Economic Quarterly—Volume 94, Number 3—Summer 2008—Pages 197–218

New Keynesian Economics: A Monetary Perspective

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Since John Maynard Keynes wrote the *General Theory of Employment, Interest, and Money* in 1936, Keynesian economics has been highly influential among academics and policymakers. Keynes has certainly had his detractors, though, with the most influential being Milton Friedman, Robert Lucas, and Edward C. Prescott. Monetarist thought, the desire for stronger theoretical foundations in macroeconomics, and real business cycle theory have at times been at odds with Keynesian economics. However, Keynesianism has remained a strong force, in part because its practitioners periodically adapt by absorbing the views of its detractors into the latest "synthesis."

John Hicks's IS-LM interpretation of Keynes (Hicks 1937) and the popularization of this approach, particularly in Samuelson's textbook (Samuelson 1997), gave birth to the "neoclassical synthesis." Later, the menu cost models developed in the 1980s were a response to a drive for a more serious theory of sticky prices (Mankiw 1985, Caplin and Spulber 1987). More recently, New Keynesian economists have attempted to absorb real business cycle analysis and other ideas from post-1972 macroeconomics into a "new neoclassical synthesis" (Goodfriend and King 1997).

The important New Keynesian ideas, as summarized, for example in Clarida, Galí, and Gertler (1999) and Woodford (2003), are the following:

1. The key friction that gives rise to short-run nonneutralities of money and the primary concern of monetary policy is sticky prices. Because some prices are not fully flexible, inflation or deflation induces relative price distortions and welfare losses.

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2. Modern monetary economics is not part of the New Keynesian synthesis. New Keynesians typically regard the frictions that we encounter in deep (e.g., Lagos and Wright 2005) and not-so-deep (e.g., Lucas and Stokey 1987) monetary economics as being second-order importance. These frictions are absence-of-double-coincidence problems and information frictions that give rise to a fundamental role for monetary exchange, and typically lead to intertemporal distortions that can be corrected by monetary policy (for example, a ubiquitous result in monetary economics is Friedman's zero-nominal-interest-rate rule for correcting intertemporal monetary distortions). The Friedman rule is certainly not ubiquitous in New Keynesian economics.

3. The central bank is viewed as being able to set a short-term nominal interest rate, and the monetary policy problem is presented as the choice over alternative rules for how this nominal interest rate should be set in response to endogenous and exogenous variables.

4. There is a short-run Phillips curve tradeoff. A monetary policy that produces an increase in unanticipated inflation will tend to increase real aggregate output.

The goal of this paper is to construct a simple sticky-price New Keynesian model and then use it to understand and evaluate the ideas above. In this model there are some important departures from the typical New Keynesian models studied by Clarida, Galí, and Gertler; Woodford; and others. However, these departures will highlight where the central ideas and results in New Keynesian analysis are coming from.

For monetary economists, key aspects of New Keynesian economics can be puzzling. For example in Woodford (2003), the apparently preferred framework for analysis is a "cashless model" in which no outside money is held in equilibrium. Prices are denominated in terms of some object called money, and these prices are assumed to be sticky. The interest rate on a nominal bond can be determined in the cashless model, and the central bank is assumed capable of setting this nominal interest rate. Then, the monetary policy problem is formulated as the choice over rules for setting this nominal interest rate. This approach can be contrasted with the common practice in monetary economics, where we start with a framework in which money overcomes some friction, serves as a medium of exchange, and is held in equilibrium in spite of being dominated in rate of return by other assets. Then, studying the effects of monetary policy amounts to examining the consequences of changing the stock of outside money through various means: open market operations, central bank lending, or outright "helicopter drops." It is usually possible to consider monetary policy rules that dictate the contingent behavior of a nominal interest rate, but in most monetary models we can see what underlying actions the central bank must take concerning monetary quantities to support such a policy. What is going on here? Is the New Keynesian approach inconsistent with the principles of monetary economics? Is it misleading?

The first task in this article is to construct a cashless model with sticky prices. This model departs from the usual New Keynesian construct in that there are competitive markets rather than Dixit-Stiglitz (1977) monopolistic competition. This departure helps to make the model simple, and yields information on the importance of the noncompetitive behavior of firms for New Keynesian economics. In general, given the emphasis on the sticky-price friction in New Keynesian economics, we would hope that it is something inherent in the functioning of a sticky-price economy, rather than simply strategic behavior, that is at the heart of the New Keynesian mechanism.

Our cashless model is consistent with most of the predictions of standard Keynesian models, new and old. The sticky-price friction leads to a relative price distortion in that with inflation (deflation), too large (too small) a quantity of sticky-price goods is produced and consumed relative to flexible-price goods. Optimally, the inflation rate is zero, which eliminates the relative price distortion. One aspect in which this model differs from standard New Keynesian models is that it does not exhibit Phillips curve correlations. If the substitution effect dominates in the labor supply response to a wage increase (which we consider the standard case), then output is decreasing (increasing) in the inflation rate when the inflation rate is positive (negative). This is because the distortion caused by sticky prices rises with the deviation from a constant price level, and the representative consumer supplies less labor in response to a larger sticky-price distortion. Thus, under these circumstances output is maximized when the inflation rate is zero and there is no output/inflation tradeoff. In the case where the income effect dominates in the labor supply response to a change in wages, output increases (decreases) for positive (negative) inflation rates. Here there is a Phillips curve tradeoff if the inflation rate is positive, but a zero inflation rate is optimal.

In most New Keynesian models, Phillips curve correlations are generated because of the strategic forward-looking behavior of price-setting firms. A firm, given the opportunity to set the price in units of money for its product, knows it will not have this opportunity again until some time in the future. Roughly, what matters to the firm is its expectation of the path for the price level during the period of time until its next price-setting opportunity. If the inflation rate is unusually high in the future, then the firm's relative price will be unexpectedly low, and then, by assumption, it will be satisfying higher-than-expected demand for its product. Given that all firms behave in the same way, unanticipated inflation will tend to be associated with high real output. One message from our model is that Phillips curve behavior can disappear in the absence of strategic behavior by firms, even with sticky prices.

