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The Case for Price Stability

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Abstract

Reasoning within the New Neoclassical Synthesis (NNS) we previously recommended that price stability should be the primary objective of monetary policy. We called this a *neutral* policy because it keeps output at its potential, defined as the outcome of an imperfectly competitive real business cycle model with a constant markup of price over marginal cost. We explore the foundations of neutral policy more fully in this paper. Using the principles of public finance, we derive conditions under which markup constancy is optimal monetary policy.

Price stability as the primary policy objective has been criticized on a number of grounds which we evaluate in this paper. We show that observed inflation persistence in U.S. time series is consistent with the absence of structural inflation stickiness as is the case in the benchmark NNS economy. We consider reasons why monetary policy might depart from markup constancy and price stability, but we argue that optimal departures are likely to be minor. Finally, we argue that the presence of nominal wage stickiness in labor markets does not undermine the case for neutral policy and price stability.

1. Introduction

Building on new classical macroeconomics and real business cycle (RBC) analysis, macroeconomic models of the New Neoclassical Synthesis (NNS) incorporate intertemporal optimization and rational expectations into dynamic macroeconomic models. Building on New Keynesian economics, the new synthesis models incorporate imperfect competition and costly price adjustment. Like the RBC program, the New Neoclassical Synthesis seeks to develop quantitative models of economic fluctuations.

The combination of rational forward-looking price setting, monopolistic competition, and RBC components in benchmark NNS models provides considerable guidance for monetary policy, as we previously stressed in Goodfriend and King (1997).[1] Monetary policy must respect

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[1] We associate a broad range of models with the New Neoclassical Synthesis. Our view is that NNS models feature a) complete microeconomic foundations as in RBC economies, and b) imperfect competition and sticky prices as in New Keynesian economics. In our earlier paper we pointed out that

the RBC determinants of real economic activity on average over time. Even though output may be demand determined on a period-by-period basis due to monopolistic competition and sticky prices, output must be supply-determined on average. The NNS locates the transmission of monetary policy to real economic activity in its influence on the ratio of the average firm's price to its marginal cost of production, which we call the average markup. A monetary policy action which raises aggregate demand raises marginal cost and lowers the average markup. The lower markup works like a reduction in the tax rate on work effort in an RBC model to sustain an increase in output and employment.

There is little long run trade-off between inflation and real activity at low rates of inflation and a positive long run relationship at higher inflation. Moreover, the steady state markup is minimized at (near) zero inflation. Hence, reasoning within the New Neoclassical Synthesis we recommended making price stability the objective of monetary policy. We described stabilization of the price level path as a *neutral policy* because it keeps output at its potential, defined as the outcome of an imperfectly competitive RBC model so that potential output is plausibly far from constant through time as agents respond to productivity shocks and other disturbances. Neutral policy must be activist to manage aggregate demand in order to accommodate movements in potential output though time.

In our prior paper, we argued informally that the central bank should stabilize the price level for three reasons. First, markup constancy would make the real economy respond to shocks as if all prices were perfectly flexible. Second, markup constancy corresponds to tax smoothing in the public finance literature. Third, markup constancy is consistent with the traditional focus in macroeconomics on eliminating gaps between actual and potential output.

In this paper we explore the underpinnings of our recommendation for price stability, markup constancy, and neutral policy. We do so by exploiting the strengths of the New Neoclassical Synthesis more fully than we did in the last paper. The RBC core of NNS models allows us to bring the tools of general equilibrium welfare analysis to bear on the question of optimal monetary policy. Our strategy is to utilize procedures developed in the general equilibrium literature on optimal tax policy to evaluate conditions under which tax rates should be fully smoothed over states of nature and time. We then explore whether the markup should be fully smoothed across states of nature in a very simple NNS model. In this regard, we build on Ireland's (1996) analysis of an NNS model with preset prices and King and Wolman's (1999) analysis of a staggered pricing model. In general, perfect tax rate smoothing is not optimal in the public finance literature. Optimal state dependent tax rate policy will depend on the nature of the preferences and the shocks. However, in the macroeconomic context, tax rate smoothing turns out to be a relatively good approximation to the optimum.[2]

Section 2 develops the methodology for determining optimal tax policy in a purely real public finance framework and demonstrates the formal conditions for income tax rate smoothing.

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the benchmark NNS model, one in which prices are sticky but neither inflation nor nominal wages are sticky, provided particular guidance for monetary policy, namely, a case for price stability. In this paper, we explore in greater depth the strong case for price stability implied by the benchmark NNS model.

[2] Chari, Christiano, and Kehoe (1994) report that there is a quantitative presumption in a real business cycle model that optimal labor tax rates should be constant.

The presentation is in two parts. First, the conditions for optimal tax policy are derived for a small open economy. In addition to being of interest for those countries in this category, the first stage analysis allows us to introduce the principles of tax policy with the simplification that financial prices and wealth are stabilized by access to international financial markets. In a second step, optimal tax policy is characterized for a closed economy as is appropriate for largely closed economies such as the Euro area and the United States.

In Section 3, principles from public finance are utilized to derive optimal monetary policy within a simple NNS macromodel with non-storable output and only one-period price stickiness. This application formally illustrates the case for markup constancy and price level stability as an objective for monetary policy.

In Section 4 we exploit important features of the unabridged NNS model in order to develop more fully the argument for price stability. The structure of the complete NNS model – with storable output (capital) and staggered price setting –is laid out. The mechanics of the complete model are reviewed as a prelude to the analysis that follows.

Section 5 focuses on the nature of inflation dynamics in NNS models. An important feature of benchmark NNS models with staggered price setting is that although the price level is sticky, inflation is not: there is no inherent (structural) persistence to inflation in the model. The absence of structural inflation persistence is one reason why the pursuit of price stability is optimal in the basic NNS model: price stability always stabilizes output at its potential.

Yet U.S. macro data exhibit inflation persistence. If structural inflation persistence were a feature of actual price setting, then monetary policy would have to confront a short-run trade-off in inflation and output relative to its potential. Price stability would have to be sacrificed at times in order to stabilize output at its potential. Section 5 addresses this important empirical question. We show that an NNS model with flexible inflation can easily generate data that appear to exhibit inflation persistence as in U.S. macro data. We argue that inflation persistence in the U.S. results from the way that the Federal Reserve has pursued monetary policy, specifically how the central bank has allowed the markup to covary with inflation. After analyzing the problem in quantitative and statistical terms, Section 5 discusses features of Federal Reserve monetary policy that can plausibly explain inflation persistence in U.S. data.

In Section 6 we consider a number of reasons why perfect markup smoothing and price stability might not be optimal. But in doing so we argue that optimal departures from markup constancy and price stability are likely to be minor. We also show (via an example which is related to results in Khan, King and Wolman (2000)) that departures from markup constancy may well not be those suggested by the traditional logic of stabilization policy.

In Section 7 we consider the case for neutral monetary policy, markup constancy, and strict price stability in the presence of temporarily rigid nominal wages in the labor market. The nominal and real wage adjusts flexibly to clear a competitive labor market in the benchmark NNS model. When only nominal goods prices are sticky there is no trade-off between price stability and output stability around its potential. However, there would appear to be a trade-off when both nominal prices and wages are sticky. For instance, in a basic RBC model with capital, a temporary adverse productivity shock requires a fall in aggregate demand and in hours worked.

In the comparable basic NNS model with the markup stabilized and the price level constant, the adjustments are the same. In both models, reduced hours are accompanied by a low real wage. If the nominal wage is sticky so that the real wage cannot fall, then a monetary policy aimed at stabilizing the markup and the price level must steer output below its potential and raise the marginal physical product of labor sufficiently to keep the markup constant. Thus it would seem that there is a trade-off between output and inflation in the face of a productivity shock when wages are sticky.

There is a large body of evidence showing about the same degree of temporary rigidity in nominal wages as in nominal prices. Thus, we take seriously the potential cost that sticky nominal wages might create for price stability. However, there is a fundamental asymmetry between product and labor markets. The labor market is characterized by long-term relationships where there is opportunity and reason for firms and workers to neutralize the allocative effects of temporarily sticky nominal wages. On the other hand, spot transactions predominate in product markets where there is much less opportunity for the effects of sticky nominal prices to be privately neutralized. On this basis we argue that the consequences of temporary nominal wage rigidity are likely to be minor, but that temporarily sticky nominal product prices can influence the average markup tax significantly over time. Hence, neutral monetary policy (that maintains markup constancy, keeps output at its potential, and supports price stability) should continue to be optimal in the presence of sticky nominal wages.

We conclude the paper with a brief review of our case for price stability.

2. Principles of Optimal Fiscal Policy

Recent work on optimal fiscal policy has studied the circumstances under which it is desirable to smooth tax rates across time and states of the world. Our goal in this section is to understand the conditions under which perfect tax smoothing is optimal. Building on the insights of Ramsey (1927) and Lucas and Stokey (1983) our analysis is conducted in a general equilibrium manner appropriate for macroeconomic policy analysis. We present the procedure for determining optimal tax rate policy to provide background for our analysis of optimal monetary policy in Section 3 and in the rest of the paper.

2.1. Structure of the economy

In order to illustrate the principles of optimal tax policy as simply as possible, we assume here that the economy has only one period of time, but many states of nature (s), where s is a continuous random variable on the unit interval.[3] The probability of any state of nature is $\phi(s)$.

The production structure of the economy is very simple[4]: output y is produced from labor input n according to

[3] At times, we consider a productivity state and a government purchases state in what follows, so strictly speaking we require a two dimensional state space. However, our exposition does not make use of a two dimensional space. To minimize notational clutter, we carry along only one state index s.

[4] We use a linear production function for three reasons: simplicity and comparability to the associated public finance literature, eg, Lucas and Stokey (1983); absence of fixed factors whose incomes should be

$$y(s) = a(s)\, n(s), \tag{2.1}$$

where the productivity level, $a(s)$, depends on the state of nature.

There are two uses of output: consumption $c(s)$ and government purchases $g(s)$, which are assumed to be determined exogenously and not to substitute directly for private consumption. We assume that productivity $(a(s))$ and government purchases $(g(s))$ are possibly complicated functions of s rather than governed by particular distributions. We do so because this makes it possible to formulate the general decision problems more simply and to exposit general results more easily.

The government is required to finance its purchases of output with a distortionary flat rate tax on income. Letting the tax rate in state s be $\tau(s)$, its revenues in that state are $\tau(s)\, y(s)$.

2.2. Constraints on fiscal policy

The government can buy and sell contingent claims at prices $q(s)$ so that its budget does not have to be balanced on a state-by-state basis. Thus, the government is free to choose tax policy that results in budget "deficits" in some states and "surpluses" in others. The government is assumed to arrange trades in the contingent claims market ex ante so that tax revenue in deficit states is supplemented with payoffs from the contingent claims market to meet its spending requirements in those states. The government finances its planned state contingent deficits by buying contingent claims that pay off in deficit states with funds acquired by selling contingent claims that pay off in surplus states. Thus, the government budget constraint is written

$$\int [\tau(s)\, y(s) - g(s)]\, q(s)\, \phi(s)\, ds \geq 0\,. \tag{2.2}$$

We assume that the government must finance an exogenous pattern of state contingent purchases. The essence of the optimal tax problem is this: the government should decide how to set tax rates in each state of nature in order to satisfy its budget constraint with the least distortion.[5]

2.3. Alternative openness assumptions

In order to help understand optimal tax policy and to evaluate departures from perfect tax rate smoothing in Section 6, we carry out the analysis here for a small open economy and a closed economy.

In the *small open economy* private agents and the government can trade in complete world financial markets without affecting the prices of contingent claims.

In the *closed economy* private agents are small and competitive so that they take contingent claims prices as given, although their actions turn out to be very important for how prices differ across states. The government is aware of how contingent prices depend on its

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confiscated, eg, Chari, Christiano, and Kehoe (1994); and as a stand-in for a more elaborate production function as in King and Rebelo (1999) in which there is variable capacity utilization.

[5] It is useful to note that the budget constraint looks superficially like it holds only in expected value, but in our complete markets model it always holds exactly.

actions and those of private agents and takes account of its effect on contingent claims prices in determining optimal tax policy.

2.4. Household and Firm Decisions

The first step in solving for optimal tax policy is to determine how households and firms behave given contingent claims prices. We discuss this behavior with an arbitrary cross-state pattern of taxes $\tau(s)$.

Households: The representative household formulates contingent plans for labor supply and consumption, so as to maximize expected utility over consumption and work effort

$$\int u\big(c(s), n(s)\big)\, \phi(s)\, ds \tag{2.3}$$

In this paper we focus on the case in which the utility function is additively separable, so that

$$u(c, n) = v(c) - h(n)$$

with $v'(c) > 0, v''(c) < 0, h'(n) > 0$ and $h''(n) > 0$: these conditions insure that the demand for consumption and the supply of work effort have the conventional shapes.[6] We also assume that these preference specifications imply constant elasticity for marginal utility, so that

$$\begin{aligned} v'(c) &= c^{-1/\gamma} \\ h'(n) &= \theta n^{1/\eta} \end{aligned}$$

Additively separable preferences allow us to highlight a number of economic issues which we think are central to optimal tax policy in general and tax smoothing in particular, while maintaining a relatively tractable model. Constant elasticity preferences are important for the tax smoothing results of this section. Departures are discussed in Section 6 below.

