Inside Money, Credit, and Investment

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Abstract

This paper presents a monetary explanation for several business-cycle facts: (i) household and business investment are procyclical, (ii) business investment lags household investment, (iii) household investment is positively correlated with M1, and (iv) household credit outstanding is positively correlated with and more volatile than household investment. We develop a dynamic general equilibrium model that features financial intermediaries accepting deposits and providing loans, credit-producing firms, and inside (bank-created) money. It is shown that the transmission of monetary shocks facilitated by credit and inside money creation is able to reconcile these real and monetary observations regarding the cyclical behavior of investment.

Keywords: Inside Money, Credit Creation, Consumer Durables, Business Cycles
JEL: C68, E39, G11

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1. Introduction

Recent research in business cycle theory has focused on capturing the observed cyclical behavior of fixed business investment and household investment (durables and residential). As documented by Kydland and Prescott (1990), Christiano and Todd (1996), Fisher (1997), and others, (i) household and business investment are positively correlated and procyclical; and (ii) business investment lags household investment over the cycle. While the emphasis of this recent literature has been on these *real* stylized facts, the co-movement of these investment series with monetary and credit aggregates reveals some corresponding *monetary* facts that have been largely unexplored. These are illustrated in impulse response plots to a standard deviation increase in the Federal Funds rate from a VAR analysis along the lines of Christiano et al. (1999).[1] Figure 1 shows that, consistent with Bernanke and Gertler (1995), household investment declines immediately to a monetary tightening while business investment declines after a lag. When extending this analysis to other variables, two other noteworthy observations emerge. First, household investment is contemporaneously correlated with M1 while business investment lags M1.[2] Second, the change in household credit outstanding is positively correlated with household investment and its response to a monetary tightening is noticeably larger. These observations are illustrated in Figures 2 and 3 by reporting the VAR responses to the same Federal Funds rate innovation. They suggest that monetary shocks may provide an important impulse in explaining these facts, and that the movements of inside money and credit creation may potentially play an important role in the propagation of these shocks.[3]

This paper provides an integrated explanation of these real and monetary observations in a model where financial intermediaries and the market for credit services play a central role in the monetary transmission mechanism. A standard limited participation framework, where agents choose portfolio decisions prior to observing monetary shocks (e.g. Fuerst,

[1] See the appendix for a description of the VAR estimation exercise, and the description and construction of the data set.

[2] It is found that correlations between household investment and M1 over postwar data were stronger than correlations between household investment and the monetary base (available on request), implying the largest correlations exist between household investment and *inside* money holdings.

[3] Gertler and Gilchrist (1995) take this idea a step further by supporting the notion that credit market imperfections play a role in monetary transmission.

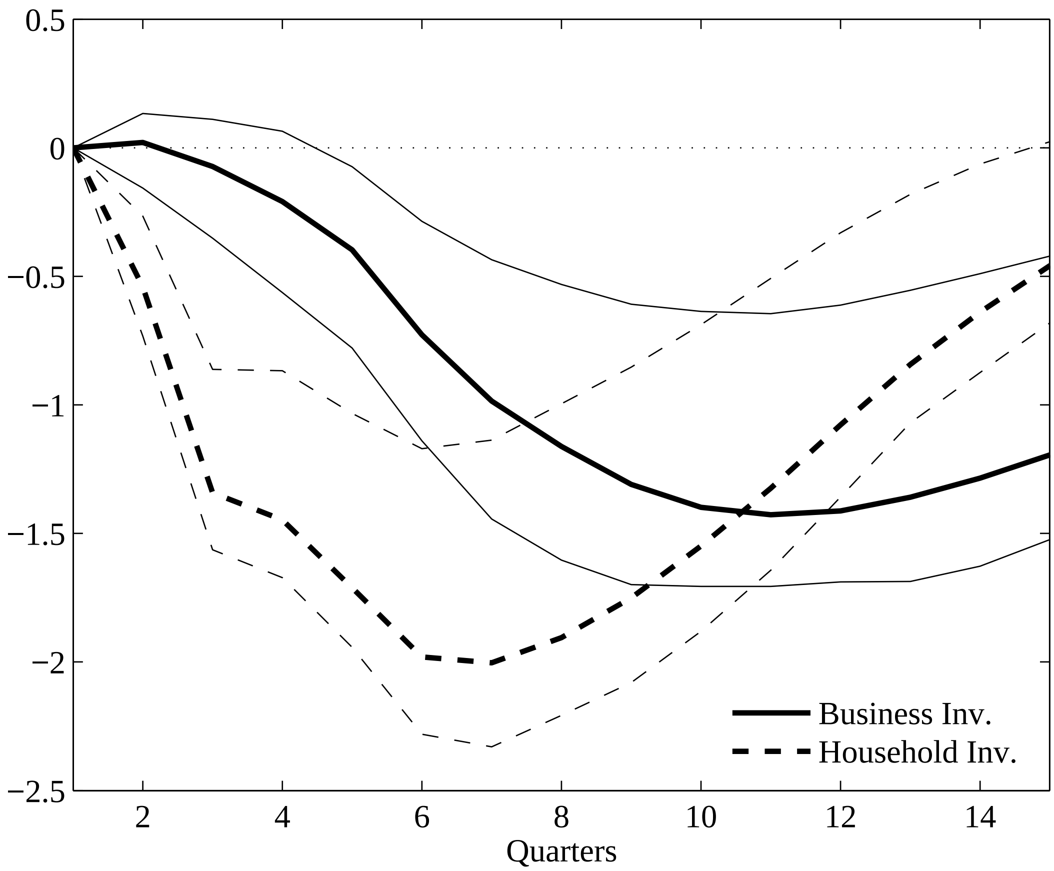

Figure 1: Response to a positive, one-standard deviation impulse to the Federal Funds rate. Narrow solid (dashed) lines denote a 90 percent confidence interval around the response of business (household) investment calculated via the bootstrap method.

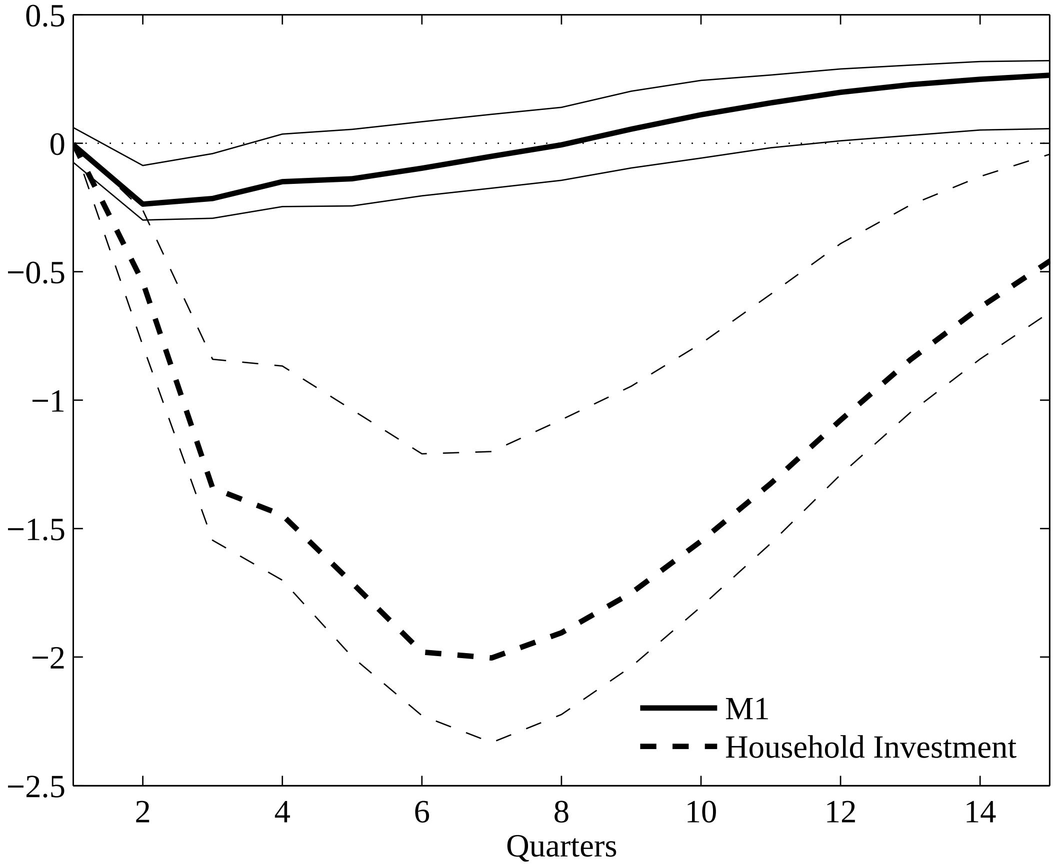

Figure 2: Response to a positive, one-standard deviation impulse to the Federal Funds rate. Narrow solid (dashed) lines denote a 90 percent confidence interval around the response of M1 (household investment) calculated via the bootstrap method.