We live in a world where outside money is held by consumers, firms, and financial institutions in the form of currency and reserve balances, and this outside money is supplied by the central bank and used in various transactions at the retail level and among financial institutions. In using a cashless model to analyze monetary policy, we should feel confident that we are not being led astray by a quest for simplicity. To evaluate what we might lose in focusing on a cashless model, we develop a monetary model that is a straightforward cash-in-advance extension of the cashless model. Then, in the spirit of Woodford (2003), we explore how the behavior of this model compares to that of the cashless model and study the "cashless limit" of the more elaborate model. As it turns out, it requires very special assumptions for the limiting economy to behave in the same way as the monetary economy, and, in any case, quantity theory principles hold in equilibrium in the monetary economy. It is useful to know how monetary quantities should be manipulated to produce particular time paths of nominal interest rates, prices, and quantities in the economy, as the key instruments that a central bank has available to it are the quantities on its balance sheet. Thus, it would seem preferable to analyze monetary economies rather than cashless economies.

This article is organized as follows. In Section 1 we construct the basic cashless model, work through examples, and uncover the general properties of this model. Section 2 contains a monetary model, extending the cashless model as a cash-in-advance construct with money and credit. Section 3 is a detailed discussion of the importance of the results, and Section 4 is a conclusion.

1. CASHLESS MODEL

The goal of this section of the paper is to construct a simple sticky-price model that will capture the key aspects of New Keynesian economics, while also taking a somewhat different approach to price determination, in order to simplify and illuminate the important principles at work. The model we construct shares features with typical New Keynesian "cashless" models (see Woodford 2003), which are the following:

1. Money is not useful for overcoming frictions, it does not enter a cash-in-advance constraint or a utility function, nor does it economize on transactions costs.

2. Money is a numeraire in which all prices are denominated.

3. The money prices of goods are sticky in that, during any period, some goods prices are predetermined and do not respond to current aggregate shocks.

This model captures the essential friction that New Keynesians argue should be the focus of monetary policy—a sticky-price friction. New Keynesians argue that the other frictions that we typically encounter in monetary models—absence-of-double-coincidence problems and intertemporal price distortions, for example—are of second order for the problem at hand. Further, New Keynesians feel that it is important to model the monetary policy problem in terms of the choice of nominal interest rate rules and that this framework is a very convenient vehicle in that respect.

The model we will work with here has an infinite-lived representative consumer who maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[u(c_t^1) + u(c_t^2) - v(n_t) \right], \tag{1}$$

where c_t^i denotes consumption of the i^{th} good, $i = 1, 2$, and n_t is labor supply. Assume that $u(\cdot)$ is strictly increasing, strictly concave, twice continuously differentiable, and has the property $u'(0) = \infty$. As well, $v(\cdot)$ is strictly increasing, strictly convex, and twice differentiable with $v'(0) = 0$ and $v'(h) = \infty$ for some $h > 0$. We have assumed a separable period utility function for convenience, and a two-good model is sufficient to exposit the ideas of interest. Goods are perishable. There are linear technologies for producing goods from labor input, i.e.,

$$y_t^i = \gamma_t n_t^i, \tag{2}$$

where y_t^i is output of good i, γ_t is aggregate productivity, and n_t^i is the quantity of labor input applied to production of good i. Assume that γ_t follows an exogenous stochastic process.

This model is very simple. There is no investment or capital, and an optimal allocation is a sequence $\{\tilde{n}_t^1, \tilde{n}_t^2, \tilde{c}_t^1, \tilde{c}_t^2\}_{t=0}^{\infty}$ satisfying $\tilde{n}_t^1 = \tilde{n}_t^2 = \tilde{n}_t$ and $\tilde{c}_t^1 = \tilde{c}_t^2 = \tilde{c}_t$, with $\tilde{c}_t = \gamma_t \tilde{n}_t$, where $\tilde{n}_t$ solves

$$\frac{v'(2\tilde{n}_t)}{u'(\gamma_t \tilde{n}_t)} = \gamma_t. \tag{3}$$

Therefore, at the optimum, consumption of the two goods should be equal in each period with the same quantity of labor allocated to production of each good, given symmetry. As well, from (3) the ratio of the marginal disutility of labor to the marginal utility of consumption should be equal to aggregate productivity for each good in each period.

There is another object, which we will call money, that plays only the role of numeraire. We will assume a form of price stickiness reminiscent of what obtains in the staggered wage-setting models of Fischer (1977) and Taylor (1979). That is, assume that prices are sticky, in the sense that, if the price of a good is flexible in period t, then it remains fixed at its period t value through period $t + 1$, and is subsequently flexible in period $t + 2$, etc. In any given period, one good is flexible and the other is sticky. Now, since in (1) and (2) the two goods are treated symmetrically in preferences and technology, we can let good 1 be the flexible-price good in each period. Then, let P_t denote the price in units of money of the flexible-price good in period t, and then P_{t-1}

is the price of the sticky-price good. As well, let W_t denote the nominal wage rate.

The Keynesian modeler must always deal with the problem of how firms and consumers behave in the face of price and/or wage stickiness, as well as how quantities are determined. In typical textbook sticky-wage approaches, the nominal wage is exogenous, and the quantity of labor traded is determined by what is optimal for the representative firm. Standard textbook sticky-price models have a single good sold at an exogenous nominal price, and the quantity of output is demand-determined.[1]

In New Keynesian economics, the emphasis is on price stickiness (as opposed to wage stickiness), the distribution of prices across goods, and relative price distortions. Clearly, if there is a homogeneous good, constant returns to scale, competitive equilibrium, and perfect information, we cannot have anything other than a degenerate distribution of prices in equilibrium, where all firms producing positive output charge the same price. The New Keynesian approach at least requires heterogeneous goods, and the standard model in the literature is currently one with monopolistically competitive firms. For example, a typical approach is to assume monopolistic competition with Calvo (1983) price setting (or "time-dependent pricing"). In such a model, each firm randomly obtains the opportunity to change its nominal price each period, so that with a continuum of firms, some constant fraction of firms changes their prices optimally, while the remaining fraction is constrained to setting prices at the previous period's values. Alternatively, it could be assumed that each of the monopolistically competitive firms must set their prices one period in advance, before observing aggregate (or possibly idiosyncratic) shocks. Woodford (2003), for example, takes both approaches.

Neither Calvo pricing nor price setting one period in advance in monopolistic competition models is without problems. In a Calvo pricing model, each monopolistically competitive firm is constrained to producing one product. There may be states of the world where some firms will earn negative profits, but they are somehow required to produce strictly positive output anyway, and firms cannot reallocate productive factors to the production of flexible-price goods that will yield higher profits. With prices set one period in advance, firms are constrained to produce, even in the face of negative ex post profits.