Since households can trade in markets for state-contingent securities, the household has a budget constraint of the form

$$\int \big[\big(1 - \tau(s)\big)\, w(s)\, n(s) - c(s)\big]\, q(s)\, \phi(s)\, ds \geq 0 \tag{2.4}$$

with $w(s)$ being the wage rate in state s and after-tax income being $[1 - \tau(s)]\, w(s)\, n(s)$.

The household maximizes utility by equating the marginal utility of consumption to the cost of consumption and by equating the marginal disutility of work to its benefit

$$\begin{aligned} v'(c) &= \lambda q(s) \\ h'(n) &= \lambda\big(1 - \tau(s)\big)\, w(s)\, q(s)\,. \end{aligned} \tag{2.5}$$

[6] We also assume that the household always chooses some consumption and some work, which can be guaranteed by Inada-type conditions.

In these expressions, λ is a multiplier whose level is determined so that the budget constraint is satisfied. These first-order conditions determine the household's contingency plans given market prices. For our constant elasticity preferences, the first-order conditions take on a very simple form, which implies that we can easily solve for the consumption and work effort behavior of the households

$$\begin{aligned} c(s) &= \left[\frac{1}{\lambda q(s)}\right]^{\gamma} \\ n(s) &= \left[\frac{\lambda\big(1-\tau(s)\big)\, w(s)\, q(s)}{\theta}\right]^{\eta}. \end{aligned}$$

This example illustrates a number of important points. First, households choose plans which involve consumption smoothing across states of nature: if the prices of all states were equal, $q(s) = q$, then households choose perfect consumption smoothing. Second, relative to the full-smoothing outcome, households choose low consumption in states of nature that are costly ($q(s)$ high) and high consumption in states that are inexpensive ((s) low), with the elasticity of this response given by γ. Third, individuals choose to work more in states which have high after-tax wages and less in states with low after-tax wages. The elasticity of labor supply across states is given by η. Fourth, the overall level of consumption and work effort is governed by λ and is thus determined by the household's budget constraint. Even without our constant elasticity assumption for preferences, the first-order conditions provide the basis for cross-state comparative statics, as follows. We can determine the effect of having a state with a slightly higher wage or price by differentiating these expressions, holding fixed λ.

Firms: In presenting our model economies in this section, we assume that there is a simple, essentially static, role for firms. We assume profit-maximizing, perfectly competitive firms, so that in equilibrium the marginal product of labor $a(s)$ equals the real wage $w(s)$. Given that this equality holds, firms willingly supply any amount of output. We consider monopolistically competitive firms when we talk about monetary policy below.

2.5. Reference real business cycle solutions

Our approach to understanding optimal tax policy begins by characterizing the behavior of a reference real business cycle model with constant tax rates, i.e., the full smoothing of tax rates across states of nature. We lay out the fiscal authority's tax problem and determine the conditions for perfect tax smoothing in Section 2.6. We begin in this section by describing the nature of equilibrium for our small open economy and closed economy cases. In each case, the level of the constant tax rate is set so that the government budget constraint is satisfied given the behavior of private agents. The nature of the RBC solution in the two cases is characterized by utilizing the first-order conditions (2.5) for consumption and work effort, together with the equilibrium condition $w(s) = a(s)$, and the relevant feasibility condition for the economy.

2.5.1. The RBC solution for the small open economy

The small open economy solution is essentially the pattern of state-contingent behavior of the representative household given by first-order conditions (2.5) above except that (a) we impose constancy of the tax rate across states of nature and (b) we require that the government and household budget constraints are satisfied. In effect, this determines the parameters λ and τ in the above equations. For the purpose of characterizing the behavior of the small open economy RBC model in response to shocks we can hold λ and τ fixed, just as we previously did for the household. The reason is that both the households and the government are assumed to be able to trade at exogenous prices in complete contingent claims on international markets. Our model presumes that households and the government take advantage of such opportunities to insure fully against any wealth effects of shocks. Note this would only lead to perfectly smooth consumption if contingent prices were identical across states of nature.

The key characteristics of the small open reference RBC economy are these. First, a high productivity shock exerts a substitution effect on households, inducing them to work harder. Output increases as a direct result of the productivity shock and due to the induced rise in work effort. The is no wealth effect that might have exerted a negative effect on labor supply. There is no concurrent rise in consumption: since wealth has been fully insulated against this shock. Second, there is no effect on consumption or work effort due to a rise in government purchases: households and the government have previously purchased insurance against this event, so it has no consequences for equilibrium quantities. To reiterate, these properties stem from the fact that complete contingent claims markets eliminate the wealth effects of shocks for a small open economy, as stressed in the literature on open economy macroeconomics, e.g., Stockman and Hernandez (1988) and Baxter (1995).

On the other hand, shifts in the mean of the distribution of various disturbances such as government purchases or productivity shocks will have wealth effects. Mean shifts will be reflected in the levels of λ and τ that are necessary to satisfy household and government budget constraints. For instance, the constant tax rate τ will be determined as required to meet the government's revenue requirements

$$\int g(s)\, q(s)\, \phi(s)\, ds\,.$$

An increase in the government's revenue requirement will exert a negative wealth effect, inducing a decline in consumption and a rise in work effort which will be reflected in an increase in λ. Recall, however, that such wealth effects are not relevant for how the small open economy responds to shocks.

2.5.2. The RBC solution for the closed economy

A closed economy's resource constraint must hold on a state-by-state basis so that

$$c(s) + g(s) = y(s)\,. \tag{2.6}$$

In contrast to the case of the small open economy, no net trade is possible between states although there may be exchanges between households and the government.

In competitive equilibrium the markets for goods, labor and contingent claims must clear. Technically, a competitive equilibrium is described by functions which specify how consumption $c(s)$, work effort $n(s)$ and prices $q(s)$ depend on the state of nature. Even in relatively simple environments such as this one, it can be difficult to determine analytically how quantities and prices respond to shocks in equilibrium. It is not possible to solve explicitly for these responses using constant elasticity preferences.

One key difference between the behavior of the closed economy and the small open economy model is that increases in government purchases now typically lower consumption and raise output, whereas these had no effect in the small open economy model where wealth effects of shocks were neutralized by access to international financial markets at given prices.[7] Another notable difference is that an increase in productivity now has an ambiguous effect on work effort (in contrast to the purely positive effective highlighted above) and an unambiguously positive effect on consumption (in contrast to the zero effect above).

The way to understand these differences is to ignore the contingent claims markets, since there can be no ex post trade in goods across states of nature, and concentrate on the results which arise if these markets are absent. From this perspective, the key point is that an increase in government purchases has a negative wealth effect through the resource constraint ($c(s) + g(s) = a(s)\,n(s)$) and an increase in productivity has a positive wealth effect. With consumption positively related to wealth and work effort negatively related to wealth, the preceding responses follow directly. In particular, the response of work effort to productivity is now ambiguous because of counteracting wealth and substitution effects.[8]

2.6. Optimal fiscal policy

To set tax rates optimally the fiscal authority maximizes expected utility of the representative household subject to two constraints: the government budget constraint 2.2 and the competitive equilibrium that will prevail given the function $\tau(s)$ that describes its tax rate settings. Conceptually, this is a very straightforward task. But practically, the difficulty is that the behavior of the competitive economy cannot be described until tax policy is specified.

Lucas and Stokey (1983) suggested an approach to deal with the problem, building on the work of Ramsey (1927). They showed that it is possible to reformulate the fiscal authority's optimization problem, eliminating the tax rate as a choice variable. We apply the logic of their approach in the small open economy and the closed economy, in turn.

The Lucas and Stokey approach suggests the following programming problem for the fiscal authority:

$$\max_{c(s),n(s)} \int u\big(c(s), n(s)\big)\, \phi(s)\, ds$$

[7] It is straightforward to log-linearize the budget constraint and first order conditions to determine how the closed economy responds to shocks in a form of cross-state comparative statics: these are closely related to the results of approximately log-linear models in the RBC literature.

[8] An alternative way to interpret the differences between the small open economy and the closed economy involves considering the effect of endogenous state prices on contingent demands. From this perspective, for example, a state with high productivity could have no effect on work effort if it also generated a countervailing decline in the state price, so that the product $a(s)q(s)$ in (2.5) with $w(s) = a(s)$ was unchanged relative to some benchmark level.

subject to (i) the requirements of private sector optimization, namely the first-order conditions (2.5), $w(s) = a(s)$ from firm profit maximization, and the household budget constraint (2.4); (ii) the government budget constraint (2.2); and (iii) a feasibility constraint which depends on whether the economy is open or closed.

For the small open economy, the constraint is that there is feasibility of trade with the rest of the world,

$$\int [c(s) + g(s)]\, q(s)\, \phi(s)\, ds \leq \int a(s)\, n(s)\, q(s)\, \phi(s)\, ds\,. \tag{2.7}$$

Note that this is not an additional restriction, since it is implied by the government and the household budget constraints.[9] We work with the feasibility of trade constraint and the government budget constraint, and leave the household budget constraint in the background.

For the closed economy the resource constraint is

$$c(s) + g(s) \leq a(s)\, n(s)\,, \tag{2.8}$$

which must hold on a state-by-state basis.[10] As we have just seen, this condition requires that state prices $q(s)$ are endogenously determined. The economy-wide resource constraint and the government budget constraint imply the household budget constraint. Thus, we can again work with the feasibility condition (resource constraint) and the government budget constraint.

2.6.1. Framing the tax policy problem for a small open economy

Since contingent claims prices are exogenous for the small open economy, it is optimal for the fiscal authority to move consumption across states of nature in response to prices according to the household's first order condition for consumption in (2.5). The fiscal authority must choose how to make work effort vary across states of nature via manipulation of the state contingent pattern of taxation. In order to present formally the optimal tax problem and its solution, we follow Lucas and Stokey's (1983) strategy and eliminate the tax rate from the government budget constraint (2.2) using the first order condition for the household's choice of work effort from (2.5), and we use the condition for firm profit maximization to replace $w(s)$ with $a(s)$.[11] The transformed government budget constraint is

$$0 = \int \Big(\big(a(s)\, n(s) - g(s)\big)\, \lambda q(s) - n(s)\, h'\big(n(s)\big) \Big)\, \phi(s)\, ds\,, \tag{2.9}$$

[9] This constraint reflects the fact that residents of a small open economy can trade contingent claims at given prices with the rest of the world to decouple state contingent production and consumption.
[10] There can be no trade in contingent claims for the closed economy, since output cannot be shifted between states. State contingent prices adjust so that no trade is the equilibrium outcome.
[11] We do not impose $c(s) + g(s) = a(s)n(s)$ since households and the government can decouple purchases from domestic production by trading contingent claims at prices given in world financial markets.

where $h'(n(s)) = \theta n^{1/\eta}$ for our constant elasticity specification of preferences. Since household choices of consumption and work do not depend on the absolute scale of state prices, we may also normalize $\lambda = 1$ in this expression and eliminate it from the decision problem.

The small open economy's optimal tax problem can be written as the following Lagrangian:

$$L = \int u\big(c(s), n(s)\big)\,\phi(s)\,ds + \Lambda\left\{\int (a(s)\,n(s) - [c(s) + g(s)])q(s)\,\phi(s)\,ds\right\}$$
$$+\Gamma\left\{\int \Big(\big(a(s)\,n(s) - g(s)\big)\,q(s) - n(s)\,h'\big(n(s)\big)\Big)\,\phi(s)\,ds\right\},$$

where the fiscal authority maximizes the expected utility of the representative household subject to a feasibility of trade constraint and the transformed government budget constraint which embodies the first order conditions for work and firm profit maximization. The multipliers on the two constraints are Λ and Γ, respectively. The fiscal authority finds the optimal state contingent tax policy by first optimizing the Lagrangian over the choices of $c(s)$ and $n(s)$, and then substituting the optimal state contingent consumption and work effort allocations into the first order conditions (2.5) with $w(s)$ replaced by $a(s)$.

The first order conditions for the state contingent choices of consumption in the fiscal authority's optimization problem are

$$v'(c(s)) = \Lambda q(s)\,, \tag{2.10}$$

where $v'(c(s)) = c(s)^{-1/\gamma}$ for our constant elasticity specification of preferences. The similarity of the fiscal authority's first order conditions and the household's from (2.5) reflects the fact that the fiscal authority chooses optimal consumption across states of nature in response to the incentives in the world financial market.

The fiscal authority's state contingent first order condition for work effort contains three terms

$$h'\big(n(s)\big) = (\Lambda + \Gamma)\,a(s)\,q(s) - \Gamma\big\{h'\big(n(s)\big) + n(s)\,h''(n(s))\big\}\,, \tag{2.11}$$

where $h'(n(s)) = \theta n(s)^{1/\eta}$. The first term is the marginal disutility of work. The second term is the contribution of an additional unit of work in state s to the feasibility of trade constraint. The third term is the effect of work effort $n(s)$ on the transformed government budget constraint. The fiscal authority's behavior with respect to work effort is very different than it is for consumption: the tax authority recognizes that it can affect the extent of its revenue by its work effort choices, i.e., by the tax rate policy that it chooses.

2.6.2. Verifying that a constant tax rate is optimal

The fiscal authority must implement the optimal plan $c(s), n(s)$ indirectly by selecting state contingent income tax rates to induce households to choose the optimal state contingent allocations for consumption and work. In competitive equilibrium, the fiscal authority can engineer substitution of work effort across states of nature by making the tax rate depend on the state. If the fiscal authority does not wish work effort to depart from the levels that would prevail with a constant tax rate, then it can elect to keep the tax rate constant. Accordingly, we check whether the fiscal authority chooses the same quantities $c(s), n(s)$ as will arise with constant taxes.

