shock to productivity as involving a period in which productivity grows more rapidly or more slowly than its long-run average, but is expected to return shortly to its long-run growth path. To analyze the effect of a temporary productivity shock in the benchmark NNS model, we abstract from trend productivity growth and consider a shortfall of current productivity a_1 with no effect on expected future productivity a_2.

The adverse shock to current productivity expected to be temporary has little effect on lifetime income prospects and, therefore, on current aggregate demand. Hence, the negative productivity shock causes firms to hire more labor to meet the initial demand. Real wages rise as firms bid for more labor. Household wage income rises at the expense of profit income, but aggregate real income remains largely unchanged.

The markup is compressed directly because lower productivity raises marginal cost and indirectly because the real wage is elevated. Firms are inclined to raise prices to restore the profit maximizing markup, but the price level does not change much if the negative productivity shock is not too large and is expected to be temporary.

Again the central bank can stabilize employment and inflation fully, in principle. According to (14) and (17), it does so by raising the real interest rate to contract current aggregate demand enough to stabilize the current markup at μ^*. When the markup is stabilized, current output, income, consumption, and the real wage all fall proportionally with productivity.

A Shift in Trend Productivity Growth

To understand the effect of shifting trend growth, suppose that current and future productivity are related by $a_2 = (1+g)\cdot a_1$, where g is the trend growth rate, and current productivity a_1 is taken as given. Assume that interest rate policy is expected to keep the actual markup at the profit maximizing markup in the future so that $\mu_2 = \mu^*$. In this case, future income prospects vary directly with the growth rate g since $y_2 = (1+g)a_1\frac{1}{1+\mu^*}$.

Shifting trend productivity growth affects current variables in the same way as changing optimism or pessimism about future income prospects. Substituting the above expression for y_2 into (19), we see that for a given real interest rate target $\bar{r}$, current aggregate demand, output, and employment all

move in the same direction as the trend growth rate g. For instance, an increase in trend growth raises current aggregate demand, raises current labor demand, raises the real wage, and compresses the markup. Contrary to popular belief, an increase in trend productivity growth is inflationary at the initial real interest rate target because it compresses the current markup.

According to (14) the central bank can stabilize the current markup, employment, and inflation against a shift in trend productivity growth by moving its real interest rate target point for percentage point with the growth rate g. To see this, substitute $(1 + g)a_1$ for a_2 in (14) and note that $r^* \cong \rho + g$.[19] Higher trend growth requires a higher real interest rate target to give households an incentive not to consume the proceeds prematurely. Instead of providing a reason to keep interest rates low, higher trend productivity growth actually requires a higher real interest rate target on average over time to stabilize the markup and maintain credibility for low inflation.

5. WELFARE MAXIMIZING MONETARY POLICY

The benchmark NNS model presented here recommends that interest rate policy should stabilize the markup at its profit maximizing level in order to stabilize the price level and make employment and output behave as in the core RBC model with perfectly flexible prices. The recommended policy is referred to as "neutral" because it stabilizes the price level, neutralizes fluctuations in employment and output that would otherwise occur due to sticky prices, and makes aggregate demand conform to fluctuations in productivity as in a pure real business cycle.

Neutral monetary policy is recommended because it maximizes household welfare.[20] This can be understood in four steps:

1) The central bank can only stabilize the markup at the value that maximizes firm profits μ^*. Firm price adjustments will undo any attempt by the central bank to move the markup permanently away from μ^*.

2) It is feasible for monetary policy to stabilize the markup at μ^*. Interest rate policy can do so by making aggregate demand c conform to movements in productivity a given the production technology $c = an$ so as to stabilize employment at $n^* = \frac{1}{1+\mu^*}$.

3) Household labor supply n^s is invariant to productivity a when the markup is stabilized at its profit maximizing value μ^*. A greater abundance of consumption makes households want to take more leisure, but a higher real wage raises the opportunity cost of leisure just enough to neutralize the overall effect of productivity on desired labor supply. Thus, household

[19] The approximate one-for-one correspondence is an implication of log utility.

[20] Goodfriend and King (1997, 2001), Ireland (1996), and Woodford (2003).

welfare is maximized when consumption moves with productivity at the profit maximizing markup.