Here, we have assumed differentiated products, but we will maintain competitive pricing. This model is certainly not typical, so it requires some explanation. First, the consumer's budget constraint will imply that all wage income will be spent on the two consumption goods, so

$$P_t \gamma_t n_t^1 + P_{t-1} \gamma_t n_t^2 - W_t (n_t^1 + n_t^2) = 0. \tag{4}$$

[1] See Williamson (2008) for examples of standard Keynesian sticky-wage and sticky-price models.

However, this would then seem to imply that, unless $P_t = P_{t-1}$, the production and sale of one good will earn strictly positive profits and production and sale of the other good will yield strictly negative profits. Thus, it seems that it cannot be profit-maximizing for both goods to be produced in equilibrium. However, suppose that we take for granted, as is typical in much of the New Keynesian literature, that there will be some firms that are constrained to producing the sticky-price good, and that the firms who produce this good will satisfy whatever demand arises at the price P_{t-1}. How then should we determine which firms produce which good? For this purpose, assume that there is a lottery, which works as follows. Before a firm produces, it enters a lottery where the outcome of the lottery determines whether the firm produces the flexible-price good or the sticky-price good. If it is determined through the lottery that a particular firm produces the flexible-price good, then that firm receives a subsidy of s_t^1 in nominal terms, per unit of output. If it is determined that a particular firm produces the fixed-price good, that firm receives s_t^2 per unit of output. The agent that offers the lottery will set s_t^1 and s_t^2 so that any firm is indifferent between producing the fixed-price and flexible-price goods, i.e.,

$$P_t - s_t^1 = P_{t-1} - s_t^2. \tag{5}$$

Further, the agent offering the lottery breaks even, so that

$$s_t^1 n_t^1 + s_t^2 n_t^2 = 0, \tag{6}$$

so solving for the subsidy rates, we obtain

$$s_t^1 = \frac{n_t^2(P_t - P_{t-1})}{(n_t^1 + n_t^2)} \text{ and}$$

$$s_t^2 = \frac{n_t^1(P_{t-1} - P_t)}{(n_t^1 + n_t^2)}.$$

Given these subsidy rates, the agent offering the lottery breaks even and each firm is willing to enter the lottery as profits per unit produced are zero in equilibrium, whether the firm ultimately produces the flexible-price or sticky-price good. Though this cross-subsidization setup may seem unrealistic, it does not seem less palatable than what occurs in typical Keynesian sticky-price models. In fact, the randomness in determining which firms produce which good is reminiscent of the randomness in Calvo (1983) pricing, but our approach is much more tractable.

Now, let π_t denote the relative price of flexible-price and sticky-price goods, which is also the gross rate of increase in the price of the flexible-price good. Under some special circumstances, π_t will also be the measured inflation rate, but in general that is not the case. However, π_t is the relative price that captures the extent of the effects of the sticky-price friction. Letting

w_t denote the relative price of labor and flexible-price goods, we can rewrite equation (4) as

$$\gamma_t n_t^1 + \frac{\gamma_t n_t^2}{\pi_t} - w_t(n_t^1 + n_t^2) = 0. \tag{7}$$

Optimization by the consumer is summarized by the following two marginal conditions:

$$u'(c_t^1) - \pi_t u'(c_t^2) = 0 \text{ and} \tag{8}$$

$$w_t u'(c_t^1) - v'(n_t^1 + n_t^2) = 0. \tag{9}$$

In equilibrium all output must be consumed, so

$$c_t^i = \gamma_t n_t^i \tag{10}$$

for $i = 1, 2$. Further, letting q_t denote the price at time t of a claim to one unit of money in period $t + 1$, we can determine q_t in the usual fashion by

$$q_t = \beta E_t \left[\frac{u'(c_{t+1}^1)}{\pi_{t+1} u'(c_t^1)} \right]. \tag{11}$$

An equilibrium is defined to be a stochastic process $\{\pi_t, w_t, q_t, n_t^1, n_t^2, c_t^1, c_t^2\}_{t=0}^{\infty}$ given an exogenous stochastic process for γ_t, that satisfies (7)–(11) and $q_t \leq 1$, so that the nominal interest rate is nonnegative in each state of the world. There is clearly indeterminacy here, as there appears to be nothing that will pin down prices. In equilibrium there is an object called money that is in zero supply, and which, for some unspecified reason, serves as a unit of account in which prices are denominated. The path that π_t follows in equilibrium clearly matters, because prices are sticky, but the possibilities for equilibrium paths for π_t are limitless.

Examples

One equilibrium is $\pi_t = 1$ for all t, which from (7)–(11) gives the optimal allocation with $\tilde{n}_t^1 = \tilde{n}_t^2 = \tilde{n}_t$ and $\tilde{c}_t^1 = \tilde{c}_t^2 = \tilde{c}_t$, where $\tilde{c}_t = \gamma_t \tilde{n}_t$, and where $\tilde{n}_t$ solves (3). Solving for q_t from equation (11), we get

$$q_t = \beta E_t \left[\frac{u'(\gamma_{t+1} \tilde{n}_{t+1})}{u'(\gamma_t \tilde{n}_t)} \right], \tag{12}$$

and so long as the variability in productivity is not too large, we will have $q_t \leq 1$ for all t, so that the nominal interest rate is always nonnegative, and this is indeed an equilibrium.

Alternatively (for example, see Woodford 2003), we could argue that the central bank can set the nominal interest rate $i_t = \frac{1}{q_t} - 1$. In this instance, if the central bank sets the nominal interest rate from equation (12) according to

$$i_t = \left\{ \beta E_t \left[\frac{u'(\gamma_{t+1} \tilde{n}_{t+1})}{u'(\gamma_t \tilde{n}_t)} \right] \right\}^{-1} - 1, \tag{13}$$

an equilibrium with $\pi_t = 1$ for all t can be achieved, which is optimal.

