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Banks, Bonds, and the Liquidity Effect*

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1. Introduction

The nature of banking has changed significantly in recent years. Deregulation, financial innovation, and advances in information technology have brought sweeping changes to the financial markets generally and have significantly altered the niche once filled by depository institutions. Among the important roles that banks have traditionally played in the economy is to provide short-term funding to the business sector for its working capital expenses. Competition for this business has come from nonbank financial institutions, such as finance companies and from an expanding commercial paper market. However, while the volume of commercial and industrial loans in U.S. commercial banks relative to GDP experienced a steep decline in the early 1990s as shown in Figure 1, it has since recovered to equal roughly the long-run average recorded over the 1973.Q1-2001.Q1 period.[1] Therefore, commercial banks remain an important player in this market.[2] Given this fact, and the relative importance of short-term working capital finance over the business cycle, many researchers have been examining how significant this market may be in the transmission of monetary policy decisions to the economy.

Exactly how changes in monetary policy are transmitted to the rest of the economy is not well understood. It is generally believed that when the Federal Reserve chooses to "ease" its stance on monetary policy, it supports this decision by accelerating its purchases of bonds in the open market and when these transactions clear, reserves in the banking system have risen. To the extent that these reserves are turned over into loans, the supply of bank credit in the economy expands and interest rates decline. In recent years, the Federal Reserve has chosen how much to expand bank reserves in order to achieve a certain target level for the federal funds rate. The federal funds rate is the interest rate that clears the market for bank reserves where the marginal borrowing bank in need of bank reserves,

[1] There has been substantial growth recently in the commercial and industrial lending by foreign bank affiliates operating in the United States, which accounts for the difference between the domestically chartered banks vesus all commercial banks depicted in Figure 1. For a discussion of this issue, see McCauley and Seth (1992).

[2] Increasingly, banks are securitizing their loan portfolios and taking those loans off balance sheet. However, commercial and industrial loans are "information-intensive" and are thus not particularly good candidates for securitization. See Kwan (2001).

perhaps to meet its reserve requirements, is brought together with the marginal lending bank that has excess reserves to lend. These bank reserves are therefore fully contained within the banking system and the Federal Reserve can affect the equilibrium interest rate in this strictly interbank lending market by exercising control over the supply of bank reserves.

This article first surveys some of the recent research on one channel by which monetary policy is transmitted to the economy in which banks play a central role owing to the fact that they represent a principal source of short-term financing of the current operations of businesses. This research hinges to some extent on empirical evidence that is reproduced in Section 2, which suggests that in response to an unexpected increase in (nonborrowed) bank reserves, the federal funds rate declines and this is followed by an increase in output and employment.[3] With a considerable lag, the federal funds rate then rises back to its original equilibrium level, and the stimulus effect on the economy ceases. However, had this accelerated rate of reserves growth continued, the federal funds rate would have eventually risen above its original equilibrium level. The theoretical rationale for the higher long-run interest rate response is that faster growth in bank reserves ultimately leads to faster growth in the money supply and hence to higher inflation. The markets observe this faster growth rate in bank reserves, expect higher inflation, and factor an inflation premium into nominal interest rates. If this expectation were realized immediately into pricing assets, then interest rates would not fall in response to an "easier" monetary policy, as the data suggest, but would instead rise to their long-run equilibrium level. It is therefore necessary to identify frictions in the economy that preclude this long-run adjustment from taking place quickly. There are in fact two puzzles here: What causes nominal interest rates initially to fall rather than to rise in response to an unexpected injection of reserves into the banking system by the Federal Reserve? What causes this effect to be so persistent?

A principal focus of the theoretical research that seeks explanations for these phenomena is the role played by the "precommitment" of bank deposits (and other liquid

[3] Christiano and Eichenbaum (1999) discuss the identification of "monetary policy shocks" as coincident unanticipated changes in nonborrowed reserves and the federal funds rate that are negatively correlated with each other.

assets) by households, whereby deposit levels are not quickly adjusted in response to the unexpected injection of reserves into the banking system. This precommitment can be conceptualized (and modeled) as an "information friction" under which households do not take into account this unexpected increase in bank reserves when choosing their deposit positions. A lack of response in bank deposits can cause excess reserves, or reserves that banks hold over-and-above those required by regulation, to exceed desired levels. Given that reserves are non-interest-bearing assets, banks would like to turn over the surplus reserves into loans. To entice borrowers, the bank loan rate may have to fall, thus inducing the "liquidity effect." However, this liquidity effect may vanish as soon as the household adjusts its deposits to reflect the central bank's actions, that is, once the information friction is removed.

One limitation of the models used in much of this literature is the absence of a corporate bond market that can allow direct lending to take place between households and firms. In the absence of this market, all household lending to firms is required to be intermediated through the banking system, and the only interest-bearing asset available to households is bank deposits. One purpose of this article is to illustrate how the presence of a corporate bond market can increase the magnitude of and induce significant persistence in the liquidity effect that results from a minimalist view of the information friction desribed above. In effect, as the economy picks up, households respond to their higher income by increasing their savings in the form of bond holdings in order to smooth over time the greater implied future consumption. This greater demand for bonds further lowers market interest rates, thus enhancing the liquidity effect, and given that this increase in bond demand dissipates slowly, it keeps interest rates low over time, thus producing significant persistence in the liquidity effect.

An overview of the theoretical literature related to the liquidity effect is provided in Section 3. A theoretical model is developed in Section 4 that can be used to examine how the information friction and the availability of a corporate bond market to households for saving and to firms for borrowing can offer one explanation for the puzzles of the persistent liquidity effect as described above. Conclusions are contained in Section 5.

2. Empirical Evidence of a Persistent Liquidity Effect

This section presents empirical results on the relationship between Federal Reserve policy variables and macroeconomic data. It utilizes the models of Christiano, Eichenbaum, and Evans (1996) and Evans and Marshall (1998) and draws on the work of Christiano (1991) and Sims (1992). The models rely on vectorautoregressions (VARs) which contain two policy variables, and a vector of "information variables" that the Federal Reserve is assumed to monitor in its policy deliberations.

The policy variables are the federal funds rate and an empirical measure that is intended to capture the extent to which bank reserves are actively managed by the Federal Reserve through its open market operations. To construct the latter measure, it is noted that total reserves in the banking system are comprised of "borrowed reserves," or the amount of bank reserves borrowed directly from the Federal Reserve at the discount window, which historically has accounted for less than 4 percent of the total, and in the past several years has declined to less than one percent, and "nonborrowed reserves," which constitutes the remainder. It is presumed, as in Chari, Christiano, and Eichenbaum (1995) that the Federal Reserve passively administers the discount window to supply reserves on demand, while it actively manages the quantity of nonborrowed reserves in order to attain its monetary policy objectives. Those objectives take the form of inflation and output (or employment) goals. Since monetary policy influences those goal variables with long and variable lags, the Federal Reserve attempts to achieve its goals by setting an intermediate target for one but not both of its policy variables. That is, either it can choose to set the rate of growth of (nonborrowed) reserves and allow the federal funds rate to clear the market for bank reserves in response to fluctuations in demand, or it can choose a federal funds rate that it would like to clear the market and supply reserves through its open market operations in order to ensure that the market clears at that target rate, thus accommodating fluctuations in demand.

In constructing an empirical measure of bank reserves that reflects active monetary policy, the passive supply response of borrowed reserves must be taken into account. In addition, the Federal Reserve has also had to accommodate secular changes in reserves demand resulting from an important change in the structure of the federal funds market with the introduction of "sweep accounts" at commercial banks, under which checking account balances in excess of a maximum set by the bank are automatically swept into savings accounts. From the standpoint of depositors, checking accounts pay low interest but have a high liquidity value as they can be used directly as media of exchange for many purchases. Savings accounts are less liquid, that is, they cannot be used to effect transactions, but pay a higher rate of interest. From the bank's perspective, checking accounts are more costly to service, due to the cost of check-clearing, and unlike savings accounts, require banks to maintain bank reserves in the form of vault cash or deposits that the banks hold with the Federal Reserve, neither of which is an interest-earning asset for the bank. Sweep accounts therefore represent a product that is valuable to depositors, who are able to increase their interest income on bank deposits without actively managing their bank accounts, and are valuable to the banks, since they allow banks to avoid the "reserve tax" on a larger share of their bank deposits. Since their introduction in the mid-1990s, sweep accounts have had a dramatic effect on the demand for bank reserves, as is shown in Figure 2.

To account for the changes in total bank reserves that are unrelated to monetary policy, a measure of bank reserves that reflects active monetary policy could be based on the ratio of nonborrowed reserves to total reserves (as, e.g., in Evans and Marshall 1998), where an unexpected increase in this ratio would be associated with an "easing" of monetary policy, and a decline would be associated with a "tightening" of monetary policy. Using unexpected changes in this ratio to identify the policy shocks is consistent with the suggestion of Strongin (1995), who noted that the insensitivity exhibited by the federal funds rate to shocks to total reserves is evidence of an endogenous supply response of borrowed reserves. Therefore, under this construct, a monetary policy shock initially changes only the composition of total reserves between nonborrowed reserves and borrowed reserves.[4] This identification of policy shocks from the data also captures the need of the

[4] Strongin argues that total reserves are relatively unresponsive to policy changes in the very short run, and that balance sheet adjustments made by banks to policy shocks occur only with a significant lag. He provides empirical evidence in support of this argument by

Federal Reserve to adapt to the falling demand for bank reserves as sweep accounts spread nationwide across the banking system.

