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Monetary Aggregates and Liquidity in a Neo-Wicksellian Framework

Woodford (2003) describes a popular class of neo-Wicksellian (NW) models in which monetary policy is characterized by an interest rate rule, and the money market and financial institutions are typically not even modeled. Critics contend that these models are incomplete and unsuitable for monetary policy evaluation. Our banks and bonds (BB) model starts with a standard NW model and then adds banks and a role for bonds in the liquidity management of households and banks. The BB model gives a more complete description of the economy, but the NW model has the virtue of simplicity. Our purpose here is to see if the NW model gives a reasonably accurate account of macroeconomic behavior in the more complete BB model. We do this by comparing the models' second moments, variance decompositions, and impulse response functions. We also study the role of monetary aggregates and velocity in predicting inflation in the two models.

WOODFORD (2003) DESCRIBES a class of New Keynesian models that has become the favored paradigm for macroeconomic analysis, and especially for monetary policy evaluation. "Woodford himself likes to call these models neo-Wicksellian" (NW) to draw attention to the fact that interest rates transmit directly to intertemporal spending decisions and that monetary policy need not be framed in

terms of monetary aggregates.[1] Indeed, monetary policy is generally specified as an interest rate rule in these NW models, and the modeling of monetary aggregates is often viewed as a needless complication.

While these NW models have been remarkably successful, there are reasons to be uneasy about the lack of modeling of money markets and financial institutions. Some central banks use monetary aggregates in forecasting inflation, and some economists are uncomfortable performing monetary policy analyses in an NW framework. Goodfriend and McCallum (2006) say, "Prominent among these [reasons for unease] are the absence from the standard framework of any significant role for money aggregates, financial intermediation, or distinctions among various short-term rates that play different roles in the transmission mechanism."[2] And Woodford (2006) discusses the concern of some that NW models "are coherent as far as they go, but that they are incomplete."[3]

In this paper, we develop a model in which banks create deposits and make loans. Both of these activities are costly, creating financial frictions that make monetary aggregates "matter" for economic activity. Moreover, bank deposits offer an alternative way for households to do their transacting, and the bank loans may affect aggregate supply and demand in a variety of ways, depending upon how they are modeled (and we have considered alternative approaches). We also assume that government bonds are used by banks and (indirectly) households in managing their liquidity. This creates a spread between the consumption capital asset pricing model (CCAPM) rate (in the consumption Euler equation) and the government bond rate, since government bonds can command a liquidity premium. This spread offers one view of the disconnect between money market rates and the rate of return that affects aggregate demand. And in theory, this spread can buffer the liquidity crunch created by a contractionary open market operation (OMO); this has implications for interest rate surprises and for the systematic component of the interest rate rule governing monetary policy.

A standard NW model is embedded within our model. It is obtained by stripping out the banks and assuming that only cash is useful to households in transacting. There is a money (or cash) demand equation in the NW model, but it is decoupled from the rest of the model; its sole purpose is to determine the OMO required to implement the central bank's interest rate rule. There are no financial frictions other than the seigniorage tax. The money demand equation could be dropped from the NW model for most applications.

Our model with banks and liquid bonds offers a more complete description of the economy than the NW model, but the NW model has the virtue of simplicity.

1. Footnote 7 of Woodford (2006) gives a concise statement of this.

2. Goodfriend and McCallum (2006) develop a model with money and banks, a variety of interest rates, and bonds and capital that serve as collateral; they use their model to illustrate potential pitfalls of ignoring money and banking when formulating monetary policy. While our modeling of banks is different from theirs, their analysis is in many ways complementary to our own.

3. Woodford's (2006) wide-ranging discussion of this and related issues gives other references to economists who have expressed concern. His paper was presented at the 4th ECB Central Banking Conference, The Role of Money and Monetary Policy in the Twenty First Century, November, 2006; many of the conference papers discuss related issues.

And it is quite possible that this simpler model gives an adequate account of the macroeconomic behavior for both the business cycle analyst and the monetary policy analyst. To investigate this possibility, we calibrate the two models and compare their implications for the variables that they share. We compare unconditional moments generated by the models. We use impulse response functions to compare how various shocks pass through our model economies. And finally, we ask if the NW model undervalues the usefulness of various monetary aggregates in forecasting inflation. Here, we generate artificial data sets from the two models, and we test the predictive power of various aggregates in bivariate relationships between inflation and nominal growth of the aggregate in question; this appears to be the primary (formal) way in which monetary aggregates are used at the European Central Bank (ECB).[4] We also test the predictive power of velocity, since that variable played a prominent role in traditional monetarist discussions of inflation.

The rest of the paper is organized as follows: Section 1 outlines the two models and explores some of their theoretical differences. Section 2 describes the models' steady-state solution, and Section 3 explains how we calibrated the models. Section 4 investigates the quantitative significance of the differences between the two models and whether the NW model offers an adequate view of the economy for business-cycle analysts and monetary-policy analysts alike. Section 5 summarizes our results, and puts several of them—including the use of monetary aggregates—into a more general perspective.

1. TWO MODELS

In this section, we outline two models. The NW model, which belongs to a class of models described by Woodford (2003), features Calvo price setting, flexible wage rates, fixed firm-specific capital, and an interest rate rule that governs monetary policy. We have included a money demand equation in the NW model, as does Woodford (2006), but money plays no independent role in the transmission of monetary policy to inflation or real economic activity. Moreover, the model is Ricardian; therefore, the government's debt management policy plays no important role either.

Our banks and liquid bonds (BB) model adds several features to the standard NW model: new monetary aggregates, financial frictions, and a non-Ricardian element that gives fiscal policy a direct role in creating transactions balances. The cost of creating bank deposits and loans provide the financial frictions, and our assumption that government bonds provide transactions services makes the model non-Ricardian. We begin our discussion with the BB model, since the NW model is embedded within it.

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4. Fischer et al. (2006) report that "simple bivariate forecasting models have increased in prominence over time at the expense of forecasts that were produced on the basis of money demand equations. . . . Indeed, the rising prominence of the bivariate approach can be interpreted as one practical response to a situation from 2001 onwards where growing questions emerged about the stability of money demand equations used in the Quarterly Monetary Assessment."

1.1 The BB Model

Households. In the BB model, each household goes to the bank in every period (which we take to be a quarter) to make a deposit and refinance its loan for a fixed durable good, which we might think of as a house. In our benchmark model, bank loans do not feed back into real economic activity, as say a loan to a firm might; we will return to this issue later in the paper.

A representative household maximizes

$$
\begin{aligned}
U_t = \mathrm{E}_t \sum_{j=t}^{\infty} \beta^{j=t} \big\{ &\log(c_t - \eta c_{t-1}) + \phi_{m,t} \log(m_{h,t}) + \phi_{d,t} \log(d_{h,t}) \\
&+ \phi_b \log(b_{h,t}) - \phi_n (1+\chi)^{-1} \big[\mu n_t^{1+\chi} + (1-\mu)n_{b,t}^{1+\chi} \big] \big\}
\end{aligned}
, \quad (1)
$$

where c_t is consumption of a constant elasticity of substitution (CES) aggregate of goods, ηc_{t-1} reflects habit in consumption preferences, $m_{h,t}$ are real cash balances, $d_{h,t}$ are real deposits at the bank, and $b_{h,t}$ are real government bond holdings. The household has a continuum of workers of measure one. It supplies $1 - \mu$ workers to the banking sector and μ workers to firms producing consumer goods; n_t and $n_{b,t}$ are the hours worked in these two sectors. We assume each household works at all of the firms and all of the banks; with this convenient assumption, the households will be identical in equilibrium despite the dispersion of work effort across firms (due to Calvo price setting), and we can take the shortcut of discussing a representative agent. Since the continuum of households has measure one, aggregate values will also be per capita values.

The household uses cash and bank deposits to do its transacting; this is why these variables appear in equation (1). We interpret bank deposits broadly, so the sum of household cash balances and deposits is equal to $M2$; in real terms, $m2_t = m_{h,t} + d_{h,t}$. In reality, government bonds provide liquidity in a number of ways; banks, money-market funds, mutual funds, pension funds, and insurance companies all use them to manage their liquidity. We model banks directly, but we do not model these other financial institutions. We put government bonds into household utility to reflect their value in providing liquidity services outside the banking sector. The parameters $\phi_{m,t}$, $\phi_{d,t}$, and ϕ_b measure the relative usefulness of these aggregates to the household; we make the parameters $\phi_{m,t}$ and $\phi_{d,t}$ time dependent to allow for an $m2$ demand shock.

$$
\begin{aligned}
\log(\phi_{m,t}) = (1 - \rho_{m2}) \ln(\phi_m) + \rho_{m2} \ln(\phi_{m,t-1}) + \varepsilon_{m2,t} \\
\log(\phi_{d,t}) = (1 - \rho_{m2}) \ln(\phi_d) + \rho_{m2} \ln(\phi_{d,t-1}) + \varepsilon_{m2,t}
\end{aligned}
, \quad (2)
$$

where $0 < \rho_{m2} < 1$, ϕ_m and ϕ_d are the steady-state values of these parameters, and $\varepsilon_{m2,t}$ is the shock.

The household's budget constraint is

$$
\begin{aligned}
c_t + m_{h,t} + d_{h,t} + b_{h,t} + a_{h,t} + \big(I_{l,t-1}/\Pi_t \big) l_{h,t-1} + \tau_t &\leq \mu w_t n_t \\
+ (1-\mu)w_{b,t} n_{b,t} + (1/\Pi_t) m_{h,t-1} + \big(I_{d,t-1}/\Pi_t \big) d_{h,t-1} & \\
+ \big(I_{g,t-1}/\Pi_t \big) b_{h,t-1} + \big(I_{c,t-1}/\Pi_t \big) a_{h,t-1} + l_{h,t} + \Omega_t &
\end{aligned}
, \quad (3)
$$

where $I_l, I_d,$ and I_g are gross nominal interest rates on loans, deposits, and government bonds. The household can also purchase a risk-free bond, $a_{h,t}$, that does not provide liquidity services; its gross nominal return is $I_{c,t}$. Wages are flexible; w_t and $w_{b,t}$ are the wage rates in manufacturing and banking. Ω_t are dividends from the firms; banks are competitive and earn no profits. $\Pi_t = P_t/P_{t-1}$, where P_t is the implicit price deflator for the CES aggregate of consumption goods, c_t. Finally, τ_t is a lump sum tax. Another constraint is that the household must also get a loan each period to finance its fixed durable good, ℓ, so,

$$l_{h,t} \geq \ell > 0. \tag{4}$$

The household maximizes equation (1) subject to equations (3) and (4). Its first-order conditions are:

$$\lambda_t = (c_t - \eta c_{t-1})^{-1} - \mathrm{E}_t[\beta \eta (c_{t+1} - \eta c_t)^{-1}], \tag{5}$$

$$\lambda_t = \phi_n n_t^\chi / w_t = \phi_n n_{b,t}^\chi / w_{b,t}, \tag{6}$$

$$I_{c,t}^{-1} = \beta \mathrm{E}_t[(\lambda_{t+1}/\lambda_t)/\Pi_{t+1}], \tag{7}$$

$$\phi_{m,t}/m_{h,t} = \lambda_t(I_{c,t} - 1)/I_{c,t}, \tag{8}$$

$$\phi_{d,t}/d_{h,t} = \lambda_t(I_{c,t} - I_{d,t})/I_{c,t}, \tag{9}$$

$$\phi_b/b_{h,t} = \lambda_t(I_{c,t} - I_{g,t})/I_{c,t}, \tag{10}$$

$$l_{h,t} = \ell(\text{if } I_{l,t} > I_{c,t}). \tag{11}$$

where λ_t is the marginal value of wealth (or the Lagrange multiplier for equation (3)). Equation (6) is a labor supply equation. Equation (7) is the standard consumption Euler equation, and I_c is the CCAPM interest rate. The left-hand side of equation (8) is the marginal utility of holding one more $m_{h,t}$, and the right-hand side is the marginal disutility of holding the extra $m_{h,t}$ instead of an $a_{h,t}$. Equations (9) and (10) have similar interpretations for the household's demand for deposits and government bonds.