There is nothing in the model that tells us why the central bank can control i_t, and why it cannot control π_t, for example. In New Keynesian models, the justification for treating the market nominal interest rate as a direct instrument of the central bank comes from outside the model, along the lines of "this is what most central banks do." In any case, an optimal policy implies that, since $\pi_t = 1$, the price level is constant and the inflation rate is zero. This optimal policy could then be characterized as an inflation rate peg, or as a policy that requires, from (13), that the nominal interest rate target for the central bank fluctuate with the aggregate technology shock. More simply, from (13), the nominal interest rate at the optimum should equal the "Wicksellian natural rate of interest" (see Woodford 2003).

There are, of course, many suboptimal equilibria in this model. For example, consider the special case where $u(c) = \ln c$ and $v(n) = \delta n$, for $\delta > 0$. Though $v(\cdot)$ does not satisfy some of our initial restrictions, this example proves particularly convenient. We will first construct an equilibrium with a constant inflation rate, which has the property that $\pi_t = \alpha$, where α is a positive constant (recall that π_t is not the gross inflation rate, but if π_t is constant then the inflation rate is constant). From (7)–(11), the equilibrium solution we obtain is

$$w_t = \frac{2\gamma_t}{1+\alpha}, \tag{14}$$

$$q_t = \frac{\beta\gamma_t}{\alpha} E_t\left(\frac{1}{\gamma_{t+1}}\right), \tag{15}$$

$$n_t^1 = \frac{1}{\delta(1+\alpha)}, \tag{16}$$

$$n_t^2 = \frac{\alpha}{\delta(1+\alpha)}, \tag{17}$$

$$c_t^1 = \frac{\gamma_t}{\delta(1+\alpha)}, \text{ and} \tag{18}$$

$$c_t^1 = \frac{\alpha\gamma_t}{\delta(1+\alpha)}. \tag{19}$$

In this equilibrium, the rate of inflation is $\alpha - 1$. Note, from (14)–(19), that higher inflation causes a reallocation of consumption and labor supply from flexible-price to sticky-price goods. From equation (15) for $q_t \leq 1$, it is sufficient that α not be too small and that γ_t not be too variable. This equilibrium is of particular interest because it involves an inflation rate peg. Of course, as we showed previously, $\alpha = 1$ is optimal.

Alternatively, consider the same example as above, with log utility from consumption and linear disutility to supplying labor, but now suppose that π_t is governed by a rule that responds to productivity shocks, for example,

$$\pi_t = \frac{\gamma_{t-1}}{\gamma_t}.$$

Then, from (7)–(11), we obtain the equilibrium solution

$$w_t = \frac{2\gamma_t^2}{\gamma_{t-1} + \gamma_t}, \tag{20}$$

$$q_t = \beta E_t \left[\frac{\gamma_t(\gamma_t + \gamma_{t+1})}{\gamma_{t+1}(\gamma_{t-1} + \gamma_t)} \right], \tag{21}$$

$$n_t^1 = \frac{2\gamma_t}{\delta(\gamma_{t-1} + \gamma_t)}, \tag{22}$$

$$n_t^2 = \frac{2\gamma_{t-1}}{\delta(\gamma_{t-1} + \gamma_t)}, \tag{23}$$

$$c_t^1 = \frac{2\gamma_t^2}{\delta(\gamma_{t-1} + \gamma_t)}, \text{ and} \tag{24}$$

$$c_t^1 = \frac{2\gamma_t\gamma_{t-1}}{\delta(\gamma_{t-1} + \gamma_t)}. \tag{25}$$

From (21) it is sufficient for the existence of equilibrium that γ_t not be too variable. Note in the solution, (20)–(25), that equilibrium quantities and prices all exhibit persistence because of the contingent path that prices follow. Complicated dynamics can be induced through the nominal interest rate rule, of which (25) is an example in this case. Indeed, it is possible (see Woodford 2003), given some nominal interest rate rules, to obtain equilibrium solutions where current endogenous variables depend on anticipated future aggregate shocks. Typical New Keynesian models also obtain equilibrium solutions with such properties through the forward-looking price-setting behavior of monopolistically competitive producers. This latter mechanism is not present in our model.

General Properties of the Model

To further analyze our model, we find it useful to consider how we would solve for an equilibrium in this model in the absence of sticky prices. The model is purely static, so we can solve period-by-period. An equilibrium for period t consists of relative prices π_t and w_t, and quantities n_t^1, n_t^2, c_t^1, and

c_t^2 that solve the marginal conditions (8) and (9), the equilibrium conditions (10), and two zero-profit conditions:

$$\gamma_t n_t^1 - w_t n_t^1 = 0 \text{ and} \tag{26}$$

$$\frac{\gamma_t n_t^2}{\pi_t} - w_t n_t^2 = 0. \tag{27}$$

Of course, the solution we get is the optimum, with $w_t = \gamma_t$, $\pi_t = 1$, $n_t^1 = n_t^2 = \tilde{n}_t$, and $c_t^1 = c_t^2 = \tilde{c}_t = \gamma_t \tilde{n}_t$, with $\tilde{n}_t$ determined as the solution to (3).

Now, how should we think about solving the system (7)–(11) under sticky prices? It seems most useful to think of this system in the traditional Keynesian sense, as a model where one price, π_t, is fixed exogenously. Given any exogenous $\pi_t \neq 1$, it cannot be the case that all agents optimize and all markets clear in equilibrium. The solution we have chosen here, which is in line with standard New Keynesian economics, is to allow for the fact that (26) and (27) do not both hold. Instead, we allow for cross-subsidization with zero net subsidies across production units and zero profits in equilibrium net of subsidies for production of each good, which gives us equation (7).

Given this interpretation of the model, how should we interpret q_t, as determined by equation (11)? Since π_t is simply the relative price of good 2 in terms of good 1 in period t, q_t is the price, in units of good 1 in period t, that a consumer would pay for delivery of one unit of good 2 in period $t+1$. Why, then, should we require an arbitrage condition that $q_t \leq 1$, or why should

$$\beta E_t \left[\frac{u'(c_{t+1}^1)}{\pi_{t+1} u'(c_t^1)} \right] \leq 1 \tag{28}$$

hold? Such a condition requires the existence of a monetary object. Then we can interpret (11) as determining the price in units of money in period t of a claim to one unit of money delivered in period $t+1$, and inequality (28) is required so that zero money balances are held in equilibrium. Thus, in equilibrium the model is purely atemporal. There is no intertemporal trade, nevertheless there exist equilibrium prices for money in terms of goods and for the nominal bond in each period.