The information variables that are included in the empirical model are the current and past history of the goals variables, that is, measures of inflation and output (or employment), and an index of sensitive commodity prices. The last of these is intended to capture market expectations of future inflation, and given that commodity prices are determined in auction markets, it should be informationally efficient.[5]

Quarterly and monthly estimates of the model over the period January, 1960 through March, 2001 are reported below to indicate the robustness of the results with respect to sampling frequency. The "goal variables" of GDP and the GDP implicit price deflator (denoted PGDP) that are used in the quarterly model are not available at the monthly frequency; industrial production (IP) and the personal consumption deflator (PCE) are substituted in the monthly model. The remaining variables include an index of sensitive commodity prices (PCOM), and the two policy variables, taken to be the federal funds rate (RFF) and the ratio of nonborrowed reserves to total reserves (RES).[6] The ordering of the variables in the VAR can affect the results if there is a strong contemporaneous correlation between variables, implying that they carry similar statistical information. When two variables are highly correlated, the variable entered first in the VAR will tend to exhibit greater "explanatory power." In this model, the two policy variables are highly correlated. Therefore, the results are reported for two orderings. The first is: GDP(IP), PGDP(PCE),

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including total reserve in the VAR described below and demonstrating that the "liquidity effect" identified below is essentially unchanged quantitatively.

[5] Eichenbaum (1992) and Sims (1992) have discussed a so-called "price puzzle" in which goods prices appear to rise in response to a tightening of monetary policy. Sims has suggested that this response could simply be a reflection of the fact that it was price pressure that induced the Federal Reserve to tighten its policy in the first place. Hence, the information of higher future goods price inflation should already be imbedded in commodity prices, which the policymakers can easily monitor. As shown by Sims (1992) and others, including this index of commodity prices resolves the price puzzle. See Barth and Ramey (1997) for an alternative explanation of the price puzzle based on a "cost channel" for monetary policy.

[6] The data are all entered into the VAR in logarithms except for RFF, which is in percent. Four lags are included in the quarterly model and twelve lags in the monthly model.

PCOM, RFF, RES. Qualitatively similar results obtain under the second ordering where RFF and RES are reversed. However, the "liquidity effect," or the decline in RFF in response to a positive shock to RES is more pronounced in the latter case.[7]

The empirical questions are: How do the macroeconomic variables respond to an unexpected policy change? Is there evidence of a persistent "liquidity effect" as described in the introduction, on which rests a meaningful role for banks to play in the transmission of monetary policy?

Figure 3 displays the results of shocking the models with an unexpected "easing" of monetary policy in terms of the dynamic response of each of the five variables in the model. Rows 1 and 2 correspond to the quarterly model, where the responses to a one standard deviation shock to RES (row 1) and to a one standard deviation *negative* shock to RFF (a *cut* in the federal funds rate) (row 2) are displayed for 16 quarters. Similar responses from the monthly model are displayed in row 3 for an RES shock and row 4 for an RFF shock, with responses to these shocks given for the subsequent 48 months. The ordering of the policy variables in the VARs are RES first and RFF second in rows 1 and 3, and vice versa in rows 2 and 4. The first column indicates a positive output (GDP or IP) response to an easing of monetary policy that begins after approximately one quarter. The second column implies a more sluggish adjustment of prices (PGDP and PCE) that sets in after a lag of approximately one year. The third column indicates that commodity prices (PCOM) also rise with the anticipated increase in future inflation. These responses are consistent with the general view that an "easing" of monetary policy due to a cut in the federal funds rate or an expansion of bank reserves stimulates output with a lag and subsequently leads to higher prices.

The last two columns in Figure 3 offer empirical evidence of the "liquidity effect." As seen in column five of rows 1 and 3, an unexpected expansion of nonborrowed reserves (incresase in RES) lowers the federal funds rate (decline in RFF). Using the ordering of RFF preceding RES, similar results are in evidence in rows 2 and 4, where an unexpected cut in the federal funds rate (a lower RFF) induces an expansion of bank reserves (rise

[7] Christiano, Eichenbaum, and Evans (1998) attach significance to the ordering of RFF and RES by suggesting that the "instrument" of policy should appear first in the VAR.

in RES). These latter results are very robust to sample periods, and they are consistent with theoretical models that emphasize the role played by the banking system in the transmission of monetary policy decisions to the real economy.[8]

3. Review of the Literature on the Liquidity Effect

The early theoretical work of Lucas (1990) and Fuerst (1992) identified a possible source of the liquidity effect as a form of market incompleteness in which financial market participants could not fully insure against monetary policy shocks, such that asset portfolios were not immediately adjusted in response to an unanticipated change in monetary policy. Versions of this form of market incompleteness have come to be characterized as "limited participation" in some financial market(s) by economic agents. As a consequence of this limited pariticipation, an easing of monetary policy corresponds to an unanticipated increase in liquidity in the financial markets, and without a full response on the demand side of those markets, interest rates would have to fall to absorb the additional supply. Fuerst focused the lack of a demand response on the part of households who would precommit to a liquid asset position that included their holdings of bank deposits. When the central bank injected additional reserves into the banking system, and with no change in bank deposits, the banks would hold non-interest earning excess reserves that they would wish to lend out. Given the importance to firms of commercial lending by banks over the business cycle, Fuerst conceived a model under which those excess funds were turned over into working capital loans to firms. In his model, there was no direct lending from households to firms. He illustrated the feasibility of how this slow, liquid asset portfolio adjustment of households to unexpected changes in monetary policy could thus lead to a liquidity effect, or a lowering of market interest rates in response to an easing of monetary policy characterized by an injection of reserves into the banking system.

Using simulations from theoretical models that were calibrated to fit U.S. macroeconomic data, Christiano (1991), Christiano and Eichenbaum (1995), Chari, Christiano, and

[8] For an "easing" of monetary policy to have an expansionary effect on the real economy, interest rates that directly affect firm borrowing must also exhibit a "liquidity effect." Replacing RFF with the 90-day commercial paper rate yields results similar to those displayed in Figure 3.

Eichenbaum (1995), Christiano, Eichenbaum, and Evans (1997), Edge (2001), and Einarsson and Marquis (2001a) have examined conditions under which the theoretical possibility of a liquidity effect as described by Fuerst is supported by the data. Christiano (1991) concluded that a precommitment of households to a liquid asset position prior to the reserves shock as in Fuerst was insufficient to induce a dominant liquidity effect, i.e., where the tendency of interest rates to fall in response to the reserves injection is stronger than the tendency of interest rates to rise due to the anticipation of higher future inflation. However, a dominant liquidity effect does result if firms also precommit to their investment decisions prior to the reserves injection. Even then, the liquidity effect does not exhibit the degree of persistence that is evident in the data. One way to obtain this additional persistence is to impose costs on households for adjusting their portfolios quickly as in Christiano and Eichenbaum (1995) and Chari, et al. (1995).[9]

Much of the theoretical literature on monetary policy that does not give banks any significant role in the transmission of monetary policy, but instead relies on an *ad hoc* formulation of "sticky" or slowly-adjusting goods prices. Christiano, et al. (1997) demonstrate that in the absence of incomplete markets as described above, the liquidity effect is incompatible with sticky prices. However, Edge (2001) shows that two features of the model economy that have been used in other macrotheoretic contexts can render a liquidity effect consistent with sticky prices. One feature is that the investment decision of firms involves "time-to-plan" and "time-to-build" before new capital is put into place, and that once the decision is made it is costly to change. The second feature is to modify household preferences to include "habit persistence," which characterizes the value that households place on consumption today not in terms of the level of consumption today, but rather in terms of how today's consumption compares with the average level of consumption attained in the recent past.

Einarsson and Marquis (2001a,b) add a bond market to the model, which allows firms to have an alternative to banks for their working capital financing needs. They find

[9] Alvarez, Lucas, and Weber (2001) model the market incompleteness described above while abstracting from a financial intermediary, and illustrate conditions under which this can lead to a liquidity effect. They simply assume that only a fraction of the households have access to a bond market and the remainder do not.

that in the presence of the bond market, the precommitment by households to their bank deposit position prior to the reserves injection induces a persistent liquidity effect. This persistence requires an overshooting of goods prices from their long-run equilibrium level. They also find that the model predicts a countercyclical role in the degree to which firms rely on banks versus alternative sources of financing, and find empirical support for this prediction. The logic of these latter findings, as well as depiction of models with deposit precommitment are described in a simplified version of the Einarsson and Marquis models in the following section.

4. A Theoretical Model of a Persistent Liquidity Effect.

This theoretical model conceives of four major participants in the economy that are each represented by a single decisionmaker: households, firms, banks, and the monetary authority, and it structures time by a sequence of uniform, discrete intervals called "periods" over which decisions are made and markets clear. Those periods should be thought of as one quarter in duration. Households own the firms and the banks, and they also hold a portfolio of financial assets that include money, bank deposits, and bonds. Each period, they receive lump-sum dividend payments from firms and banks, and receive interest income on bank deposits and bonds. Money and bank deposits are used for transactions in which households purchase consumption goods. Households also provide labor services to firms for which they receive labor income. Firms borrow from households and banks to finance their wage bill, and use revenues from sales to finance their capital investment and to retire their debt. Banks take in deposits from households, set aside a sufficient amount of reserves to meet their reserve requirements, and loan out the remainder to firms. The monetary authority supplies bank reserves and currency to the economy. The details of how the important economic decisions of each sector are modeled and how those decisions come together to form a general equilibrium for the economy are described below.

4.1 The household sector.

The overall objective of the representative household is to maximize the expected present value of a stream of utilities, where each period the household derives positive utility from consumption and from leisure. This objective is expressed mathematically as:

$$\max E \sum_{t=0}^{\infty} \beta^t U(C_t, L_t), \quad \beta \in (0,1) \tag{1}$$

where $U(C_t, L_t)$ is the period utility function that quantifies the level of utility the household receives in period t given that its consumption is C_t and its leisure time is L_t. The symbol β is the discount factor that establishes how impatient the household is by determining the extent to which it discounts utility that it expects to receive in future periods. A high value of β, i.e., close to one, implies that the household values future expected consumption highly and hence attaches to it a low rate of discount. The symbol E is the mathematical expectations operator, which is required since the future is uncertain. The information that the household has available when making its various decisions must be fully specified and is not necessarily the same for all decisions.