All of the interest rate spreads will be positive in equilibrium. The spread between the CCAPM rate and the government bond rate—$I_{c,t} - I_{g,t}$—will play a large role in what follows; it is positive because government bonds provide liquidity services, and therefore they command a liquidity premium. This spread is the BB model's interpretation of the disconnect between money market rates and the rates that affect aggregate demand via the consumption Euler equation.

Banks. In the BB model, competitive banks issue deposits and make loans. These activities are not costless. The representative bank uses labor in making loans,

$$l_{b,t} = Z_l n_{b,t}, \tag{12}$$

and the bank holds cash and government bonds to manage the liquidity of its deposits,

$$d_{b,t} = Z_d m_{b,t}^{\delta} b_{b,t}^{1-\delta}, \tag{13}$$

where Z_l and Z_d are productivity parameters, and $\delta \in (0, 1)$. Unlike Goodfriend and McCallum (2006), we do not model the federal funds market directly. In the United States, banks have to meet reserve requirements over a 2-week reserve maintenance period. A bank with a reserve shortage can borrow federal funds, sell T-bills or use repos to meet its reserve requirements. This keeps the T-bill yield closely tied to the federal funds rate. In our quarterly model, we simply assume that the central bank targets the T-bill rate, and this is the money market rate that appears in its interest rate rule.

The bank raises funds by issuing deposits and borrowing at the CCAPM rate; its balance-sheet constraint is

$$l_{b,t} + m_{b,t} + b_{b,t} = d_{b,t} + a_{b,t}. \tag{14}$$

The bank maximizes the present discounted value of its profits,

$$\mathrm{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \lambda_s [(I_{l,s}/\Pi_{s+1})l_{b,s} + (1/\Pi_{s+1})m_{b,s} \\ + (I_{g,s}/\Pi_{s+1})b_{b,s} - (I_{c,s}/\Pi_{s+1})a_{b,s} - (I_{d,s}/\Pi_{s+1})d_{b,s} - w_s n_{b,s}], \tag{15}$$

subject to equations (12), (13), and (14). Its first-order conditions are:

$$I_{d,t} + \kappa_t = I_{c,t}, \tag{16}$$

$$1 + \kappa_t \delta(d_{b,t}/m_{b,t}) = I_{c,t}, \tag{17}$$

$$I_{g,t} + \kappa_t (1 - \delta)(d_{b,t}/b_{b,t}) = I_{c,t}, \tag{18}$$

$$(I_{l,t} - I_{c,t})/I_{c,t} = w_{b,t}/Z_{l,t}, \tag{19}$$

where $\kappa_t = (I_{c,t} - 1)^{\delta} (I_{c,t} - I_{g,t})^{1-\delta}/Z_b \, \delta^s \, (1 - \delta)^{1-\delta}$.

These equations have straightforward interpretations. $I_{c,t} - 1$ is the opportunity cost of holding an $m_{b,t}$ instead of an $a_{b,t}$, while $I_{c,t} - I_{g,t}$ is the opportunity cost of holding a $b_{b,t}$ instead of an $a_{b,t}$. So, κ_t is the marginal cost of creating a $d_{b,t}$ via equation (13). The bank can raise funds by creating deposits or by borrowing at the

CCAPM rate. Equation (16) says that the bank will raise funds by creating deposits up to the point where marginal cost of doing so is equal to the marginal cost of borrowing at the CCAPM rate; equations (17) and (18) have similar interpretations. Equation (19) says that the marginal cost of making a loan must equal the marginal revenue from that loan, implying that the loan rate must be higher than the CCAPM rate.[5]

Firms. Our discussion of firms can be quite brief since our treatment of it is now standard.[6] A continuum of firms, indexed by f on the unit interval, produces a continuum of differentiated consumer goods. Household preferences for these goods are represented by a CES aggregator,

$$c_t = \left[\int_0^1 c_t(f)^{(\sigma-1)/\sigma} \, df \right]^{\sigma/(\sigma-1)}, \tag{20}$$

where $\sigma > 1$, and the implicit price deflator is

$$P_t = \left[\int_0^1 P_t(f)^{1-\sigma} df \right]^{1/(1-\sigma)}. \tag{21}$$

Firm f's production function is

$$y_t(f) = Z_{y,t} \bar{k}^{1-\omega}[\mu n_t(f)]^\omega, \tag{22}$$

where $\bar{k}$ is the fixed capital stock, and $Z_{y,t}$ is total factor productivity; $Z_{y,t}$ follows a process that is common to all firms,

$$\ln(Z_{y,t}) = (1 - \rho_y) \ln(\bar{z}_y) + \rho_y \ln(Z_{y,t-1}) + \varepsilon_{y,t}, \tag{23}$$

where $0 < \rho_y < 1$ and $\bar{z}$ is the steady-state value of $Z_{y,t}$. As noted earlier, we assume the Calvo pricing. With probability $1 - \alpha$, firm f gets to reset it price $P_t(f)$; otherwise, its price is simply scaled up by the steady-state rate of inflation. Aggregate output is given by:

$$y_t = Z_{y,t} \bar{k}^{1-\omega}(\mu n_t)^\omega / \left[\int_0^1 (P_t/P_t(f))^{\sigma/\omega} df \right]^\omega, \tag{24}$$

where the integral is a price dispersion term that measures the inefficiency due to the Calvo pricing.

This composite good is consumed by households and the government; that is, the goods market equilibrium condition is: $y_t = c_t + g_t$. We also note that the New

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5. This implies, from equation (11) that $l_{h,t} = \ell$. Households do not want to borrow any more than necessary at this high rate.

6. The details can be found in many places; Canzoneri, Cumby, and Diba (Forthcoming) is one. The real purpose of our writing down some of these equations is to identify parameters that will be important in the model's calibration.

Keynesian Phillips curve stemming from these models is a difference equation in inflation with the firms' marginal cost as an innovation; a rise in marginal cost—$w_t/Z_{y,t}$—will increase inflation. Many of our results depend heavily on this.

Monetary and fiscal policy. The government's flow budget constraint is

$$I_{g,t-1}b_{t-1}/\Pi_t = \tau_t - g_t + b_t + m_t - m_{t-1}/\Pi_t, \tag{25}$$

where g_t is government spending, and m_t and b_t are the real cash and bond holdings of households and banks ($m_{h,t} + m_{b,t}$ and $b_{h,t} + b_{b,t}$), respectively. Letting $\text{liab}_t = m_t + b_t$ be total government liabilities, the budget constraint becomes

$$\text{liab}_t = \text{liab}_{t-1}/\Pi_t + \text{def}_t, \tag{26}$$

where $\text{def}_t = (I_{g,t-1} - 1)b_{t-1}/\Pi_t + g_t - \tau_t$ is the total fiscal deficit, inclusive of interest payments.

Both m_t and b_t provide transactions services in the BB model, though these services are not of equal value. The fiscal deficit determines liab_t, which we will call the "liquidity provision" effect of fiscal policy. Then, the central bank's OMO determines the composition of liab_t, and the "effective transactions balances" of households and banks; effective transactions balances are the Cobb–Douglas aggregators defined by equation (13) for banks, and by the utility function for households. So, both monetary and fiscal policy have liquidity effects, and this will be important in what follows.

There are many potential ways to write a fiscal policy rule. The discussion above might, for example, suggest a rule in which deficits respond to total liabilities. However, we will follow most of the literature in letting the taxes respond to the level of government debt. In particular, we let government spending follow an exogenous process,

$$\ln(g_t) = (1 - \rho_g)\ln(\bar{g}) + \rho_g \ln(g_{t-1}) + \varepsilon_{g,t}, \tag{27}$$

and we let the rule for taxes be

$$\tau_t = (1 - \rho_t)\bar{\tau} + \rho_\tau \tau_{t-1} + (1 - \rho_\tau)\phi_t(b_{t-1} - \bar{b}). \tag{28}$$

We will always assume that ϕ_f is greater than the steady-state value of the real CCAPM rate, which in turn is greater than the steady-state value of the real government bond rate. Our BB model is non-Ricardian since government bonds provide liquidity, but our fiscal policies will be Ricardian in the sense of Woodford (1995) and passive in the sense of Leeper (1991): primary surpluses move to stabilize the debt, and guarantee that the government's present value budget constraint is satisfied for any price path.

Monetary policy will follow a standard interest rate rule:

$$i_{g,t} = \rho_i i_{g,t-1} + (1 - \rho)[\bar{i}_g + \theta_\pi(\pi_t - \bar{\pi}) + \theta_y(\log(y_t - \log(\bar{y}))] + \varepsilon_{i,t}. \tag{29}$$

Note that the gap term incorporates steady-state output, and not the flexible price level of output.[7]

1.2 The NW Model

The NW model is embedded in the BB model. There are no banks in the NW model; therefore, we take out all the equations and variables having to do with banks. We set $\phi_{d,t} = 0$ in the household utility function, but we retain $\phi_{m,t}$. The money demand equation, equation (8), remains, and so does the money demand shock; however, now money is just household cash balances. Finally, government bonds do not provide liquidity services in the NW model; therefore, we set $\phi_b = 0$ in the utility function. These bonds no longer command a liquidity premium, and equation (9) implies that the spread—$I_{c,t} - I_{g,t}$—collapses. In the NW model, $I_{c,t}$ appears in the interest rate rule, equation (29), and there is no disconnect between money market rates and the CCAPM rate that affects aggregate demand.

1.3 Theoretical Implications of Banks and Liquid Bonds with Transactions Services

As stated earlier, the BB model adds three basic features to the NW model: new financial assets, financial frictions, and a non-Ricardian element that gives fiscal policy a liquidity effect on inflation. In this section, we discuss some theoretical implications of these modifications of the NW model. In later sections, we calibrate the two models, and we study the quantitative significance of these theoretical implications.

Implications for monetary policy of the transactions services of bonds. Government bonds provide liquidity in the BB model, and this has two implications for monetary policy: one is the "liquidity provision" effect and the other is a "liquidity buffering" effect. We have already discussed the liquidity provision effect: government deficits determine the level of $m_t + b_t$, each of which provides transactions services. So, fiscal policy plays a new, and obvious, role in inflation policy. The liquidity buffering effect is somewhat more subtle, and it has to do with what we have called effective transactions balances.