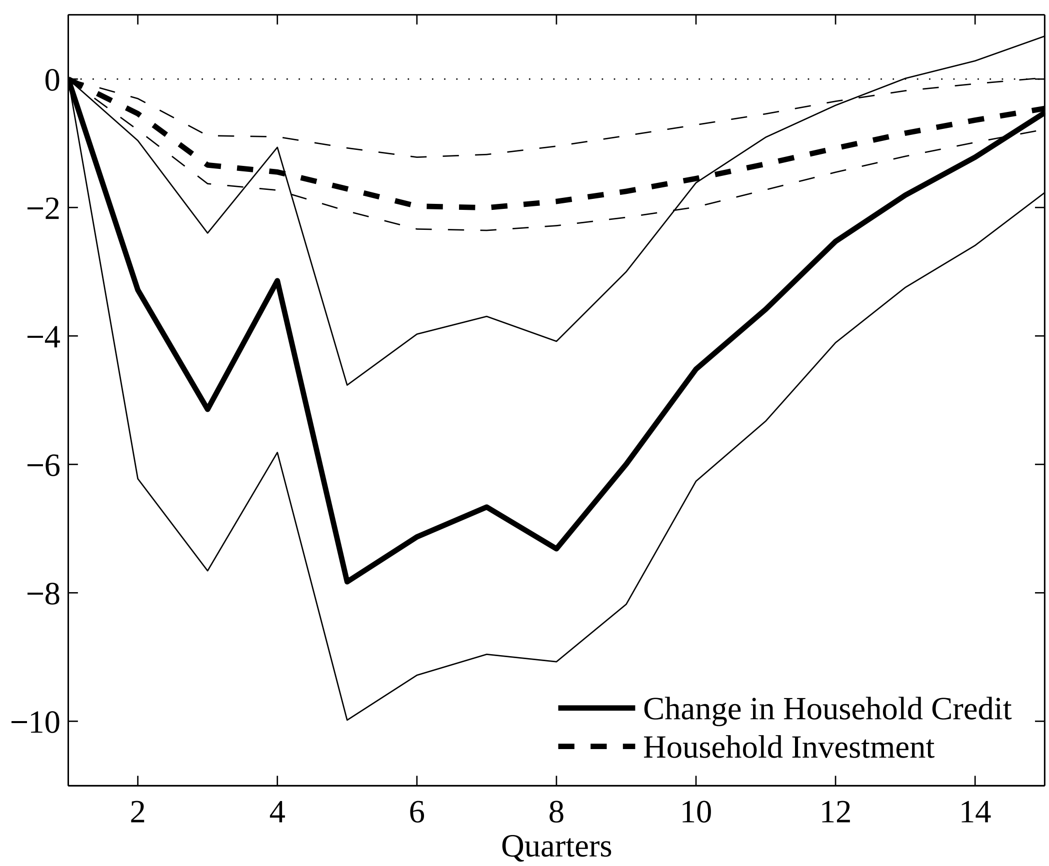

Figure 3: Response to a positive, one-standard deviation impulse to the Federal Funds rate. Narrow solid (dashed) lines denote a 90 percent confidence interval around the response of the change in household credit (household investment) calculated via the bootstrap method.

1992a and Christiano and Eichenbaum, 1995), is extended to include credit services as in Li (2000) and Chang and Li (2004), and endogenously determined monetary aggregates as in Dressler (2006). The model consists of a financial sector that provides credit services for households and firms, and financial intermediaries (i.e. banks) providing interest bearing deposit accounts to households and loanable funds to the producers of credit services. Households consume non-durable and durable goods financed with cash, deposits, and credit services while credit services are required to financed a portion of business investment. Intermediaries use household cash deposits as the reserve base for loanable funds provided to credit producing firms who use them to finance household and firm credit transactions within the period. These deposits also provide the model with the necessary inside money component of broad monetary aggregates.

It is shown that a model exhibiting these features is capable of capturing the observations detailed above in response to a monetary tightening. The intuition closely follows a textbook story of deposit contraction. With limited participation, a tightening asymmetrically drains cash reserves from the financial market, contracts overall deposits, and leads to an immediate decline in inside money and a (magnified) decrease in M1. Consequently, the supply of loanable funds to credit production falls and there is an increase in both the real price of credit services and the nominal interest rate. This negative liquidity effect leads to an immediate and sharp decline in household investment. However, there are two opposing effects on business investment. First, as a larger share of the increase in the relative price of credit falls on households, there is a substitution towards business capital. Second, anticipated deflation implies a quantitatively small but negative co-movement between the two investments and a decline in business investment. Hence, there is a gradual overall decline in business investment. In the subsequent period, anticipated deflation leads to a sharp rise in household capital and the movement in the relative prices of credit services crowds out business investment. This endogenously sluggish and lagged response of business investment following the monetary shock delivers the lead-lag behavior of the two investment series and does so in a manner consistent with their observed relation with household credit behavior and broader monetary aggregates.

In terms of the related literature, most attempts to account for the cyclical behavior of components of real investment have focused on real explanations. These include extensions to real business cycle models with home production (e.g. Benhabib et al., 1991) to include a protracted time-to-build technology on business capital, as in Gomme et. al. (2001) and treating household capital as a complementary input to market production, as in Fisher (2006). However, they do not address any of the monetary facts regarding these investment series by construction.[4]

The closest related study considering a monetary explanation to these facts is Chang and Li (2004). Their cash-in-advance economy demonstrated that an appropriately specified exogenous path for nominal interest rates can account for the dynamic path of both investment series. However, they lacked an explicit monetary transmission mechanism to account for such an interest rate path, leading to a countercyclical money supply over the cycle. The present framework delivers all observations mentioned above in a formally estimated model where monetary innovations endogenously determine nominal interest rates and the aggregate supply of inside money and credit. Since deposit creation plays a central role in the transmission of monetary policy, our analysis is also able to predict a contemporaneous movement in broad monetary aggregates.

Finally, the methodology used in this paper is related to Christiano et al. (2005) and their attempt to explain the dynamic responses of the US economy to a monetary shock. While they are able to identify model features and nominal frictions crucial to delivering persistent responses to a monetary shock, they do not consider credit markets, inside money, or household durables. We take a decidedly parsimonious approach and focus on these previously unconsidered features. Key parameters of the model are estimated by minimizing the distance between properties of the impulse responses of the VAR results outlined above and the impulse responses of the quantitative model. While ignoring nominal frictions results in a model which fails to deliver the degree of persistence observed in the data, the results ultimately stress the importance of financial intermediation, credit markets, and inside money in explaining key features of the data.

The paper is organized as follows. Section 2 presents the model and equilibrium. Section

[4]Although the focus of this analysis is the response of household and business investment to a monetary shock, it is shown that the model presented here also demonstrates that technology shocks can deliver the concurrence of the investment series as well as the procyclical behavior of M1.

3 presents the quantitative results. Section 4 concludes.

2. The Model

2.1. Environment Overview

The economy is populated by a large number of infinitely-lived households, good-producing firms, credit-producing firms, and financial intermediaries. All firms and intermediaries are assumed to be perfectly competitive.

Each identical household is endowed with an initial capital stock and one unit of time in every period. Households consume a continuum of non-durable consumption goods indexed by $j \in (0,1)$, a stock of durable goods $\left(c_t^d\right)$, and leisure in each period. A household's expected lifetime utility is expressed as

$$E_0 \sum_{t=0}^{\infty} \beta^t u \left[\min\left(\frac{c_{jt}}{2j}\right), c_t^d, n_t \right] \tag{1}$$

where c_{jt} is the consumption of non-durable good type j, and n_t is total work effort. The Leontief-type argument in (1) follows Freeman and Kydland (2000) and aides in the tractable analysis of a continuum of consumption goods (discussed below). The instantaneous function $u[.,.,.]$ is assumed to be increasing in its first two arguments, decreasing in its third argument, quasi-concave, twice continuously differentiable, and to satisfy the Inada conditions. E_0 is the expectation operator conditional on information available at time 0 and $\beta \in (0,1)$ is the discount rate.