The household has three fundamental sets of decisions to make: consumption-savings, labor-leisure, and portfolio allocation. In the first, it must decide how much of its wealth to consume today and how much to carry forward tomorrow. The more that is consumed today, the less is available for future consumption. Therefore, this decision by the household is intertemporal in nature. Given the amount of savings that the household chooses, it must decide in what form it wishes to carry this wealth forward. In this model, the household must make a portfolio allocation decision among the three financial assets of money, bank deposits, and bonds. Finally, the household must decide how much of its time to devote to labor in order to raise its labor income, at the cost of foregone leisure today.

In making these decisions, the household faces constraints. One is its budget constraint. It cannot allocate more wealth to consumption and savings than it possesses.[10] Mathematically, the budget constraint is given below with "sources" of wealth on the right-hand side and "uses" on the left-hand side.

$$P_t C_t + M_{t+1} + D_{t+1} + B_{t+1} \leq W_t N_t + (1 + r_t^d) D_t + (1 + r_t^b) B_t + M_t + \Pi_t^f + \Pi_t^b \tag{2}$$

[10] There is no borrowing by the representative household, reflecting the fact that collectively households are net suppliers of credit to the economy.

The sources consist of: labor income, or the wage rate, W_t, times the amount of labor supplied, N_t; the gross return on deposits, $(1+r_t^d)D_t$, where D_t is the quantity of deposits that the household chose last period, and r_t^d is the deposit rate; the gross return on corporate bonds, $(1+r_t^b)B_t$, where B_t is the stock of one-period bonds that the household purchased last period, and r_t^b is the bond rate; the quantity of money that the household carried over from last period, M_t; and the dividend payments that it receives from its ownership in the firms, Π_t^f, and the banks, Π_t^b. The uses are for consumption purchases, or the product of the unit price of output goods, P_t, times the quantity of consumption goods purchased, C_t; and the quantities of money, M_{t+1}, deposits, D_{t+1}, and bonds, B_{t+1} to carry over to next period, when these decisions are revisited.

A second constraint that the household faces is in its use of financial assets in conducting transactions. It is assumed that the economy's payment system restricts the household to set aside quantities of liquid assets, i.e., money and deposits, in sufficient amounts to meet its desired level of purchases of consumption goods. Assuming that money and deposits are imperfect substitutes as media of exchange, this constraint is respresented mathematically by:

$$P_t C_t \leq G(M_t, D_t) \tag{3}$$

The right-hand side is an increasing function in M_t and D_t that characterizes the amount of nominal consumption expenditures that can be supported during the period by the household's liquid asset holdings at the beginning of the period.

Finally, the household is limited in the amount of time that it has available each period, denoted T, which the sum of its labor supply and leisure cannot exceed.

$$N_t + L_t \leq T \tag{4}$$

4.2 The firm sector.

Firms are assumed to maximize the value of their enterprise. This is equivalent to maximizing the expected present value of the current and future dividends that they pay out to shareholders. It is assumed here that dividends are paid out each period and equate to a firm's net cash flows, which has been denoted Π_t^f. Mathematically, this objective can be represented as:

$$\max E \sum_{t=0}^{\infty} \beta^t \beta_t^* \Pi_t^f \tag{5}$$

Assuming that the firm is acting in the interest of the shareholders, the symbol β_t^* represents the value that the household places at date t on receiving a dollar in dividend payments at date t.[11]

The firm hires labor from households and pays its wage bill by selling bonds to households and by borrowing from the banks. The maturity of these debt instruments is assumed to be one period, reflecting the fact that firms tend to borrow short term to finance working capital expenses. The total quantity of funds raised by the firm in period t is denoted by Q_{t+1}, where the dating convention here indicates the date at which the debt instrument matures. Thus, the financing constraint that applies to this portion of the firm's working capital expenses is given by:

$$W_t N_t \leq Q_{t+1} \tag{6}$$

The labor that the firm hires is combined with its existing stock of capital, denoted by K_t, to produce output according to its production technology, which is represented mathematically by the function $F(\theta_t, K_t, N_t)$. Supply shocks that affect productivity are embedded in this expression in the random variable, θ_t. Consistent with the empirical literature dating back to Robert Solow's seminal work in the 1960s, once a shock to pro-

[11] Mathematically, $\beta_t^* = \beta(U_{C_{t+1}}/P_{t+1})G_{M_{t+1}}$, where the subscripts on the functions U and G represent partial derivatives. The logic of this expression is that the household receives the dividend at the end of the period and cannot spend it immediately, i.e., in period t. Next period, i.e., in period *t+1*, the household can use the dollar to make nominal consumption purchases in the amount given by $G_{M_{t+1}}$, which when divided by P_{t+1} determines the quantity of consumption C_{t+1} that the household purchases per dollar of dividend received. Each of these consumption units is valued at the marginal utility of consumption $U_{C_{t+1}}$, which must be discounted back one period by β to determine its present value at date t.

ductivity occurs, it is assumed to exhibit a high degree of persistence.[12]

The firm's stock of capital changes in accordance with its gross investment and the rate at which capital depreciates. The stock of capital after investment can therefore be expressed as the undepreciated portion of the beginning-of-period capital stock plus gross investment, denoted by I_t, or:

$$K_{t+1} = (1 - \delta)K_t + I_t \tag{7}$$

where the rate of depreciation per period is given by $\delta \in (0, 1)$.

To determine the firm's nominal profits or cash flow for the period, subtract the nominal value of the firm's gross capital investment, $P_t I_t$, and its repayment of principal and interest on its maturing debt, $(1 + r_t^b)Q_t$, from its nominal sales, $P_t F(\theta_t, K_t, N_t)$. This accounting exercise yields:

$$\Pi_t^f = P_t F(\theta_t, K_t, N_t) - P_t I_t - (1 + r_t^b)Q_t \tag{8}$$

The firm chooses its employment level, which determines the level of output, given its stock of capital and level of productivity, and establishes its borrowings for the current period, given the wage rate. It must also choose its level of investment, which determines the firm's dividend payout, given its level of production and its debt repayment schedule. With an increase in investment today, the funds available for dividends today are reduced, but the production possibilities of next period expand. Therefore, the investment decision is intertemporal in nature, and must be made in the face of an uncertain future.

[12] The standard modeling approach in the literature, e.g., see Kydland and Prescott (1982), is to use the following stochastic process to describe the evolution of total factor productivity: $\ln \theta_{t+1} = \mu + \rho \ln \theta_t + \epsilon_{t+1}$ where $\mu > 0, \rho \in (0, 1)$ and ϵ_t is a zero mean normal random variable with a constant variance. A high value of ρ, such as 0.99 which is often used for quarterly models, indicates a high degree of persistence. The standard deviation of ϵ_t was chosen to be 0.0092, which enabled the volatility in output from the model to roughly match the 1.68 percent standard deviation of output per capita in the quarterly data from 1973:1 to 2000:1.

4.3 The banking sector.

The banking sector is assumed to be competitive and the representative bank chooses a sequence of balance sheet positions that maximize the expected present value of net cash flows, which are paid out each period as dividends to its owners, the households. As with the firm, the bank's objective can be expressed mathematically as:

$$\max E \sum_{t=0}^{\infty} \beta^t \beta_t^* \Pi_t^b \tag{9}$$

The net cash flows of the bank are found by subtracting the principal and interest paid out on deposit accounts, $(1+r_t^d)D_t$, along with the bank's cost of servicing those accounts, ξD_t, where ξ is the marginal cost of servicing deposits, from the principal and interest that it receives on its loans to firms, $(1+r_t^b)V_t$, where V_t denotes the nominal quantity of working capital loans made to the firm, plus the reserves that the bank is required to maintain, Z_t^r.[13] Performing this accounting exercise:

$$\Pi_t^b = (1+r_t^b)V_t + Z_t^r - (1+r_t^d)D_t - \xi D_t, \quad \xi \in (0,1) \tag{10}$$

In choosing its balance sheet position, the bank must meet its reserve requirements, or:

$$Z_t^r \leq \nu D_t, \quad \nu \in (0,1) \tag{11}$$

where the reserve requirement ratio, or the fraction of deposits that the bank must hold back in the form of reserves, is denoted by ν. It must also satisfy its balance sheet constraint, such that its assets cannot exceed its liabilities, or:

$$Z_t^r + V_t \leq D_t \tag{12}$$

[13] The bank loan rate and the bond rate are identical in equilibrium, since the firm sees the two choices of funding as perfect substitutes. At some cost to the complexity of the model, this can be relaxed as in Einarsson and Marquis (2001a) and Marquis (2001).

4.4 The monetary authority.

The monetary authority chooses to operate in accordance with a rule that governs the evolution of bank reserves. Currency is supplied on demand. It is assumed that the growth of bank reserves follows a process that has a random component to it. The purpose of this modeling choice is to characterize unanticipated changes in monetary policy by shocks to the growth rate of bank reserves. It is assumed, in accordance with the data, that once a random change in the growth rate of bank reserves occurs, it exhibits a significant degree of persistence. Mathematically, this policy rule can be expressed as:

$$Z_{t+1} = \gamma_t Z_t \tag{13}$$

where Z_t denotes the stock of bank reserves determined by the monetary authority, and γ_t represents the gross growth rate of reserves that is subject to persistent, random shocks. The central bank supplies money on demand.