When the central bank conducts a contractionary OMO, it sells government bonds for cash, thereby creating a liquidity crunch. In the NW model, the OMO replaces assets (m) that have transactions value with assets (b) that do not. In the BB model, the transactions services of bonds buffer the effect on liquidity. The buffering effect manifests itself in the spread—$I_{c,t} - I_{g,t}$—between money market rates and the rates that affect aggregate demand, and this has implications for both monetary policy surprises (interest rate shocks) and the systematic component of monetary policy (the inflation term in equation (23)).

To see this buffering effect, note that equations (17) and (18) imply

$$b_{b,t}/m_{b,t} = [(1 - \delta)/\delta][(I_{c,t} - 1)/(I_{c,t} - I_{g,t})]. \tag{30}$$

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7. Canzoneri, Cumby, and Diba (Forthcoming) argue that this specification makes their model fit the data better. As is well known, using a gap term with flexible price output would raise welfare in this kind of model.

$(I_{c,t} - I_{g,t})/I_{c,t}$ is the opportunity cost to the bank of holding a $b_{b,t}$ instead of an $a_{b,t}$; similarly, $(I_{c,t} - 1)/I_{c,t}$ is the cost of holding an $m_{b,t}$ instead of an $a_{b,t}$. So, $(I_{c,t} - 1)/(I_{c,t} - I_{g,t})$ is the cost of holding cash relative to the cost of holding government bonds; when it rises, banks substitute bonds for cash in their liquidity management of deposits. Households face the same relative costs, and their ratio of bonds to cash is proportional to that of the banks,

$$b_{h,t}/m_{h,t} = \{[\delta/(1-\delta)]/[\phi_{m,t}/\phi_b]\}(b_{b,t}/m_{b,t}). \tag{31}$$

When the relative cost of holding money rises, both households and banks substitute bonds for cash.

A contractionary OMO raises the ratio of government bonds to cash. The relative cost of money rises to make households and banks accept the new ratio, decreasing the spread, $I_{c,t} - I_{g,t}$. This can be seen directly in equation (30), and it can also be understood in term of the liquidity premium on government bonds. The increase in government bonds decreases their marginal value in effective transactions balances, and this decreases the liquidity premium that bonds can command.

Now consider the implications for an interest rate surprise of say 6 basis points (or 24 basis points in annual terms). The central bank must conduct a contractionary OMO to raise $I_{g,t}$ by 6 basis points. But in the BB model, a contractionary OMO decreases the spread, and the effect on $I_{c,t}$ is less than 6 basis points. The liquidity services of government bonds buffer the effect of this OMO on the CCAPM rate and aggregate demand. In the NW model, there is, of course, no spread, and the shock goes straight through to the consumption Euler equation and aggregate demand.

Consider next the implications for the systematic component of monetary policy. When inflation rises by, say, 1%, equation (29) requires $I_{g,t}$ to increase by θ_π. This is, of course, accomplished by a contractionary OMO. In the BB model, the effect on liquidity is buffered, and $I_{c,t}$ rises less than θ_π. So, for a given value of θ_π, the systematic component of monetary policy is less aggressive in the BB model than it is in the NW model.

Implications of banks and financial frictions. Banks modify the NW model in two theoretically important ways: they provide deposits (which may reduce the need for cash), and they provide loans (which may affect aggregate supply or demand in a variety of ways, depending on how loans are modeled). Moreover, the provision of these deposits and loans is costly: the banks need money and bonds to manage the liquidity of their deposits, and they use labor to create loans. These financial frictions may inhibit economic activity in the BB model. These new elements should affect the way in which shocks pass through our two model economies.

Monetary aggregates as indicators of inflation. In the NW model, the money demand equation is a decoupled equation whose only role is to determine the OMOs necessary to implement the central banks interest rate rule. The central bank simply accommodates any increase in money demand, leaving interest rates and everything

else unchanged. But in the BB model, the money demand equation is part of a nexus of equations determining household and bank demands for a variety of assets. For this reason alone, one might expect monetary aggregates to play a more important role in forecasting inflation.

Banks also provide an aggregate—$M2$—that has been used by some central banks in forecasting inflation, and $M2$ velocity has played an historical role in monetarist thought. Moreover, in the BB model, the liquidity provision effect of fiscal policy leads one to expect that government liabilities will be useful in forecasting inflation. We will investigate these issues in Section 5.

2. STEADY-STATE EQUILIBRIUM OF THE BB MODEL

In this section, we show that the BB model has a unique steady-state equilibrium for suitable specifications of monetary and fiscal policy. As we shall see, the steady-state values of consumption, output, and work do not depend on monetary policy or on steady-state inflation; in this sense, the model has a recursive structure and satisfies the proposition of the superneutrality of money. However, the steady-state relationship between inflation and the instrument of monetary policy, I_g, is more complicated in the BB model than in the more conventional NW model, and this is a matter of some independent interest. (For notational simplicity, we will drop t subscripts to denote steady-state values in this section.)

In the steady states of both models, the real CCAPM rate is tied to consumer preferences: $I_c/\Pi = 1/\beta$. So, the familiar Fisher equation links the nominal CCAPM rate and inflation. The instrument of monetary policy is however I_g, and the steady-state relationship between I_g and inflation depends on an interest rate spread: $I_g = \Pi/\beta - (I_c - I_g)$. In the NW model, the spread vanishes, and the steady-state monetary policy can be specified as an inflation target or equivalently as a value of the instrument, I_g. Monetary policy clearly determines steady-state inflation in the NW model independently of fiscal policy. In the BB model, government bonds have non-pecuniary returns, and the spread is positive. Moreover, the spread is endogenous, and it depends on fiscal policy. So, one question we will address is whether, for a given fiscal policy, we can work from an inflation target back to a setting of I_g. This will generally be the case; however, there is one simple specification of fiscal policy that determines steady-state inflation all by itself.

On the spending side, we will always assume that the fiscal authority sets a target for g/y ($= \gamma_g$), the steady-state ratio of government spending to output. To solve for the steady-state level of employment, we use the labor-demand equilibrium condition linking the real wage to the marginal product of labor.[8] The Cobb–Douglas production

8. The actual derivation of the following equation would use the pricing equations of firms.

function in equation (24) implies:

$$w = \frac{(\sigma - 1)\omega y}{\sigma \mu n} \tag{32}$$

We next solve for the steady-state work effort. Using equation (32), the household's first-order conditions in equations (5) and (6), and the market clearing condition, $c = (1 - \gamma_g)y$:

$$\phi_n n^{1+\chi} = \frac{(\sigma - 1)(1 - \beta\eta)\omega}{\sigma(1 - \eta)(1 - \gamma_g)\mu}. \tag{33}$$

Given the work effort, n, the production function determines output, the market clearing condition pins down consumption, and equation (32) determines the real wage. Therefore, other than setting γ_g, monetary and fiscal policies play no role in the determination of n, y, c, and w.

To solve for the other variables, we have to specify tax policy. In our benchmark tax policy, the fiscal authority uses its instrument to meet a target for b/y, the steady-state ratio of debt to output. Later in the section, we will consider tax policies that target a deficit or a ratio of public sector liabilities to output.

First, we derive an expression that relates the CCAPM rate, I_c, to the instrument of monetary policy, I_g. To do this, we use a steady-state version of equation (16),

$$I_d = I_c n - \frac{(I_c - 1)^\delta (I_c - I_g)^{1-\delta}}{Z_b d^\delta (1 - d)^{1-\delta}}, \tag{34}$$

and equation (9) to get an expression linking the demand for deposits and the CCAPM rate. Then, using equations (13), (17), and (18), we solve for the bank's demand for bonds:

$$b_b = \left[\frac{(1 - \delta)\phi_d(1 - \eta)c}{1 - \beta\eta} \right] \left(\frac{I_c}{I_c - I_g} \right). \tag{35}$$

In equilibrium, the household's demand for bonds in equation (10) and the bank's demand in equation (36) must add up to the supply, which is pinned down by the fiscal target for b/y, and we get:

$$I_c = \frac{I_g}{1 - \left(\frac{1 - \gamma_g}{b/y} \right) \left(\frac{[\phi_b + (1 - \delta)\phi_d](1 - \eta)}{(1 - \beta\eta)} \right)}. \tag{36}$$

Since $\Pi = \beta I_c$, this is the expression we need to relate steady-state inflation to the monetary policy instrument, I_g. For a given fiscal policy—characterized by γ_g and the target for b/y—the central bank can calculate the instrument setting it needs to achieve a given inflation target. (Of course, we can also read equation (36) the other

way around: if the central bank is already committed to a particular value for I_g, the fiscal authority can achieve, say, a lower steady-state inflation by choosing either a higher γ_g or a higher target for b/y.)

Note that equation (36) places a constraint on the fiscal authority's choice of b/y: the target must be high enough, given γ_g, for the denominator to be positive; otherwise, an equilibrium with positive interest rates will not exist. However, this constraint is (at least in part) an artifice of our choice of functional forms. Our Cobb–Douglas specifications of "effective transactions balances" make it essential for households and banks to hold bonds, even if the gross interest rate on those bonds goes to zero. The denominator of equation (36) will be positive if the target for b/y makes b larger than what would be demanded when $I_g = 0$.

Finally, we turn to the money and bond markets. Under our benchmark policies, the money stock is endogenous. Using equations (8), (9), (10), (17), (18), and the market-clearing conditions for money and bonds, we obtain

$$\frac{m}{b} = \left[\frac{\phi_m + \delta\phi_d}{\phi_b + (1 - \delta)\phi_d} \right] \left(\frac{I_c - I_g}{I_c - 1} \right), \tag{37}$$

which determines the composition of public sector liabilities in the steady state. Note that our benchmark policies also make total public sector liabilities (cash plus bonds) endogenous.[9]

We now turn to alternative specifications of the steady-state tax policy. Suppose the fiscal authority sets a target for the broader aggregate of total liabilities; that is, it sets a target for $(m + b)/y$ (which includes bonds monetized by the central bank). For a given monetary policy, equation (37) pins down the composition of liabilities, and our steady-state results remain basically unchanged.[10] For a given fiscal policy, a higher value of I_g corresponds to setting a higher inflation target; and given an I_g, a higher fiscal target for $m + b$ leads to a lower inflation rate.

Tax policy might also target the deficit. If the target is set equal to zero, however, then it follows from equation (26) that the steady-state inflation rate is zero, regardless of monetary policy.[11] In this rather peculiar case, monetary policy determines the real value of the public debt. Setting aside this special case, all the policy specifications we have considered suggest that monetary policy can set and implement an inflation target, even though the "right" value of its instrument, I_g, depends on the fiscal policy. Given the solution for inflation and I_c, the rest of our steady-state calculations are straightforward.

9. Equation (36) illustrates another way we could characterize monetary policy in the steady state. OMO determines the ratio m/b, and then equation (36) determines the interest rate spread. We do not pursue this here other than to note that a permanent OMO (or choice of a new target for m/b) will change the nonpecuniary returns on bonds and (for a given fiscal policy) bring a new steady-state rate of inflation.