Households can purchase durable and non-durable goods using cash, deposits, and credit. Cash goods require currency which is free to use, while deposits incur a real fixed cost γ for each *type* of good purchased. This can be interpreted as a check-clearing or identity-verification cost, and is independent of the amount of the good type purchased. Carrying out credit transactions require the purchase of household credit services q_t^h produced in the financial sector. The total quantity of goods purchased by households is given by $c_t + i_t^d$ where i_t^d denotes the investment flow of durables at period t. The evolution of durable consumption goods is given by

$$F\left(i_t^d, i_{t-1}^d\right) = c_{t+1}^d - \left(1 - \delta^d\right) c_t^d, \tag{2}$$

where $F\left(i_t^d, i_{t-1}^d\right)$ has the potential to deliver frictions with respect to adjustments in the flow of durable goods as in Christiano et al. (2005), and $\delta^d \in (0,1)$ is the depreciation rate of durable consumption. The analysis considers versions of the model with and without investment frictions.

Firms in the goods-producing sector employ capital (k_t) and labor (n_{1t}) to produce output Y_t according to a CRS production technology: $Y_t = f\left(k_t, n_{1t}\right)$. As in the case of consumer durables, capital evolves according to

$$F\left(i_t^k, i_{t-1}^k\right) = k_{t+1} - \left(1 - \delta^k\right) k_t, \tag{3}$$

where i_t^k denotes capital investment in period t and $\delta^k \in (0,1)$ is the depreciation rate of physical capital.[5]

Similar to household credit goods, a portion of capital investment can be financed by firm credit services q_t^f produced in the financial sector. Firms in the credit producing sector employ labor $n_{2t} = n_{ht} + n_{ft}$ and produce household and firm credit services according to $q_t^h = Q^h\left(n_{ht}\right)$ and $q_t^f = Q^f\left(n_{ft}\right)$, respectively.[6]

Financial intermediaries accept cash deposits from households and provide them with check writing services. In addition, financial intermediaries supply loans to credit producing firms which are assumed to entirely finance their household and firm credit purchases with these funds. An intermediary is required to keep a certain fraction θ of its total deposits in currency reserves. Given this restriction, an intermediary issues loans through a deposit-creation technology by first issuing a deposit in the desired loan amount. This implies that all cash deposits from households are combined with a monetary injection X_t from the monetary authority and serve as a cash reserve base for a much larger amount of deposits

[5] This is the investment friction explicitly used by Christiano et al. (2005), since their model does not consider consumer durables.

[6] Modeling the explicit production of credit services follows Aiyagari and Eckstein (1996).

(which are also considered loans to credit producing firms). The monetary injection follows $X_t = M_t - M_{t-1}$ where M_t is the end-of-period t nominal money supply (the monetary base). It evolves according to $M_t = \mu_t M_{t-1}$ where μ_t is the stochastic money growth rate between periods $t-1$ and t, and $\mu_t = (1-\rho)\,\bar{\mu} + \rho\mu_{t-1} + \varepsilon_t$ with $\bar{\mu} > 0$, $\rho \in [0,1)$, and $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$.

As is standard in the liquidity effects literature, the interactions in the economy involve a representative family consisting of a worker / shopper pair, a goods producing firm, a credit producing firm, and a financial intermediary. Monetary injections occurring through the financial sector will be asymmetric within the family, but will be symmetric across families after reuniting and pooling their cash receipts prior to the end of a period. Given this structure, the timing of events within a period proceeds as follows. The family begins with amounts of capital k_t, consumer durables c_t^d, currency m_{t-1}, and deposits d_{t-1}. *Before* the current period's monetary injection is observed, the family chooses new currency holdings m_t and deposits d_t of cash into the financial intermediary and then separates. The monetary injection X_t is then realized and the financial intermediary now has cash reserves from the monetary authority and the depositing agents. The worker travels to the labor market and supplies n_t total labor hours in both the goods and financial sector in exchange for nominal wage W_t. Goods and credit services are then produced using n_{1t}, n_{ht}, n_{ft}, and k_t according to their respective production functions.

After production takes place, the shopper travels to the financial sector to purchase a given amount of credit services at price P_{ht}, and then travels to the goods market to purchase durable and non-durable consumption goods at price P_t with cash, deposits, and credit. In addition, firms purchase investment goods i_t^k from the goods market at price P_t. It is assumed that a fraction κ of these goods must be financed with credit services purchased from credit producers at price P_{ft}. These credit purchases, q_t^h and q_t^f, must be financed with loans from the financial intermediary.

These interactions deliver several constraints on the behavior of the goods producing firms, credit producers, financial intermediaries and shoppers. Since good producing firms are required to finance a fraction of their investment purchases, their finance constraint is given by

$$P_t q_t^f \geq \kappa P_t i_t^k. \tag{4}$$

Since credit producing firms are required to finance their credit services with nominal loans L_t, their finance constraint is given by

$$L_t \geq P_t \left[Q^h \left(n_{ht} \right) + Q^f \left(n_{ft} \right) \right]. \tag{5}$$

Letting B_t and Θ_t denote loans and reserve holdings of the financial intermediary, a required reserve constraint and a balance-sheet constraint for a given amount of deposits D_t are given by

$$\Theta_t \geq \theta D_t, \tag{6}$$

$$B_t + \Theta_t = D_t. \tag{7}$$

Finally, since m_t and d_t are chosen and spent in the present period, a shopper's money balance conditions take the form

$$\tau m_t \geq \int_{J(m)} P_{jt} c_{jt} dj \tag{8}$$

$$\tau d_t \geq \int_{J(d)} P_{jt} c_{jt} dj + P_t \left(i_t^d - q_t^h \right) \tag{9}$$

where P_{jt} is the price of non-durable consumption good j, and $J(\cdot)$ is a notation for the measure of non-durable consumption good types purchased with each type of money balance.

Conditions (8) and (9) make two assertions. First, households purchase non-durables with either currency or deposits, while durables are purchased with either deposits or credit. This is done primarily for simplifying the model with multiple means of payment, and does not influence the quantitative results since durables and non-durables both sell at price P_t (discussed below). Second, there is a fixed velocity of both currency and deposits given by τ. This departure from endogenous velocity as in Dressler (2006) and Freeman and Kydland (2000) is necessary in order to have a meaningful liquidity effect. For example, if velocity were chosen after the monetary injection was observed, then total deposits spent within the period could effectively respond after the shock allowing the environment to reduce to one where nominal shocks are completely neutral. Nonetheless, the fixed velocity component of these constraints could also be interpreted as solvency conditions set forth by the commercial bank as in Balke and Wynne (2000).

At the end of the period, the family reunites and consumes. All loans (between households, credit producers, goods producers, and the financial intermediary) are repaid and the family pools its currency and deposits and enters period $t+1$. This delivers a family budget constraint given by

$$\left[W_t n_t + d_{t-1} + m_{t-1} - \int_J P_{jt} c_{jt} dj - P_t i_t^d - P_{ht} q_t^h - m_t - \frac{d_t}{R_t^D} - P_t \gamma\left(J\left(d\right)\right)\right] +$$

$$\left[R_t^L B_t - R_t^D \left(D_t - X_t\right) + \Theta_t\right] +$$

$$\left[P_t f\left(k_t, n_{1t}\right) - W_t n_{1t} - P_t i_t^k - P_{ft} q_t^f\right] +$$

$$\left[P_{ht} Q^h\left(n_{ht}\right) + P_{ft} Q^f\left(n_{ft}\right) - W_t\left(n_{ht} + n_{ft}\right) - \left(R_t^L - R_t^D\right) L_t\right] \geq 0. \tag{10}$$

The first bracketed expression represents the budget of the worker / shopper, the second is the profits of the financial intermediary, the third is the profits of the goods producing firm, and the fourth is the profits of the credit producer net of financing. There are two prominent items to note from (10). First, present money balances (m_t and d_t) appear in the first bracketed expression, indicating that they bring those money balances into next period. Second, since loans to credit producers are issued by creating deposits, the amount L_t in the fourth bracketed expression is charged a loan rate R_t^L while the deposit for the same amount is paid R_t^D.