4.5 Equilibrium.

For this economy to be in equilibrium, households, firms, and the banks must be making their respective choices described above such that they attain the objectives of maximizing lifetime utility for households and maximizing the value of the enterprise for firms and banks, while satisfying all of the constraints that the respective decisionmakers face. Those decisions must also produce prices and quantities that clear all of the markets. Notably, the goods market must clear, such that consumption plus investment equals output, or:

$$C_t + I_t = F(\theta_t, K_t, N_t) \tag{14}$$

Also, the total borrowings of the firm must equate to the sum of bonds purchased by the household and the quantity of loans that the firm receives from the bank, or:

$$Q_t = B_t + V_t \tag{15}$$

Finally, the amount of reserves supplied by the monetary authority is just equal to the quantity of reserves that the bank chooses to hold to meet its required reserves, or

$$Z_t = Z_t^r \tag{16}$$

4.6 Calibration of the Models.

To perform the simulation exercises that will enable the short-run dynamics of the model to be compared with the data, the steady-state version of the model must first be calibrated to the long-run features of the data. For the calibration, the following functional forms were chosen: $U = \ln C_t + \eta \ln L_t, \eta > 0$, $G = g_0 M_t^{g_1} D_t^{1-g_1}, g_0 > 0, g_1 \in (0,1)$, and $F = A\theta_t K_t^{\alpha} N_t^{1-\alpha}, A > 0, \alpha \in (0,1)$. The calibration procedure is a slight modification of Einarsson and Marquis (2001a), where it is described in detail. Ten constraints were needed to identify the ten parameters: $\beta, \eta, g_0, g_1, \alpha, \delta, A, \xi, \nu$, and the mean growth rate of bank reserves, $\bar{\gamma}$. These constraints include a quarterly depreciation rate of $\delta = 0.0212$ and a value for capital's share of income, $\alpha = 0.314$,[14] a currency-deposit ratio of 0.365 (where deposits were defined as OCDs and DDAs, with the average taken over the 1960-1998 period), a required reserve ratio of $\nu = 0.1$, a bond rate of $r^b = 7.451$ (which equated to the 1973-1998 average for the 90-day commercial paper rate), a deposit rate of $r^d = 4.721$ (which is the average of the Federal Reserve's OMS rate for 1973-1999), and an average inflation rate of 3.98 percent (consistent with the 1960-1998 average for the CPI). Leisure time was set to 68 percent of the total time allocated each period [based on the diary studies reported by Juster and Stafford (1991)]. The scale parameter in production was arbitrarily set to $A = 1$. Finally, using the *Quarterly Financial Reports for Manufacturing Companies, 1980*, the ratio of bonds to bank loans, $B/V = 0.824$ (which is the ratio of commercial paper outstanding plus "other short-term debt" to short-term bank debt). These choices are consistent in the steady state with the remaining unidentified parameter values: $g_0 = 3.1076, g_1 = 0.4995, \eta = 1.8621, \beta = 0.9914$, and $\eta = 0.0050$.

[14] To obtain values for δ and α, we use data from 1960 to 1998 and follow the procedure that is outlined Cooley and Prescott (1989), with two exceptions. Government capital is excluded from the capital stock, and the stock of and service flows from consumer durables were obtained from estimates derived by the Federal Reserve Board.

The purpose of constructing this model is to examine theoretical conditions that are consistent with a persistent liquidity effect. One ingredient in these models is policy shocks associated with unanticipated changes in the growth rate of bank reserves. This feature of the model requires a characterization of the time series for γ_t in equation (13). One approach is simply to estimate a univariate stochastic process for the growth rate of nonborrowed reserves, where the residuals from that series are taken as the policy shocks. Christiano, et al. (1999) criticize this approach as ignoring the feedback into nonborrowed reserves that may occur as a reaction of the monetary authorities to the response of the economy to its policy change. One way to capture that feedback is to use the dynamic response of the policy variable in a VAR to a prior policy shock as is depicted, for example, in Figure 3 for RES in row 1. This graph maps out the history of changes in the policy variable induced by a one-time unexpected change in the policy variable itself after accounting for the fact that interest rates, output and prices are also responding to the policy change. Estimates of the two versions of the policy shocks are given below, where they are referred to as the "Univariate" and "VAR" models, respectively.[15]

Univariate model of the policy shock: $\tilde{\gamma}_t = \bar{\gamma}^U + 0.73\tilde{\gamma}_{t-1} + \tilde{\epsilon}_t, \quad \bar{\gamma}^U > 0, \ \sigma_{\tilde{\epsilon}} = 0.015$

VAR model of the policy shocks: $\hat{\gamma}_t = \bar{\gamma}^V + \hat{\epsilon}_t + 0.78\hat{\epsilon}_{t-1}, \quad \bar{\gamma}^V > 0, \ \sigma_{\hat{\epsilon}} = 0.023$

The magnitude and persistence of a policy shock described by these two measures can be compared by examining the evolution of the growth rate to bank reserves in response to positive policy shocks that have an equal probability of occurrence. These (one standard deviation) shocks are displayed in Figure 4. Note that while the patterns of the two shocks are similar, the shock described by the Univariate model exhibits a moderately lower value on impact than the shock from the VAR model, but is more persistent.

Three versions of the above model were calibrated and estimated using the Univariate model to identify the policy shocks.[16] The first version is referred to as the "No Pre-commitment Model with a Bond Market." In this model, it is assumed that all decisions

[15] There is an equivalence between the mean growth rates in the two models such that $\bar{\gamma}^V = \bar{\gamma}^U/0.27$.

[16] The stochastic models are estimated using the Parameterized Expectations Algorithm (PEA) of DenHaan and Marcet (1990).

described above are made with full contemporaneous information. In this case, the shocks to productivity and to the growth rate of reserves are both observed before any decisions are made. Note that this does not incorporate any incomplete markets or limited participation of the type that is the focus of this literature. To see what effect such market incompleteness has, the second model, labeled "Deposit Precommitment Model with a Bond Market," includes a weak form of the limited participation assumption. It is assumed that households precommit to their deposit position and banks set the deposit rate, that is, that the deposit market clears after observing the productivity shock, but prior to observing the monetary policy shock. All other decisions are made with full information, including full knowledge of the Federal Reserve's current monetary policy decisions. Finally, to illustrate the effect of allowing firms a choice between banks and the bond market as a source of funds, a third version of the model, labeled "Deposit Precommitment Model without a Bond Market," is calibrated, and estimated.[17] The same limited participation assumption is maintained as in the "Deposit Precommitment Model with a Bond Market," in that the deposit market is assumed to clear after observing the productivity shock and prior to observing the monetary policy shock.

4.7 Business Cycle Properties of the Models.

One gauge of how well a model captures important features of the short-run dynamic behavior of the economy is a comparison of its business cycle properties with actual data. The cyclical behavior of model economies such as those discussed in this subsection are typically dominated by the nonmonetary shocks to the economy. How the economy responds exlusively to monetary shocks, which is the principal focus of this article, is discussed at length in the next subsection 4.8.

The first two columns of Table 1 present the volatility (measured as a percent standard deviation) of selected quarterly (detrended) data for the U.S. economy, along with the contemporaneous correlation of those data with output. Among the cyclical features of the data (over the sample period 1973:1 to 2000:1) that you would like the model economy

[17] This version of the model required a slight modification to the calibration, i.e., with $B = 0$.

to replicate are the procyclicality of consumption and investment (i.e., their correlations with output are positive), and the fact that while consumption is less volatile than output, investment is significantly more volatile than output. As the statistics reported in Table 1 indicate, all three versions of the model exhibit this behavior.[18]

The statistics that are of particular interest to this study are those that depict the cyclical behavior of short-term interest rates and bank lending. Referring to Table 1, column 2, the deposit (OMS) rate, the bond (90-day commercial paper) rate, and the bank (prime) lending rate are all procyclical, while the volume of real bank (commercial and industrial) loans is very weakly procyclical. Again, all three models are qualitatively similar, albeit with correlations that are often too high, which could be attributed to some stochastic features of the economy from which the models abstract.

An especially noteworthy statistic reported in the last row of the second colum of Table 1 is the negative correlation of the "degree of bank intermediation," defined as the ratio of commercial and industrial loans to GDP, with output. This statistic suggests that even though the working capital requirements of firms is procyclical, the reliance that firms place on bank lending in financing working capital expenditures is countercyclical. As reported in Table 1, all three versions of the model carry this prediction. The explanation that the theory provides for this feature of the U.S. business cycle is that a major source of funding for bank loans is derived from bank deposits that are linked to consumption. Households' desire to smooth consumption over the business cycle also smooths the ability of banks to raise deposit funds. When the economy is booming and the demand for bank loans is high, banks have difficulty raising funds in amounts that are sufficient to meet the additional demand. Hence bank lending as a share of GDP falls, as firms find alternative financing sources. The reverse is true during recessions, when firms rely relatively more on banks for working capital finance.

[18] The data were detrended using the Hodrick-Prescott filter. The statistics for the U.S. data reported in Tables 1 and 2 are taken from Einarsson and Marquis (2001a). The simulated data reported in Tables 1 and 2 are for 100 simulations of length 120 periods, where the simulated data were also Hodrick-Prescott filtered.

4.8 Dynamic Response of the Model Economies to a Monetary Shock.

To examine how monetary policy can affect the macroeconomy, it is of particular interest to know how market interest rates more generally, and not simply the interbank lending rate, react to monetary policy decisions. One implication of a strong liquidity effect resulting from a change in monetary policy is that a policy that eases bank credit by expanding bank reserves should induce a decline in the bond rate. If this effect is strong enough, empirical evidence consistent with this prediction can be found, for example, by estimating the cross-correlation function between the (detrended) growth rate of nonborrowed reserves and the (detrended) 90-day commercial paper rate. As shown in row 1 of Table 2, for the sample period 1973.Q1 to 2000.Q1, there is not only a negative contemporaneous correlation between the growth rate of bank reserves and the bond rate equal to -0.25, but this negative relationship is stronger at a one-quarter lag of the bond rate, where it peaks (in absolute value) at -0.27. The interpretation of these results is that, on average over the sample period, an increase in the growth rate of nonborrowed reserves above trend is accompanied by a fall in the bond rate in the current quarter and in the succeeding quarter, suggesting persistence in the interest rate response to the expansion of nonborrowed reserves. Note that these results are simple correlations that make no attempt to account for other macroeconomic conditions that could affect these two variables independently, and thereby weaken any estimate of a systematic relationship that may exist between them.

How well do the theoretical models predict this response? To examine this question, simulations of the three models were run and the cross-correlations of the theoretical counterparts to nonborrowed reserves growth and the bond rate were estimated. In row 2 of Table 2, the cross-correlations between the (gross) growth rate of nonborrowed reserves, γ_{t-s}, and the bond rate, r_t^b, that are reported for the No Precommitment Model with a Bond Market are seen to be positive or near zero at all leads and lags. There is no evidence of a liquidity effect. This is confirmed in Figure 5, where the dynamic responses of the bond rate, output, and the price level from the model economy are displayed in row 1. Note that the model predicts that an injection of reserves into the banking system induces an immediate *increase* in the bond rate, which then gradually dissipates. These higher interest rates raise the borrowing costs of the firms in the model who reduce employment, and investment slows, with the model economy reaching its nadar in response to the policy shock in about three quarters.