Thus far, this may be somewhat puzzling for most monetary economists, who are accustomed to thinking about situations in which money is not held in equilibrium as ones in which the value of money in units of goods is zero in each period. This does not happen here, but no fundamental principles of economic analysis appear to have been violated.

The key question, then, is what we can learn from this model. First, we will get some idea of the operating characteristics of the model through linear approximation. If we treat π_t as exogenous, following our interpretation above, then the exogenous variables are γ_t and π_t. Substitute using equation (10) in (7)–(9), and then linearize around the solution we get with $\gamma_t = \bar{\gamma}$ and

$\pi_t = 1$, where $\bar{\gamma}$ is a positive constant. The equilibrium solution we get in this benchmark case is $w_t = \bar{\gamma}$, $n_t^1 = n_t^2 = \bar{n}$, and $c_t^1 = c_t^2 = \bar{\gamma}\bar{n}$, where $\bar{n}$ solves

$$\bar{\gamma}u'(\bar{\gamma}\bar{n}) - v'(2\bar{n}) = 0.$$

The solution to the linearized model is (leaving out the solution for the wage, w_t) :

$$n_t^1 = \bar{n} + \frac{u'(-2v'' + \bar{\gamma}^2 u'')}{2\bar{\gamma}u''(\bar{\gamma}^2 u'' - 2v'')}(\pi_t - 1) - \frac{u' + \bar{\gamma}\bar{n}u''}{\bar{\gamma}^2 u'' - 2v''}(\gamma_t - \bar{\gamma}), \quad (29)$$

$$n_t^2 = \bar{n} + \frac{u'(2v'' - \bar{\gamma}^2 u'')}{2\bar{\gamma}u''(\bar{\gamma}^2 u'' - 2v'')}(\pi_t - 1) - \frac{u' + \bar{\gamma}\bar{n}u''}{\bar{\gamma}^2 u'' - 2v''}(\gamma_t - \bar{\gamma}), \quad (30)$$

$$c_t^1 = \bar{\gamma}\bar{n} + \frac{u'(-2v'' + \bar{\gamma}^2 u'')}{2u''(\bar{\gamma}^2 u'' - 2v'')}(\pi_t - 1) - \frac{2\bar{n}v'' + \bar{\gamma}u'}{\bar{\gamma}^2 u'' - 2v''}(\gamma_t - \bar{\gamma}), \text{ and} \quad (31)$$

$$c_t^2 = \bar{\gamma}\bar{n} + \frac{u'(2v'' - \bar{\gamma}^2 u'')}{2u''(\bar{\gamma}^2 u'' - 2v'')}(\pi_t - 1) - \frac{2\bar{n}v'' + \bar{\gamma}u'}{\bar{\gamma}^2 u'' - 2v''}(\gamma_t - \bar{\gamma}), \quad (32)$$

and aggregate labor supply and output are given, respectively, by

$$n_t^1 + n_t^2 = 2\bar{n} - \frac{2(u' + \bar{\gamma}\bar{n}u'')}{\bar{\gamma}^2 u'' - 2v''}(\gamma_t - \bar{\gamma}) \text{ and} \quad (33)$$

$$c_t^1 + c_t^2 = 2\bar{\gamma}\bar{n} - \frac{2(2\bar{n}v'' + \bar{\gamma}u')}{\bar{\gamma}^2 u'' - 2v''}(\gamma_t - \bar{\gamma}). \quad (34)$$

Therefore, from (29)–(34), in the neighborhood of an equilibrium with constant prices, an increase in π_t, which corresponds to an increase in the inflation rate, results in a decrease in the production and consumption of the flexible-price good, an increase in production and consumption of the fixed-price good, and no effect on aggregate labor supply and output. Thus, this model does not produce a Phillips curve correlation, at least locally, and increases in the inflation rate serve only to misallocate production and consumption across goods.

As well, from (29)–(34), a positive shock to aggregate productivity has the same effect on production and consumption of both goods. If

$$u' + \bar{\gamma}\bar{n}u'' > 0, \quad (35)$$

then the substitution effect of the productivity increase offsets the income effect on labor supply so that aggregate labor supply increases. In what follows, we assume that the substitution effect dominates, i.e., (35) holds. From (34), aggregate output increases with an increase in productivity, regardless of whether the substitution effect dominates.

The absence of a Phillips curve effect here might seem puzzling, as a positive relationship between inflation and output often appears as a cornerstone of new and old Keynesian economics. Thus, we should explore this further to see how π_t affects output outside of the neighborhood of our baseline equilibrium. Consider an example that will yield closed-form solutions, in particular $u(c) = \frac{c^{1-\alpha}-1}{1-\alpha}$ and $v(n) = \delta n$, with $\alpha > 0$ and $\delta > 0$. Solving (7)–(10), we obtain

$$n_t^1 = \gamma_t^{\frac{1}{\alpha}-1}\delta^{-\frac{1}{\alpha}}\left(\frac{1+\pi_t^{\frac{1}{\alpha}-1}}{1+\pi_t^{\frac{1}{\alpha}}}\right)^{\frac{1}{\alpha}}, \tag{36}$$

$$n_t^2 = \gamma_t^{\frac{1}{\alpha}-1}\delta^{-\frac{1}{\alpha}}\left(\frac{\pi_t^{\frac{1}{\alpha}}+\pi_t^{\frac{2}{\alpha}-1}}{1+\pi_t^{\frac{1}{\alpha}}}\right)^{\frac{1}{\alpha}}, \tag{37}$$

$$c_t^1 = \gamma_t^{\frac{1}{\alpha}}\delta^{-\frac{1}{\alpha}}\left(\frac{1+\pi_t^{\frac{1}{\alpha}-1}}{1+\pi_t^{\frac{1}{\alpha}}}\right)^{\frac{1}{\alpha}}, \tag{38}$$

$$c_t^2 = \gamma_t^{\frac{1}{\alpha}}\delta^{-\frac{1}{\alpha}}\left(\frac{\pi_t^{\frac{1}{\alpha}}+\pi_t^{\frac{2}{\alpha}-1}}{1+\pi_t^{\frac{1}{\alpha}}}\right)^{\frac{1}{\alpha}}, \text{ and} \tag{39}$$

$$w_t = \gamma_t\left(\frac{1+\pi_t^{\frac{1}{\alpha}-1}}{1+\pi_t^{\frac{1}{\alpha}}}\right). \tag{40}$$