2.2. Equilibrium

A statement of the family's problem and a competitive equilibrium gets simplified by considering the household's non-durable consumption decision for each good of type j. Given a desired level of total non-durable consumption over *all* good types, c_t^*, the Leontief argument in (1) induces agents to follow an optimizing rule when distributing c_t^* over the j types,

$c_{jt} = 2jc_t^*$. Substitution of this rule delivers a standard objective function.

$$E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t^*, c_t^d, n_t\right) \tag{11}$$

Now consider the composition of money balances (currency and deposits) needed to purchase c_t^*. For every c_{jt}, a household must decide whether deposits or currency should be used to facilitate the purchase. Deposits pay interest at the end of the period, but incur a transactions cost for their use. Since households are required to bring portions of both money balances into the next period, the optimal composition can be analyzed by comparing the real opportunity cost of purchasing c_{jt} with currency (c_{jt}/τ), and deposits $\left(c_{jt}/\tau R_t^D + \gamma\right)$.[7] Comparing these costs and rearranging yields the relation

$$\frac{1}{R_t^D} + \frac{\gamma\tau}{2jc_t^*} \lesseqgtr 1, \tag{12}$$

where the left (right)-hand side is the normalized opportunity cost to using deposits (currency). Note that the left-hand side of (12) is decreasing in j; the opportunity cost associated with using deposits for purchasing consumption approaches infinity as j approaches zero. This implies that there is a critical good type j^* such that the opportunity costs to purchasing c_{j^*t} with either money balance are equal, and every good type indexed by $j < (>)\, j^*$ will be purchased with currency (deposits).[8] The remainder of the analysis concentrates on the case where $j^* < 1$.

Substituting j_t^* and c_t^* into (8), (9), and (10) result in simpler expressions of the constraint set. The family's problem can now be stated as choosing an optimal sequence $\{k_{t+1}$, c_{t+1}^d, i_t^k, i_t^d, d_t, m_t, c_t^*, j_t^*, n_t, n_{1t}, n_{ht}, n_{ft}, q_t^h, q_t^f, L_t, B_t, D_t, $\Theta_t\}$ to maximize (11) subject to (2) - (7),

$$\tau m_t \geq P_t j_t^{*2} c_t^*, \tag{13}$$

$$\tau d_t \geq P_t \left(1 - j_t^{*2}\right) c_t^* + P_t \left(i_t^d - q_t^h\right), \tag{14}$$

[7] These costs represent the total amount of wealth which cannot be held in the return-dominating capital asset due to the decision to hold m_t and d_t in nominal assets across periods t and $t+1$.

[8] The preferences can now be seen as an alternative to those used in standard cash / credit - type models which allow for the choice of 'cash' and 'deposit' good proportions through the choice of j_t^*.

and

$$
\begin{aligned}
&\left[W_t n_t + d_{t-1} + m_{t-1} - P_t c_t^* - P_t i_t^d - P_{ht} q_t^h - m_t - \frac{d_t}{R_t^D} - P_t \gamma \left(1 - j_t^*\right)\right] + \\
&\left[R_t^L B_t - R_t^D \left(D_t - X_t\right) + \Theta_t\right] + \left[P_t f\left(k_t, n_{1t}\right) - W_t n_{1t} - P_t i_t^k - P_{ft} q_t^f\right] + \\
&\left[P_{ht} Q^h\left(n_{ht}\right) + P_{ft} Q^f\left(n_{ft}\right) - W_t\left(n_{ht} + n_{ft}\right) - \left(R_t^L - R_t^D\right) L_t\right] \geq 0.
\end{aligned} \tag{15}
$$

Letting λ_t denote the multiplier on (15), the efficiency conditions of the family's optimal decisions of d_t, m_t, c_{t+1}^d, and k_{t+1} are given by

$$
E_{t-1}\left[\lambda_t\left(\frac{1}{R_t^D} - \frac{P_{ht}}{P_t}\right)\right] = \beta E_{t-1}\left[\frac{\lambda_{t+1}}{\pi_t}\right] \tag{16}
$$

$$
E_{t-1}\left[\lambda_t\left(1 - \tau\frac{\gamma}{2 j_t c_t^*} - \tau\frac{P_{ht}}{P_t}\right)\right] = \beta E_{t-1}\left[\frac{\lambda_{t+1}}{\pi_t}\right] \tag{17}
$$

$$
\lambda_t\left(1 + \frac{P_{ht}}{P_t}\right) = \beta E_t\left[u_{2,t+1} + \left(1 - \delta^d\right)\left(1 + \frac{P_{ht+1}}{P_{t+1}}\right)\lambda_{t+1}\right] \tag{18}
$$

and

$$
\lambda_t\left(1 + \kappa\frac{P_{ft}}{P_t}\right) = \beta E_t\left[\lambda_{t+1}\left(f_{1,t+1} + \left(1 - \delta^k\right)\left(1 + \kappa\frac{P_{ft+1}}{P_{t+1}}\right)\right)\right] \tag{19}
$$

where $u_{2,t+1}$ and $f_{1,t+1}$ denote derivatives of the instantaneous utility and good production functions with respect to the relevant argument, $\pi_t = \frac{P_{t+1}}{P_t}$, and the multiplier is equated to the marginal value of an additional unit of non-durable consumption, net of financing and transaction costs,

$$
\lambda_t = u_{1t}\left[1 + \frac{P_{ht}}{P_t} + \frac{\gamma j_t}{2 c_t^*}\right]^{-1}. \tag{20}
$$

Equations (16) and (17) equate the expected marginal costs of holding money balances with the expected benefits of having additional money balances in the following period. The marginal costs for money balances are both net of their respective returns and costs of use, while the marginal benefits are both dependent on the expected value of nominal balances. Equations (18) and (19) equate the marginal cost of an additional unit of consumer durables and physical capital with its expected future benefit, respectively. The item worth noting about these last two efficiency conditions is that the marginal cost is directly related to the present relative price of credit. The higher the price of credit, the higher the marginal cost of investment relative to the expected marginal benefit. These relative prices turn out to be a driving force in the dynamics of the model and will be discussed in the following section.

The model is closed by the clearing of the various markets. Clearing of the labor market requires that all labor supplied by the household must be demanded by the goods or credit producing firms.

$$n_t = n_{1t} + n_{ht} + n_{ft} \tag{21}$$

Good market clearing requires that all production is either consumed, invested, or used to settle transaction costs.

$$f\left(k_t, n_{1t}\right) = c_t^* + i_t^d + i_t^k + \gamma\left(1 - j_t^*\right). \tag{22}$$

After the monetary injection, the financial intermediary has $d_t/R_t^D + X_t$ in cash reserves. Positive nominal interest rates imply that the financial intermediary will hold minimum required reserves ($\Theta_t = \theta D_t$), which together with the clearing of the loan market ($B_t = L_t$) imply

$$D_t = \frac{1}{\theta}\left(\frac{d_t}{R_t^D} + X_t\right), \tag{23}$$

$$L_t = \frac{(1-\theta)}{\theta}\left(\frac{d_t}{R_t^D} + X_t\right). \tag{24}$$

Holding minimum reserves and perfect competition further imply that the deposit rate is a convex combination of the asset rates it receives, $R_t^D = (1-\theta) R_t^L + \theta$.

The clearing of the currency market requires that the monetary base equals the currency held by the households and commercial banks at the end of the period.

$$M_t = m_t + d_t \tag{25}$$

The total stock of money ($M1_t$), is defined to be the sum of the monetary base and the entire stock of deposits.

$$M1_t = M_t + R_t^D D_t = M_t \left[1 + \frac{\left(d_t + R_t^D X_t\right)}{\theta\left(m_t + d_t\right)} \right] \tag{26}$$

The third expression uses (23) and (25) to express the total stock of money as the product of the base and the endogenously determined money multiplier.

A competitive equilibrium is defined as a list of prices $\left\{R_t^L, R_t^D, W_t, P_t, P_{ht}, P_{ft}\right\}_{t=0}^{\infty}$ and allocations $\{k_{t+1},\, c_{t+1}^d,\, i_t^k,\, i_t^d,\, d_t,\, m_t,\, c_t^*,\, j_t^*,\, n_t,\, n_{1t},\, n_{ht},\, n_{ft},\, q_t^h,\, q_t^f,\, L_t,\, B_t,\, D_t,\, \Theta_t\}_{t=0}^{\infty}$ such that a family maximizes (11) subject to their constraint set and all markets clear.

3. Quantitative Results

The dynamic properties of the model are ultimately dependent upon the parameter values. The parameters are partitioned into two groups and determined via a combination of estimation and calibration. The parameters η, ρ, and $\varkappa$ are estimated to match particular dynamic properties of the impulse responses of household and business investment from the model with those illustrated in Figure 1 (see Lee and Ingram, 1991). The remaining parameters are calibrated so the resulting steady-state of the model matches particular long-run properties of the US economy. The remainder of this section discusses the functional form assumptions, the estimation and calibration of each parameter group in detail, and concludes with the quantitative properties of the model and a sensitivity analysis.