These dynamics contrast sharply with the predictions from the Deposit Precommitment Model with a Bond Market. As shown in row 3 of Table 2, the cross-correlations between nonborrowed reserves growth and the bond rate that the model predicts match reasonably well with the actual data in row 1. They suggest the presence of a strong liquidity effect. Given a rise in the growth rate of nonborrowed reserves, the bond rate tends to fall immediately, with a contemporaneous correlation between the two variables of -0.29. This is followed by an even stronger negative correlation in periods subsequent to the shock, with the peak (absolute) correlation occurring after one quarter, when the correlation is -0.47, although after two quarters it remains high (in absolute value) at -0.33. The explanation for these results suggested by the model is that with the deposit market slow to respond to the policy shock, required reserves in the banking system are not quickly altered by the injection of reserves and hence the banks find themselves with excess reserves to lend. To entice the firms into borrowing, they lower in the interest rate. Hence, market interest rates fall. The dynamic response of the economy to this shock is displayed in Figure 5, row 2. Note that this model predicts a pronounced and *persistent* liquidity effect, that is, in response to the increase in nonborrowed reserves, the bond rate falls *and* it remains significantly below its long-run level for several quarters thereafter. This decline in the borrowing costs for firms induces them to hire more workers, and this results in a persistent increase in output that peaks in the second quarter after the initial easing of monetary policy.

In Section 2, it was stated that there were really two puzzles associated with the liquidity effect. What produces it? Why is it persistent? The answer provided by the model to the first question is given above. To understand the logic of the model that predicts persistence in this response, the results from the Deposit Precommitment Model without a Bond Market can be examined. This model is identical to the Deposit Precommitment Model with a Bond Market with the exception that all borrowing by the firms for the financing of the wage bill must come from the banks. First note in Table 2 that there is no evidence of a liquidity effect in the cross-correlations of bank reserves growth and the interest rate. The correlations are positive or close to zero at all leads and lags, although much smaller than observed for the No Precommitment Model with a Bond Market. These results imply that the limited participation associated with the early clearing of the deposit market is affecting the relationship between bank reserves and market interest rates, but it does not appear to be very significant. Now turning to row 3 of Figure 5, a weak liquidity effect is in evidence. In response to an injection of reserves into the banking system, the interest rate does fall. However, the decline is entirely contained within one period, and is subsequently reversed in the following quarter. The liquidity effect in this model is not only weak, but it lacks persistence.

The lack of persistence in this version of the model is a direct result of closing down an avenue of savings for the household. After an easing of monetary policy, the economy picks up and household income rises. In each of these models, all of the additional income must be saved in the form of financial assets. However, when there is no bond market available to the household, this additional nominal income must be channeled into liquid asset holdings of money and deposits, which have a relatively high opportunity cost due to their low rates of return. When a bond market is available to the household, as in the Deposit Precommitment Model with a Bond Market, households have a greater incentive to save and hence spread out over several periods the additional consumption possibilities that are implied by the additional wealth. This is evident in the final graph displayed in row 2 of Figure 5. It shows how the household's financial asset portfolio gives more weight to bonds relative money and only gradually adjusts to its optimal long-run portfolio. In the interim, the greater demand for bonds keeps the bond rate lower than its long-run equilibrium value, implying a highly persistent liquidity effect associated with the unanticipated reserves injection into the banking system.

One counterfactual prediction of the Deposit Precommitment Model with a Bond Market is the strong price response. As shown in row 2, the price level initially overshoots its long-run price level which it then asymptotically approaches from above. One is left to conclude that this model is missing some relevant features that are required to explain the sluggish price dynamics similar to those displayed in Figure 3. This shortcoming is not unique to this model. Currently, there is no accepted theory that can explain why prices adjust slowly.

5. Conclusion

Despite deregulation and the rapid pace of technological change and financial innovation that have significantly altered the U.S. banking industry, the traditional role that banks play in the economy as an intermediary between households and firms has not significantly diminished. The volume of commercial and industrial (C&I) lending as a fraction of GDP remains near its long-run (post-1973) average, while the bulk of funds that banks raise to finance C&I loans is derived from deposits that households value in part due to the liquidity services that they provide. These features of the banking system are central to a class of theoretical models that attempt to understand one channel through which monetary policy affects the real economy. That channel depicts an "easing" on monetary policy as a cut in the federal funds rate that is supported by an increase in the growth rate of bank reserves through open market operations. These additional bank reserves can stimulate economic activity if they are turned over into loans to businesses that are used to finance working capital expenditures with the attendant expansion of employment and output.

The theoretical literature has identified two puzzles associated with this depiction of how monetary policy affects the real economy. Both relate to the behavior of nominal interest rates in response to a change in monetary policy that is both a central feature of the previously described channel of monetary policy and is evident in the data. The first is that nominal interest rates decline with an unexpected increase in the growth rate of (nonborrowed) bank reserves, which is referred to as the "liquidity effect." This interest rate response is seen to be a puzzle given that a faster expansion of bank reserves ultimately leads to faster money growth and higher inflation. This higher inflation eventually *raises* nominal interest rates. Thus, in a frictionless world, if this higher inflation is incorporated into expectations quickly, then nominal interest rates will rise rather than fall with an easing of monetary policy. One theoretical explanation for the empirical finding of a liquidity effect is that deposit markets do not respond quickly to unexpected changes in monetary policy. This can be conceptualized and modeled as an information friction, whereby households and banks do not factor the most recent monetary policy actions that had not been fully anticipated into their decisions on how much of the wealth households should retain in deposit accounts and what interest rate banks should pay on deposits. In this case, with the level of bank deposits predetermined, an injection of reserves into the banking system by the central bank increases the volume of funds available for business lending and bank lending rates may fall as banks entice firms into borrowing more heavily for working capital expenditures which then expands employment and output.

The second puzzle is the empirical evidence that suggests that the liquidity effect associated with a period of monetary ease persists for several quarters. The theoretical explanation of the liquidity effect that was just described fails to generate any persistent or long-lasting effect on interest rates due to an unexpected increase in the growth rate of bank reserves. Once the new monetary policy action is factored into the pricing of assets, which requires households to take account of the policy when choosing their deposit holdings, and this information is fully reflected in the deposit rate, the "liquidity effect" vanishes. This article presents a theoretical model that illustrates how access by households to a corporate bond market can induce both a larger and a persistent liquidity effect. The logic of the theoretical model is that the increase in household income associated with the increase in economic activity induced by the initial liquidity effect (which is amplified through the lowering of the corporate bond rate) is partially "saved" by households who increase their demand for bonds. This additional savings is extended for several quarters. Therefore, firms expand their supply of bonds and reduce their reliance on banks for working capital finance as interest rates continue to be low, and employment and output continue to expand.

References

Alverez, Fernando, Robert E. Lucas, Jr., and Warren E. Weber. 2001. "Interest Rates and Inflation," *American Economic Review*, 91(2), (May): 219-225.

Barth, Marvin J., III and Valerie A. Ramey. 2001. "The Cost Channel of Monetary Policy," University of California, San Diego, Manuscript (April).

Chari, V.V., Lawrence J. Christiano, and Martin Eichenbaum. 1995. "Inside Money, Outside Money, and Short-Term Interest Rates," *Journal of Money, Credit and Banking* 27(4), Part 2 (November): 1354-1386.

Christiano, Lawrence J. 1991. "Modeling the Liquidity Effect," Federal Reserve Bank of Minneapolis *Quarterly Review* (Winter): 3-34.

Christiano, Lawrence J. and Martin Eichenbaum. 1999. "Monetary Policy Shocks: What Have We Learned and to What End?" in *Handbook of Macroeconomics, Volume 1*, Ch. 2: 66-148.

Christiano, Lawrence J. and Martin Eichenbaum. 1995. "Liquidity Effects, Monetary Policy, and the Business Cycle," *Journal of Money, Credit, and Banking* 27(4), Part 1 (November): 1113-1158.

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans. 1998. "Modeling Money," *NBER Working Paper 6371* (January).

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans. 1997. "Sticky Price and Limited Participation Models of Money: A Comparison," *European Economic Review* 41(6), (June): 1201-1249.

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans. 1996. "The Effects of Monetary Policy Shocks: Evidence from the Flow of Funds," *Review of Economics and Statistics* 78(1), (February): 16-34.

Cooley, Thomas F. and Edward C. Prescott. 1995. "Economic Growth and Business Cycles," in *Frontiers in Business Cycle Research*, ed. by Thomas F. Cooley, Ch. 2 (Princeton: Princeton University Press): 1-38.

DenHaan, Wouter J. and Albert Marcet. 1990. "Solving the Stochastic Growth Model by Parameterizing Expectations," *Journal of Business and Economics Statistics*," 8(1), (January): 31-34.

Edge, Rochelle M. 2001. "Time-to-Build, Time-to-Plan, Habit-Persistence, and the Liquidity Effect," Board of Governors of the Federal Reserve System *International Finance Discussion Papers Number 6673* (December).

Eichenbaum, Martin. 1992. "Comments on 'Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy' by Christopher A. Sims," *European Economic Review*, 36(5), (June): 1001-1012.

Einarsson, Tor and Milton H. Marquis. 2001a. "Bank Intermediation and Persistent Liquidity Effects in the Presence of a Frictionless Bond Market," *Federal Reserve Bank of San Francisco Working Paper 00-08*, (June, revised).

Einarsson, Tor and Milton H. Marquis. 2001b. "Bank Intermediation over the Business Cycle," *Journal of Money, Credit and Banking*, (November): (forthcoming).

Evans, Charles L. and David A. Marshall. 1998. "Monetary Policy and the Term Structure of Nominal Interest Rates: Evidence and Theory," *Carnegie-Rochester Conference Series on Public Policy*, 49, (December): 53-112.