4) Household welfare would be reduced if monetary policy were to allow the markup μ to fluctuate around the profit maximizing markup μ^*. It is true that households would be better off in periods when the markup tax is low. But the markup tax would have to average as much time above as below μ^* to be consistent with firm profit maximization on average over time. With diminishing marginal utility, the utility gain from above average consumption and leisure would be insufficient to offset the utility loss from below average consumption and leisure. Among other things, such logic means that interest rate policy would reduce welfare if it moved the markup to smooth consumption against productivity shocks.

The key characteristics of neutral monetary policy are these:

First, neutral policy stabilizes employment at the "natural rate," $n^* = \frac{1}{1+\mu^*}$.[21] In effect, neutral policy enables the macroeconomy to operate as if firms adjusted their prices costlessly and continuously to maintain the profit maximizing markup at all times.

Second, when employment is stabilized at the natural rate n^*, actual output moves with "potential output" $y^* = an^*$, where potential output grows and fluctuates over time with productivity a. In other words, neutral policy aims to eliminate the "output gap," the difference between actual and potential output.

Third, the consistent pursuit of neutral policy perpetuates low inflation according to (15) if the central bank has already attained credibility for low inflation by its past policy actions.

Fourth, low inflation confers a number of benefits in addition to its consistency with neutral policy.[22] For instance, low inflation produces low nominal interest rates and less economization on the use of currency; low inflation minimizes costly pricing decisions; low inflation minimizes relative price distortions; and low inflation guards against disruptive inflation scares.

Fifth, a central bank can implement neutral policy by maintaining price stability. There is no need to target the profit maximizing markup directly in practice. The reason is that an economy in which firms show little inclination to raise or lower prices on average is one in which the profit maximizing markup is realized on average.

Sixth, price stability can be maintained by consistently raising the real interest rate target to preempt inflation and lowering it to preempt deflation. In practice, interest rate policy should utilize measures of the output gap, employment relative to the natural rate, and unit labor costs to help recognize and preempt potential departures from price stability.[23]

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[21] Friedman (1968).

[22] Khan, King, and Wolman (2003).

[23] McCallum (1999).

Seventh, according to (14) the real interest rate target $\bar{r}$ that consistently achieves price stability shadows the real interest rate r^* that supports pure real business cycles. Price stability must be maintained by activist interest rate policy that makes aggregate demand conform to potential output to keep $\mu = \mu^*$, and makes the real interest rate move with expected productivity growth a_2/a_1.

Eighth, an inflation target facilitates the implementation of neutral monetary policy in three ways.[24] An inflation target mandated by the legislature helps secure credibility for low inflation against the temptation to stimulate employment excessively. A mandated target for low inflation reduces the incidence of destabilizing inflation or deflation scares. And an inflation target enables the central bank to cut its interest rate instrument more aggressively to stimulate economic activity when necessary without fear of an inflation scare.

6. CHALLENGES TO THE POLICY RECOMMENDATIONS

According to the benchmark NNS model, credible price stability keeps output at its potential and employment at its natural rate. So from this perspective even those who care mainly about output and employment can support strict inflation targeting. Yet the *benchmark* NNS model presented in this paper is only one of many possible specifications of the new synthesis model. Taking other features of the macroeconomy into account might overturn the strong implication that price stability is always welfare-maximizing monetary policy. The purpose of this section is to consider briefly three additional aspects of the macroeconomy and whether they call for optimal departures from strict inflation targeting.[25]

Nominal Wage Stickiness

Empirical studies of wage and price dynamics suggest that nominal wages exhibit about the same degree of temporary rigidity as do nominal prices.[26] Yet, nominal wages are perfectly flexible in the benchmark NNS model and are determined in perfectly competitive labor markets. So it is worth asking to what extent nominal wage stickiness might overturn the strict inflation targeting policy prescription. Consider a temporary adverse productivity shock. With flexible nominal wages, stabilization of the markup and the price level

[24] Bernanke, Laubach, Mishkin, and Posen (1999), Haldane (1995), Leiderman and Svensson (1995), and Svensson (1999).