3.1. Functional Forms Assumptions

The utility function (11) is assumed to take the form

$$u\left(c_t^*, c_t^d, n_t\right) = \upsilon \ln\left(c_t^*\right) + (1-\upsilon)\varsigma \ln\left(c_t^d\right) + A\left(1-n_t\right).$$

Production in the goods market is standard Cobb-Douglas, $k_t^\alpha n_{1t}^{1-\alpha}$, while the functional forms for credit production are assumed to be $q_t^e = \phi_e n_{et}^\eta$ for $e = \{h, f\}$.

Finally, investment adjustment costs stated in (2) and (3) are taken from Christiano et al. (2005) and given by

$$F\left(i_t^e, i_{t-1}^e\right) = \left(1 - S\left(\frac{i_t^e}{i_{t-1}^e}\right)\right) i_t^e \text{ for } e = \{d, k\},$$

where the function S satisfies the following properties: $S(1) = S'(1) = 0$, and $S''(1) = \varkappa \geq 0$. Given our solution procedure, no other features of the function S need to be specified for our analysis.

3.2. Calibration and Estimation of the Parameters

While the steady state of the model is independent of $\varkappa$, it is dependent on η. Estimating the model with and without investment costs lead to slightly different values of η which imply different values for several of the calibrated parameters. In particular, these parameters are those associated with credit production $\left(\phi_h, \phi_f\right)$ and leisure (A). These parameters depend upon η because total labor (n_t) is restricted so the representative household's average allocation of time devoted to market activity (net of sleep and personal care) is one-third as estimated by Ghez and Becker (1975), and the model's average fraction of total credit purchased by firms is 0.57.[9] The remaining parameters are independent of η and are determined for both versions of the model according to the business cycle literature (e.g. Cooley and Hansen, 1989) and so the resulting steady-state of the model matches particular long-run properties of the US economy. Capital's share parameter α is set to 0.36, depreciation rates

[9]Source: Federal Reserve Bulletin, Feb. 1997, Table I.26, Assets and Liabilities of Large Commercial Banks, Loans and Leases in Bank Credit, commercial and industrial; consumer.

δ^k and δ^d are both set to 10 percent annually, and the discount parameter β is set to 0.9855. This discount parameter results in an effective gross return on physical capital of roughly 6 percent annually, which is slightly higher than standard calibrations because of the added credit costs visible in (19). The steady-state average money growth rate and nominal deposit rate are set to 3 percent annually.

The utility parameters $\upsilon = 0.1$ and $\varsigma = 0.0745$ are calibrated so the average ratio of consumer non-durables to durables is roughly 2.5 as in US data (source: Federal Reserve Bank of St. Louis). The parameter κ is calibrated to 0.8388 so the ratio of consumer durables to physical capital is 1.13 as estimated by Greenwood and Hercowitz (1991). Finally, the parameters γ and τ are calibrated to 0.0066 and 1.0781 so the average deposit-currency ratio is 0.9.[10] These parameter values result in a value added of the banking sector of 2.3 percent which is consistent with the findings of Diaz-Gimenez et al. (1992).

One parameter which deserves individual attention is the required reserve ratio θ. This parameter is important because it determines the size of the deposit multiplier, which from (23) is given by $1/\theta$. To see the importance of this multiplier, a value in line with US reserve ratios of $\theta = 0.15$ implies that a one dollar reduction of cash reserves require the financial intermediary to reduce deposits by an additional 5.5 dollars. In our quantitative experimentations, we find that a monetary tightening with this level of required reserves results in an excessive decline in aggregate prices and an *increase* in non-durable consumption. Primary reasons for this outcome are the simplifying assumptions of credit production having to be entirely financed, that financial intermediaries hold minimum required reserves creating the maximum possible amount of deposits, and linear loan-creation technology forming a direct link between deposit and lending rates. To avoid complicating the model with deposit creation frictions or technologies requiring excess reserve holdings as in Chari et al. (1995), or monopolistically competitive financial intermediaries, we set $\theta = 0.5$. A sensitivity analysis at the end of this section illustrates that $\theta = 0.15$ still allows us to explain the dynamic behavior of household and business investment despite the counterfactual observation of non-durable consumption.

[10] This ratio is determined considering the amount of US currency held abroad ranges between two-thirds to three-quarters of the total currency base (see Porter and Judson, 1996). This ratio is exactly that used by Freeman and Kydland (2000) and Dressler (2006).

With the calibrated parameters pinned down, the remaining parameters are estimated by minimizing the dynamic correlations between the impulse responses of household and business investment from the model and those illustrated in Figure 1. While this estimation procedure is similar in spirit to Christiano et al. (2005), the present model fails to incorporate many features considered necessary to display persistent responses to monetary policy shocks.[11] In particular, the estimation procedure focuses on the contemporaneous correlations of the two investment paths (0.21), and the correlations between business investment and household investment at one lead (0.46), and one lag (-0.24). These three correlations were chosen to depict the dynamic response of the two investment paths without attempting to obtain persistent responses from this simplified model.[12] With three empirical moments comprising our goal, the procedure allows estimation of up to two parameters while preserving at least one degree of freedom. Version 1 of the model removes investment frictions $(\varkappa = 0)$, and the parameters to be estimated are η and ρ. Version 2 of the model maintains the value of ρ from the previous estimation, and the parameters to be estimated are η and $\varkappa$. It should be noted that in the model, the values of η and $\varkappa$ are assumed to be shared among credit production and investments frictions, respectively. While this facilitates the estimation of these parameters, the technologies and frictions are all given equal footing in matching the selected dynamics of interest. In other words, the results presented below are not a result of credit productions having differing marginal products of labor or differing investment frictions.

3.3. Estimation and Model Results

The first column of numbers in Table 1 are the estimates and resulting parameter values corresponding to Version 1 of the model without investment frictions. The final column

[11] Christiano et al. (2005) conclude that model features such as Calvo-style wage contracts and habit persistence in nondurables are necessary for obtaining a persistent real response to a monetary policy shock.

[12] Let Ψ denote a vector of correlations calculated from data, and $\Psi(\Theta)$ denote the corresponding correlation vector calculated from a simulation of the model where Θ denotes a vector of parameters to be estimated. The parameter vector delivered by the SMM procedure is that which minimizes

$$(\Psi(\Theta) - \Psi)' \Sigma^{-1} (\Psi(\Theta) - \Psi),$$

where Σ^{-1} is a weighting matrix that corresponds to the inverse of the variance-covariance matrix of Ψ and was computed as suggested by Newey and West (1987).

Table 1: Estimation Results

	Version 1	Version 2
η	0.6659 (0.1251)	0.7926 (0.1339)
$\varkappa$	0	0.0033 (0.0018)
ρ	0.3339 (0.0605)	0.3339
$\chi(1)$	2.2752	0.0009
Resulting Parameters		
A	0.3388	0.3400
ϕ_h	33.783	72.296
ϕ_f	4.942	7.448

Note: Asymptotic std. errors are in parentheses.

reports the estimation results of Version 2 of the model with $\varkappa > 0$. These values are used to solve the decision rules of the representative family (see Christiano, 2002). Before discussing the model's dynamics, it is worth noting that the estimates for η and ρ from Version 1 are significant and strikingly similar to previously reported results. In particular, Aiyagari and Eckstein (1996) find average labor's share of aggregate credit production in the US economy to be 0.65, while Fuerst (1992a) and Christiano (1991) both set $\rho = 0.32$ in their numerical analyses.[13] For Version 2, the estimates indicate that a very small amount of investment friction improves the overall quality of the results as determined by the smaller chi-square statistic relative to Version 1.

3.3.1. Benchmark Cases

To better understand the model features driving our quantitative results, we consider two benchmark cases. First, the model is considered without the limited participation constraint (NLP). This implies that currency holdings m_t and deposits d_t are chosen after the realization of the monetary shock. Second, the limited participation model is considered with an i.i.d. money growth rate process (IID). The NLP model will allow us to isolate the anticipated inflation effect of monetary shocks, while the IID case will allow us to isolate the pure liquidity effects. Quantitatively, the cyclical responses of our general model to a

[13] Aiyagari and Eckstein model aggregate credit production as a Cobb-Douglas technology which takes labor, and credit specific capital (indexed by aggregate capital) as inputs.

persistent monetary shock will embody both of these effects.

The impulse responses to a one percent monetary tightening for the NLP model in period $t = 2$ are illustrated in Figure 4.[14] All nominal variables have been normalized by the end-of-period base money supply. For NLP, as cash reserves are drained from intermediaries, household deposits respond positively to equate the marginal value of cash across the goods and financial markets. The nominal interest rate follows Fisherian fundamentals and declines from the anticipated deflation effect. The decline in the aggregate price level indicates an increase in real balances. The decrease in the real cost of cash transactions decreases household demand for credit services and the additional non-durable consumption and household investment expenditures is financed with the increase in currency and deposit usage. Employment in goods production and aggregate output rises. Finally, notice that this version of the model predicts a negative co-movement between business and household investment. That is, business investment expenditures are crowded out by the additional spending on both household investment and non-durable consumption.[15] While household investment is procyclical, the model fails to capture the dynamic correlations between the two investment series and has counterfactual predictions for the co-movement between M1 and nominal interest rates, non-durable consumption and real output.