10. For a unique equilibrium to exist, fiscal policy must still incur enough liabilities to satisfy the demand for bonds at some positive interest rate.

11. Note that we are abstracting from growth in the steady state.

3. CALIBRATION OF THE BB MODEL

The NW model is now standard in the literature, and for that part of the model, we can take parameter values that are familiar.[12] We set the Calvo parameter, α, equal to 0.75, so that prices change once a year on average; we set the elasticity of demand, σ, equal to 7, so that the gross markup is 1.17 in the steady state; we set the Frisch elasticity of labor supply, $1/\chi$, equal to 1; we set the elasticity of output with respect to labor, ω, equal to 0.67; and finally, we set the habit persistence parameter, η, equal to 0.7. We set the persistence parameters, ρ, in the autoregressive processes for all of the shocks at 0.9. We assume the standard deviations of the shocks are: 0.008 for the productivity shock, 0.01 for the government purchases shock and money demand shock, and 0.00245 for the interest rate shock (in the central bank's interest rate rule). Since we do not have investment in our model, we set the share of government purchases in output to 0.25.

For our benchmark monetary and fiscal policies, we rely on estimates discussed in earlier papers.[13] We set the benchmark parameters in the central bank's interest rate rule at: $\theta_\pi = 2.0$, $\theta_y = 0.2$, and $\rho_i = 0.8$. And we set the benchmark parameters in the fiscal policy rule at: $\theta_f = 0.018$ (which is three times the real government bond rate and is also larger than the CCAPM rate), and $\rho_g = \rho_\tau = 0.9$.

For the financial sector, we calibrated (using the steady-state equations) the parameters ϕ_m, ϕ_d, ϕ_b, Z_l, Z_b, and δ to match key averages of monetary and fiscal variables in the U.S. data from 1990 to 2005. In the data, government bonds held by the banking sector are about 25% of (quarterly) consumption, and bank reserves (vault cash and deposits at the Fed) are about 5% of consumption. The banking sector employs about 1.5% of the labor force. Bank loans (including securities held by banks) are 4.25 times consumption. Deposits (including checking accounts as well as small-scale saving and time deposits) are about 3.15 times quarterly consumption, but deposits issued to households are only about 2.45 times consumption. In our model, we make deposits 2.45 times consumption and scale all the banking sector data above by the ratio 2.45/3.15. Cash held outside banks is about 30% of consumption, and we attribute it all to household cash balances. We also attribute government bonds held by individuals, insurance companies, and pension funds, which amounts to 80% of consumption, to households.

Finally, we set the steady-state inflation and federal funds rates at their quarterly averages for this period: 0.7% and 1.1% per quarter, respectively. And, we set the value of μ so that hours and wages in the steady state are equal across the banking and production sectors.

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12. See, for instance, Christiano, Eichenbaum, and Evans (2005).

13. See Canzoneri, Cumby, and Diba (Forthcoming). For θ_f, we relied on work by Henning Bohn; see Canzoneri et al. (2006).

4. A QUANTITATIVE COMPARISON OF THE TWO MODELS

In Section 1, we identified a number of theoretical differences between the BB and NW models. In this section, we examine the quantitative significance of these differences. Even if the BB model is thought to be a more complete modeling of the true economy, the much simpler NW model may give a reasonably good account of the way the economy behaves, and its implications for monetary policy may not be too misleading. We begin by comparing time series statistics and impulse response functions generated by the two models. Then, we turn to the potential role of monetary aggregates in inflation forecasting.

4.1 Comparing Time Series Statistics in the Two Models

Tables 1, 2, and 3 present a number of statistics generated by the two models. All variables except interest rates and the inflation rate are in logarithms. The benchmark monetary and fiscal policies were used in the simulations that generated these statistics. The means and standard deviations in Table 1 show a remarkable similarity between the two models. The models were calibrated to have very similar steady states for the variables they share, and the means of those variables bear this out. What is remarkable is the similarity of the standard deviations of inflation, output, and the CCAPM rate. Real monetary aggregates are quite volatile in both models.

An interesting difference does emerge in the variance decompositions reported in Table 2. Productivity shocks play a dominant role in explaining real economic activity in both models, and especially in the NW model. This is typical of models of in this class; indeed, it is difficult to get demand side shocks to do very much in this so-called "New Keynesian" paradigm. Government spending shocks explain less than 1% of the variation in inflation in the NW model and only 7% of the variation in consumption. By contrast, government spending shocks explain 18% of the variation in inflation in the BB model. This is due, at least in part, to the fact that deficits are financed with bonds that provide transactions services in that model. In addition, government spending shocks explain the lion's share of the variation in

TABLE 1

THEORETICAL MEANS AND STANDARD DEVIATIONS IN THE BENCHMARK MODELS

	BB model			NW model	
Variable	Mean	Std. deviation	Variable	Mean	Std. deviation
Π	0.0070	0.0038	Π	0.0076	0.0033
y	0.9044	0.0099	y	0.9019	0.0104
Rc	0.0101	0.0035	Rc	0.0101	0.0039
m_h	−0.5873	0.2854	m	−0.6267	0.2711
liab	0.9044	0.1974	liab	0.4089	0.3598
$m2$	1.6283	0.1431			
deposits	1.5128	0.1598			

TABLE 2

VARIANCE DECOMPOSITIONS (INFINITE HORIZON) IN THE BENCHMARK MODELS

	BB model					NW model			
Variable	ε_p	ε_i	ε_g	ε_m	Variable	ε_p	ε_i	ε_g	ε_m
Π	77.35	5.06	17.58	0.01	π	91.08	8.84	0.08	0.00
Rc	17.52	81.16	1.30	0.02	Rc	14.44	83.98	1.58	0.00
y	80.13	6.20	13.67	0.00	y	82.47	6.81	10.72	0.00
c	86.60	6.70	6.70	0.00	c	85.92	7.10	6.98	0.00
n	88.89	3.47	7.64	0.00	n	88.58	4.75	6.67	0.00
m_h	52.90	32.52	13.99	0.59	m	58.12	40.08	1.09	0.72
dM	11.23	87.55	0.80	0.42	dM	10.11	89.08	0.33	0.48
dLIAB	14.06	11.02	74.92	0.01	dLIAB	6.49	6.60	86.90	0.01
$dM2$	11.12	83.23	1.80	3.85					
$m2$	15.43	10.29	73.09	1.19					
deposits	5.65	6.75	86.73	0.86					
b_h	3.90	9.31	86.63	0.15					
$R_c - R_g$	5.76	10.15	83.95	0.14					
$R_l - R_c$	35.50	62.32	2.15	0.03					

TABLE 3

CORRELATIONS IN THE BENCHMARK MODELS

	BB model			NW model	
Variable	Π	y	Variable	Π	y
Π	1.00	−0.50	Π	1.00	−0.64
dM	−0.07	−0.05	dM	−0.07	−0.04
dLIAB	0.38	−0.10	dLIAB	0.12	−0.00
$dM2$	−0.01	−0.07			

$m2$, deposits, and household bond holdings; deficits increase the supply of government bonds, requiring households and banks to substitute among their various liquid assets.

The variance decompositions in Table 2, along with the unconditional correlations in Table 3, give some indication of the role that monetary aggregates may play in the two models. The productivity shocks and government spending shocks that explain almost 95% of the variation inflation in the BB model only explain a little more that 10% of the variation in dM (growth in nominal base money) and $dM2$ (growth in nominal $M2$); moreover, the correlation between the growth in these aggregates and inflation is essentially zero. By contrast, these two shocks explain about 90% of the variation in dLIAB (growth in nominal $m + b$). So, it is not surprising that the correlation between inflation and dLIAB is strong (0.38). This suggests that dLIAB may be a good indicator of inflation in the BB model, but dM and $dM2$ may not be so. In the NW model, dM (the growth in nominal cash balances) shares the same fate as dM in the BB model; it will probably not be a good indicator of inflation. In the NW model, government spending shocks explain 87% of the variation in dLIAB, but here government shocks do virtually nothing to inflation. The correlation between

inflation and dLIAB is weaker (0.12). This suggests that monetary aggregates may not be good indicators of inflation in the NW model.

4.2 Comparing Impulse Response Functions in the Two Models

Impulse response functions show how shocks pass through our model economies. In Section 2, we noted that in the BB model, government bonds buffer the liquidity effects of OMO, and government deficits provide liquidity. Here, we use impulse response functions to see if these facts significantly alter the way the economy responds to shocks. Once again, we use the benchmark policy rules for monetary and fiscal policy.

Interest rate shocks. Figure 1 shows how an unanticipated increase in $I_{g,t}$ passes through our two model economies; there is, of course, no spread between $I_{g,t}$ and $I_{c,t}$ in the NW model. The NW model, in the top panel, illustrates a conventional story. The $I_{g,t}$ shock is implemented with an OMO that increases the supply of bonds relative to cash. The real CCAPM rate (R_c) rises, lowering consumption demand via the Euler equation. Output and labor demand fall, decreasing the real wage and marginal cost; and a lower marginal cost means less inflation. The original OMO produces a negative dM, but the systematic part of monetary policy then works in the other way, and dM becomes positive in the next period. So, dM does not appear to be a very good indicator of inflation for interest rate shocks; we return to this issue in Section 4.3.

This conventional story repeats itself in the BB model, but the "buffering effect" of government bonds is evident: the spread—$I_c - I_g$—narrows (not pictured), and this cushions the effect on inflation and economic activity. R_c rises less (by about 14%), inflation falls less (by about 19%) and returns to steady state sooner, and consumption falls less (by about 11% at its trough). The general patterns of the impulse response functions are the same as in the NW model, but quantitative differences range from about 10% to 20%, and this would seem to be of some importance.[14]

The financial markets story is, of course, richer in the BB model. The contractionary OMO forces banks and households to substitute bonds for cash. Bank deposits also fall, and $m2$ falls. dM and d$M2$ fall on impact, but are positive thereafter. Moreover, the rise in the real government bond rate increases the deficit, and government liabilities rise (recall equation (26)); therefore, dM, d$M2$, and dLIAB are all positive from the second period on. None of the monetary aggregates appear to be very good indicators of inflation for interest rate shocks.