Fuerst, Timothy S. 1992. "Liquidity, Loanable Funds, and Real Activity," *Journal of Monetary Economics*, 29(1), (February): 3-24.

Kydland, Finn E. and Edward C. Prescott. 1982. "Time to Build and Aggregate Economic Fluctuations," *Econometrica*, 50(6): 1345-1370.

Kwan, Simon. 2001 "Financial Modernization and Banking Theories," *Federal Reserve Bank of San Francisco Economic Letter*, Number 2001-37, (December 21).

Lucas, Robert E., Jr. 2000. "Inflation and Welfare," *Econometrica*, 68(2), (March): 247-274.

Marquis, Milton H. 2001. "Bank Credit versus Nonbank Credit and the Provision of Liquidity by the Central Bank," in *Challenges for Central Banking*, ed. by Anthony M. Santomero, Staffan Viotti, and Anders Vredin, Ch 14, (Boston: Kluwer Academic Publishers): 247-270.

McCauley, Robert N. and Rama Seth. 1992. "Foreign Bank Credit to U.S. Corporations: The Implications of Offshore Loans." Federal Reserve Bank of New York *Economic Review* 17 (Spring): 52-65.

Sims, Christopher A. 1992. "Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy," *European Economic Review*, 36(5) (June): 975-1000.

Strongin, Steven. 1995. "The Identification of Monetary Policy Disturbances: Explaining the Liquidity Puzzle," *Journal of Monetary Economics*, 34(3) (December): 463-497.

Figure 1: Ratio of Commercial and Industrial Loans to GDP

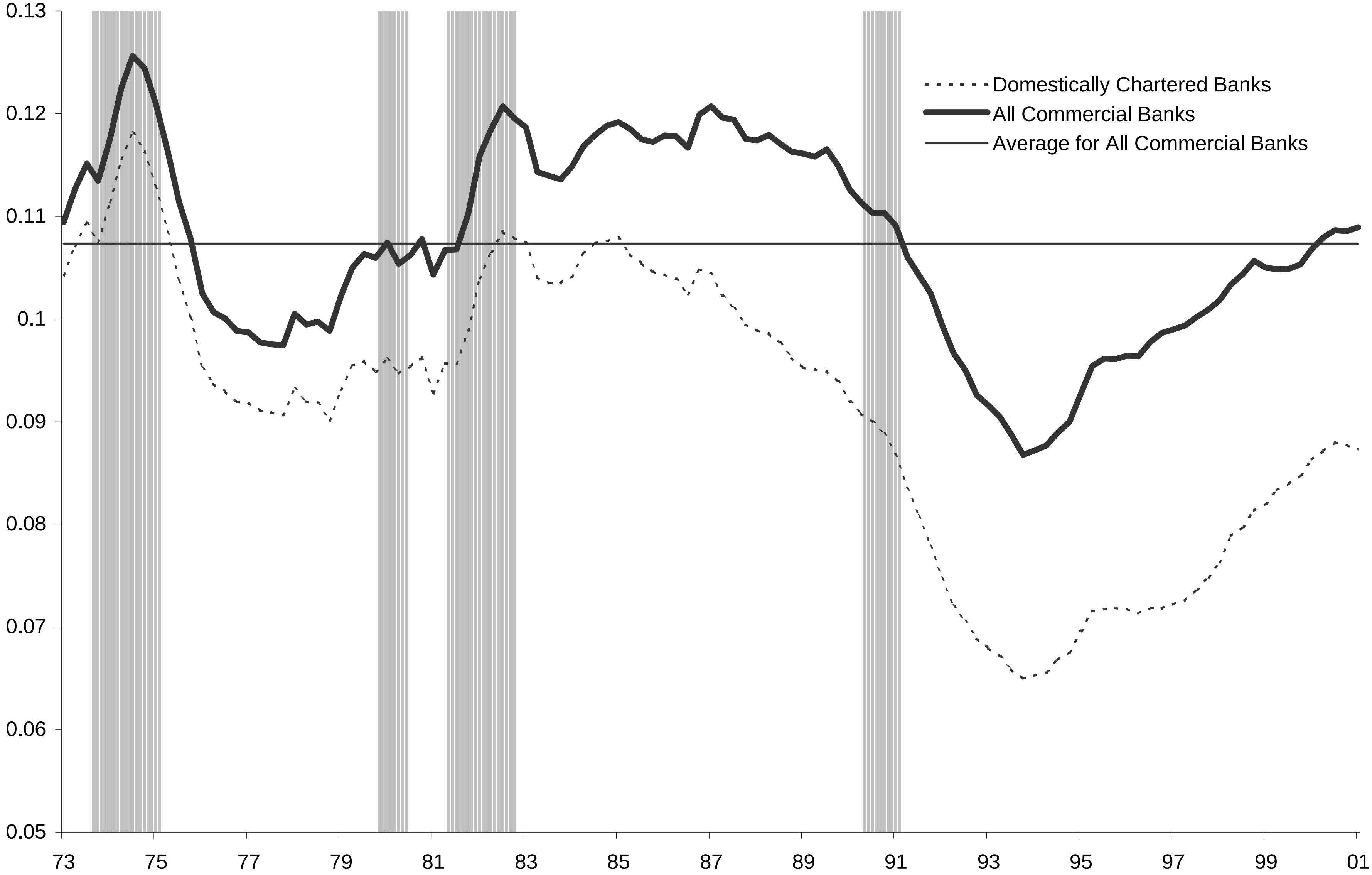


Figure 2: Total Reserves in Banking System

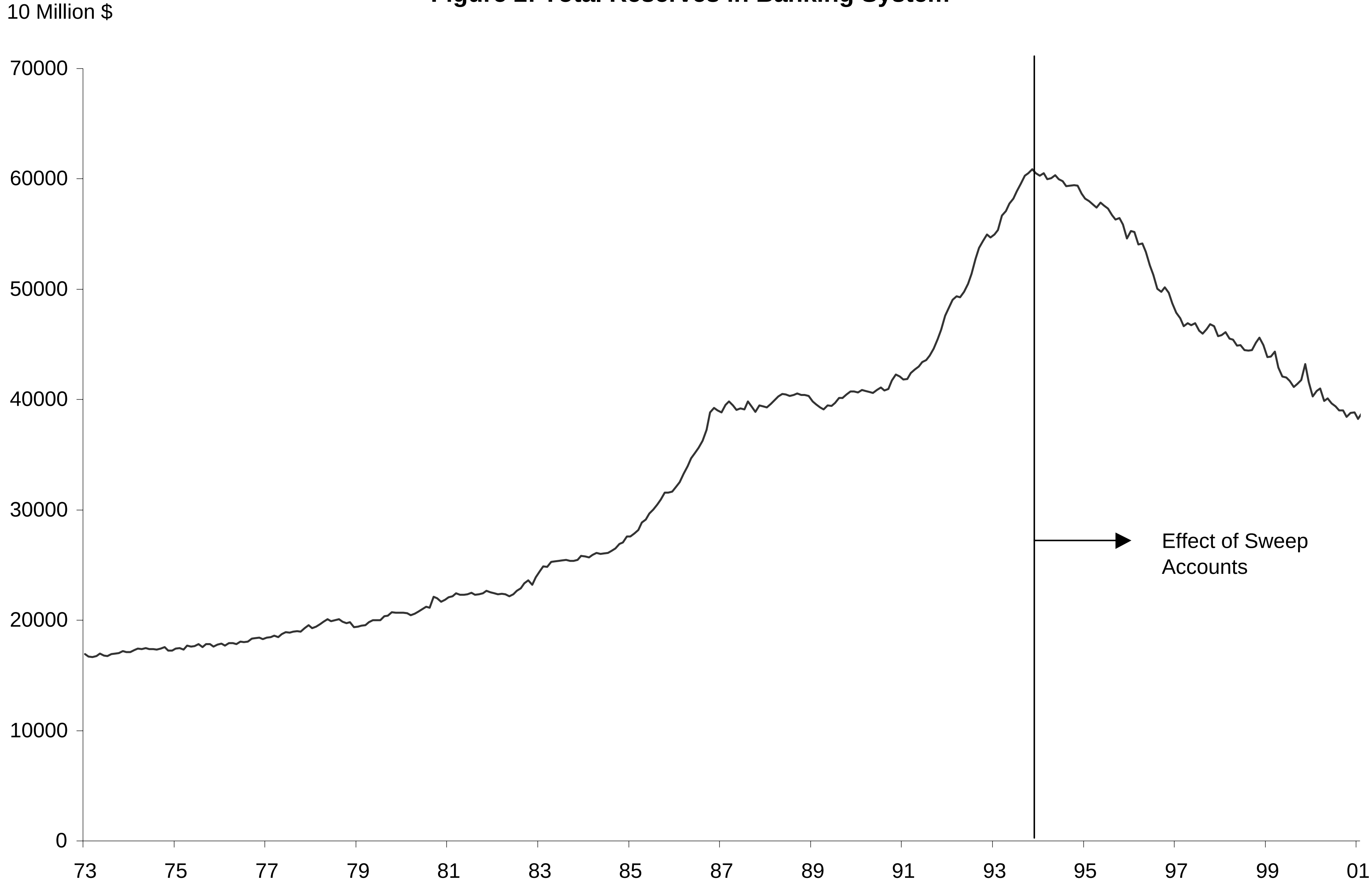


Figure 3: Dynamic Response of Macroeconomic Variables to (one-standard deviation) Monetary Policy Shocks