The impulse response plots for the IID model are given in Figure 5.[16] The liquidity effect drains cash reserves and nominal rates rise, M1 declines in the period of the shock, and there is a decline in output. There is a disproportionate increase in the relative price of household credit services and a substitution away from household credit production and towards firm credit production. Household consumption of non-durables and durable investment declines while business investment rises in the period of the shock. Hence the IID case of our model reaches an opposite conclusion regarding the cyclical behavior of the two investments compared to NLP. That is, while there continues to be a negative co-movement between household and business investment, business investment is now countercyclical. Most of the

[14]The NLP model uses the parameter estimates reported for version 1 of the model. The NLP model was attempted to be estimated separately, but this attempt failed because the counterfactual movement of the investment series (see Figure 4) cannot be corrected by varying the estimated variables.

[15]This feature can also be seen from the efficiency condition for business investment in Equation (19) which embodies an inverse relationship between consumption growth (i.e. the real interest rate) and firm capital accumulation along the optimal path.

[16]Similar to the NLP analysis, the Version 1 estimate of η was used (see previous footnote).

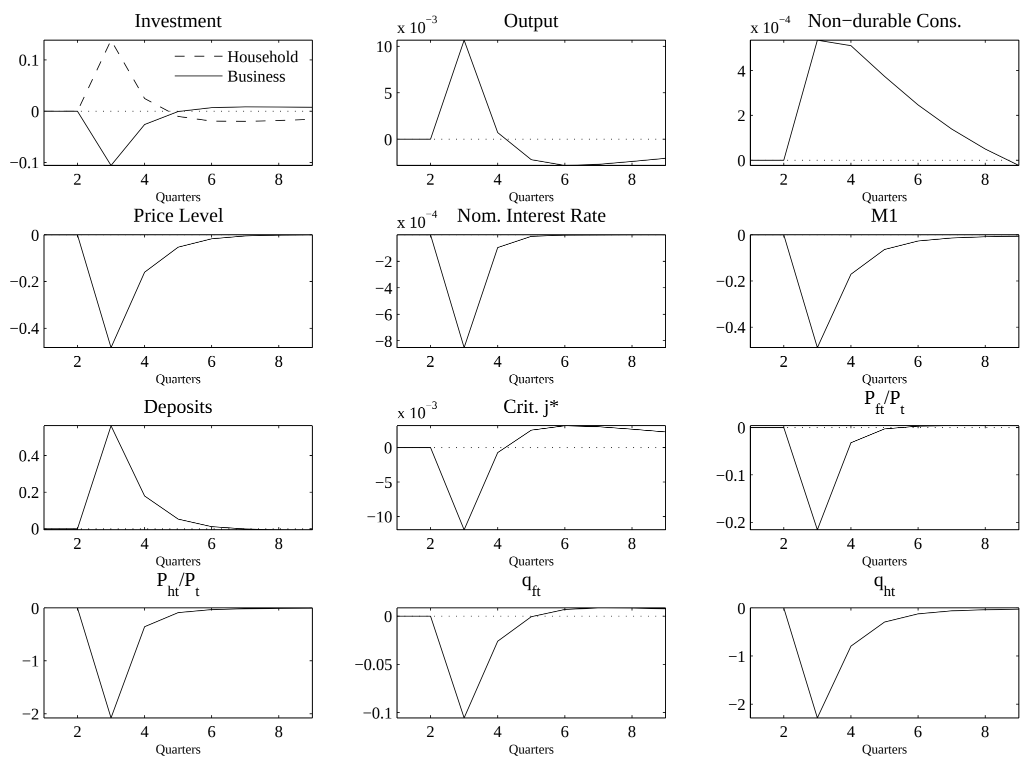

Figure 4: Impulse responses from a negative monetary shock; without limited participation assumption. Y-axis denote percentage change from steady state.

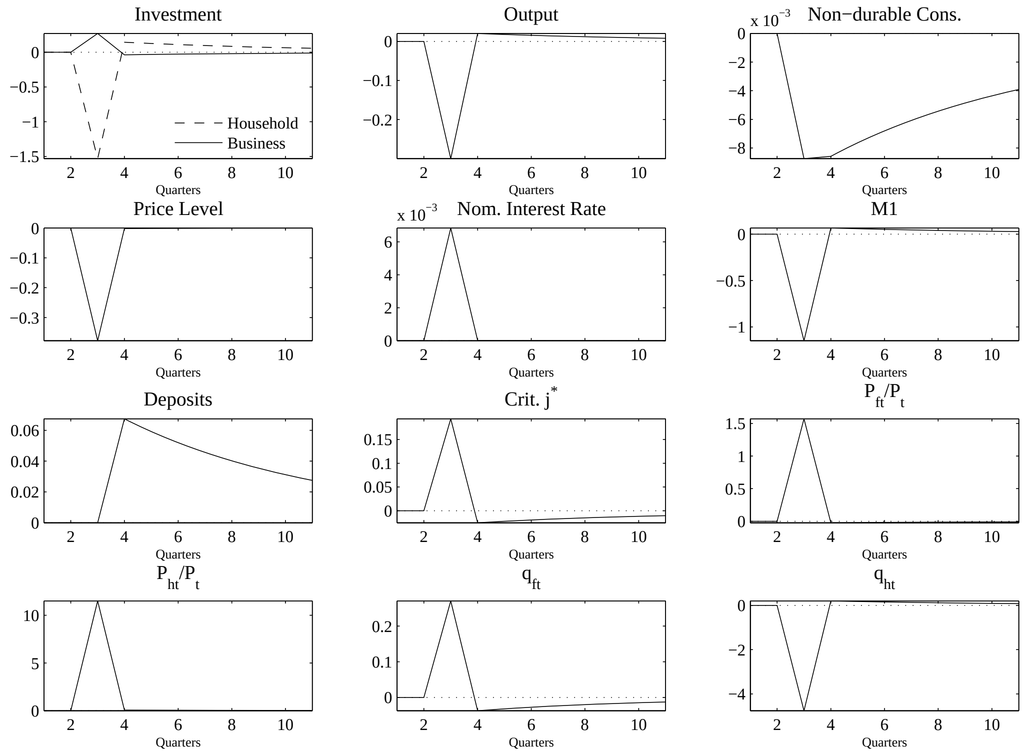

Figure 5: Impulse responses from an iid negative monetary shock. Y-axis denote percentage change from steady state.

real effects of the negative monetary innovation dissipates in the period following the shock as household deposits are adjust to the unanticipated shock.

3.3.2. The General Case

The previous exercises illustrated that a monetary contraction that creates either an anticipated deflation effect *or* a liquidity effect is unable to account for the real or monetary facts regarding the two investment series. We now return to our general model and investigate whether the interaction between limited participation and a persistent monetary innovation can improve the model's predictions. Impulse responses to a one percent monetary tightening for versions 1 and 2 of the model are illustrated in Figures 6 and 7. With the exception of firm credit production and business investment, the responses qualitatively resemble the IID case in the period of the shock. Again, the monetary tightening at period

$t = 2$ immediately drains cash reserves from financial intermediaries and we see an immediate decline in M1. The negative liquidity effect drives nominal rates are driven upwards and the resulting contraction in the supply of credit increases in the relative prices of credit services. This leads to a decline in the quantity of both household and firm credit services, $q^h$and q^f. As consumer durables can only be financed with deposits and household credit, constraint (14) implies that the decline in q^h must be associated with a decrease in both non-durable and durable consumption and constraint (13) states that a greater portion of real non-durable consumption will be financed with cash. As business investment also responds negatively to the higher price of firm credit, there is a positive co-movement between the two investments. Furthermore, similar to the IID case, there is again a disproportionate impact on the relative price of household credit, the decline in household investment exceeds that of business investment. The decline in overall output indicates their procyclical behavior.[17]

In the period after the shock, household deposits increase and the anticipated deflation effect drives the nominal interest rate and the relative price of credit below their steady state values. M1, the normalized price level, and household credit production all move back towards steady state. Subsequent movements in output, employment in goods production, the nominal rate, the relative price of credit, and the two investment series resemble those in the NLP model (see Figure 4). This is not surprising as the liquidity effect is only present in the initial period of the shock. The exceptions are household credit production which continues to rise, and non-durable consumption which continues to fall. Note that contrary to what happens in NLP, household deposits and M1 both increase in the period after the shock. This reinforces the increased availability of loanable funds to credit producers and goes disproportionately to household credit production. The boom in household investment is financed with the additional credit services and deposits at the expense of slightly less non-durable consumption.[18] Hence the economy's investment resources shift towards household investment and business capital is crowded-out. This negative co-movement between the

[17]As the increase in the relative price of household credit services exceeds that of firm credit, the model displays a sharper decline in household investment consistent with Figure 1. The effect of increases in the marginal cost of household investment relative to firm investment can be seen in equations (18) and (19).