For this small open economy, constant elasticity preferences for work are sufficient to deliver perfect tax rate smoothing. We do not need constant elasticity preferences for consumption. Also, with constant elasticity preferences for work, perfect tax smoothing is optimal in the presence of both productivity shocks $a(s)$ and aggregate demand shocks $g(s)$.

There are two, complementary ways of understanding the rationale for constant tax rates in this setup. First, there is the perspective of the public finance literature. Public finance theory recommends that tax rates should be chosen to minimize the distortion (excess burden) utility cost of raising a given revenue.[12] Roughly speaking, the idea is to tax more heavily goods whose supply is more inelastic, since a given amount of revenue can be raised with less distortion that way. In our context, then, we think of work effort supplied in different states of nature as different "goods." The elasticity of supply of work is identical across states if there are constant elasticity preferences, as we assume here. Hence, it is optimal to set a tax rate that is constant across states of nature.

Second, for the application to monetary policy that follows, it is important to understand that state contingent work and consumption generated by the fiscal authority's optimal choice of tax policy are identical to the outcomes in the constant tax rate, small open reference RBC economy that we discussed in Section 2.5. We can see that this is the case as follows. First, with our constant elasticity preference specification the first order condition for work (2.11) from the fiscal authority's optimal tax problem may be rewritten as

$$\theta n(s)^{1/\eta} = \kappa_{no}[a(s)\, q(s))]$$

with $\kappa_{no} = (\Lambda + \Gamma)/[1 + (\Gamma(1+\eta)/\eta)]$. This implies that the fiscal authority's first order condition for work (2.11) looks just like the household's first order condition for work (2.5) if we set the combination of multipliers so that $\kappa_{no} = (1-\tau)\,\lambda$. Second, the first order condition for consumption in the fiscal authority's optimal tax problem resembles that in the constant tax rate RBC reference case. Third, we know that the constant tax RBC reference economy satisfies all the budget constraints. Hence, we know that (constant) multipliers can be chosen so that the household's choice of consumption in the reference RBC economy matches the fiscal authority's consumption choices.[13]

2.6.3. Tax policy in the closed economy

In contrast to the small open economy, the fiscal authority can manipulate contingent claims prices $q(s)$ across states of nature according to the household's first order condition (2.5) by its choice of state contingent consumption $c(s)$. As stressed by Lucas and Stokey (1983), this makes possible a lower average tax rate on labor income, lower tax distortions, and higher

[12] See, for instance, Atkinson and Stiglitz (1980), Lecture 12, pp. 366-393.
[13] We are assuming, here and below, that there is a single solution with a constant tax rate or constant markup. This should be the case with the preferences that we use.

expected utility for households. For instance, other things the same, the fiscal authority would want contingent claims prices $q(s)$ to be low when government spending $g(s)$ is high. Then, high spending could be partly financed by claims paying off in high states purchased with funds obtained from selling claims on low-spending states. Likewise, the fiscal authority would like high state prices when productivity $a(s)$ is high, so it could sell off excess revenue at a high price for claims on output in states when it needed revenue. However, the fiscal authority must manipulate state contingent prices indirectly though the income tax rate. A high income tax rate raises contingent claims prices in a given state by inducing lower output and consumption. Hence, the extent to which the fiscal authority will want to manipulate tax rates across states to this end will depend on the nature of preferences and technology.

Formally, the optimal tax problem involves the maximization of expected utility subject to a government budget constraint and a resource constraint. We use the transformed government budget constraint (2.9) as before except that we substitute for state contingent prices using the household first order condition for consumption $q(s) = v'(c(s))/\lambda$. For the closed economy, the resource constraint $c(s) + g(s) = a(s)\, n(s)$ must hold on a state-by-state basis. Attaching a multiplier $\Lambda(s)$ to the resource constraint in each state s and a multiplier Γ to the government budget constraint, we find that the first-order condition for optimal work effort is very similar to that above,

$$h'\big(n(s)\big) = \Lambda(s)\, a(s) - \Gamma\{h'(n(s)) + n(s)\, h''(n(s))\} \tag{2.12}$$

except that the rewards to work effort in state s must now be evaluated at $\Lambda(s)$ rather than $\lambda q(s)$. As before, we assume $h'(n(s)) = \theta n(s)^{1/\eta}$. The first-order condition for consumption is

$$v'(c(s)) = \Lambda(s) - \Gamma\{v'(c(s)) + c(s)v''(c(s))\} \tag{2.13}$$

which takes a parallel form to the work effort condition in state s: the marginal utility of consumption must be equated to the shadow price on the resource constraint $\Lambda(s)$, plus an additional term which takes into account the influence of consumption on state contingent prices $q(s)$. We assume $v'(c(s)) = c(s)^{-1/\gamma}$, which facilitates the manipulation of this first order condition below.

2.6.4. Verifying that a constant tax rate is optimal

As before, the fiscal authority must implement the optimal plan indirectly by choosing state contingent income tax rates to induce households to choose optimal state contingent allocations for consumption and work. We find that state contingent tax policy by substituting the solutions for optimal work and consumption from (2.12) and (2.13) into the household's first order conditions for work and consumption (2.5). Then we solve the household conditions simultaneously for $q(s)$ and $\tau(s)$. The bottom line is this: with constant elasticity preferences over work and consumption, optimal tax policy $\tau(s)$ depends on the constant multiplier Γ on the government budget constraint, but not on state-dependent variables. Optimal tax rates do not respond to state contingent productivity or government spending. The tax rate is fixed ex ante so that it raises just enough revenue to finance the government's needs.

There are three important points to note about the constant tax rate optimum. First, although the fiscal authority has the power to use tax policy to manipulate state contingent claims prices in the closed economy, it is not optimal to do so. The result is reminiscent of the behavior of a monopolist with constant elasticity demand: the profit-maximizing markup is invariant to demand and productivity shocks, even though the monopolist has the pricing power to manipulate his markup in response to such shocks.

Second, the requirement that consumption preferences *as well as* preferences over work be constant elastic seems to contradict the public finance intuition given for the small open economy. The difference is that the small open economy is a partial equilibrium in the sense that exogenous contingent claims prices determine the marginal utility of consumption. The public finance intuition works well in partial equilibrium. In the closed economy, whether or not it is efficient for the fiscal authority to manipulate tax rates − to push contingent claims prices down in states where the government budget is in deficit and raise such prices in states where the government budget has a surplus − depends on things other than the elasticity of work effort. For example, the fiscal authority raises a contingent claims price in a given state by planning to raise the income tax rate in that state. A higher tax rate induces a cut in work, output, consumption, and thereby a higher contingent claims price. The chain by which the fiscal authority might exploit its leverage over claims prices makes clear that both the elasticities of work and consumption matter. The result obtained above says that when both elasticities are constant, the marginal benefit of manipulating tax rates to reduce revenue is exactly offset by the marginal distortion cost of moving away from constant tax rates.

A third way to see the optimality of constant tax rates is to observe that the first order conditions for optimal tax policy induce the same behavior as in the closed, constant income tax rate reference RBC economy in Section 2.5, In other words, the response of consumption and work to productivity and government purchase shocks in the constant tax reference RBC model is the one that minimizes the dead weight cost of raising revenue with distortionary income taxes. We can see this as follows. Working with our preference specification, we can rewrite (2.13) as

$$c(s)^{-1/\gamma} = \kappa_c \Lambda(s)$$

where $\kappa_c = [1 + \Gamma(1 - (1/\gamma))]^{-1}$. In this closed economy setting, optimal allocations depend on the state contingent multipliers $\Lambda(s)$ which are endogenously determined so that the resource constraint holds. But the fiscal authority's effective marginal rate of substitution between work effort and consumption does not. Our rearrangement of the work effort and consumption first order conditions for the fiscal authority yields:

$$\frac{h'(n(s))}{v'(c(s))} = \frac{\kappa_n}{\kappa_c} a(s)$$

where $\kappa_n = [1 + (\Gamma(1 + \eta)/\eta)]^{-1}$. The fiscal authority must respect the household's marginal rate of substitution between work and consumption from (2.5). Comparing the two, we see that the fiscal authority must make $(\kappa_n/\kappa_c) = (1 - \tau)$. That is, the fiscal authority must make the tax rate constant so that quantities behave as in the constant tax rate closed RBC economy. The fiscal authority chooses Γ so that the constant tax rate raises just enough revenue to satisfy the government budget constraint. As previously, we know that the government budget constraint and the resource constraints are satisfied at the constant tax rate solution for the reference RBC economy.

3. Principles of Optimal Monetary Policy

The Ramsey (1927) perspective has been applied to the study of two central issues in monetary economics in recent years. There has been a great deal of research over the last decade on optimal monetary policy in competitive, flexible price models. In this literature, the main focus has been on the conditions under which the Friedman rule − maintaining the nominal interest rate equal to zero − is optimal.[14] More recently, there is a smaller, but quite active, line of research that uses Ramsey principles to study optimal monetary policy in the sticky price, imperfectly competitive macroeconomic models of the New Neoclassical Synthesis. In this section, we present a new synthesis model which is closely related to the frameworks developed by Ireland (1996) and Adao, Correia, and Teles (2000). We carry along from Section 2 the main assumptions about preferences and production technology, adding imperfect competition and sticky prices to the core real business cycle model in order to study optimal monetary policy. However, we suppress government fiscal policy, i.e., government purchases and income taxes, to concentrate on monetary policy.

3.1. Introducing imperfect competition and sticky prices

We continue to assume that there is a single final good, which perfectly competitive final goods firms assemble from differentiated intermediate goods that are produced by imperfectly competitive firms. Following the bulk of the literature on New Keynesian macroeconomics, we assume that this final good must be produced−from a range of differentiated input goods indexed by z − according to

$$y(s) = \left[\int y(s,z)^{\frac{\varepsilon-1}{\varepsilon}} dz\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

where $y(s,z)$ is the amount of the zth intermediate product; $y(s)$ is the amount of the final good; and $\varepsilon > 1$ is a parameter which governs the elasticity of substitution across goods. As is well known from the work of Dixit and Stiglitz (1977), the implied demand functions take the form,

$$y(s,z) = \left(\frac{P(z)}{P}\right)^{-\varepsilon} y(s)$$

where $P(z)$ is the price of the zth good and P is an index of the general price level.[15]

[14] See Chari and Kehoe (1999).

[15] Kimball (1995) proposes a generalization of this approach in which

$$g(y(s)) = \int g(y(s,z))dz$$

Imperfect competition: If its price is flexible, an intermediate goods firm maximizes profit (firm value) by setting its relative product price at a fixed markup over real marginal cost $\psi(s)$,

$$\frac{P(z)}{P} = \frac{\varepsilon}{\varepsilon - 1}\psi(s)$$

where the extent of the gross markup $\left(\mu = \frac{\varepsilon}{\varepsilon-1}\right)$ is governed by the elasticity of demand, with a more elastic demand leading to a lower markup. When prices are flexible, the profit maximizing markup is invariant with respect to demand or cost shocks. Accordingly, the equilibrium real wage rate

$$w = \psi a = \frac{\varepsilon - 1}{\varepsilon} a$$

is less than the marginal product of labor due to the market power of intermediate goods firms. Since real marginal cost ψ is nominal marginal cost divided by the price level, its reciprocal is the average markup (the price level divided by nominal marginal cost). Hence, we see that a gross markup greater than unity implies a real wage below the marginal product of labor. Thus, we can interpret the markup in product markets as a tax on work effort.

Sticky prices and imperfect competition: This model's version of the sticky price assumption is reflected in our chosen notation: the zth intermediate goods producer sets the nominal product price $P(z)$ in advance of the state of nature. Accordingly, the general price level P will also be determined before the state of nature is realized. With sticky prices, the intermediate goods producer selects its product price to maximize the firm's value in the contingent claims market,

$$\int \left[\left(\frac{P(z)}{P} - \psi(s)\right)\ y(s,z)\right] q(s)\ \phi(s)\ ds\ .$$

where the firm takes into account its demand function,

$$y(s,z) = \left(\frac{P(z)}{P}\right)^{-\varepsilon} y(s)$$

in choosing the value maximizing price. In this market value expression, $\psi(s)$ is real marginal cost. We continue to assume that production is linear, $y(s,z) = a(s)\ n(s,z)$, and that labor can be purchased at wage rate $w(s)$. Hence, real marginal cost is simply the ratio of the real wage to the marginal product of labor $\psi(s) = w(s)/a(s)$.

Maximization of firm value requires that

where g is an invertible funciton, so that the demand elasticity need not be globally constant. All of our arguments in this section are robust to this extension.

$$0 = \int \left[\frac{1}{P}(1-\varepsilon)\left(\frac{P(z)}{P}\right)^{-\varepsilon} y(s) + \varepsilon\psi(s)\frac{1}{P}\left(\frac{P(z)}{P}\right)^{-\varepsilon-1} y(s)\right] q(s)\, \phi(s)\, ds.$$

In a symmetric market equilibrium, all firms choose $P(z) = P$ and the value maximizing price-setting condition then implies that

$$0 = \int [(1-\varepsilon) + \varepsilon\psi(s)]\, y(s)\, q(s)\, \phi(s)\, ds \qquad (3.1)$$

This expression implies that intermediate goods firms impose a constraint on the behavior of the markup (or real marginal cost) that holds on average across states of nature. We can express (3.1) in deviations of marginal cost from the certainty (single state) case

$$0 = \int [\psi(s) - \psi]\, y(s)\, q(s)\, \phi(s)\, ds\ . \qquad (3.2)$$

where we have multiplied the condition by -1 to facilitate interpretation later. When we consider the monetary authority's policy problem below, (3.2) will play a role analogous to the role played by the government budget constraint in the fiscal authority's policy problem in Section 2. The government budget constraint gave the fiscal authority the flexibility to make the tax rate vary with the state of nature, as long as tax policy in conjunction with purchases and sales of contingent claims satisfied the government's budget. Here, the firm's price setting condition gives the monetary authority the flexibility to make the markup (real marginal cost) vary with the state of nature, as long as "markup policy" in conjunction with purchases and sales of contingent claims by firms satisfies the firm's value maximizing price setting condition. We explain the monetary authority's leverage over the markup below.