The credit tightening passes to the loans market as well. In fact, the real loan rate, R_l (not pictured) increases more than the CCAPM rate. However, this does not affect household behavior since the amount of loans is effectively fixed in our benchmark model. Following Christiano et al. (2007) and others, we also tried making firms borrow from the bank to meet their wage bill. This modification did not change our

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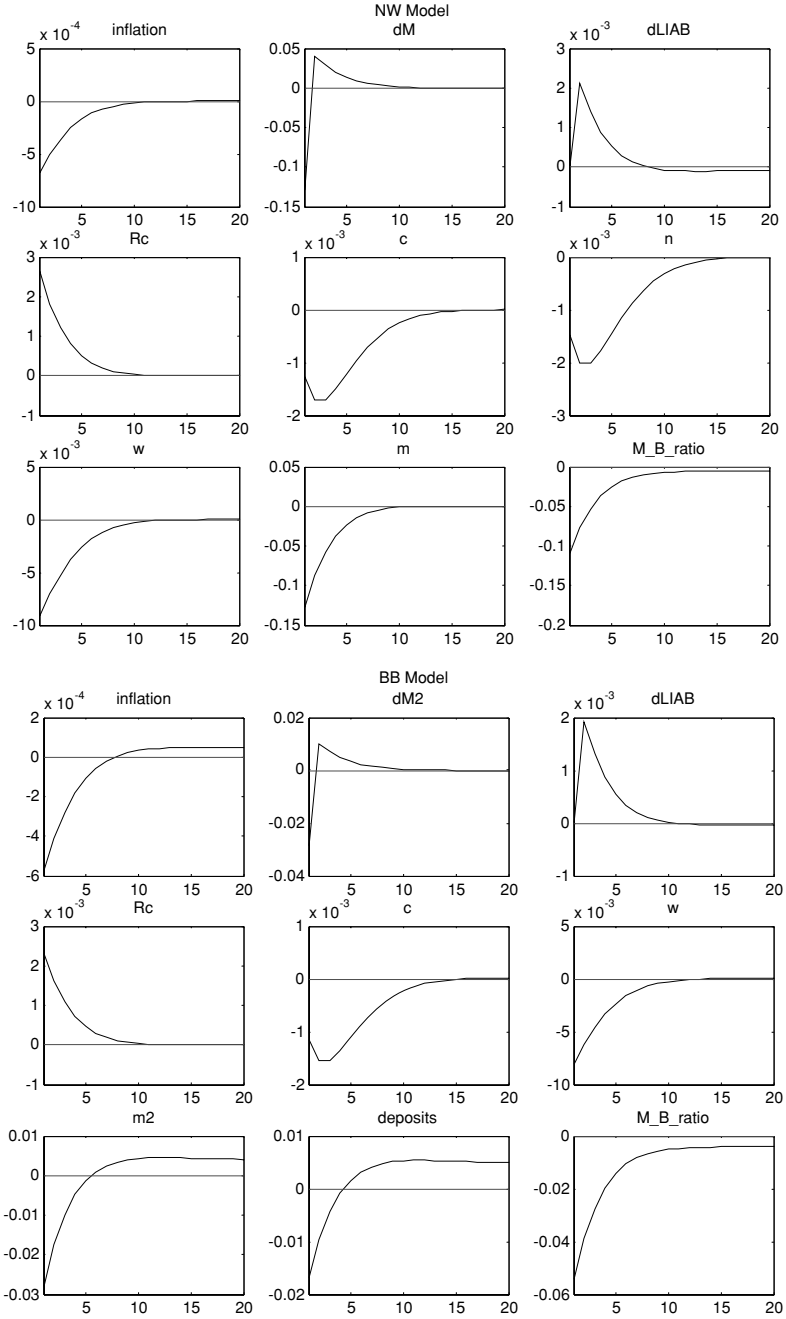14. The differences are larger for lower values of θ_π.

FIG. 1. Interest Rate (*Ig*) Shock.

results in a quantitatively significant way, and therefore we have presented the simpler model. Apparently, the demand for loans will have to be modeled in a different way if the loans channel is to have a significant effect on aggregate supply or demand; we return to this issue in the Conclusion.

Productivity shocks. Figure 2 shows how an unanticipated increase in the total factor productivity of firms passes through our two models. In the NW model, a positive productivity shock leads to higher consumption. However, aggregate demand does not increase enough to accommodate the increase in productivity; therefore, labor demand and the real wage fall. Marginal cost, $w_t/Z_{y,t}$, and inflation fall. The central bank responds to the shock by lowering the nominal CCAPM rate (as evidenced by the rise in the ratio of cash to bonds); m rises, and dM is positive. For productivity shocks, dM is not a good indicator of inflation, and as noted earlier, productivity shocks explain most of the variation in inflation in both models.

Moving on to the BB model, the "liquidity buffering effect" of government bonds dampens the systematic component of monetary policy, and this enhances the effect of the productivity shock as it passes through the economy. Real wages and inflation fall more, though consumption rises less. Once again, the general pattern of the responses is the same in the two models, but here the quantitative difference is not as large (generally in the order of 5% to 10%).

The more interesting story may be in the monetary aggregates. As in the NW model, the central bank responds to the shock by lowering I_g (as can be seen in the rise in the ratio of cash to bonds). Both dM and d$M2$ rise, suggesting that they will not be good indicators of inflation. However, dLIAB is consistently negative; dLIAB may be a good indicator of inflation for productivity shocks. And once again, productivity shocks explain about 75% of the variation in inflation in the BB model.

Government spending shocks. Figure 3 shows how an unanticipated increase in government spending passes through the model economies, and here the differences are dramatic. The NW model gives the conventional results. Households want to work more, and consume less, to pay the expected future taxes. However, the total aggregate demand rises, and the demand for labor is greater than the increased supply; therefore, the real wage rises, increasing the marginal cost. Inflation and output go up. The central bank raises the CCAPM rate, killing off the inflation very quickly. The rise in the CCAPM rate, along with the decline in consumption, lowers the demand for cash. dM is negative, at least initially, making it a rather poor indicator of inflation in the case of government spending shocks.

Much more is happening in the BB model. The initial increase in inflation is four times the increase in the NW model, and it is much longer lasting.[15] Why is this? First note that the R_c actually falls in the BB model, and its subsequent rise is less than that in the NW model. The central bank's interest rule is active, and the real

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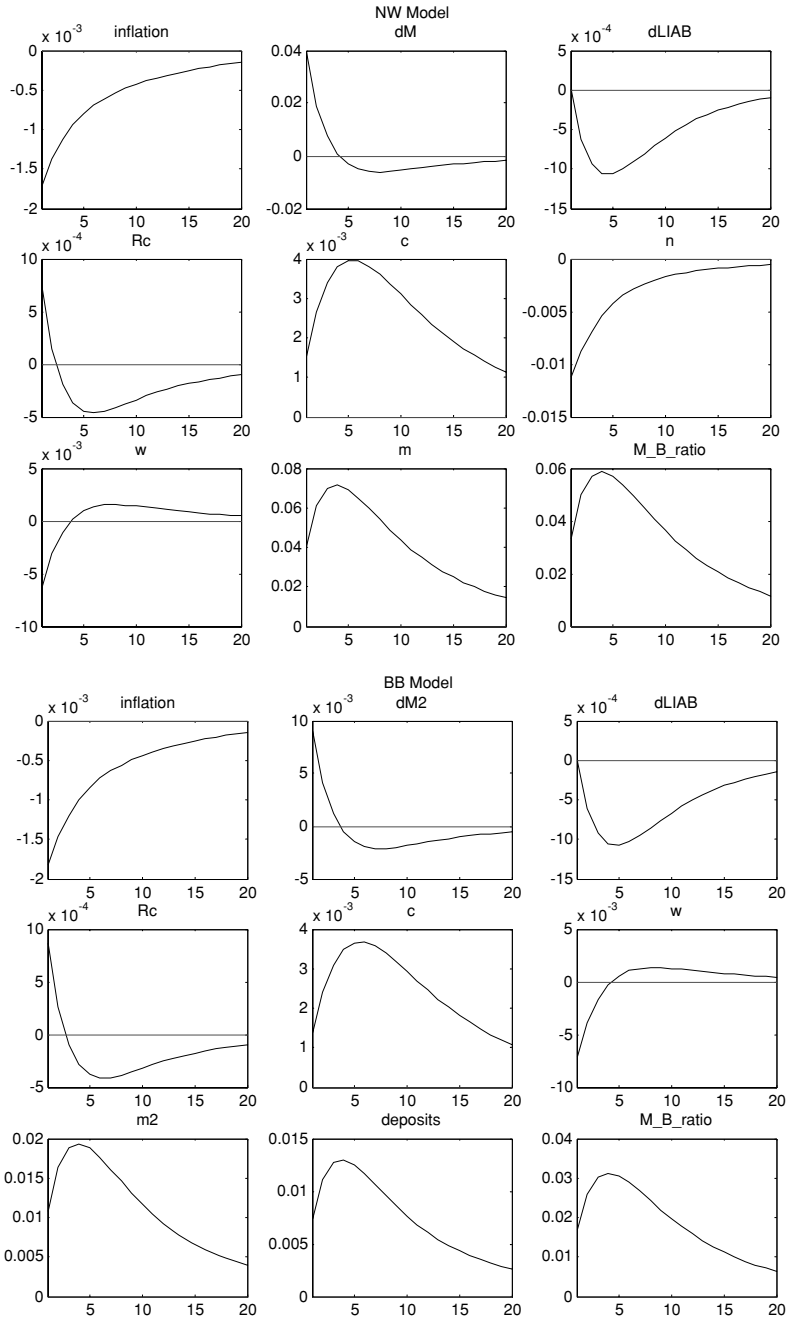15. This presumably accounts for the differences in the variance decompositions in Table 2.

FIG. 2. Productivity Shock in Manufacturing.
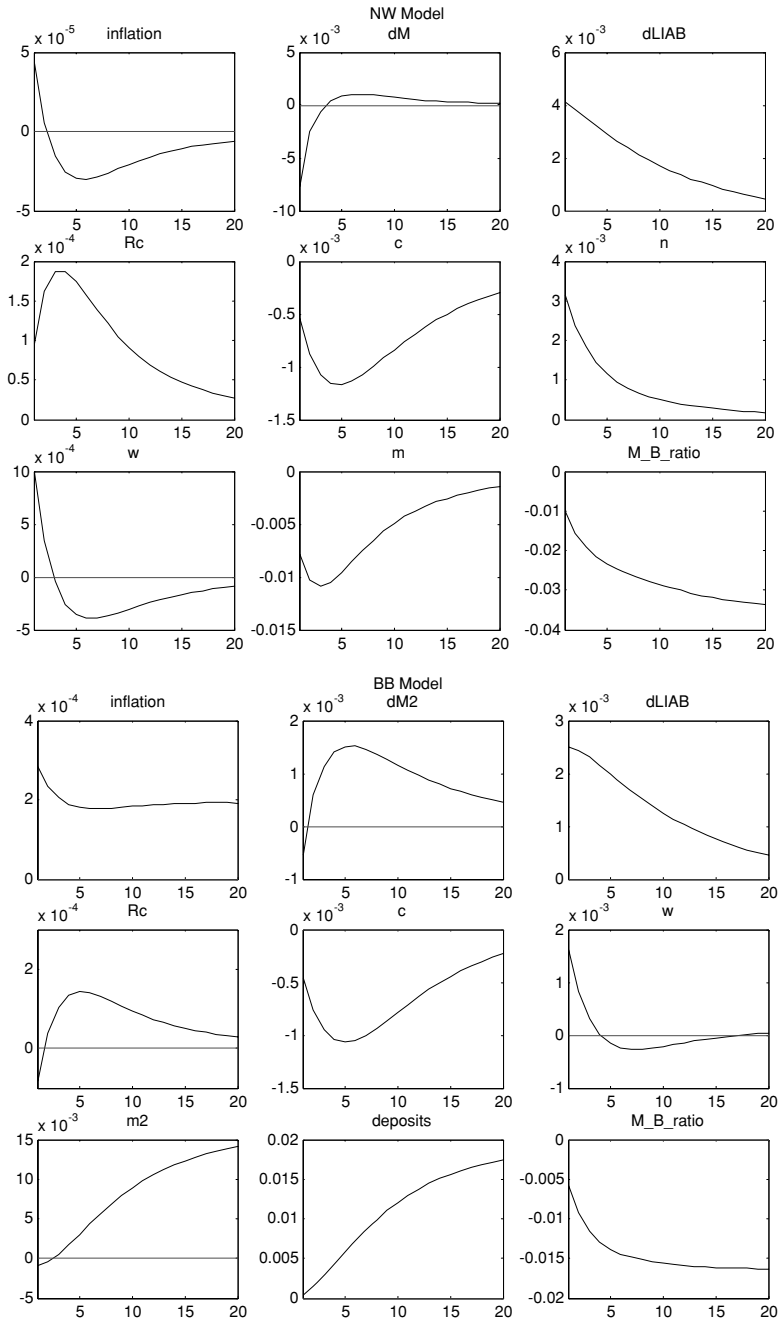
FIG. 3. Government Spending Shock.

government bond rate, R_g, rises (not pictured). However, the "buffering effect" of government bonds allows R_c to fall. The lower real CCAPM rate makes consumption fall less. More importantly, the fiscal deficits implied by the government spending shock increase total transactions balances, as can be seen by the rise in dLIAB. But this is only part of the story.