Then, aggregate labor supply and aggregate output are given by

$$n_t^1 + n_t^2 = \gamma_t^{\frac{1}{\alpha}-1}\delta^{-\frac{1}{\alpha}}\left(1+\pi_t^{\frac{1}{\alpha}-1}\right)^{\frac{1}{\alpha}}\left(1+\pi_t^{\frac{1}{\alpha}}\right)^{1-\frac{1}{\alpha}} \text{ and} \tag{41}$$

$$c_t^1 + c_t^2 = \gamma_t^{\frac{1}{\alpha}}\delta^{-\frac{1}{\alpha}}\left(1+\pi_t^{\frac{1}{\alpha}-1}\right)^{\frac{1}{\alpha}}\left(1+\pi_t^{\frac{1}{\alpha}}\right)^{1-\frac{1}{\alpha}}. \tag{42}$$

Now, in the solution (36)–(42), the condition (35) is equivalent to $\alpha < 1$. Given this, labor supply in both sectors is increasing in productivity, as, of course, is consumption of each good and total output.

Our primary interest in this example is what it tells us about the relationship between π_t and aggregate output. Note from equation (42) that this relationship is determined by the properties of the function

$$G(\pi) = \left(1+\pi^{\frac{1}{\alpha}-1}\right)^{\frac{1}{\alpha}}\left(1+\pi^{\frac{1}{\alpha}}\right)^{1-\frac{1}{\alpha}}.$$

Differentiating, we obtain

$$G'(\pi) = \pi^{\frac{1}{\alpha}-2}\left(1+\pi^{\frac{1}{\alpha}-1}\right)^{\frac{1}{\alpha}-1}\left(1+\pi^{\frac{1}{\alpha}}\right)^{-\frac{1}{\alpha}}\frac{1}{\alpha}\left(\frac{1}{\alpha}-1\right)(1-\pi).$$

Therefore, for the case $\alpha < 1$, we have $G'(1) = 0$, $G'(\pi) > 0$ for $\pi < 1$, and $G'(\pi) < 0$ for $\pi > 1$. Thus, output is maximized for $\pi = 1$ and the Phillips curve has a negative slope when inflation is positive and a positive slope when inflation is negative. The key to the Phillips curve relationship is how labor supply responds to the distortion created by inflation or deflation due to the the sticky-price friction. When the substitution effect on labor supply of an increase in productivity dominates the income effect, an increase or decrease in the inflation rate from zero implies that the marginal payoff from supplying labor falls, and the consumer therefore reduces labor supply.

The interesting aspect of these results is that they point to a nonrobust link between price stickiness and Phillips curve correlations. In spite of the fact that firms do not set prices strategically in a forward-looking manner, intuition might tell us that there should still be a Phillips curve correlation. That is, with higher inflation, it might seem that the additional quantity of output produced by sticky-price firms should be greater than the reduction in output by flexible-price firms, and aggregate output should increase. However, our analysis shows that this need not be the case and that the key to understanding the mechanism at work is labor supply behavior.

In our model, since not all prices are sticky, the key effect of inflation on output comes from the relative price distortion, and labor supply may increase or decrease in response to higher inflation, with a decrease occurring when the elasticity of substitution of labor supply is sufficiently high. As we commented earlier, the assumptions on price stickiness and firm behavior in our model seem no less palatable than what is typically assumed. Thus, the nonrobustness of the Phillips curve we find here deserves attention.

2. A MONETARY MODEL AND THE "CASHLESS LIMIT"

In New Keynesian economics (e.g., Woodford 2003), baseline "cashless" models are taken seriously as frameworks for monetary policy analysis. As we have seen, the cashless model focuses attention on the sticky-price friction as the key source of short-run nonneutralities of money. New Keynesian arguments for using a cashless model appear to be as follows: (i) the standard intertemporal monetary distortions—for example, labor supply distortions and the tendency for real cash balances to be suboptimally low when the nominal interest rate is greater than zero—are quantitatively unimportant; (ii) in models where there is some motive for holding money, if we take the limit as the motive for holding money goes to zero, then this limiting economy has essentially the same properties as does the cashless economy. The purpose of this section is to evaluate these arguments in the context of a particular monetary model.

For our purposes, a convenient expository vehicle is a cash-in-advance model of money and credit where we can parameterize the friction that makes money useful in transactions. There are other types of approaches we could take here; for example, we could use a monetary search and matching framework along the lines of Lagos and Wright (2005),[2] but the model we use here allows us to append monetary exchange to the cashless model in Section 2 with the least fuss. Our framework is much like that in Alvarez, Lucas, and Weber (2001), absent limited participation frictions, but including the labor supply decision and the sticky-price friction we have been maintaining throughout. The structure of preferences, technology, and price determination is identical to that which we assumed in the cashless model.

Here, suppose that the representative consumer trades on asset markets at the beginning of each period and then takes the remaining money to the goods market, where goods can be purchased with money and credit. The consumer faces the cash-in-advance constraint

$$P_t c_t^1 + P_{t-1} c_t^2 + q_t b_{t+1} \leq \theta W_t (n_t^1 + n_t^2) + m_t + \tau_t + s_t l_t + b_t, \tag{43}$$

where b_t denotes one-period nominal bonds purchased by the consumer in period $t-1$, each of which pays off one unit of money in period t; m_t denotes nominal money balances carried over from the previous period; τ_t is a nominal lump-sum transfer from the government; and $s_t l_t$ is a within-period money loan from the central bank, where l_t is the nominal amount that must be returned to the central bank at the end of the period. Also, θ denotes the fraction of current-period wage income that can be accessed in the form of within-period credit when the consumer trades in the goods market. Note that $\frac{1}{s_t} - 1$ is the within-period nominal interest rate on central bank loans, and, as above, $\frac{1}{q_t} - 1$ is the one-period nominal interest rate. Here $0 \leq \theta \leq 1$, and θ is the critical parameter that captures the usefulness of money in transactions. With $\theta = 0$, this is a pure monetary economy, and with $\theta = 1$, money is irrelevant.