3.2. The core real business cycle model

In the introduction we stressed that models of the New Neoclassical Synthesis have a real business cycle core that can be analyzed given the behavior of the markup (or real marginal cost). We now discuss the core real business cycle models for the open and closed NNS economies.

3.2.1. Common elements

In either setting, households maximize utility subject to their contingent claims budget constraint. This takes the form

$$\int c(s)\, q(s)\, \phi(s)\, ds \le \int\ [w(s)\, n(s)]\, q(s)\, \phi(s)\, ds + \Omega$$

where Ω is the market value of intermediate goods firms that arises from monopoly profits. The first-order conditions for consumption and work effort are

$$\begin{aligned} v'(c(s)) \quad &= \lambda q(s) \\ h'(n(s)) \quad &= \lambda w(s) q(s) = \lambda\psi(s)\, a(s)\, q(s) \end{aligned} \qquad (3.3)$$

where the second equality in the labor efficiency condition arises from the definition of real marginal cost. Thus, the household's first order conditions are identical in the income tax economy of Section 2 and the monopolistic competitive economy of Section 3 except that $\psi(s)$

replaces $(1 - \tau(s))$. This should not be surprising since, as we saw above, the markup pushes the real wage below the marginal product of labor. In effect, the markup is an income tax collected by intermediate goods firms and redistributed to households as profit. A gross markup in excess of unity is reflected in real marginal cost below unity in the household's first order condition for work.

Working with the definitions of profits and imposing the symmetric equilibrium as above, we find that in equilibrium the household's contingent claims budget constraint is just $\int [c(s)\, q(s)\, \phi(s)\, ds \leq \int a(s)\, n(s)\, q(s)\, \phi(s)\, ds$.[16] However, a competitive household does not take into account the implied effect of work effort on profits in choosing how to behave. This simplification of the household's budget constraint reflects the fact that profits generated by markups are a tax and transfer program with no wealth effects.

3.2.2. Differences

Depending on whether the economy is closed or open, there will be differences that are exactly parallel to those in our consideration of fiscal policy in the preceding section. In the small open economy contingent claims prices are exogenous and there is typically a reason for cross-state trade with the world financial market. In the closed economy, state prices are endogenous and there can be no trade across states.

3.2.3. The response of economic activity

In the small open economy, the state-contingent pattern of consumption is pinned down by the combination of the budget constraint and the first-order condition for consumption. Changes in the average markup $\mu(s)$ or, equivalently, in real marginal cost $\psi(s)$ cause changes in work effort, inducing individuals to substitute across states of nature in a way that is just like the response to productivity $a(s)$ or tax rates $\tau(s)$. A high level of $\psi(s)\, a(s)\, q(s)$ induces high labor supply, with the magnitude of this response being governed by the labor supply elasticity η. If the markup is constant across states of nature, then the response to shocks is just like the reference RBC solution in the small open economy, with economic activity differing from the standard competitive case only in that the average level of work effort and consumption are lower.

In the closed economy, consumption must obey the resource constraint $(c(s) = a(s)\, n(s))$ on a state-by-state basis, and contingent claims prices must adjust to clear financial markets since there is no trade between states. Productivity shocks have offsetting wealth and substitution effects as discussed above. Changes in the markup work like changes in productivity except that the markup exerts a substitution effect but no wealth effect on labor supply. Hence, a change in the markup has a more powerful effect on work effort than an equivalent change in productivity. However, the work effort response to markup movements is smaller than in the open economy, since a low markup is partly offset by a decline in state prices. Again, if the markup is constant across states of nature, then the response to shocks is just like the closed, constant tax reference RBC economy, with economic activity differing from a perfectly

[16] The budget constraint involves wage income and profit income from intermediate goods firms.

competitive RBC economy case only in that the average level of work effort and consumption are lower.

3.3. Optimal monetary policy

Models of the New Neoclassical Synthesis, such as this one, locate the transmission of monetary policy to real economic activity in its influence on the average markup, or real marginal cost. The monetary authority exercises its leverage over real aggregate demand through a money demand function, using the nominal money stock as its policy instrument.[17] If we assume that the demand for real money balances depends only on real spending, then we can think of state contingent aggregate demand $y(s)$ as determined by the state contingent money stock $M(s)$ according to $y(s) = M(s)/P$, where P is the predetermined price level.[18] Monopolistically competitive intermediate goods firms accommodate whatever output is demanded at their predetermined prices. The demand for intermediate goods is derived from aggregate final goods demand $y(s)$. And real output is determined by monetary policy through this transmission mechanism. A monetary policy action which raises real aggregate demand raises marginal cost and lowers the average markup sufficiently to bring forth an accommodating increase in employment and aggregate supply. The lower markup works like a reduction in the tax rate on work effort in the core RBC model to sustain the required increase in employment and output.

Our approach to monetary policy thus reflects two ideas from the New Neoclassical Synthesis. First, monopolistically competitive firms that fix nominal prices in advance give the monetary authority leverage over real aggregate demand. Second, that leverage creates accommodating movements in employment and aggregate supply through its effect on the markup tax on work.[19]

The monetary authority's policy problem is analogous to the fiscal authority's tax problem in Section 2. The monetary authority should maximize the household's expected utility subject to the relevant resource constraint (for the closed or open economy) and the intermediate good firms value maximizing price setting condition (3.2), which like the government budget constraint in Section 2 is a constraint on the average (markup) tax rate across states of nature. From this perspective, we determine optimal state contingent monetary policy $M(s)$ to realize the welfare maximizing state contingent pattern of markups and output after we determine what these should be.

3.3.1. Optimal monetary policy in the small open economy

[17] Optimal monetary policy could also be implemented with an interest rate rule.

[18] While this may seem arbitrary, King and Wolman (1999) argue that the quantity equation $M/P = \phi y$ can be derived from a standard "shopping time" approach to the demand for money, as a limiting case in which interest is paid on money at just below the maket rate so that the triangles under the demand for money are thus suppressed.

[19] Goodfriend (1997) and Kimball (1995) stress the importance of markup variations in accounting for the real effects of monetary policy. See also the discussion in Rotemberg and Woodford (1999), pp. 1113-1118. Goodfriend explicitly solves for optimal monetary policy as optimal tax policy using a procedure analogous to that used in this paper, though he uses a very different pricing technology.

We analyze optimal monetary policy using the same approach as in the optimal fiscal policy analysis of Section 2. We begin by rewriting (3.2) using the household's first order condition for work from (3.3) to yield

$$0 = \int \left[h'\big(n(s)\big)\, n(s) - \psi a(s)\, n(s)\, q(s)\right] \phi(s)\, ds \tag{3.4}$$

where we normalize $\lambda = 1$ for convenience as in the fiscal policy analysis.[20]

For the small open economy, there is also a feasibility-of-trade constraint for the economy as a whole $\int c(s)\, q(s)\, \phi(s)\, ds \leq \int a(s)\, n(s)\, q(s)\, \phi(s)\, ds$. Maximizing the household's expected utility subject to implementation constraint (3.4) and the trade constraint yields a first order condition for consumption

$$v'(c(s)) = \Lambda q(s)$$

and one for work effort

$$h'\big(n(s)\big) = (\Lambda + \psi\Gamma)\, a(s)\, q(s) - \Gamma\left\{h'\big(n(s) + n(s)\, h''\big(n(s)\big)\right\}$$

where Λ is the multiplier on the trade feasibility constraint and Γ is the multiplier on the implementation constraint. Note that, except for the presence of ψ, the first order conditions for optimal monetary policy in a small open economy correspond to those for optimal fiscal policy above.

3.3.2. Verifying that a constant markup is optimal

Here we ask whether the optimal quantities from the monetary authority's perspective differ from those that arise in a fixed markup (imperfectly) competitive RBC reference model. We proceed to answer the question exactly as before: we consider whether it is possible to rearrange the monetary authority's first order conditions so that they look just like those of a household in the flexible price, imperfectly competitive RBC economy where the markup is constant. The consumption plan is already clearly in this form. With our constant elasticity preferences, the monetary authority's first order condition for work effort may be rewritten as

$$\theta n(s)^{1/\eta} = \kappa_{no} a(s)\, q(s)$$

with $\kappa_{no} = (\Lambda + \psi\Gamma)/[1 + (\Gamma(1+\eta)/\eta)]$. Our constant elasticity preference specification implies that it is optimal to choose work effort so that it varies in exactly the same way as in the constant markup reference RBC economy, even though it is feasible to find other patterns. In fact, a comparison of the monetary authority's first order conditions indicates that $\kappa_{no} = \psi = \frac{\varepsilon - 1}{\varepsilon}$. We conclude that it is optimal for the monetary authority to make the markup constant across states even though it could in principle be varied. Optimal monetary policy is nevertheless activist. The state contingent money supply $M(s)$ should vary so that aggregate demand

[20] We do not impose $c(s) = a(s)\, n(s)$ because households can decouple consumption from production by trading contingent claims at given prices in world financial markets.

accommodates fluctuations in potential output generated by the RBC core of the new synthesis model.

3.3.3. Optimal monetary policy in the closed economy

In the closed economy, the monetary authority is constrained by the state-by-state resource constraint, $c(s) = a(s)\, n(s)$, with no possibility of smoothing consumption across states via trade. At the same time, the monetary authority gains leverage over the state prices $q(s)$ which enter the implementation constraint (3.4). Using the household's first order condition to substitute out for $q(s)$, we write the implementation constraint as

$$0 = \int \left[h'\big(n(s)\big)\, n(s) - \psi v'\big(c(s)\big)\, c(s)\right]\, \phi(s)\, ds\, . \tag{3.5}$$

The monetary authority now maximizes expected household utility subject to the state-by-state resource constraint and the implementation constraint (3.5). Optimal choice of consumption mandates

$$v'(c(s)) = \Lambda(s) - \psi\Gamma[v'(c(s)) + c(s)\, v''(c(s))]$$

with $\Lambda(s)$ being the multiplier on the resource constraint in state s and Γ again being the multiplier on the implementation constraint. Optimal choice of work effort requires that

$$h'(n(s) = \Lambda(s)\, a(s) - \Gamma\{h'(n(s) + n(s)\, h''(n(s))\}$$

Note that except for the presence of ψ, the first order conditions for the monetary authority's problem match those from the corresponding optimal tax problem for the closed economy.

3.3.4. Verifying that a constant markup is optimal

Not surprisingly, with constant elasticity preferences for both work and consumption as before, we can determine that the allocations which prevail with a constant markup are optimal. Again, the procedure is to transform the first order conditions from the monetary authority's problem. For consumption, we can write

$$c(s)^{-1/\gamma} = \kappa_c \Lambda(s)$$

with $\kappa_c = [1 + \psi\Gamma(1 - (1/\gamma))]^{-1}$. For work effort, we can write

$$\theta n(s)^{1/\eta} = \kappa_n \Lambda(s)\, a(s)$$

with $\kappa_n = [1 + (\Gamma(1 + \eta)/\eta)]^{-1}$. As before, we know that the monetary authority must respect the first order conditions of firms. Comparing the ratio of the monetary authority's first order conditions to the ratio of the household's first order conditions from (3.3), we see that optimal monetary policy requires $\psi = \kappa_n/\kappa_c$, which corresponds to the $1 - \tau = \kappa_n/\kappa_c$ condition in the closed economy income tax problem. Further, when we require $\psi = \kappa_n/\kappa_c$, we learn that $\Gamma = (1 - \psi)/\left(\psi\left[\frac{1}{\eta} + \frac{1}{\gamma}\right]\right) > 0$, so that we may usefully think of the implementation constraint as a budget constraint. With a constant markup, the implementation constraint is necessarily satisfied and the constant markup solution also satisfies the resource constraint.

Thus, for a closed economy, we find that optimal monetary policy maintains markup constancy when preferences for consumption and work are constant elastic. Monetary policy should manage the stock of money to make aggregate demand accommodate movements in potential output in the closed economy core RBC economy with a fixed markup.

3.4. What we have learned about price stability

We have described two closely related setups in which a monetary and fiscal authority choose policy optimally and in which policy has a simple and intuitive form. More specifically, we have made more precise the relationship between tax smoothing and markup smoothing that we originally suggested in our exposition of the New Neoclassical Synthesis [Goodfriend and King (1997)]. We will see later that this correspondence is quite helpful for knitting together results in diverse literatures and in forecasting profitable lines of research activity.

Yet, the simple monetary model that we have described is one in which the price level is stable by construction: all firms must set their prices in advance of the state of nature and no firms can adjust their prices in the face of actions by the monetary authority. We argue that the model is nevertheless revealing about the case for price stability. We do so by describing here two feasible extensions of the model that make the price level endogenous, but do not alter the implication that the markup should be stabilized. The reason is that with markup constancy those firms which can adjust their prices choose not to do so and the price level does not move under optimal policy. Neither of the extensions changes the underlying real structure so as to alter the desirability of markup constancy.