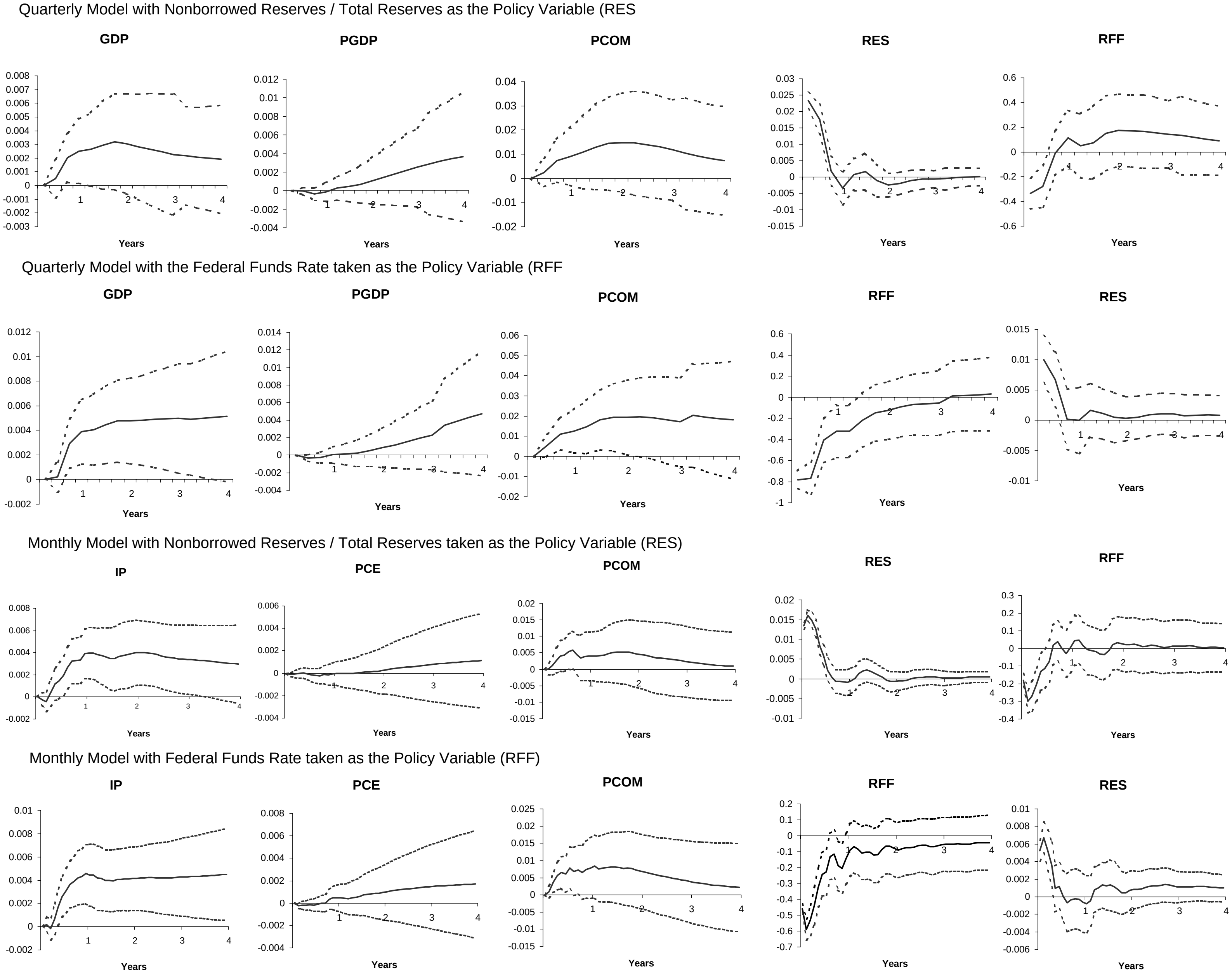


Figure 4: Magnitude & Persistent of One Standard Deviation Policy Shocks

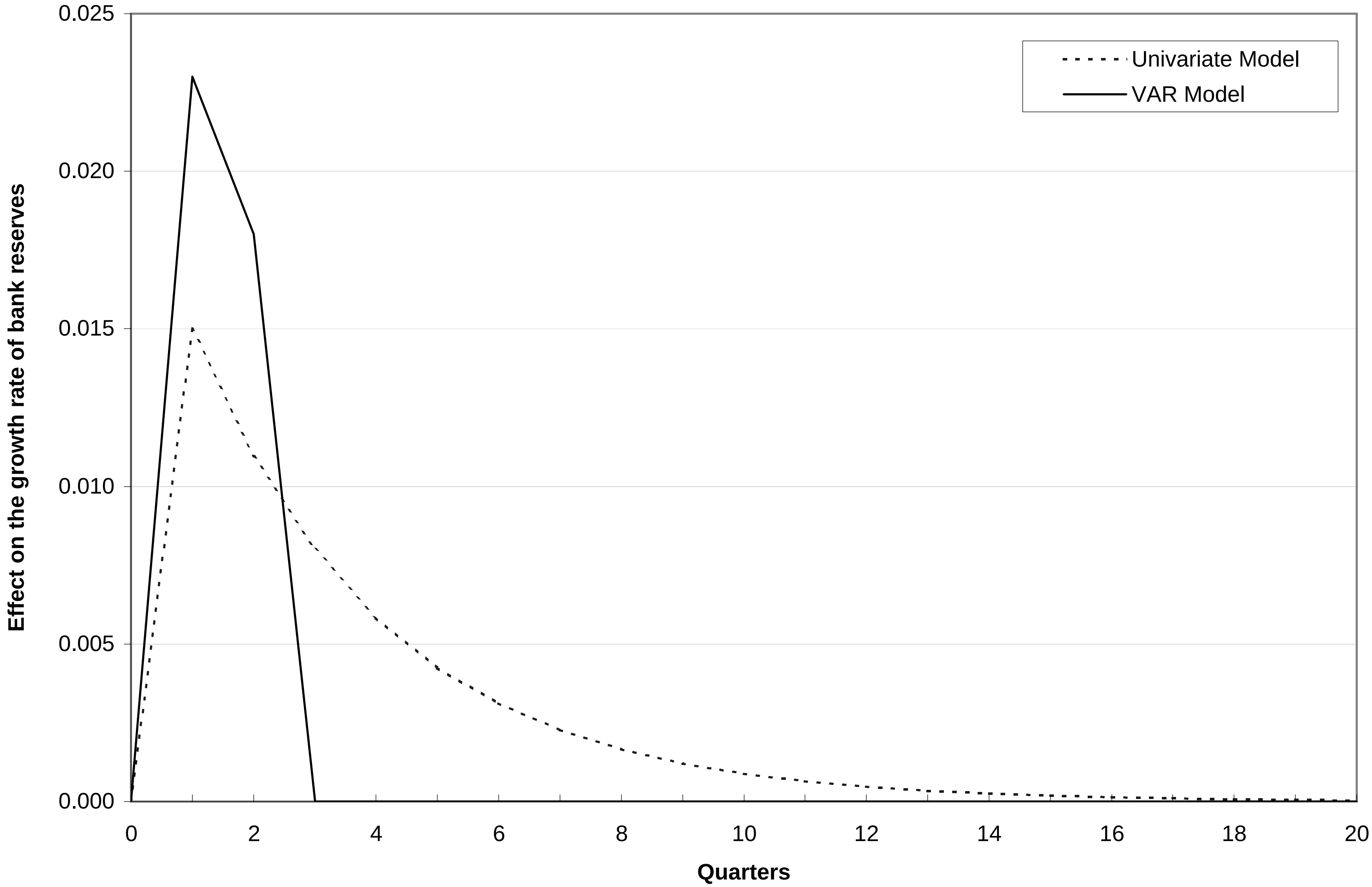
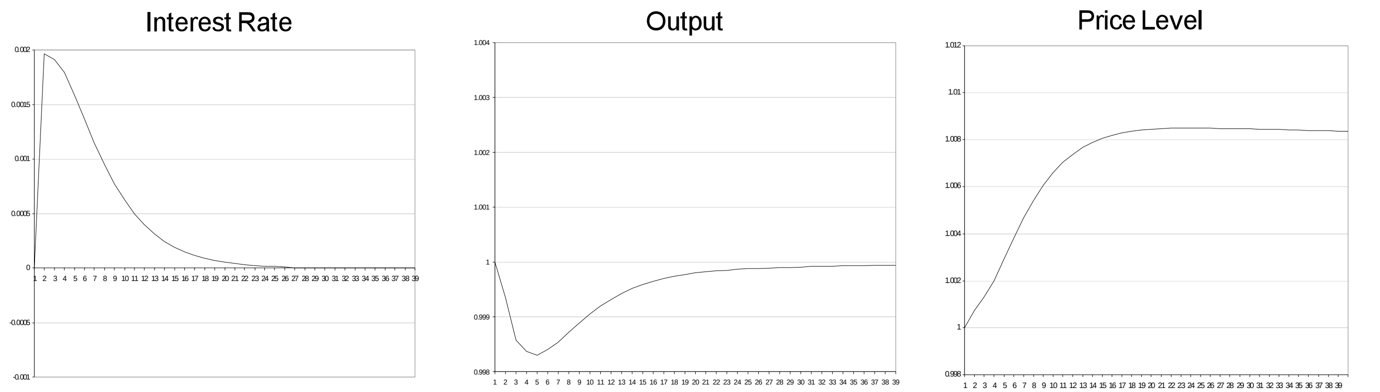
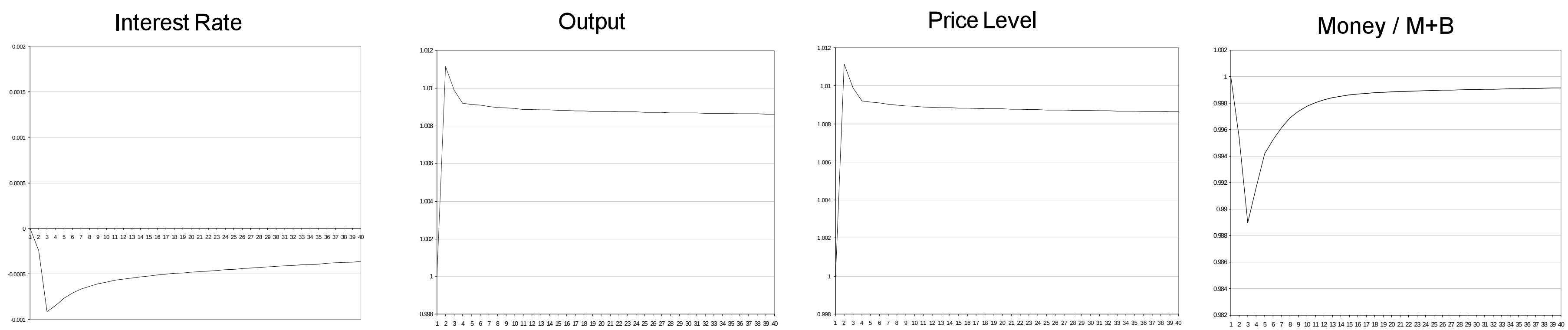