The consumer must also satisfy his or her budget constraint, given by

$$P_t c_t^1 + P_{t-1} c_t^2 + m_{t+1} + q_t b_{t+1} = W_t (n_t^1 + n_t^2) + m_t + \tau_t + (s_t - 1)\, l_t + b_t. \tag{44}$$

Let M_t denote the supply of money and L_t denote the supply of central bank loans. Then the asset market equilibrium conditions are

$$m_t = M_t;\ b_t = 0;\ l_t = L_t, \tag{45}$$

or, money demand equals money supply, the demand for bonds equals the supply, and the demand for central bank loans equals the supply.

[2] See, for example, Aruoba and Schorfheide (2008), where a monetary search model with nominal rigidities is constructed for use in quantitative work.

Eliminating Intertemporal Distortions with Central Bank Lending

In general, an equilibrium in this model is difficult to characterize, as price stickiness complicates the dynamics. In part, our goal will be to determine the features of a "cashless limit" in this economy, along the lines of Woodford (2003). To that end, given the New Keynesian view that intertemporal distortions are unimportant, suppose that the regime of central bank lending is set up so that those distortions are eliminated. That is, suppose that the central bank supplies no money, except through central bank loans made at the beginning of the period at a zero nominal interest rate.

Let $s_t = 1$, and suppose that the central bank accommodates whatever demand for central bank loans arises at a zero nominal interest rate. We then have $M_t = \tau_t = 0$ for all t and $L_t = (1-\theta)W_t(n_t^1+n_t^2)$. Then, given (43)–(45), optimization, and goods market equilibrium, we can define an equilibrium in terms of relative prices and quantities, just as in the cashless economy.

This monetary regime is then one where all economic agents have access to a daylight overdraft facility, much like the Federal Reserve System uses each day to accommodate payments among financial institutions. Given a zero nominal interest rate on daylight overdrafts, money will not be held between periods, which we can interpret as a system in which holdings of outside money are zero overnight (interpreting a period as a day). This setup is extreme, as it allows universal access to central bank lending facilities and does not admit anything resembling currency-holding in equilibrium.

In equilibrium, (7)–(11) must be satisfied, just as in the cashless economy. The key difference in this monetary economy will be in the determination of π_t. Supposing for convenience that (43) always holds with equality in each period, then, given (7), we can determine π_t by

$$\pi_t = \frac{L_t w_{t-1}(n_{t-1}^1 + n_{t-1}^2)}{L_{t-1} w_t (n_t^1 + n_t^2)}, \tag{46}$$

for $t = 1, 2, 3, ...,$ with π_0 given. An equilibrium is a stochastic process $\{n_t^1, n_t^2, c_t^1, c_t^2, w_t, \pi_t, q_t\}_{t=0}^{\infty}$, with π_0 given, solving (7)–(11) and (46). The solution must satisfy $q_t \leq 1$ for all t, which assures that an equilibrium exists where (43) holds with equality. In general, it is not straightforward to characterize a solution, but it is clear from (46) that the solution is consistent with the quantity theory of money. That is, L_t is the nominal quantity of money available to spend in period t, and $w_t(n_t^1 + n_t^2) = \gamma_t n_t^1 + \frac{\gamma_t n_t^2}{\pi_t}$ is total GDP. Therefore, (46) states that the rate of increase in the price of the flexible-price good is roughly equal to the rate of money growth minus the rate of growth in real GDP. Note that the parameter θ does not appear anywhere in (7)–(11) and (46). That is, we can treat the equilibrium solution as the cashless limit, as we will obtain the same solution for any $\theta > 0$. Note here that the cashless limit of this monetary economy is *not* the cashless economy, and the quantity of money is important for the solution, along quantity theory lines, in spite of the fact that no money is held between periods. Thus, we have followed the logic of Woodford (2003) here, but we do not get Woodford's results.

What is an optimal monetary policy here, given that the within-period nominal interest rate is zero? The key choice for the central bank is L_t, the nominal loan quantity in each period. If L_t can be set so that $\pi_t = 1$ for all t, then clearly this would be an optimal policy, since from (7)–(11) we will obtain $n_t^i = \tilde{n}_t$ for all t and $i = 1, 2$. From equation (46), this requires that

$$\frac{L_t}{L_{t-1}} = \frac{\gamma_t \tilde{n}_t}{\gamma_{t-1}\tilde{n}_{t-1}}. \tag{47}$$

This optimal policy then implies a nominal bond price

$$q_t = \beta E_t \left[\frac{u'(\gamma_{t+1}\tilde{n}_{t+1})}{u'(\gamma_t \tilde{n}_t)} \right], \tag{48}$$

and for this optimal policy to support an equilibrium, we require that $q_t \leq 1$ for all t, which is satisfied provided the variability in γ_t is sufficiently small. Thus, we can define the optimal monetary policy as a rule for monetary growth, which accommodates GDP growth according to (47) or as a nominal interest rate rule governed by (48), i.e., the money growth rule and nominal interest rate rule are flip sides of the same monetary policy. On the one hand, the money growth rule in (47) states that the money supply should always grow at the same rate as optimal GDP. On the other hand, the nominal interest rate rule states that the nominal interest rate should move in response to productivity shocks in such a way that it is equal to the optimal real interest rate.

Part of the New Keynesian justification for use of a cashless model (see Woodford 2003) is that if intertemporal frictions are insignificant, even if there is a monetary friction in the model, then the prescription for the optimal nominal interest rate rule is the same as in the cashless economy. This is certainly true here, as the nominal interest rate rule implicit in (48) is the same as (12). For our purposes, though, the monetary economy is more informative about policy, as it says something about the monetary policy regime that is necessary to get this result, and gives us a prescription for how the central bank should manipulate the quantities that it has under its control.

3. DISCUSSION

In this section we will discuss our results, organized in terms of monetary policy instruments, Phillips curves, and monetary frictions.

Monetary Policy Instruments

What can a central bank control? Ultimately, if we ignore the central bank's regulatory powers, a central bank can control two sets of things. First, it can determine the quantities on its balance sheet, including lending to private sector economic agents. Second, it can determine the interest rates on deposits (reserves) held with the central bank and the interest rates on the loans it makes, in particular the interest rates on daylight overdrafts associated with payments made using outside money and the interest rates on overnight central bank lending or lending at longer maturities. The key power a central bank holds is its monopoly on the issue of fiat money. Essentially, a central bank is much like any other bank in that its liabilities serve as a means of payment, and it performs a type of liquidity transformation in intermediating assets that are difficult to use as means of payment. Central bankers, and many economists, hold the view that the quantity of intermediation that the central bank carries out, reflected in the quantity of fiat money outstanding, has consequences for real economic activity in the short run and for prices.