The first extension is one which allows a specific fraction of firms, α, to adjust their prices after seeing the state of nature while requiring the remainder of the firms $(1-\alpha)$ to keep their prices fixed. This structure is an adaptation of the stochastic adjustment model of Calvo (1983) to our simple environment. The price level can move in response to shocks. However, since underlying technologies and preferences are not influenced by this price adjustment structure, there is no reason for optimal policy to change. In particular, the forgoing analysis implies that the optimal constant markup also maximizes firm profits. Thus, monetary policy that maintains optimal markup constancy gives adjusting firms an incentive to renew their relative, and therefore, their nominal prices.

The second extension is one which allows every firm to adjust after the fact, but with a differential resource cost of adjusting prices, ranging from low to high. This structure is an adaptation of the state dependent pricing model of Dotsey, King and Wolman (1999) to our simple environment. An individual firm can make a comparison between the costs of price adjustment and the benefits, with adjustment occurring if it is privately desirable. Once again, however, the constant markup policy avoids the necessity of any such costly price adjustment. Underlying technologies and preferences are not influenced by the introduction of the costly opportunities for price adjustment. Since the optimal constant markup also maximizes firm profits, firms have no reason to change their prices. As before, there is no reason for monetary policy to depart from markup constancy, and markup constancy stabilizes the price level.

4. NNS Models As Quantitative Laboratories

The simple monetary model that we just discussed featured imperfect competition and prices that were sticky for a single period. While it is possible to interpret the single period as one of many, in which there are no intertemporal links across periods, most recent work on NNS models has introduced dynamic linkages which we think are critical for matching observed features of business fluctuations and for evaluating the consequences of alternative monetary policies. These richer NNS models are quantitative laboratories that can be used for both positive and normative purposes. In what follows, we exploit important features of unabridged NNS models highlighted below to develop our case for price stability more fully.

4.1. The RBC Core

NNS models have a real business cycle core which features intertemporal choices for households with respect to consumption, saving, and work effort. NNS models also frequently, but not always, incorporate investment decisions on the part of firms within the RBC core. Some NNS studies are beginning to allow firms to vary the utilization of the capital stock as well.

Lessons from RBC modeling carry over to the associated NNS model. For example, the response to productivity or government spending shocks in RBC economies depends in a crucial manner on the extent to which these shocks are permanent or transitory. Small wealth effects − similar to those in the complete markets case above − are associated with transitory shocks, with larger wealth effects − similar to those in the closed economy case − coming about for more permanent shocks. RBC models also indicate that the transitory or permanent nature of a shock is important for the intertemporal substitution responses of households and firms to changes in wages and interest rates. For instance, the storability of output facilitates consumption smoothing, which helps the wealth effects of temporary shocks to be distributed over many periods. Consumption smoothing works like insurance in contingent claims as discussed in the previous sections to allow work effort to respond more elastically to temporary improvements in wages and productivity than otherwise.

4.2. Staggered price-setting

In NNS models, price-setting is typically modeled as staggered, with the most common version being time dependent pricing as in Taylor (1980) and Calvo (1983). Relative to the simple model, this extension retains the implication that optimal pricing involves a markup over marginal cost, but the pricing decision involves intertemporal considerations because the price may be held fixed for several periods. Past prices become elements of the relevant history of the economy. The price level, as Taylor (1980) stressed, involves both inertia due to the influence of past prices and expectations due to the forward-looking pricing rules of firms.

However, as stressed in Goodfriend and King (1997), the prices chosen by adjusting firms are functions of the expected path of nominal marginal cost, to a first approximation. So, the price level and the inflation rate depend, in general, on the past history of individual prices and the expected path of nominal marginal cost. Accordingly, a policy which stabilizes real marginal cost also stabilizes the price level.[21]

Staggered prices have two implications for the design of optimal monetary policy. First, as discussed in the introduction, staggering gives the monetary authority some small leverage over the steady state markup (or real marginal cost). Second, staggering means that there is a distribution of prices and there are effects of monetary policy on the extent of relative price distortions.

4.3. Channels of monetary influence in NNS models

NNS models are being employed to isolate and evaluate the channels by which monetary policy can affect the macroeconomy. For example, the extent of relative price distortions is very sensitive to the secular rate of inflation; but such distortions do not contribute much to cyclical variability at modest inflation rates. On the other hand, the steady state markup varies little with the secular rate of inflation. However, movements in the markup are a potentially important source of fluctuations in employment and output, since the markup acts like a tax on work effort, exerting a powerful substitution effect with no countervailing wealth effect on labor supply. Since the price level continues to be sticky under staggered pricing, the monetary authority can exert significant leverage over employment and output through its effect on the markup tax as we described in Section 3.3.

Moreover, as we emphasize in Section 5, staggered pricing makes inflation depend on a distributed lead of expected future markups. Thus, monetary policy can effectively stabilize inflation by credibly anchoring expected future markups. The powerful role of credibility in NNS models is an important part of the case for price stability.

4.4. RBC models as fiscal laboratories

Without money, imperfect competition, or price rigidities, RBC models have been used as laboratories to study positive and normative aspects of fiscal policy. Shifts in income tax rates have been shown to be a potentially powerful influence on economic activity in RBC models. However, changes in income tax rates have not contributed too much to U.S. business cycles because they have been relatively small and predictable. Optimal fiscal policy typically involves only very small changes in tax rates on labor income when the driving variables are government purchases and productivity. The responses are small within the basic RBC model (Chari, Christiano, and Kehoe (1994)) and even smaller when variable capacity utilization is added (Zhu (1995)).

Optimal fiscal policy analysis is ahead of monetary policy analysis in terms of the richness of the RBC core that is employed. For this reason, we use some of the lessons from fiscal policy analysis in our discussion below to conjecture what results will obtain in future analysis of optimal monetary policy.

[21] Under some versions of price-setting, there can be an initial transitional interval in which the effects of lagged individual prices are worked off. See Goodfriend and King (1997).

5. Inflation Dynamics

As we have emphasized, the average markup and its reciprocal, real marginal cost, play a dual role in NNS models. On one hand, variations in the markup operate like a tax on work effort which moves through time, potentially influencing the real economic activity. On the other hand, variations in real marginal cost are central to the pricing decisions of firms and the evolution of the price level. In this section, we review recent theoretical and empirical work that bears on the nature of price dynamics.

The nature of inflation dynamics is central to our case for neutral policy, markup constancy, and price stability. The key is that NNS models with staggered pricing do not exhibit structural inflation persistence: although staggered price setting makes the price level sticky, it does not make inflation sticky. Therefore, an inflation shock need not be followed by persistently high inflation if firms expect the monetary authority to pursue a policy supportive of price stability. Hence, fully credible neutral policy that anchors inflation expectations induces firms to return quickly to zero inflation after a shock.

If actual price setting were characterized instead by structural inflation persistence, then firms would have an inclination to perpetuate an inflation shock over time, regardless of monetary policy. The monetary authority would find it costly to return to price stability immediately after an inflation shock. Monetary policy would have to move aggregate demand below potential output to restore price stability quickly. Structural inflation persistence would confront the monetary authority with a trade-off in the variances of inflation and output relative to potential so that neutral policy, markup constancy, and price stability would generally no longer be optimal.

Inflation exhibits significant persistence in U.S. macro data. The question is whether that persistence is structural in the sense defined above, or induced entirely by the behavior of the central bank, in this case the Federal Reserve. Our goal in this section is to show that inflation persistence in U.S. time series could have been generated by an NNS model with no structural persistence. In particular, we show that U.S. inflation could have been generated by a purely forward-looking inflation generating equation implied by Calvo staggered pricing in the context of an NNS macromodel. We conclude by sketching other aspects of an NNS model, including plausible central bank behavior, that could account for the observed inflation persistence.

5.1. Forward-looking inflation dynamics

The simple form of stochastic adjustment suggested by Calvo (1983) leads to a very tractable representation of inflation dynamics, which is

$$\pi_t = \beta E_t \pi_{t+1} + \phi \log(\psi_t) \tag{5.1}$$

where $\pi_t = \log(P_t) - \log(P_{t-1})$ is the inflation rate and $\log(\psi_t)$ is the log of real marginal cost. Derivations of this inflation equation from the underlying price-setting and price level equations indicate that ϕ is a composite parameter which depends on the frequency of price adjustment posited in the Calvo model, with less frequent price adjustment leading to a smaller value of ϕ.[22] In this expression, as above, β is a quarterly real discount factor that is very close to one. Since the long-run relationship between inflation and real marginal cost implied by (5.1) is $(1-\beta)\pi = \phi \log(\psi_t)$, an exact invariance occurs if $\beta = 1$ and an approximate invariance holds if β is close to one.

If the inflation equation is solved forward, as in Sargent (1979), then the resulting rational expectations solution is

$$\pi_t = \phi \sum_{j=0}^{\infty} \beta^j E_t \log\left(\psi_{t+j}\right) \tag{5.2}$$

This solution highlights a property of the Calvo model stressed by Buiter and Miller (1985), which is that inflation is purely forward-looking: there is no influence of past inflation on current inflation. In terms of the discussion above, (5.2) exhibits no structural inflation persistence. For instance, if monetary policy is expected to maintain the markup (real marginal cost) at an optimal level consistent with static firm profit maximization, then firms will maintain stable prices. There is no structural persistence because price setting firms would stabilize current inflation in this case, regardless of inflation in the recent past.

To make this expression an operational one for empirical purposes, it is necessary to decide how to measure real marginal cost. A reference procedure for the case of the Cobb-Douglas production function $y_t = a_t k_t^{1-\alpha} n_t^{\alpha}$, discussed for example in Bils (1987), is to use the cost-minimization implication $w_t = \psi_t \frac{\partial y_t}{\partial n_t}$ to determine that

$$\psi_t = \frac{w_t}{\alpha(y_t/n_t)} .$$

One desirable feature of this approach is that constructed real marginal cost is not sensitive to omitted productive factors. For example, it would not be influenced by whether there was variable utilization of capital. Galí and Gertler (1999) and Shordone (1998) make use of this measure of real marginal cost to provide evidence on the whether U.S. inflation dynamics are consistent with this basic pricing model.

5.2. A cursory look at US data on inflation and marginal cost

One way of summarizing the post-war U.S. data on inflation and real marginal cost is via a vector autoregression, which we estimated using the data from the Galí and Gertler (1999) study which were kindly supplied to us by Jordi Galí. The estimates of a second order vector autoregression over 1961–1998 are as follows:[23]

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[22] For various derivations, see Roberts (1995), Yun (1996), Galí and Gertler (1999) and King (2001, appendix A). These derivations indicate that inflation is related to the deviation of real marginal cost from its steady state level ψ.

[23] We do not report standard errors for the estimated VAR specification, since our purpose in this section is to make a theoretical point about the reduced form inflation relationship which will prevail if (a) real marginal cost is persistent, and (b) inflation forecasts real marginal cost. We want to make this theoretical point using an empirically plausible "driving process" so we estimate and report the point estimates of the VAR coefficients. It would be straightforward to report standard errors on the estimated VAR, but readers

$$\pi_t = 0.07 \log(\psi_{t-1}) - 0.07 \log(\psi_{t-2}) + 0.69\pi_{t-1} + 0.21\pi_{t-2} + e_{\pi t}$$
$$\log(\psi_t) = 0.88 \log(\psi_{t-1}) - 0.07 \log(\psi_{t-2}) + 0.12\pi_{t-1} + 0.12\pi_{t-2} + e_{\psi t}$$

where the e_t are forecast errors that should be close to white noise.

The first equation of the VAR highlights the well-known persistence of inflation in U.S. time series captured by the sizable coefficients on lagged inflation. Fuhrer and Moore (1995) have argued that forward-looking price-setting models, such as the representative NNS specification described above, cannot explain this feature of the data. They have accordingly developed models with structural inflation persistence. In light of substantial research on price equations, dating back at least to Eckstein and Fromm (1968), it is notable that real marginal cost has a small estimated coefficient in this VAR equation, which also seems to call into question the linkage described above.

The statistical properties of U.S. data on real marginal cost (or log labor's share) were less well known to us, although there is a long tradition of looking at nominal wages relative to output per man-hour (unit labor costs) in research on price equations. The second VAR equation displays considerable persistence of real marginal cost, and there is also some tendency for past inflation to raise real marginal cost.

5.3. Borrowing results from recent empirical studies

Galí and Gertler (1999) estimate various versions of the specification (5.1) using a GMM estimation strategy that does not require knowledge of the forcing process on real marginal cost.[24] One of their battery of results is based on imposing $\beta = 1$ and estimating ϕ so that the specification is:

$$\pi_{t+1} = \pi_t - \phi \log(\psi_t) + \xi_{t+1} \tag{5.3}$$

where ϕ is estimated to be 0.035 with inflation measured in percent per quarter. In addition to this particular example, Galí and Gertler (1999) provide various econometric checks on a battery of estimated specifications and develop an empirical model with some potential for structural inflation via the behavior of "myopic" price-setters.

We work with the estimated restricted specification (5.3) for two reasons. First, it imposes a zero long-run effect of inflation on the average markup (real marginal cost) which is consistent with the behavior of theoretical NNS specifications at modest inflation rates. Second, our goal is to check whether purely forward-looking price setting behavior with no structural inflation persistence, as in (5.1) and (5.2), is potentially consistent with U.S. data.