The non-Ricardian behavior of households really accounts for the differences with the NW model. The future tax liability grows at the rate R_g, but it is discounted at the higher rate R_c. So, the negative wealth effect is smaller than in the NW model, and labor supply does not increase as much. So, the real wage goes up 50% more than in the NW model, increasing marginal cost and inflation. Consumption also falls less than that in the NW model (by about 9% at the troughs).

Household demand for cash balances, m_h, goes down for the same reasons as in the NW model. But, households substitute toward deposits as well as government bonds. And deposits go up enough to make $m2$ rise; d$M2$ is positive for a sustained period. Both d$M2$ and dLIAB seem to be good indicators of inflation for government spending shocks. And government spending shocks explain almost 20% of the variation in inflation.

Money demand shocks. Figure 4 shows how an unanticipated increase money demand—a cash shock in the NW model, and an $m2$ shock in the BB model—passes through our model economies. In the NW model, the money demand equation is a decoupled equation whose only role is to determine the OMOs necessary to implement the central bank's interest rate rule. Figure 4 shows all that there is to be seen. In the BB model, an increase in the $m2$ demand is a contractionary shock that affects inflation and real economic activity. However, the effects are small: the effects on inflation and consumption are two orders of magnitude smaller than the size of the shock itself. The central bank's use of an interest rate rule insulates the real economy from financial shocks.

In summary, the "buffering effect" of government bonds is apparent in the BB model: it cushions the economy from a contractionary OMO, and it implies that the systematic part of monetary policy provides less stabilization in response to the other shocks. For interest rate shocks and productivity shocks, the impulse response functions from the two models show similar patterns, but the quantitative differences range from 5% to 20%. Moreover, money demand shocks have little effect in the BB model. Government spending shocks are a different story; they have a much larger, and a much more prolonged, impact on inflation in the BB model.

4.3 The Role of Monetary Aggregates (and Velocity) in Forecasting Inflation

Some central banks use monetary aggregates in forecasting inflation, and most central banks use some measure of the output gap. The NW model generates only one aggregate, cash balances held by households. The BB model actually generates three additional aggregates: $m2$ (m_h + deposits), liquidity ($m2 + b_h$), and government liabilities ($m + b$). If the BB model is the more complete description of the true economy, does the NW model give a misleading view of the usefulness of monetary
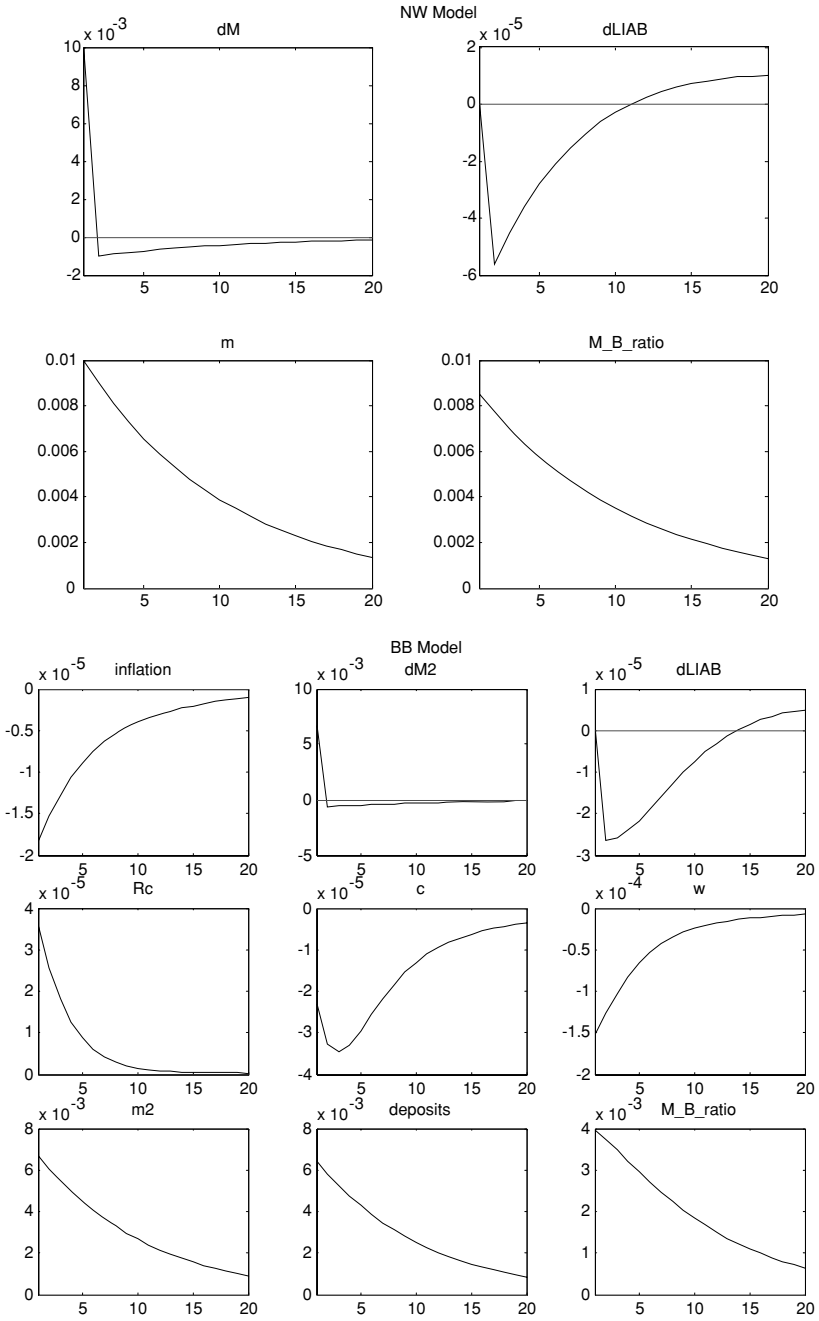
FIG. 4. Money Demand Shock.

aggregates in forecasting inflation? To answer this question, we imagine a central bank economist using data generated by one or the other of our models to estimate small unrestricted vector autoregressions (VARs). The question the staff economist asks is if any of the monetary aggregates is useful in predicting inflation.[16]

For each of our models, we generate 1,000 data sets, each consisting of 40 years of quarterly data. Then, for each data set, we estimate a series of VARs. For each monetary aggregate, we estimate a bivariate VAR with inflation and the rate of growth of the nominal aggregate in question; then, we estimate a VAR that adds either the output gap or the nominal interest rate on government bonds.[17] Finally, for each of these VARs, we generate the impulse response function for inflation to an innovation in the aggregate, and we plot the median along with a confidence interval constructed using the 33th and 67th percentiles (corresponding to 1 standard deviation).

Figures 5 and 6 illustrate the basic results for our two models. Figure 5 shows the plots for shocks to dM, d$M2$, dL, and dLIAB in the BB model. We also test the predictive power of $M2$ velocity since that variable played a prominent role in traditional monetarist discussions of inflation.[18] dM is clearly of little or no use in forecasting inflation, either in the bivariate VAR or in the VAR with the output gap added. But, the impulse response functions for d$M2$ are marginally significant, and innovations in $M2$ velocity do seem to contain information that is useful in predicting inflation. dL and (especially) dLIAB would also be useful predictors of inflation.

These financial market variables may not be particularly helpful in forecasting inflation a few quarters out, but they do seem to have predictive power in the medium run, when inflation reaches its peak. That is, they would seem to serve as a medium-run "reality check" for central banks, even when information contained in the output gap is taken into account.[19, 20]

Figure 6 shows the corresponding plots for the NW model; there is, of course, no $m2$ in that model. Neither dM nor dLIAB produces anything of interest. Similarly, base velocity is of no use in predicting inflation.

In summary, growth in nominal cash balances is not useful in forecasting inflation in either the BB model or the NW model. But d$M2$, $M2$ velocity, dL, and dLIAB do seem to have predictive power in the BB model. dLIAB is not, however, useful in the NW model. Why the difference? Not surprisingly, government spending shocks

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16. As explained in footnote 4, this appears to be consistent with the way the ECB uses monetary aggregates.

17. Here, the output gap is defined as the log of output minus its steady-state value.

18. The impulse response function for velocity was generated in the same manner as the impulse response functions for the monetary aggregates.

19. This appears to be the purpose of the ECB's Monetary Pillar. If we interpret the output gap as containing the information gleaned from the Economics Pillar, then the three variable VARs suggest that (in our model, anyway) the Monetary Pillar provides useful additional information about the course of inflation.
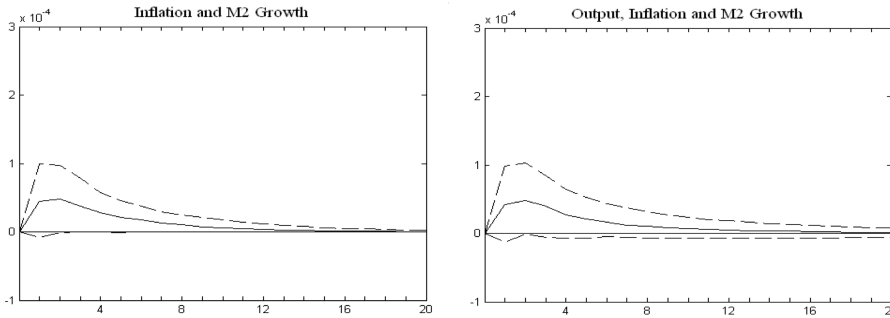
20. Plots for the VARs in inflation, the nominal interest rate, and the monetary aggregate look much like those for output, inflation, and the monetary aggregate. This is not surprising since our data are generated with an interest rate rule that responds to inflation and the output gap.