[25] Goodfriend and King (2001) consider a number of reasons to depart from perfect markup constancy and price stability in an NNS model: fully dynamic multi-period pricing, distortions involving monetized exchange, variable labor supply elasticities, and government spending shocks. They argue that optimal departures arising from these sources are likely to be quantitatively minor.

[26] Taylor (1999).

calls for aggregate demand to contract proportionally with productivity. At the optimum, employment is unchanged because the markup is perfectly stabilized. The nominal and the real wage both fall with productivity, exactly offsetting the effect of lower productivity on marginal cost and the markup. And the economy settles temporarily at the reduced potential output with a perfectly stabilized price level.

Things don't work out as neatly if nominal wages are sticky. In order to maintain price stability, monetary policy must now steer output *below* potential. Monetary policy must push employment below the natural rate to offset the adverse effect of lower productivity on marginal cost. This is possible because labor is more productive at the margin the less it is utilized, i.e., there is diminishing marginal physical product of labor.[27] In the presence of nominal wage stickiness it is no longer feasible for monetary policy to both stabilize the price level and keep output at potential. In principle, then, a negative productivity shock could present the central bank with a short-run tradeoff between price stability and output stability (relative to potential) when both nominal wages and prices are sticky. In general, such a tradeoff would call for a departure from strict inflation targeting.

There are two reasons, however, why such situations should be of relatively little concern in practice. First, an inflation target between 1 and 2 percent per year and trend productivity growth of around 2 percent produces average nominal wage growth in the 3 to 4 percent range. Such high average nominal wage growth should keep the economy safely away from situations in which significant downward nominal wage rigidity, as opposed to slower nominal wage growth, is required to keep price inflation on target and output at its potential.[28] If the economy were to suffer a protracted productivity growth slowdown, then the central bank could stick to its inflation target and maintain markup constancy by allowing slower nominal wage growth to match the slower productivity growth. Downward nominal wage stickiness should not present a problem in this case. Upward nominal wage stickiness would not cause problems either. If nominal wages were temporarily rigid upward in the face of a favorable productivity shock, then the central bank could stick to its inflation target by steering the economy temporarily above potential output.

Second, implicit or explicit long-term relationships govern most labor transactions in developed economies. For reasons analogous to those discussed in Section 2, it can be efficient for firms to fix nominal wages for a period of time and to consider wage changes only at discrete intervals. Yet it would be inefficient for either firms or workers to allow temporary nominal

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[27] Production technology (7) is specified as linear in labor for expositional purposes only. A more realistic specification such as $c = a(n)^{\alpha}$, $1>\alpha>0$, would exhibit diminishing marginal product of labor.

[28] Vinals (2001).

wage rigidity to upset the terms of otherwise efficient long-term relationships. And there is scope for firms and workers to neutralize the effect of wage stickiness since wages already resemble installment payments in the context of long-term relationships.[29] Hence, firms and workers could be expected to arrange future transactions to undo any effects of nominal wage stickiness.[30] If the price level is stabilized in the face of a negative productivity shock, those firms whose nominal wage is temporarily sticky will appear to pay an excessive real wage. However, this logic suggests that non-adjusting firms record a "due from" to be transferred from workers to the firm in the future. In this way, "effective" real wages fall as much for firms that do not adjust their nominal wages as for those firms that do adjust. To the extent that such behavior is widespread, there is little reason to depart from strict inflation targeting because nominal wages are sticky.[31]

From this perspective the consequences for monetary policy of stickiness in wages and prices are sharply different. We can expect firms and workers to *neutralize* the allocative consequences of temporarily sticky nominal wages in the context of long-term relationships in the labor market. But spot transactions predominate in product markets. There, temporarily sticky prices can cause the average markup to fluctuate significantly and persistently over time with adverse consequences for employment and inflation. The adverse consequences of temporarily sticky product prices need to be eliminated by *neutral monetary policy* that supports price stability.

Extreme Asset Price Fluctuations

Some analysts suggest that interest rate policy should react directly to asset prices in order to preempt extreme fluctuations such as those experienced in Japan and the United States in recent years.[32] They would urge a central bank to take such action even if it has full credibility for low inflation. Such advice amounts to a recommendation to risk recession or deflation in order to preempt what *may* become an unsustainable increase in asset prices. It is certainly debatable whether that risk would ever be worth taking.