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would likely be more interested in the standard errors on our implied reduced form. This would not be straightforward because the price equation "slope" is estimated using GMM in a separate exercise from the VAR.

[24] The NNS structural model isolates a purely expectational error term, which under rational expectations should be uncorrelated with the inflation and real marginal cost variables in (5.1).

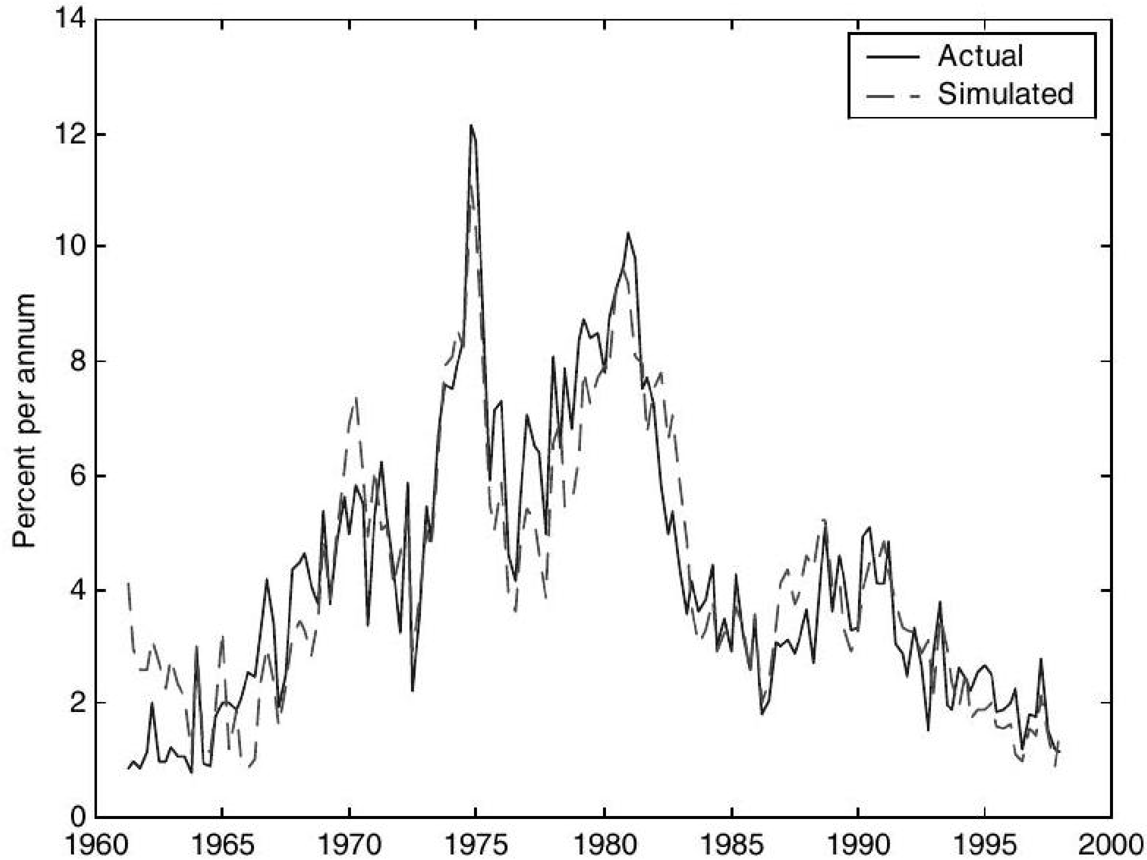

Figure 1. U.S. actual and simulated inflation, 1961: 2 through 1998: 1

As a first step in judging how well the benchmark NNS pricing model fits the U.S. data, Figure 1 compares actual U.S. inflation and simulated inflation from (5.2) and (5.3) using the methods of Galí and Gertler (1999) and Sbordone (1998).[25] The results are striking: although the simulated inflation does not capture every wiggle in the data, the pricing model without structural inflation persistence tracks actual U.S. inflation remarkably well.

5.4. Inflation persistence and the Lucas critique

What we really want to know, however, is whether the pricing model without structural persistence of inflation is consistent with the reduced form inflation persistence, as indicated by the coefficients in the inflation equation from our VAR. To answer this question we begin by following the procedure by which GGS actually construct their simulated inflation series. We substitute forecasts of future real marginal cost from our estimated vector autoregression into

[25] The simulation method was originally developed by Campbell and Shiller (1987) for the analysis of financial markets.

(5.2), with β restricted to unity and ϕ equal to 0.035 as estimated in (5.3).[26] This method generates simulated inflation, which we call $\hat{\pi}_t$, as

$$\hat{\pi}_t = \xi_1 \log(\psi_t) + \xi_2 \log(\psi_{t-1}) + \zeta_3 \pi_t + \xi_4 \pi_{t-1}$$

where the ζ coefficients depend on $\beta = 1,\ \phi = 0.035$ and on the estimated coefficients from the real marginal cost equation in our VAR. This does not look quite like our VAR inflation equation for two reasons. First, the left-hand side variable is not actual inflation, but simulated inflation. Second, current real marginal cost and current inflation enter on the right hand side. However, we can use our VAR to eliminate current real marginal cost and inflation

$$\pi_t = \omega_1 \log(\psi_{t-1}) + \omega_2 \log(\psi_{t-2}) + \omega_3 \pi_{t-1} + \omega_4 \pi_{t-2} + v_t \tag{5.4}$$

where the v_t residual is a composite error term.[27] In this expression, current inflation is a distributed lag of past inflation and real marginal cost only because these variables help to forecast real marginal cost in (5.2). When we solve numerically for the coefficients in (5.4) we obtain a counterpart to the inflation equation in our VAR in which there are important inflation lags even though there is no structural inflation persistence by construction

$$\pi_t = 0.16 \log(\psi_{t-1}) - 0.05 \log(\psi_{t-2}) + 0.51\pi_{t-1} + 0.14\pi_{t-2} + v_t\ .$$

This is not exactly the VAR inflation equation estimated above, which may be an indication of misspecification of either the structural model of inflation or of the forecasting model for real marginal cost or both. But, nevertheless, our computed distributed lag does share an important property with the estimated VAR equation: there are positive coefficients on lagged inflation which could easily be misinterpreted as suggesting the presence of underlying structural inflation persistence.

Our point is, of course, an application of a line of argument made famous by Lucas in his 1976 critique of macroeconometric modeling. This critique brought forth the rational expectations revolution in macroeconomics and thus led to the modeling of forward-looking price-setting. Our demonstration is even more directly an application of the classic short note by Sargent (1971), who warned about the dangers of misinterpreting distributed lags in the analysis of the Phillips curve.

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[26] We are solving the inflation difference equation forward with $\beta = 1$ which might make some readers nervous. There are three comments to make about this practice. First, with $0 < \beta < 1$, the solution practice involves the conventional ruling out of unstable dynamics, as in Sargent (1979). Second, we think of our solution as being the limit of solutions as β is raised toward one. Third, since the eigenvalues of the estimated VAR system are less than one in absolute value, our solution is a stationary inflation process even if $\beta = 1$.

[27] The disturbance term has two components. First, actual inflation π_t differs from simulated inflation $\hat{\pi}_t$ by an approximation error, which we will call α_t. Second, the process of replacing $\zeta_1 \log(\psi_t) + \zeta_3 \pi_t$ by the conditional expectations based on the VAR introduces another error, which is $\xi_1 e_{\psi t} + \xi_2 e_{\pi t} + \zeta_3 \pi_t$.

5.5. Monetary policy and inflation persistence

We showed above that if lagged real marginal cost and lagged inflation help to forecast real marginal cost as in our estimated VAR, and inflation is generated according to (5.2) with structural coefficients from (5.3), then inflation is forecast roughly as in the VAR. Thus, we argued that the inflation persistence in U.S. time series appears to be consistent with a NNS model in which persistence is not structural. To complete our non-structural interpretation of observed inflation persistence we must suggest how the interaction of central bank behavior with the private economy could generate a forecasting equation for real marginal cost that resembles the one from our estimated VAR. The key is to explain why lagged inflation should help forecast real marginal cost.

We think of an economy where there are various underlying shocks including shifts in productivity, government purchases, and so on. Under neutral monetary policy, the markup would be stabilized. To the extent that fluctuations in the markup were unforecastable, coefficients in the VAR equation for real marginal cost would be zero. Productivity shocks would have important effects on output, but no effect on real marginal cost because they would bring about changes in both wages and output per man-hour. But the U.S. time series have not been generated by a central bank following neutral policy: inflation has been far from constant and real marginal cost exhibits the substantial dynamics described by the VAR equation.

Why might real marginal cost have moved around in this manner? The behavior of real marginal cost is governed by the interaction of the central bank and the private economy. Suppose, for concreteness, that the central bank has been following a version of the Taylor rule, in which it responds to inflation and real activity. In this setting, nearly every shock – certainly productivity and government purchase shocks, if not money demand shocks – will cause departures from the potential output which would prevail under neutral monetary policy. It is clear that there can be persistent departures of output from potential (and associated departures of real marginal cost from its average level).

For example, if there is a persistent rise in productivity, then the economy will feature an increase in output, investment, consumption and work effort. The real interest rate will rise as well, as the economy displays expected growth in consumption and output. But if the policy rule does not call for the interest rate to increase enough, then there will be an additional stimulus: output will rise even further, with an associated rise in real marginal cost and an accompanying rise in inflation. How the dynamics work out depend on the details of the model and the policy rule. However, real marginal cost may only slowly move back toward its long run level and past inflation may help forecast this movement, because past prices are part of the state vector in the full NNS model. Since real marginal cost may depend on many shocks, which have different implications for inflation–perhaps because of their duration or their effect on the underlying real interest rate − lagged real marginal cost will likely not be a sufficient predictor for future real marginal cost.

It is important to note that the non-structural NNS view of inflation predicts that its persistence in U.S. data would tend to disappear if the Federal Reserve followed a neutral monetary policy that maintained expected markup constancy and price stability. According to the non-structural view of inflation, if monetary policy erased the serial correlation in real marginal cost, then lagged inflation would not help predict real marginal cost, and so would not appear in the inflation equation of the VAR. That prediction gets support from evidence presented by Cogley and Sargent (2000) and Taylor (2000) that inflation was less persistent in the 1950s, 1960s, and again in the 1990s than in the intervening years.

6. Why Depart From Price Stability in an NNS Model?

In this section we consider some reasons for departing from perfect price stability within the full NNS model. Since optimal monetary policy has not yet been studied in these richer NNS models, we use the links between fiscal and monetary policy that we developed in Sections 2 and 3 to suggest what will be found when it is. We begin with results from more elaborate NNS models that have been studied.

6.1. Multiperiod price-setting: a reference result

As we stressed in sections 4 and 5, one implication of multiperiod price-setting is that inflation dynamics become forward-looking. Another implication, which we stressed in our earlier paper, is that the monetary authority has some leverage over the average markup via its choice of the steady state inflation rate. We reported that the monetary authority can lower the steady state markup slightly around zero inflation, but that at higher rates of inflation there is actually a positive relationship between inflation and the average markup since firms seek to avoid having their real prices eroded.[28] The steady state inflation rate in an NNS model also influences the extent of relative price distortions. There are no relative price distortions at zero, but positive or negative rates of inflation bring about these distortions, which reduce the amount of consumption that can be obtained from labor input. Since marginal relative price distortions are zero at price stability and a higher inflation rate slightly reduces the average markup, we conjectured, incorrectly as it turns out, that NNS models would rationalize a case for a slightly positive inflation rate.

Working in a model with Keynesian sticky price and monopolistic competition frictions, but without any distortions associated with monetized exchange, King and Wolman (1999) showed that the optimal inflation rate is asymptotically zero under commitment.[29] This result occurs despite the fact that their model implies some slight leverage for the monetary authority over the steady state markup as described above. While it has this leverage, the monetary authority chooses not to employ it, for reasons that are similar to why a planner chooses not to maximize steady-state consumption in the neoclassical growth model. Zero inflation is a "modified golden rule" for monetary policy.

[28] Goodfriend and King (1997), pp. 263-265.

[29] King and Wolman (1999) construct a basic NNS model with staggered price-setting, which is flexible enough to contain the distributed lag structures of Taylor (1980), Calvo (1983) and those used in empirical work on price dynamics (for example, Taylor (2000)). King and Wolman utilize a dynamic version of the approach to optimal policy design as in Section 3 but without investment and capital as in Section 3. More specifically, King and Wolman construct a model with the stochastic adjustment structure due to Levin (1989). The main body of the paper concerns Taylor pricing. But the concluding section makes clear that the central result holds for the rich class of adjustment patterns that can arise within Levin's analysis.

King and Wolman also found that the price level should be fully stabilized in the face of time-varying productivity shocks, despite the fact that there are substantial distortions from imperfect competition present in their model. As in the simple model of Section 3, this policy is consistent with complete smoothing of real marginal cost and the average markup. Also as in the simple model of Section 3, optimal monetary policy requires the monetary authority to accommodate productivity shocks, supplying money when output expands and contracting money when output falls.

6.2. A tension: the Friedman rule versus price stability

The Ramsey approach to policy design has been employed in perfectly competitive economies with flexible prices to rationalize Friedman's rule for the optimum quantity of money, namely deflating at the real rate of interest to make the nominal interest rate zero so as to minimize various distortions that arise when there is costly monetary exchange. The modern literature on this topic – summarized by Chari and Kehoe (1999) – reaches Friedman's conclusion within rich RBC models, so that it applies this logic to fluctuations as well as steady states.