A. Shock to Growth of Monetary Base (dM)
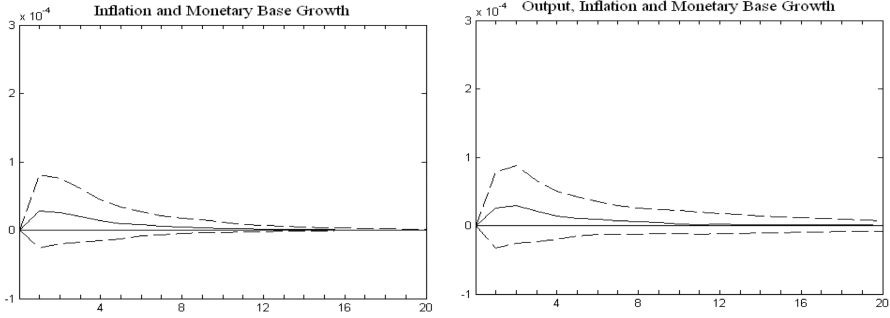
B. Shock to Growth of M2 (dM2)
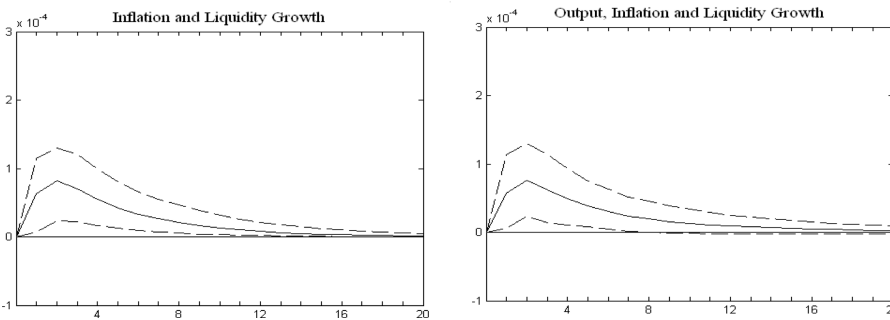

C. Shock to Growth of Liquidity (dLIQ)

Fɪɢ. 5. Response of Inflation to a Shock to Nominal Growth in Monetary Aggregates in the BB Model.

Nᴏᴛᴇs: (A) Shock to growth of monetary base (d*M*). (B) Shock to growth of *M*2 (d*M*2). (C) Shock to growth of liquidity (dLIQ). (D) Shock to growth of liabilities (dLIAB). (E) Shock to *m*2 velocity.

explain more than 75% of the variation in dLIAB in both of the models. But, for reasons that were given in Section 4.2, government spending shocks explain almost 20% of the variation in inflation in the BB model, and less than 1% in the NW model.

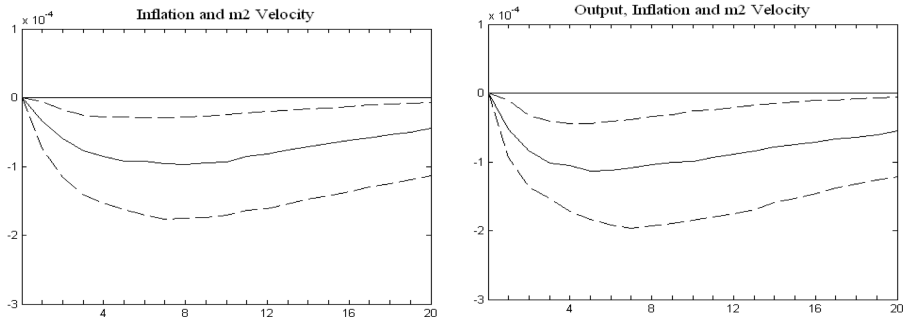D. Shock to Growth of Liabilities (dLIAB)
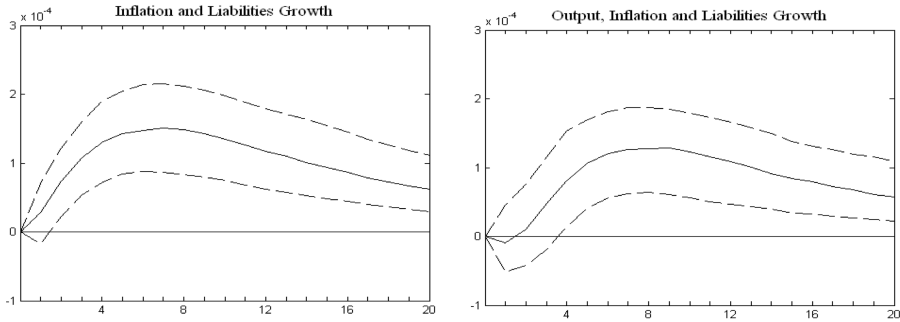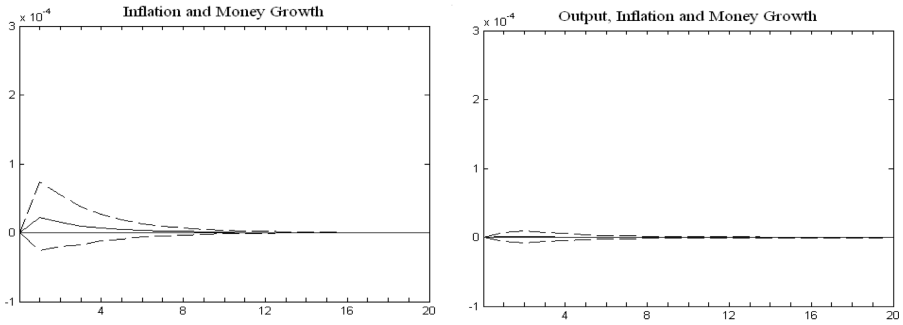

E. Shock to m2 Velocity

Fɪɢ. 5. (Continued)

In any case, the implication of these results would seem to be clear. The NW model may give a misleading view of the usefulness of monetary aggregates in predicting inflation in a more complete model.

### 4.4 Monetary Aggregates: A Reality Check for Inactive Policy Rules?

Inflation seems well in check in many countries whose central banks no longer pay much attention to monetary aggregates. Lucas (2006) worries that this recent success may "lead monetary policy analysis back to the muddled eclecticism that brought us the 1970s inflation." Estimates of the interest rate rule during the pre-Volcker period usually place θ_π at about 0.8,[21] and this weak response to inflation is thought by some to have been responsible for the high rates of inflation of the 1970s. Would paying more attention to monetary aggregates have alerted the Fed to the problem?

21. See, for example, Lubik and Schorfheide (2004).

A. Response of Inflation to Money Growth (dMh)

B. Response of Inflation to Liabilities Growth (dLIAB)
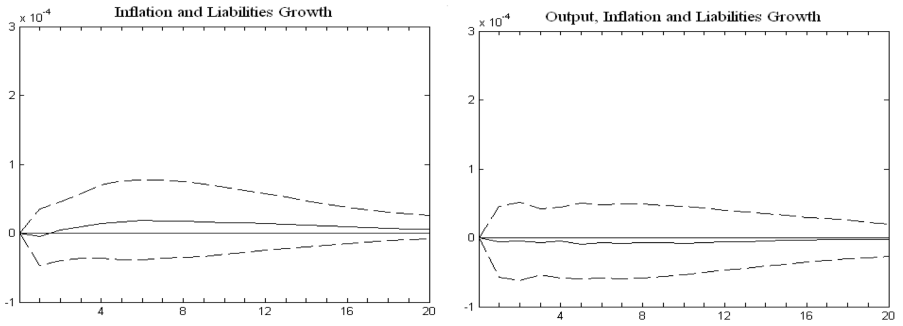
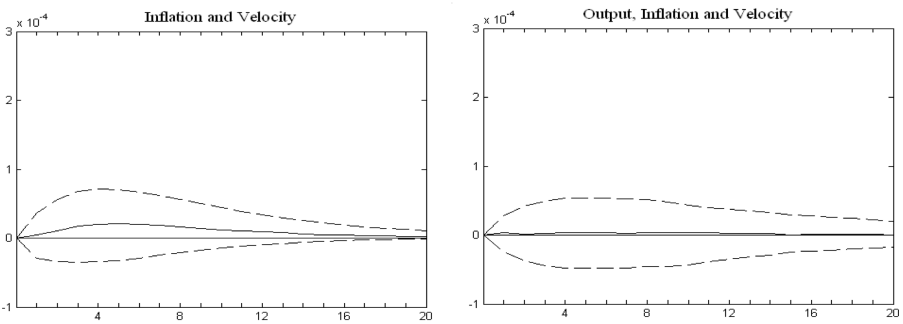C. Response of Inflation to Velocity

FIG. 6. Response of Inflation to a Shock to Growth in Monetary Aggregates in the Neo-Wicksellian Model.

NOTES: (A) Response of inflation to money growth (dMh). (B) Response of inflation to liabilities growth (dLIAB). (C) Response of inflation to velocity.
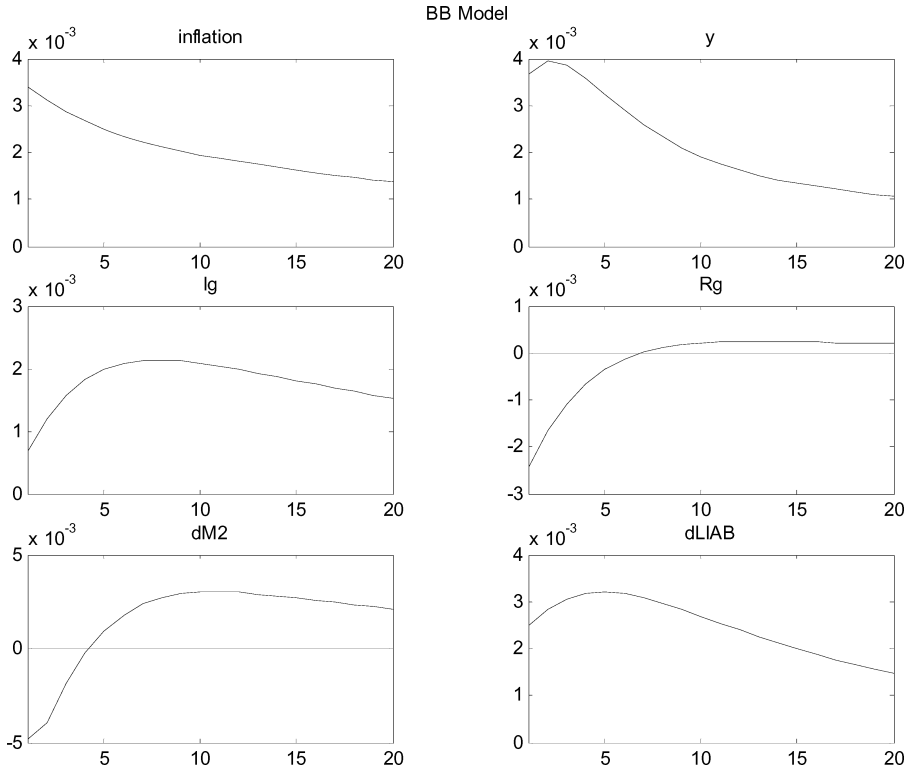
FIG. 7. Government Spending Shock: Inactive Monetary Policy ($\theta_\pi = 0.8$, $\theta_f = 0.012$).