The main problem with this recommendation, however, is that it is virtually impossible to put into practice.[33] The reason boils down to this: When asset prices *first* appear to be surprisingly elevated, the central bank is disinclined to react directly to them because asset prices are not yet so high as to be

[29] Hall (1999).

[30] Barro (1977).

[31] Goodfriend and King (2001).

[32] Interest rate policy ordinarily takes indirect account of asset prices in so far as they help forecast aggregate demand.

[33] Bernanke and Gertler (1999), Goodfriend (2003), and Greenspan (2002).

clearly unsustainable. However, interest rate policy cannot react aggressively to asset prices *after* they become clearly unsustainable either. At that point a collapse of asset prices itself, even without a tightening of policy, could put the economy into recession. The best way to handle extreme fluctuations in asset prices is to make sure that supervisory and regulatory safeguards are in place to prevent a precipitous asset price correction from immobilizing financial institutions and markets, and to make sure that monetary policy is sufficiently sensitive to the risk of recession and deflation after a correction takes place.

The Zero Bound on Interest Rate Policy

This potential challenge to strict low inflation targeting stems from the fact that nominal interest rates cannot go below zero because neither banks nor the public will lend money at negative nominal interest when bank reserves and currency are costless to carry over time. The zero bound on nominal interest is a potential problem for monetary policy in a low inflation environment for two main reasons. First, if expected inflation is nearly zero, then the central bank cannot make *real* short-term interest negative if need be to fight deflationary shocks. Second, when short-term nominal rates are zero, further disinflation *raises* real short-term interest rates and worsens the deflationary pressure.

One could keep nominal short-term interest rates safely away from zero by targeting inflation at 3 or 4 percent per annum; but that would mean accepting the costs of excessive inflation forever. Moreover, such a high inflation target would invite credibility problems. An inflation target between 1 and 2 percent is a good compromise. Inflation is kept low, but far enough from zero to avoid deflation. One could conceivably raise the inflation target temporarily whenever more leeway for negative real interest was thought necessary to fight a recession. However, a policy that resorted to higher inflation in such circumstances would cause inflation expectations to rise whenever the economy weakened. Variable inflation expectations would be difficult to manage. Inflation scares would again become a significant source of shocks to the economy. Strictly targeting inflation between 1 and 2 percent could firmly anchor expected inflation and *still* give a central bank leeway to push the real short-term rate 1 to 2 percentage points below zero. Evidence from U.S. monetary history suggests that such leeway would be enough to enable a central bank to preempt deflation and stabilize the economy against most adverse shocks.[34] Moreover, other effective monetary policy options are available if short-term nominal rates become immobilized at the zero bound.[35]

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[34] Reifschneider and Williams (2000) and Vinals (2001).

[35] Goodfriend (2000) and McCallum (2000).

7. CONCLUSION

Economists and central bankers will surely make further progress on the theory and practice of monetary policy in the future. Nevertheless, it seems clear that price stability will continue to be regarded as the foundation of good monetary policy. For almost two decades low and relatively stable inflation around the world has proved its worth. In the United States the period included the two longest peacetime cyclical expansions and two mild recessions in 1990–91 and in 2001. The benchmark new neoclassical synthesis model provides a theoretical case for price stability that supports the practical case derived from experience. Theory reinforces practice and strengthens the view that price stability should be a priority for monetary policy.

The benchmark NNS model explains why price stability works well, and why price stability is desirable from the perspective of household welfare. A credible commitment to low inflation prevents inflation or deflation scares that are destabilizing for both output and prices. Price stability is welfare-maximizing monetary policy because it anchors the markup at its profit maximizing value and thereby prevents fluctuations in employment and output that would otherwise occur due to sticky prices.

As an operational matter we saw how interest rate policy actions work to implement price stability by stabilizing the markup, and how interest rate policy secures credibility for low inflation. By anchoring *expected future* inflation we saw how such credibility strengthens the leverage that interest rate policy exerts over *current* aggregate demand. In so doing, credibility for low inflation helps monetary policy make aggregate demand conform to movements in potential output.

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