Ireland (1996) and Adao, Correia, and Teles (2000) examine optimal monetary policy in sticky price models like the one we studied in Section 3, but they incorporate alternative models of monetized exchange. They thus take a stand on the frictions which give rise to money demand and allow for the "triangles under the demand for money" that Friedman's zero interest rate policy is designed to eliminate. These studies find that deflation according to the Friedman rule is optimal, despite the introduction of imperfect competition and price stickiness. This conclusion is a natural one: the model of one period price stickiness that they consider involves no leverage for the monetary authority over the average markup stemming from its choice of the average inflation rate and there are no relative price distortions due to steady inflation. In terms of response to productivity shocks, Ireland (1996) argues that optimal monetary policy should be accommodative, but he does not stress the implication that the price level should be held constant in the face of such shocks.

Khan, King and Wolman (2000) study this topic in staggered price-setting model so that there is a genuine tension. They model money demand as arising from an environment with costly use of credit in the exchange process, building on earlier models of Prescott (1987), Dotsey and Ireland (1996) and Lacker and Schreft (1996). A higher average inflation rate induces individuals to substitute out of money into socially costly credit use, which has substitution and wealth effects on households. If the KKW economy were perfectly competitive and goods prices were perfectly flexible, then the KKW model would call for deflation on average and zero nominal interest. But, since KKW assume that there is imperfect competition and sticky prices, there is a tension. KKW studied their economy using the Ramsey approach, calibrating their model to match aspects of U.S. money holdings. They stress two findings. First, the optimal average inflation rate is negative, some deflation is optimal to get closer to the Friedman optimum even at the expense of some relative price distortion.[30] The size of the

[30] Deflation is beneficial because it saves resources wasted from the social point of view on the use of credit, and because it reduces the distortion on monetized exchange due to positive nominal interest. However, deflation is costly because it distorts relative prices in this staggered pricing environment.

optimal deflation depends on the empirical measure of money that they employ: it is negligible if currency is used and perhaps as large as a percentage point if M1 is used.[31]

The results for M1 involve greater deflation, we think, for two reasons. First, the ratio of real money balances to consumption is much higher for M1 than it is with currency. This implies that there is a larger "wedge of monetary inefficiency" associated with monetized exchange that the monetary authority would like to eliminate by reducing the nominal interest rate. Second, the demand for M1 is more interest-elastic than the demand for currency, which means that a lower nominal interest rate results in a greater resource saving in terms of credit costs. Yet, increasingly the demand deposit component of M1 is interest-bearing, so that it is less effected by the nominal interest rate. Within the KKW model with a single monetary aggregate, payment of partial interest on money would reduce the effect of monetary policy on the wedge of monetary efficiency and on credit costs, leading to a model that more closely resembled the King and Wolman (1999) model, where zero inflation is optimal. So, we conclude that the optimal rate of deflation is uncertain and may well depend on institutional factors that affect the substitutability of currency and deposits. We reason that the results for currency, rather than M1, may increasingly be the more relevant ones.

Second, KKW find that the optimal price level path changes only in a minuscule way when there are shocks to productivity, the costliness of credit, or government purchases. Since expected inflation is essentially constant and since these disturbances affect the real interest rate, the optimal policy does not stabilize the nominal interest rate. Instead, optimal policy makes nominal interest track the equilibrium real interest rate that would prevail if prices were perfectly flexible.[32]

While the KKW framework is much richer than the one we studied in Section 3, it nevertheless delivers similar conclusions about the case for price stability. However, like the model we used there, the KKW framework abstracts from capital: there is no investment, capital stock, or varying utilization.

6.3. Varying elasticities: departures from constant taxes and markups

Our economies in Sections 2 and 3 were "rigged" along lines suggested by Ramsey's original analysis to generate the result that explicit income tax rates and markups should not vary across states of nature. In fact, Ramsey's original analysis highlighted economic reasons for

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[31] KKW also conclude, but do not stress, that in such an environment, there is the possibility that the Friedman rule can still be optimal, even if the economy has a costly credit specification which implies that there is a negligible resource cost (credit cost) of having a slightly higher inflation rate than that prevailing at the Friedman rule. This is a "second best" result, which arises because there is imperfect competition. The Friedman rule minimizes the wedge of monetary inefficiency, which acts like a tax on consumption. Since there is imperfect competition, it can be undesirable to raise this wedge because the economy is distorted by the markup tax at the Friedman rule. But it is not an outcome when the model is calibrated to a "realistic" money demand, although it might be if one built in the higher estimates of the costs of inflation that have been suggested by some recent studies.

[32] There are some puzzles about the behavior of real activity in response to government purchases. Optimal output does depart slightly and temporarily from what would occur if there was monopolistic competition but price flexibility. We discuss this matter further in Section 6.5.

departures from uniform taxation across products. The constancy of the tax rate on labor income across states of nature is, essentially, a version of uniform taxation. Here, we address the possibility of optimal departures from tax rate smoothing due to variable elasticities.

To begin, recall the household's first order condition for work from the optimal fiscal policy analysis in Section 2: $h'\big(n(s)\big) = \lambda\big(1-\tau(s)\big)\, w(s)\, q(s)$. Using this condition, the elasticity $\eta(n(s))$ of the supply of work effort in state s with respect to the real wage, the tax rate, and the state price can be written $\eta(n(s)) = h'(n(s))/[n(s)\, h''(n(s))]$. It is easy to verify that our assumption $h'(n(s)) = \theta(n(s))^{1/\eta}$ from Sections 2 and 3 makes the labor supply elasticity constant across states of nature. There are many specifications of preferences that do not imply constant elasticity. One specification widely used in quantitative macromodels makes utility log-linear in consumption and leisure

$$u(c,n) = \log(c) + \theta \log(1-n)$$

This specification makes $h(n) = -\theta \log(1-n)$, so that $h'(n) = \theta/(1-n)$, and the elasticity of labor supply is

$$\eta(n) = \frac{1-n}{n}$$

which is inversely related to work effort, n. Following Ramsey principles, for example, in the context of the small open economy analyzed in Section 2 , goods inelastically supplied should be taxed more heavily. Hence, in this case the optimal income tax rate should rise when employment is high and fall when it is low.

Given the similarity in the principles that govern optimal fiscal and monetary policy, it is clear that the optimal markup (real marginal cost) will also move around when the elasticity of labor supply is variable.

6.4. But when are elasticity variations likely to matter?

Two considerations will govern whether variable elasticities are likely to matter. The first is whether shocks affect the supply of the good that is being taxed. For example, Adao, Correia, and Teles (2000) study the effect of a productivity shock in a closed monetary economy like the one that we analyzed in Sections 3. They show that optimal monetary policy maintains markup constancy across states of nature in response to a productivity shock in a number of situations, one of which is that the utility function implies that there are exactly offsetting wealth and substitution effects on work effort in their closed economy. This invariance holds for a class of preferences discussed in the RBC literature by King, Plosser and Rebelo (1988) that is consistent with balanced growth. An example of these preferences is $\log(c) + \theta \log(1-n)$, which we just discussed as implying a variable elasticity of labor supply. If employment is invariant to productivity shocks, however, and these are the only shocks, then it may not to be important whether the elasticity of labor supply is variable.

Thus, our first point is this: variable elasticities will be important quantitatively for optimal monetary (markup) and income tax policy only if underlying shocks cause quantities to fluctuate so as to induce important variation in the elasticities. For example, Khan, King and

Wolman (2000) study optimal policy response to productivity shocks in a model with staggered pricing with the preferences given above. But they study an economy without capital, so productivity shocks have essentially offsetting income and substitution effects on work effort under neutral monetary policy. Hence, the monetary authority may view the labor elasticity as effectively constant because the variation in work effort is small.

Our second point is that the expected duration of shocks will matter for the effect of variable elasticities. In a model without capital or multiperiod price stickiness this is a nonissue. But we believe that persistence of disturbances can be important in more general models. On the fiscal side, Chari, Christiano, and Kehoe (1994), working within an RBC model with capital providing intertemporal links, show quantitatively that the optimal labor income tax rates should fluctuate very little in the presence of shocks to productivity and government purchases. In their rich RBC model work effort can vary through time for intertemporal substitution reasons. They use preferences such as those given above that imply a variable elasticity of labor supply. Therefore, we interpret their finding that labor income tax rates are very stable in response to changes in productivity and government purchases as indicating that the variable labor supply elasticity does not play a quantitatively important role. We conjecture that these findings may carry over to optimal markup behavior in NNS models with a rich RBC core, although there has not yet been a systematic exploration of optimal monetary policy in such models.

6.5. How should the monetary authority respond to demand shocks?

In our model of optimal monetary policy in Section 3, we had supply (productivity) but no demand shocks. We used this shock structure because the prior studies of Ireland (1996) and King and Wolman (1999) focused on such disturbances. Here we introduce government purchase shocks $g(s)$ into the closed monetary model of Section 3 and we ask whether demand shocks cause the monetary authority to depart from perfect markup smoothing. We study this question in a closed economy because the private sector fully insures against government purchase shocks in the small open economy. We are motivated to study this question because Khan, King and Wolman (2000) report that it is optimal to depart from the reference RBC solution in their staggered pricing model.

We apply the principles of optimal fiscal and monetary policy developed in Sections 2 and 3 as follows. The closed economy resource constraint becomes

$$c(s) + g(s) = y(s) = a(s)\, n(s) \; .$$

The closed reference RBC solution – which prevails if the markup is held fixed – highlights the effect of government purchases. All else equal, a positive government purchase shock creates a negative wealth effect for the private sector: there is more work $n(s)$ and less consumption $c(s)$ than would prevail in states with lower levels of government purchases. The exact breakdown of the effect on consumption and leisure will depend on the details of preferences. Again holding other things equal, the state price $q(s) = v'(c(s))$ would be higher with greater government spending because of the adverse effect on consumption.

If any departure from markup smoothing were called for, one might guess that it would be desirable to "stabilize" the effects on consumption of a government purchase shock, by lowering the markup when government spending is high to stimulate additional output and raising the markup correspondingly when there are low levels of government spending. It turns out, however, that the optimizing monetary authority in Section 3 chooses exactly the opposite pattern of interventions: the monetary authority tightens monetary policy to raise the markup when government demand is high and eases monetary policy to lower the markup when government demand is low, thus amplifying rather than reducing the volatility of consumption. This is the same optimal response of monetary policy to government purchase shocks that Khan, King, and Wolman (2000) find.[33]

We can understand the nature of this optimal departure from markup smoothing in our simple framework as follows. Adding government purchases as a use of output, using the resource constraint, and the household's first order conditions (3.3), and normalizing λ to unity, we can express the implementation constraint (3.2) as

$$\begin{aligned} 0 &= \int [\psi(s) - \psi] \; y(s)\, q(s)\, \phi(s)\, ds && (6.1) \\ &= \int \big[h'\big(n(s)\big)\, n(s) - \psi v'\big(c(s)\big)\, c(s)\big] \phi(s)\, ds - \psi \int g(s)\, v'\big(c(s)\big)\, \phi(s)\, ds. && (6.2) \end{aligned}$$

Equation (6.2) highlights the fact that government purchases shift the implementation constraint.[34] We have found that there are two complementary ways of thinking about the implications of this modification.

A budget constraint interpretation: To begin in this direction, note that we can interpret (6.1) as a state contingent budget constraint that must be respected by the monetary authority.[35] To interpret the implementation constraint this way, think of an "imaginary fiscal authority" that

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[33] While the KKW paper has the preference specification $\log(c) + \theta \log(1-n)$, which falls outside of the class used in sections 2 and 3, Alex Wolman has run a set of experiments with the alternative utility function $\log(c) + \theta \frac{1}{1+\gamma} n^{1+\gamma}$.

The government purchase results in the two versions of the KWW model with the two different specifications were virtually indistinguishable, suggesting that the implementation constraint is the dominant feature leading to the effects of government purchases. In these experiments all monetary distortions were also eliminated.

[34] There is a discrepancy between our results in this section and suggestions in Rotemberg and Woodford (1997) and Woodford (2001) that zero inflation is optimal irrespective of the nature of the shocks. There is a simple reason for this discrepancy. Rotemberg and Woodford assume that there is a subsidy that raises output to it efficient level, which would modify the monopolist's pricing condition to

$$0 = \int \; \big[h'\big(n(s)\big)\, n(s) - \sigma\psi v'\big(c(s)\big)\, (g(s) + c(s))\big]\, \phi(s)\, ds\, .$$

were σ is the "gross subsidy". Clearly, this does not alter how the government purchase shock affects the constraint, except as a scale factor. But, if the subsidy is introduced, then our multiplier is altered to $\Gamma = (1-\psi\sigma)/\left(\psi\sigma\left[\frac{1}{\eta} + \frac{1}{\gamma}\right]\right) > 0$ under neutral policy. Setting the efficient level of subsidization, as in Rotemberg and Woodford, makes the multiplier equal to zero because $(1 - \sigma\psi) = 0$. Accordingly, the implementation constraint does not bind and the monetary authority is free to maximize utility subject only to the resource constraint. We are indebted to Michael Woodford for pushing us to think about how our economy would work if there was a subsidy that produced an efficient level of capacity output.