The BB model differs from the NW model in an important way that we have not touched upon yet. Interest rate rules that violate the Taylor principle ($\theta_\pi > 1$) cause a well-known indeterminacy problem in the NW model, but not so in the BB model. Canzoneri and Diba (2005) showed that nominal indeterminacy is intimately associated with the Ricardian nature of the models that exhibit it. In the BB model, the liquidity of government bonds provides the non-Ricardian element that is needed to eliminate the problem. Elsewhere, we have analyzed the coordination of monetary and fiscal policies that is needed to eliminate the nominal indeterminacy in a model similar to our BB model.[22]

Figure 7 shows how a government spending shock passes though the BB model with an inactive monetary policy rule ($\theta_\pi = 0.8$). Inflation and output rise, and the interest rate rule calls for an increase in I_g. But the response is too weak to raise the real rate, R_g. d$M2$ falls, but dLIAB is consistently positive; it should be a useful

22. See Canzoneri, et al. (2006). Note that this is not the fiscal theory of the price level. Fiscal policy is still Ricardian in the sense of Woodford (1995) or passive in the sense of Leeper (1991).

indicator of the impending inflation. In this sense, monitoring the right aggregate would serve as a kind of reality check.

5. SUMMARY AND DIRECTIONS FOR FURTHER WORK

Our BB model adds banks and liquid government bonds to an otherwise standard NW model. In this sense, the BB model is a more complete modeling of the economy than is the NW model. The extra modeling brings a role for government bonds in household and bank liquidity management problems, financial frictions in the provision of deposits and loans, an endogenous spread between the money market rate in the central bank's interest rate rule and the rate of return in the consumption Euler equation, bank loans that may affect aggregate supply and demand, and bank deposits that can substitute for cash.

We identified two theoretically important implications of the extra modeling for monetary policy and inflation: the "liquidity provision" effect and the "liquidity buffering" effect. Both are due to the transactions services of government bonds, which is absent in the NW model. Fiscal deficits increase total liabilities $(m + b)$, and this has an effect on inflation. And the liquidity crunch created by a contractionary OMO is buffered by the liquidity of government bonds; this reduces the spread between the CCAPM rate in the consumption Euler equation and the money market rate in the central bank's interest rate rule. Interest rate surprises have less effect on inflation. And more importantly, the elastic interest rate spread makes the systematic component of monetary policy respond less aggressively to inflation; therefore, all shocks pass though the economy with less monetary stabilization.

The NW model provides a less complete modeling of the economy. But it has the virtue of simplicity, and some have suggested that it gives an adequate account of macroeconomic behavior for the business cycle analyst and the monetary policy analyst alike. To investigate this possibility, we calibrated the models to see if the theoretical differences between the BB and NW models were quantitatively significant. We found that the liquidity buffering effect is readily apparent, and that it makes a difference in the way interest rate shocks and productivity shocks pass through the economy. These differences range from about 5% to 20%, depending on the shock and the impulse response function in question. The liquidity provision effect (and the associated non-Ricardian behavior of consumers) makes a big difference with respect to fiscal shocks. Impulse response functions show that a bond-financed increase in government spending has a much bigger effect on inflation in the BB model, and the effect is much more persistent, than in the NW model.

We also found that monetary indicators—$M2$ velocity and the growth rates of $M2$, L, and public sector liabilities—are useful in forecasting inflation in the BB model; however, household cash balances are not. The two monetary aggregates in the NW model—household cash balances and public sector liabilities—are not useful in forecasting inflation in that model. So, the NW model seems to give a misleading view about the usefulness of monetary aggregates (and $M2$ velocity) in a more complete model.

We have not studied how central banks should use monetary aggregates in their policy process. However, one point should be made clear: our work does not support strict targeting of, say, $M2$ growth. The standard deviation of inflation in the BB model is 0.004 (per quarter) under our benchmark interest rate rule; if we replace the benchmark policy with a rule that leans against fluctuations in d$M2$, and does so strongly enough to virtually eliminate them, then the standard deviation of inflation rises to 0.017. The market for money does "matter" in the BB model. Figure 3 shows that an increase in $m2$ demand raises the real CCAPM rate, lowers consumption demand, and decreases inflation; however, these effects are very small. Moreover, the variance decompositions in Table 2 show that 95% of the variation in inflation is explained by the shocks to productivity and government spending. Innovations in d$M2$ predict inflation because they contain information about these underlying shocks, and not because money growth is the driving force in inflation.

Woodford (2006) addresses a number of theoretical concerns that have been raised about the NW models.[23] Our BB model offers an interesting new perspective on some of the issues involved. First, Woodford argues that the central bank's interest rate policy pins down the steady-state rate of inflation without any need to set a long-run target for money growth. Essentially, the intercept term in the interest rate rule specifies the steady-state CCAPM rate, and then the Fisher equation gives the inflation rate. There is no need to set a long-run target for money growth in the BB model either, but there is a spread between the steady-state CCAPM rate and the money market rate in the central bank's interest rate rule. And as shown in Section 2, that spread is endogenous and depends upon the fiscal target for the ratio of government bonds to GDP (among other things). This suggests that some coordination of monetary and fiscal policy is needed to control inflation in the long run.

Second, Woodford (2006) invokes historical conditions to pin down the initial price level in the NW models. There is no need to do this in the BB model: it determines the price level at each point in time. As Canzoneri and Diba (2005) show, price level determinacy is a generic implication of the government's flow budget constraint in any model that determines real bond balances; real bond balances are determined in the BB model because they provide transactions services and the Ricardian equivalence does not hold.

We view the present modeling as very much a work in progress. So far, we have focused mostly on the liabilities side of the banks' balance sheet. And even here there is much to be done. We have, for example, just postulated a unitary elasticity of substitution between the assets in what we have called effective transactions balances. These elasticities could be estimated, and different elasticities may affect the results we have reported.

In this paper, we have interpreted the quantitative differences in our models as having come form the "liquidity provision" effect or the "liquidity buffering" effect; this seemed natural since the differences appear to be consistent with those interpretations.

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23. Woodford (2006) discusses the related implications of the NW model, mainly in response to the criticisms of Alvarez, Lucas, and Weber (2001) and Nelson (2003).

However, the BB model also has financial frictions and a bank loans mechanism that are absent in the NW model. And these factors probably deserve more attention. In our benchmark model, households refinance their loan for a fixed durable (which we have likened to a house) in each period, and the fluctuating loan rates do not affect household behavior. We also tried making the firms borrow from the bank to meet their wage bill. But the impulse response functions looked virtually the same as those for the benchmark model.

It may, of course, be that the financial frictions of creating bank loans and deposits are not very costly, and that this extra modeling is not necessary for most macroeconomic applications. We think, however, that it is much too soon to be reaching such a conclusion. For example, bank loans could fund entrepreneurs, as in the financial accelerator literature discussed by Bernanke, Gertler, and Gilchrist (1999).

Those who are more interested in the implications for monetary policy will probably want to model features that bring more persistence to the inflation process. This would make a clearer distinction between short-run and the medium-run inflation dynamics. Those who advocate the use of monetary aggregates in forecasting inflation generally admit that their value is limited in the short run; they would argue, however, that monetary aggregates can provide a medium-run reality check. For example, Fischer et al. (2006) describe the ECB's policy process as drawing upon both "economic analysis" and "monetary analysis," saying: "The former attempts to identify the economic shocks driving the business cycle and thus embodies a thorough assessment of the cyclical dynamics of inflation. The latter analyses the monetary trends associated with price developments over the medium to longer term." Issing (2006) claims that 2–3 years is the horizon "that is typically considered relevant for monetary policy decisions, given the lags in monetary-policy transmission," and this is consistent with empirical analysis. The impulse response function for the interest rate shock in Section 4 peaks too soon. Moreover, our analysis suggests that it is the broader measures of liquidity—L and total government liabilities—that are the more reliable indicators of medium-term inflation. This is a controversial result that probably deserves more scrutiny.

This leads us to our final caveat. The current calibration of the NW and BB models has produced interesting comparisons of how the two models work. But, in addition to adding new structural features, future research should focus on estimation or making the BB model more coherent with the data.

LITERATURE CITED

Alvarez, Fernando, Robert E. Lucas Jr., and Warren Weber. (2001) "Interest Rates and Inflation." *American Economic Review,* 91, 219–25.

Bernanke, Ben, Mark Gertler, and Simon Gilchrist. (1999) "The Financial Accelerator in a Quantitative Business Cycle Framework." In *Handbook of Macroeconomics*, edited by John Taylor and Michael Woodford. North-Holland: Elsevier Science.

Canzoneri, Matthew, Robert Cumby, and Behzad Diba. (Forthcoming) "The Cost of Nominal Rigidity in NNS Models." *Journal of Money, Credit and Banking.*

Canzoneri, Matthew, Robert Cumby, Behzad Diba, and David Lopez-Salido. (2006) "Monetary and Fiscal Policy Coordination When Bonds Provide Transactions Services." Mimeo, Georgetown University and Northwestern University.

Canzoneri, Matthew, and Behzad Diba. (2005) "Interest Rate Rules and Price Determinacy: The Role of Transactions Services of Bonds." *Journal of Monetary Economics*, 52, 329–43.

Christiano, Lawrence, Martin Eichenbaum, and Charles Evans. (2005) "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy*, 13, 1–45.

Christiano, Lawrence, Cosmin Ilut, Roberto Motto, and Massimo Rostagno. (2007) "Monetary Policy and Stock Market Boom-Bust Cycles." Mimeo.

Fischer, B., M. Lenza, H. Pill, and L. Reichlin. (2006) "Money and Monetary Policy: The ECB Experience 1999–2006." An ECB staff paper prepared for the 4th ECB Central Banking Conference, The Role of Money and Monetary Policy in the Twenty First Century, November, 2006.

Goodfriend, Marvin, and Bennett McCallum. (2006) "Banking and Interest Rates in Monetary Policy Analysis: A Quantitative Exploration." Paper prepared for the Carnegie-Rochester Conference Series, 54(5): 1480–1507.

Issing, Otmar. (2006) "Comments." Speech at the ECB Watchers Conference, Frankfurt, May 5.

Leeper, Eric. (1991). "Equilibria under Active and Passive Monetary and Fiscal Policies." *Journal of Monetary Economics*, 29, 129–47.

Lubik, Thomas, and Frank Schorfheide. (2004) "Testing for Indeterminacy: An Application to U.S. Monetary Policy." *American Economic Review*, 94, 190–216.

Lucas, Robert. (2006) "Panel Discussion: Colloquium on Honor of Otmar Issing." Remarks presented at an ECB Colloquium, Frankfurt, March.

Nelson, Edward. (2003) "The Future of Monetary Aggregates in Monetary Policy Analysis." *Journal of Monetary Economics*, 50, 1029–59.

Woodford, Michael. (1995) "Price Level Determinacy without Control of a Monetary Aggregate." *Carnegie Rochester Conference Series on Public Policy*, 43, 1–46.

Woodford, Michael. (2003) *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton, NJ: Princeton University Press.

Woodford, Michael. (2006) "How Important Is Money in the Conduct of Monetary Policy." Mimeo, Columbia University.