Central banks cannot set market interest rates, though they might like to. New Keynesians typically model central bank behavior as the determination of a market nominal interest rate as a function of endogenous and exogenous variables. There are good reasons to think that a central bank operating procedure consisting of periodic revision of an overnight nominal interest rate target or inflation rate targeting is preferable to the money growth targeting that Friedman (1968) had in mind. That is, the predominant shocks that are of concern to the central bank in the very short run, say between Federal Open Market Committee meetings, are financial market shocks that cause fluctuations in the demand for outside money. Given that these shocks are difficult to observe, a sensible procedure may be to smooth the overnight nominal interest rate, which may serve to optimally accommodate financial market shocks.

Though it may be possible in the short run for a central bank to use the instruments at its disposal to keep a market nominal interest rate within a tight prespecified corridor, it is inappropriate to use this as a justification for a mode of analysis that eliminates monetary considerations. A model that is used to analyze and evaluate monetary policy should tell us how the economy functions under one central bank operating procedure (e.g., monetary targeting) versus another (e.g., nominal interest rate targeting), how the instruments available to the central bank (i.e., monetary quantities) need to be manipulated to implement a particular policy rule, and how using alternative instruments (e.g., central bank lending versus open market operations) makes a difference.

Phillips Curves

Some type of Phillips curve relationship, i.e., a positive relationship between the "output gap," on the one hand, and the rate of inflation or the unanticipated component of inflation, on the other hand, is typically found in New Keynesian macroeconomic models. The Phillips curve was an important example in 1970s policy debates of how policy could go wrong in treating an empirical correlation as structural (Lucas 1972). In New Keynesian economics, the Phillips curve has made a comeback as a structural relationship and plays a central role in reduced-form New Keynesian models (e.g., Clarida, Galí, and Gertler 1999).

As we have shown here, in a sticky-price model that seems as reasonable as typical monopolistically competitive New Keynesian setups, there is no tradeoff between output and inflation in the standard case where substitution effects dominate in the response of labor supply to a wage increase. With a zero inflation rate, output is maximized. Even in the case where income effects are large, more output can be obtained if the inflation rate deviates from zero, but this is inefficient. Further, in this case, more output can be obtained not only with inflation, but with deflation.

Monetary Frictions

We know that what makes a modern central bank unique is the power granted to it as the monopoly issuer of outside money, which takes the form of deposits with the central bank and circulating currency. We also know that central banking is not a necessity. Indeed, there are examples of economies that grew and thrived without a central bank. The United States did not have a central bank until 1914, and the private currency systems in place in Scotland from 1716–1845 and in Canada before 1935 are generally regarded as successes. Before asking how a central bank should behave, we might want to ask what justifies its existence in the first place.

From the viewpoint of a monetary economist, a theory of central banking should not only tell us what the role of the central bank is in a modern economy, but also why we should grant the central bank a monopoly in supplying key media of exchange. Such a central banking theory must necessarily come to grips with the principal frictions that make money useful as a medium of exchange and the frictions that may make private provision of some types of media of exchange inefficient.

New Keynesians argue that we can do a better job of understanding how monetary policy works and how it should be conducted by ignoring these frictions. By using a very simple cash-in-advance construct, we have shown these arguments require some very special assumptions. For our cashless sticky-price economy to work in the same way as does a comparable monetary economy requires that: (i) a monetary regime be in place that corrects intertemporal inefficiencies; (ii) all economic agents be on the receiving end of the central bank's actions; and (iii) currency holding be unimportant. While some countries, such as Canada and New Zealand, have moved to monetary systems without reserve requirements and with interest on reserves, thus correcting some distortions, most countries are far from the elimination of intertemporal monetary frictions. Thus, in practice it is likely that intertemporal distortions play an important role, and arguably *the* important role if we are considering the effects of long-run anticipated inflation. Also, the fact that not all economic agents are on the receiving end of monetary policy actions, which gives rise to distributional effects of monetary policy, is regarded as important in the segmented markets literature. Market segmentation (in both goods and financial markets) is perhaps of greater significance than sticky-price frictions in generating short-run nonneutralities of money (see Alvarez and Atkeson 1997; Alvarez, Atkeson, and Kehoe 2003; Williamson [ForthcomingA, ForthcomingB]). Finally, currency is still widely used in the world economy (Alvarez and Lippi 2007). In spite of technological improvements in transactions technologies, currency is a wonderfully simple transactions technology that permits exchange in the many circumstances where anonymous individuals need to transact with each other.

4. CONCLUSION

Recent events involving turmoil in credit markets and heretofore unheard-of interventions by the Federal Reserve System make it abundantly clear that the monetary policy problem is far from solved. Further, for the key questions that need to be answered in the midst of this crisis, New Keynesian economics appears to be unhelpful. How is central bank lending different from open market operations in terms of the effects on financial markets and goods markets? To which institutions should a central bank be lending and under what conditions? What regulatory power should the Federal Reserve System exercise over the institutions to which it lends? Should the Fed's direct intervention be limited to conventional banks, or should this intervention be extended to investment banks and government-sponsored financial institutions? Unfortunately, typical New Keynesian models ignore credit markets, monetary frictions, and banking and are, therefore, of little or no use in addressing these pressing questions.

What hope do we have of developing a theory of money and central banking that can satisfy monetary economists and also be of practical use to central bankers? Monetary economics and banking theory have come a long way in the last 30 years or more, and perhaps the economics profession needs to be educated as to why modern monetary and banking theory is useful and can be applied to policy problems. We now understand that recordkeeping and the flow of information over space and time is critical to the role of currency as a medium of exchange (Kocherlakota 1998). We know that decentralized exchange with currency can lead to holdup problems that accentuate the welfare losses from inflation (Lagos and Wright 2005). We understand how banks act to insure private agents against liquidity risk (Diamond and Dybvig 1983) and to economize on monitoring costs (Diamond 1984, Williamson 1986). We know that financial market segmentation and goods market segmentation are important for monetary policy (Alvarez and Atkeson 1997; Alvarez, Atkeson, and Kehoe 2003; Williamson [Forthcoming A; Forthcoming B]). Putting together elements of these ideas in a comprehensive theory of central banking is certainly within our grasp, and I very much look forward to future developments.

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