[35] This is consistent with the earlier finding that the multiplier on this constraint Γ is positive.

must use distorting tax rates to raise revenues $\int \psi(s)\, y(s)\, q(s)\, \phi(s)\, ds$ and make expenditures $\int \psi y(s)\, q(s)\, \phi(s)\, ds$.[36] In the closed economy we can move to (6.2), as described above. But these modifications do not keep us from thinking of (6.2) as a state contingent budget constraint. The monetary authority's first order condition for consumption in state s using the state s resource constraint and the implementation constraint (6.2) is

$$v'(c(s)) = \Lambda(s) - \psi\Gamma\left[v'\big(c(s)\big) + c(s)\, v''(c(s))\right] - \psi\Gamma[g(s)\, v''(c(s))] \qquad (6.3)$$

with $\Lambda(s)$ again being the multiplier on the resource constraint in state s and Γ again being the multiplier on the implementation constraint (6.2).[37] This directly generalizes the first-order condition for consumption from the monetary authority's problem for the closed economy in Section 3.

How do government purchases alter matters relative to the solution that we derived before? As before, when the monetary authority thinks about choosing consumption in state s he takes into account the effect of his actions on $q(s)$. But now the monetary authority must take into account its effect on the amount that the imaginary fiscal authority will have to spend, $\psi g(s)\, q(s) = \psi g(s)\, v'(c(s))$. Raising consumption in state s has an effect of $\psi[g(s)\, v''(c(s))]$, which is the origin of the new term in (6.3). So, a state with higher government purchases is a state in which there is now a less incentive to have consumption because it "costs" more.

Working things out: Impose constant elastic preferences as in Section 3 and manipulate the first order condition for consumption (6.3) to obtain

$$v'(c(s)) = \kappa_{cg}(s)\Lambda(s)$$

where $\kappa_{cg}(s) = \left[1 + \psi\Gamma\left(1 - \frac{1}{\gamma}\left(1 + \frac{1}{\gamma}\left(\frac{g(s)}{c(s)}\right)\right)\right)\right]^{-1}$. Nothing has changed in terms of the determination of work effort from the closed economy in Section 3, so that the comparable rearranged first order condition is $h'\big(n(s)\big) = \kappa_n \Lambda(s) a(s)$.[38]

Equating the respective marginal rates of substitution for households and the monetary authority, using (3.3) and the monetary authority's first order conditions above, we see that to implement optimal state contingent monetary policy we need real marginal cost to be

$$\psi(s) = \frac{\kappa_n}{\kappa_{cg}(s)}\,.$$

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[36] As mentioned above, one can think of monopolistically competitive firms as running a tax and transfer fiscal policy. The implementation constraint says that the monetary authority must respect the firms price-setting efficiency condition.

[37] Note that we are here assuming lump sum taxation so that we can leave the government budget constraint in the background. We are interested in whether the composite markup tax-explicit income tax that implements optimal monetary policy is constant.

[38] See Sections 3.3.3 and 3.3.4.

Thus, real marginal cost must fall (the markup must rise) whenever optimal policy calls for an increase in the ratio of government purchases to private consumption. One can establish that $g(s)/c(s)$ rises when $g(s)$ rises at the optimum.[39] Thus, optimal monetary policy "stabilizes" employment but "destabilizes" consumption with respect to government purchase shocks.

How important are such effects likely to be? We conjecture that optimal departures from markup (real marginal cost) constancy along these lines are likely to be quantitatively small if demand shocks are really government purchase disturbances, because these are likely to be fairly small outside of major war-time periods. However, investment is quite volatile cyclically and it is possible that a similar line of argument would apply to investment in a more complete business cycle model. On the other hand, investment opens an intertemporal smoothing channel for households that makes it more difficult for the monetary authority to produce transitory variations in consumption. This is important because there would be no departure from markup constancy in the presence of demand shocks if the monetary authority could not affect state prices, as in the case of our small open economy. And the monetary authority must affect state prices through its effect on consumption.

In any case, optimal departures from markup constancy in response to government purchases are likely to be quite temporary in nature. For example, in the Khan, King and Wolman (2000) analysis of a staggered pricing model, departures from markup constancy last for only a brief period during which there is substantial predetermined price stickiness. For an increase in government purchases, consumption falls temporarily relative to where it would have been with flexible prices or neutral policy; and the real interest rate rises because consumption is expected to grow.[40] Because optimal departures from markup (real marginal cost) constancy are temporary, there is little effect on the path of the price level under optimal policy, since inflation responds substantially only when there are persistent movements in real marginal cost.

7. Sticky Nominal Wages and the Labor Market

Evidence recently surveyed by Taylor (1999) finds about the same degree of temporary rigidity in nominal wages as in prices. Price changes and wage changes have about the same average frequency of about one year. On the basis of this evidence, Taylor points out that there is no empirical reason to build a model in which wages are perfectly flexible while prices are temporarily rigid, or vice versa.[41] If one recognizes that both price and wage decisions require scarce management attention, it is not surprising that there is a rough symmetry in the temporary

[39] One can use the combination of monetary authority first order conditions and the resource constraint to establish this. Alternatively, if small shocks are considered around an initial position of no government purchases, then

$$d\frac{g(s)}{c(s)} = \frac{dg}{c} - \frac{g}{c}\frac{dg}{g} = \frac{dg}{c}$$

so that there is no need to worry about the endogeneity of consumption in reaching the conclusion.

[40] In the KWW setup, this additional increase is larger than the direct effect on the real interest rate that occurs with a rise in government purchases under neutral policy.

[41] See Taylor (1999), pp. 1016 and 1020–1021.

rigidity of nominal prices and wages. After a firm resets prices or wages, it takes time for the price or wage decision to return to the top of management's priorities.[42]

Given the rough empirical symmetry of the degree of price and wage rigidity, it is reasonable to ask why benchmark NNS models have emphasized nominal price stickiness rather than wage stickiness. One reason is that New Keynesians such as Mankiw (1990) have emphasized that sticky price models seem more consistent with the somewhat procyclical real wages found in the data. Another reason is that adding nominal wage stickiness complicates the model without making much difference for most applications. However, some economists, for example, Blanchard (1997) and Erceg, Henderson, and Levin (2000), argue that the strong case for price stability in NNS models depends on the flexibility of nominal wages.

These authors point out that there appears to be a trade-off between price stability and output stability when both nominal prices and wages are sticky. For instance, in order to stabilize the markup and the price level in the basic NNS model in response to an adverse productivity shock, aggregate demand and employment must contract. In the flexible wage model, reduced labor demand causes the real wage to fall, offsetting the effect of lower productivity on the markup. If nominal wages are temporarily sticky, and price stability is to be maintained, then the real wage cannot fall, and monetary policy must steer output below its potential to raise the marginal product of labor enough to stabilize the markup and maintain a stable price level. Thus, there would appear to be a trade-off between output stability and price stability in such circumstances.

Our response to this line of argument is that although there is empirically a rough symmetry in the temporary stickiness of nominal prices and wages, there is a fundamental *asymmetry* in the structure of labor and product markets. Long-term relationships govern most labor transactions in advanced economies, while for the most part goods transactions take place in spot markets.[43] We argue below that temporary nominal wage stickiness in the context of long-term employment relationships is unlikely to influence in a fundamental way the NNS recommendation for price stability. Our argument is in the spirit of the New Neoclassical Synthesis: we accept temporary nominal wage rigidity as an empirical fact and ask what its effects are likely to be given dynamic optimization in the labor market.

The great value of firm-specific investments in human capital is the main reason for long-lived employment relationships in the labor market. An employee and a firm are more willing to invest in mutually beneficial firm-specific capital if they expect their attachment to be long-lived. Firm-specific human capital is not easily diversified or collateralizable by the employee. However, there is scope for long-term contracts to allow risk and financial intermediation to be shifted from employees to the firm. Long-term employment relationships create shared rents that introduce a wedge between the value of the current job to the employee and outside opportunities. These rents relax momentary arbitrage constraints between current wages, the

[42] Jovanovic and Ueda (1997) offer an explanation for why contracts are not indexed to the price level.
[43] There are exceptions. For instance, low-skilled labor is sometimes transacted in spot markets. Firms and their suppliers may have a long-term relationship, and bank loans are arranged in the context of long-term relationships between borrowers and banks.

fortunes of the firm, and market conditions.[44] As Hall (1980, 1999) emphasizes there is leeway for wages to take the form of installment payments in return for investment in firm-specific human capital minus an insurance premium component. Shared rents act as a mutual commitment mechanism, credibly binding firms and employees to long-term (implicit) contracts.

Under full information, an efficient labor contract in the NNS model described in Section 3 would respect the household's first order conditions (3.3). Contracts would raise the elasticity of labor supply to the extent that they help insulate workers from the wealth effects of shocks. With private information on worker preferences or productivities, a contract would also respect an incentive compatibility constraint. But there is no reason to think that contracts would not be efficient given the private information environment.

Efficient contracting gives reason to expect some degree of *real* wage stickiness in which wages take the form of installment payments in the context of long-term relationships. Contract theory per se says nothing about why *nominal* wages might be temporarily rigid. For that we continue to appeal to the argument made above that it is efficient for firms to fix nominal wages for a period of time and to consider wage changes only at discrete (perhaps stochastic) intervals. However, we think that potential allocative inefficiencies from infrequent setting of nominal wages are likely to be offset in the context of long-term employment relationships. Our argument is reminiscent of Barro's (1977) point. First, it would be inefficient for either firms or workers to allow nominal wage stickiness to upset the terms in otherwise efficient long-term relationships. Second, there is scope for firms and workers to neutralize the effect of nominal wage stickiness since wages already resemble installment payments in the context of a long term relationship. Thus, firms and workers could be expected to arrange future transfers to undo any wealth effects of nominal wage stickiness.

Reconsider the NNS economy's response to an adverse productivity shock when there are long-term employment contracts. If the price level is stabilized, then those firms whose nominal wage is temporarily sticky will pay a temporarily "excessive" real wage relative to the wage called for by an efficient contract without nominal stickiness. However, such firms will record a "due from" to be transferred from employees to the firm in the future. Consequently, "effective" real marginal cost will fall as much for firms that do not adjust their nominal wages as for those firms that do adjust. In effect, the contractual framework provides a context within which firms can bunch their consideration of nominal wage changes without distorting the present value of wage payments called for by the long-term contract.[45]

To sum up, there is convincing evidence that both nominal prices and wages are temporarily rigid. However, we expect firms and workers to *neutralize* allocative consequences of sticky nominal wages in the context of long-term relationships that predominate in the labor

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[44] See Rosen (1985), page 1147. This discussion draws on Rosen's survey. See also Milgrom and Roberts (1992), Part 5.

[45] Since long-term contracts loosen the link between wage payments and shifts in productivity or preferences for work and leisure, any inefficiency from a temporary distortion of the time path of wage payments (due to nominal wage stickiness) should be small. This part of the argument makes Akerloff and Yellen's (1985) point. A firm that optimizes over its choice of wage will incur losses that are second order with respect to small temporary departures from that optimum.

market.[46] On the other hand, spot transactions predominate in product markets where temporarily sticky nominal prices of monopolistically competitive firms can influence the average markup significantly over time. The real consequences of temporary nominal *price* stickiness in product markets needs be eliminated by a *neutral monetary policy*, a policy that supports price stability.

8. Conclusion

Our purpose in this paper was to explore the foundations of neutral policy in the New Neoclassical Synthesis. In doing so we strengthened the case for price stability as the primary objective of monetary policy. Price stability is neutral policy because it keeps output at its potential defined by the outcome of an imperfectly competitive real business cycle model with a constant markup. Interpreting the markup as a tax on work effort, we showed how principles of public finance could be used to derive conditions under which markup constancy is optimal monetary policy. We considered numerous reasons why monetary policy might depart from markup constancy and price stability, but we argued that optimal departures are likely to be minor.

We emphasized that the markup plays a dual role. In its role as a tax, a time-varying markup has the potential to create inefficient cyclical fluctuations in employment and output. The markup also plays a central role in the evolution of inflation. We showed that the optimal markup, the one that supports price stability, also maximizes firm profits. Firms considering whether to change their prices will not choose to do so when the central bank maintains optimal markup constancy, since profits will already be maximized at current prices. This logic can be turned around and put to great practical use. An environment with fully credible price stability is also one in which firms choose not to change prices because current prices already maximize profits. Importantly, our principles of optimal fiscal policy imply that the static profit maximizing markup is also the optimal constant markup in the RBC core of the new synthesis model. Thus, we see why price stability is neutral policy that keeps output at its potential as defined above. This last point is of considerable practical importance because it means that a central bank can pursue optimal monetary policy by consistently taking actions to fight inflation and deflation in order to acquire and maintain credibility for stable prices. A central bank need not target the optimal constant markup directly, or know anything about it.

[46] In his comments on our paper, Jordi Galí pointed out that if nominal wages are sticky but not allocative, then the measure of real marginal cost which is used in Section 5 is inappropriate. Instead, one should use a measure of real marginal cost which involves the shadow real wage (the marginal value of work) divided by the real marginal product of work.

We believe that this suggestion is an important one. Bils' (1987) work on the cyclical behavior of real marginal cost deals with this sort of measurement issue and shows that it is quantitatively important, although he does not tie the results to the behavior of inflation. The more precise measurement of real marginal cost will surely be at the heart of future work on inflation dynamics. We stress, however, that more accurate measurements of real marginal cost will not lead to simple relationships between inflation and output (or employment) gap measures as these are traditionally defined.

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