Figure 5: Predicted Dynamic Response of Macroeconomic Variables to a (one-standard deviation) Monetary Policy Shock

No Precommitment Model with a Bond Market



Deposit Precommitment Model with a Bond Market



Deposit Precommitment Model without a Bond Market

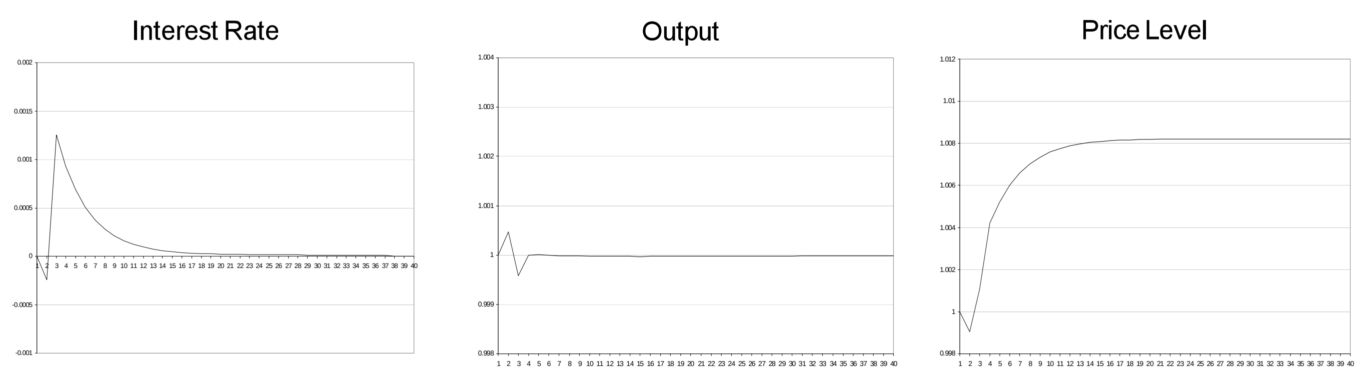


Table 1: Summary of Second Moments

	U.S. Data 1973:1-2000:1[a]		No Precommitment Model With a Bond Market[b]		Deposit Precommitment Model Without a Bond Market[b]		Deposit Precommitment Model With a Bond Market[b]	
variable, x	σ_x	ρ_{xy}	σ_x	ρ_{xy}	σ_x	ρ_{xy}	σ_x	ρ_{xy}
Output, y	1.668	1.000	1.68	1.00	1.68	1.00	1.73	1.00
Consumption, c	0.921	0.849	0.68	0.85	0.74	0.97	1.51	0.56
Investment, I	6.277	0.943	5.81	0.97	5.29	0.99	6.65	0.74
Deposit rate, r^d	0.105	0.168	0.33	0.33	0.72	0.97	0.18	0.52
Bond rate, r^b	0.383	0.331	0.36	0.33	0.79	0.96	0.19	0.53
Bank lending rate, r^v	0.387	0.174						
Real bonds, b			3.43	0.93			3.69	0.85
Real loans, v'	3.387	0.077	0.80	0.64	0.93	0.92	1.68	0.58
Degree of bank intermediation, v'/y	3.652	-0.372	1.31	-0.81	0.89	-0.92	1.57	-0.49

σ_x = Percent Standard Deviation

ρ_{xy} = Correlation of "x" with Output

Notes: [a] Data on the deposit rate and stock and flows of consumer durables were provided by the Federal Reserve Board. All remaining data were extracted from the FAME database. All series were HP-filtered. See Einarsson and Marquis (2001a) for details.

[b] Statistics based on 100 simulations of length 120 periods, with all data HP-filtered.

Table 2: Cross-correlations of the Bond Rate (r^b_t) with the Gross Growth Rate of Nonborrowed Reserves (γ_t)

Corr(r^b_t, γ_{t-s})[a]

lag, s	4	3	2	1	0	-1	-2	-3	-4
U.S. Data (1973:1-2001:1) 90-day Commercial Paper Rate[b]	-0.11	-0.08	-0.15	-0.27	-0.25	0.03	0.12	0.05	0.06
No Precommitment Model with a Bond Market[c]	0.18	0.31	0.46	0.61	0.74	0.38	0.15	-0.01	-0.11
Deposit Precommitment Model with a Bond Market[c]	-0.12	-0.20	-0.33	-0.47	-0.29	-0.08	0.05	0.12	0.15
Deposit Precommitment Model without a Bond Market[c]	-0.03	0.02	0.09	0.19	0.08	0.05	0.02	0.00	-0.01

Notes: [a] s = number of periods that γ_t leads r^b_t.

[b] Data on the deposit rate and stock and flows of consumer durables were provided by the Federal Reserve Board. All remaining data were extracted from the FAME database. All series were HP-filtered. See Einarsson and Marquis (2001a) for details.

[c] Statistics based on 100 simulations of length 120 periods, with all data HP-filtered.

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W99:08 Edmund S. Phelps: Equilibrium and Disequilibrium in 20th Century 'Macro': With Attention to the Share Price Boom of the 1990s

W99:09 Kenneth F. Wallis: Macroeconometric Modelling

W99:10 Tryggvi Thor Herbertsson, Marta G. Skúladóttir, and Gylfi Zoega: Three Symptoms and a Cure: A Contribution to the Economics of the Dutch Disease

W99:11 Tryggvi Thor Herbertsson and J. Michael Orszag: Issues in European Pension Reforms: Supplementary Pensions

W99:12 Tryggvi Thor Herbertsson, J. Michael Orszag and Peter R. Orszag: Population Dynamics and Convergence in Fertility Rates

W99:13 Ragnar Arnason: Costs of Fisheries Management: Theoretical and Practical Implications

W99:14 Ragnar Arnason: Economic Instruments to Achieve Ecosystem Objectives in Fisheries Management

W99:15 Ragnar Arnason: Property Rights as a Means of Economic Organization

W00:01 Jerry Coakley, Ana-Maria Fuertes and Gylfi Zoega: Testing the Persistence and Structuralist Theories of Unemployment

W00:02 Thrainn Eggertsson: Norms in Economics – With Special Reference to Economic Development

W00:03 Thorvaldur Gylfason: Growing Apart

W00:04 Jon Danielsson: The Emperor has no Clothes: Limits to Risk Modelling

W00:05 Thorolfur Matthiasson: The Icelandic Debate on the Case for a Fishing Fee: A Non-Technical Introduction

W00:06 Willem H. Buiter: Is Iceland an Optimal Currency Area?

W00:07 Alison L. Booth and Gylfi Zoega: Why do Firms Invest in General Training? 'Good' Firms and 'Bad' Firms as a Source of Monopsony Power

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W00:08 Eduard Hochreiter: "Exchange rate regimes and capital mobility: Issues and some lessons from central and eastern European applicant countries"

W00:09 Thorvaldur Gylfason: Fix or Flex? Alternative Exchange Rate Regimes in an Era of Global Capital Mobility

W00:10 Thorvaldur Gylfason: Natural Resources, Education and Economic Development

W00:11 Helgi Tomasson: Signal-noise Decomposition in Financial Markets: An Empirical Stochastic Process Analysis for Infrequent Trading

W00:12 Thorolfur Matthiasson: Changing Rules for Regulation of Icelandic Fisheries

W00:13 E. Tumusiime-Mutebile: Economic Reforms and their Impact in Uganda

W00:14 Sveinn Agnarsson: Productivity in Icelandic Fish Processing Industry 1985 – 1995: A Comparison of Methods

W00:15 Sveinn Agnarsson: Development of Efficiency in Icelandic Fish Processing Firms: A DEA Approach

W00:16 Jon Danielsson, Bjorn N. Jorgensen and Casper G. de Vries: Risk Management and Regulation in Incomplete Markets

W00:17 Ragnar Arnason, Gylfi Magnusson and Sveinn Agnarsson: The Norwegian Spring Spawning Herring Fishery: A Stylised Game Model

W00:18 Helgi Tomasson: Estimation of Correlations in Financial Markets when Trading is Infrequent

W00:19 Helgi Tomasson: Computations of Bayesian Estimators in ARMA Models

W00:20 Helgi Tomasson: Monitoring the trading intensity of a stock market under infrequent trading

W01:01 Tryggvi Thor Herbertsson: The Economics of Early Retirement

W01:02 Tryggvi Thor Herbertsson and J. Michael Orszag: The Costs of Early Retirement in the OECD

W01:03 Asta Herdis Hall and Solveig Frida Johannsdóttir: Generational Equality in Iceland

W01:04 Gylfi Zoega and Yu -Fu Chen: Exchange Rate Volatility as Employment Protection

W01:05 Tryggvi Thor Herbertsson and Gylfi Zoega: The Modigliani "Puzzle"

W01:06 Thorvaldur Gylfason: Lessons from the Dutch Dis ease: Causes, Treatment and Cures

W01:07 Tor Einarsson and Milton H. Marquis: Bank Intermediation over the Business Cycle

W01:08 Tor Einarsson and Milton H. Marquis: Bank Intermediation and Persistent Liquidity Effects in the Presence of a Frictionless Bond Market

W01:09 Tryggvi Thor Herbertsson, Edmund Phelps, and Gylfi Zoega: Demographics and Unemployment

W01:10 Tryggvi Thor Herbertsson: Shrinking Labour Forces and Early Retirement

W01:11 Sveinn Agnarsson: Open Access to a Cultural Heritage: An Economic Analysis of the SagaNet Project

W02:01 Tor Einarsson and Milton H. Marquis: Banks, Bonds, and the Liquidity Effect