[18]The reallocation of deposits to finance household investment can be seen by noting that in the period after the shock, household investment rises above steady state while non-durable consumption continues to decline and household credit production remains below steady state.

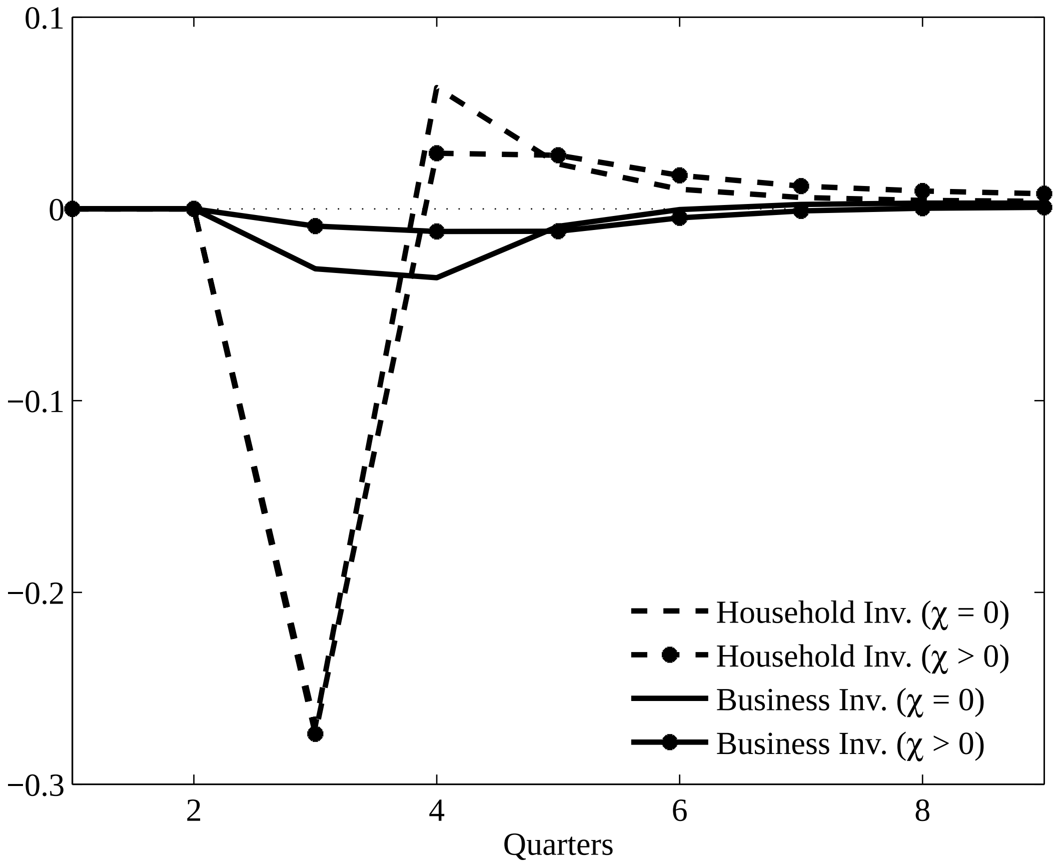

Figure 6: Impulse response to a negative monetary shock; limited participation. Y-axis denotes percentage change from steady state. Version 1 of the model assumes $\varkappa = 0$, while Version 2 of the model assumes $\varkappa > 0$.

two investments in the period after the shock captures the protracted and lagged response of business investment to household investment and M1 as in the data.

The impulse responses for Version 2 of the model with $\varkappa > 0$ only change in two significant ways relative to Version 1. First, there is more persistence in the investment series at the expense of a smaller initial impact. This is also apparent in the behavior of labor hours spent in credit production. Second, the large initial decline in durables investment incurs a cost which alters the amount of wealth a household can devote to non-durable consumption, resulting in a much sharper decline. Otherwise, the dynamic response to nominal interest rates, deposits, M1, and all aggregate and relative prices show little quantitative changes relative to Version 1.

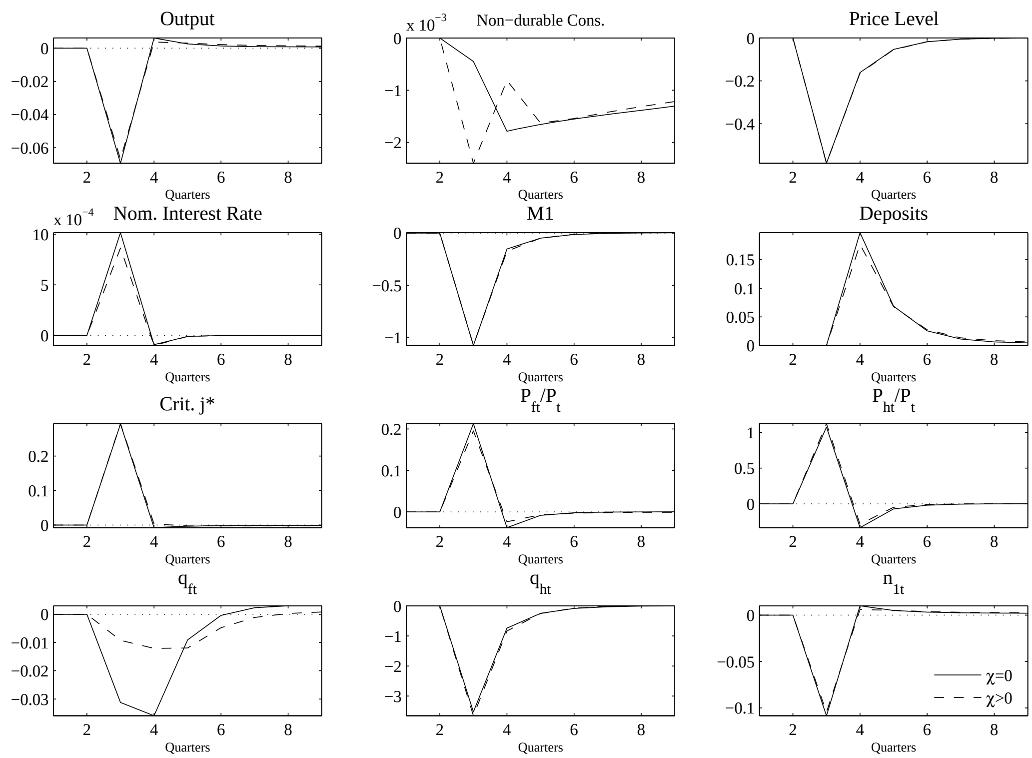

Figure 7: Impulse response to a negative monetary shock; limited participation. Y-axis denotes percentage change from steady state. Version 1 of the model assumes $\varkappa = 0$, while Version 2 of the model assumes $\varkappa > 0$.

3.4. Sensitivity Analysis

While the results presented above are fairly robust to deviations of the assumed parameter values and calibrating ratios prior to estimation, the calibration section noted the importance of the reserve requirement ratio (θ) in obtaining a decline in non-durable consumption at the onset of a monetary tightening. To show that the remaining results are not sensitive to this parameter, Version 1 of the model was estimated with $\theta = 0.15$ resulting in $\eta = 0.5833$ ($se = 0.1155$) and $\rho = 0.3735$ ($se = 0.0111$) with $\chi(1) = 3.2628$. This value for θ is in line with average reserve holdings of the banking industry.[19] The impulse responses are presented in Figure 8. As the figure indicates, the only qualitative difference is that non-durable consumption increases in response to a monetary contraction. The reason for this result stems from the size of the deposit multiplier, $1/\theta$. The larger the deposit multiplier, the larger the declines in M1 and the price level relative to the monetary base. These responses are illustrated in the middle row of the figure, with prices falling 23 percent and M1 falling 46 percent more than the benchmark results in Figure 7. This decline in prices allows households to use their present money balances to *increase* their consumption of non-durable goods. The value of θ used in the benchmark analysis suppresses this decline in prices and M1, resulting in a decline in non-durable consumption. Nonetheless, the impulse responses under both values illustrate similar qualitative responses to all other key variables, including the investment paths.

4. Investment Responses to a Productivity Shock

While the goal of this paper is to investigate the behavior of investment components to a monetary shock, it is of interest to evaluate how our credit and financial structure influences the behavior of the model to a real productivity shock. This is achieved by restating the production technology with an exogenous total factor productivity shock, $Y_t = z_t k_t^{\alpha} n_{1t}^{1-\alpha}$, with $z_t = (1 - 0.9)\,\bar{z} + 0.9 z_{t-1} + \varepsilon_{zt}$ and $\bar{z} = 1$.

Using the previously estimated parameters from Table 1 (Version 1), the impulse re-

[19] Source: Federal Reserve Bulletin. 1997; the ratio of reserves to demand deposits is roughly 15 percent while the ratio of reserves to consumer and industrial loans is roughly 4 percent.

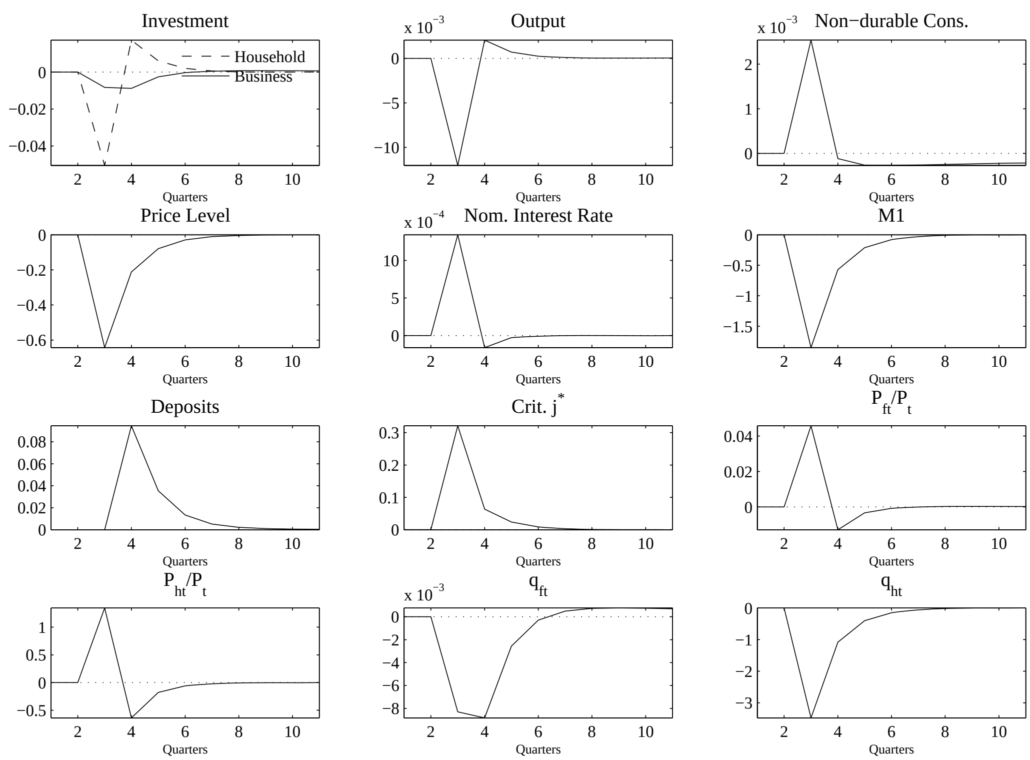

Figure 8: Impulse response to a negative monetary shock with limited participation, $\varkappa = 0$, and $\theta = 0.15$. Y-axis denotes percentage change from steady state.

sponses to a one percent deviation to z_t are illustrated in Figure 9.[20] As the figure illustrates, all real aggregates and real balances increase in response to a technology shock (as indicated by the decrease in the normalized price level). The movement in our credit and financial market variables arises from the resulting increase in the demand for loanable funds. These include an increase in household deposits and household/firm credit services, used to finance the additional household and business investment, and an increase in the nominal interest rate and relative price of credit services. Note also that while the monetary base remains constant, inside money and M1 increases. Hence, M1 will be procyclical and the financial structure of our model also embodies a reverse causation explanation of the money-output correlation. One of the more interesting results is that household and business investment both increase at the impact of a shock and have a maximum, contemporaneous correlation of 0.7933. While being far from our goal, this contemporaneous correlation is the primary result of Gomme et al. (2001), and their stated improvement over the results of Benhabib et al. (1991). While their results hinged on a time-to-build technology for physical capital production relative to household durables, the model in this analysis captures this result as a consequence of the representative family having more wealth to simultaneously devote to both types of investment.

5. Conclusion

This paper accounts for the dynamic relationships between household investment, business investment, broad monetary aggregates, and credit in a model of the monetary transmission mechanism which highlights the interaction between financial intermediaries and the credit market. The channel by which a negative monetary innovation leads to our quantitative predictions relies on the differential impact of the resulting liquidity and anticipated deflation effects on the price of household relative to firm credit services and their respective investment expenditures. Such a path was generated in the absence of ex-ante constraints regarding the timing of business and household investment. Furthermore, since monetary

[20] Re-estimating the model parameters for this exercise is not an option considering the data moments used were specifically concerning a response to a monetary shock.

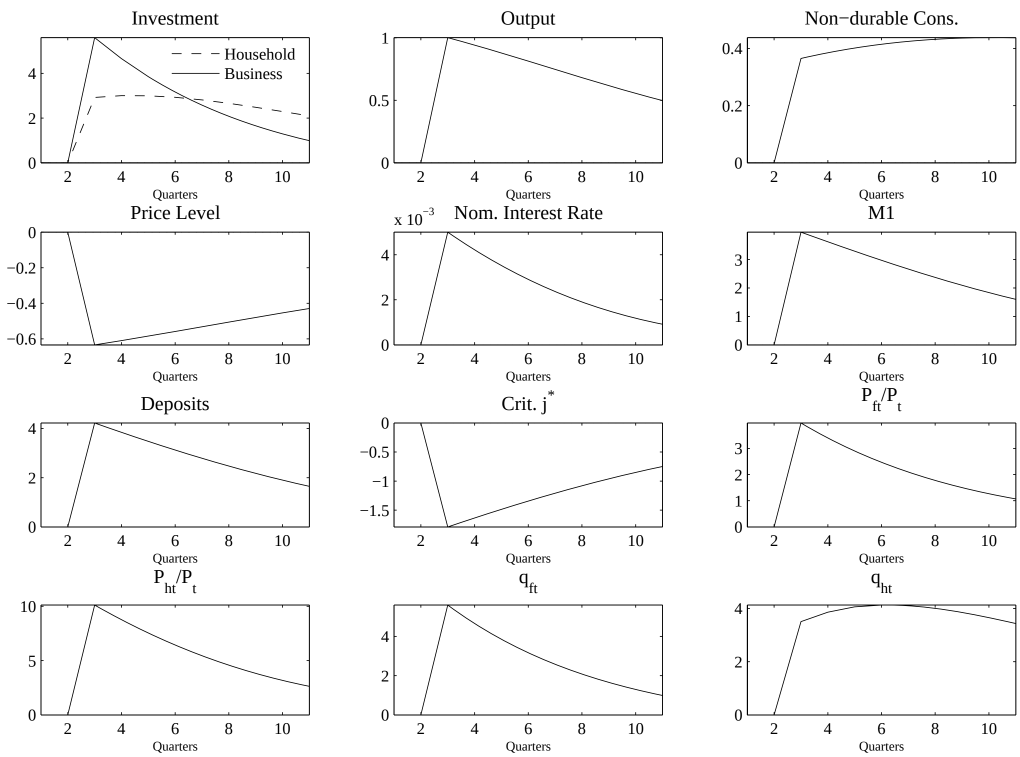

Figure 9: Impulse response to a one percent productivity shock with $\varkappa = 0$.Y-axis denotes percentage deviations from steady state.

injections effect the ability of the financial intermediaries to create deposits and issue loans, movements in broad monetary aggregates such as M1 move with household investment and are magnified beyond movements in the monetary base, as in the data.

While the benchmark results share many quantitative and qualitative features of the data in response to a monetary shock, one limitation of the model is its inability to display the observed degree of persistence. Christiano et al. (2005) conclude that model features such as nominal wage and price rigidity, habit persistence, and others combined with real frictions are necessary to observe a persistent response to a monetary shock. While including these features would help deliver persistence, it would do so at a cost of complicating the model. The goal of this paper was to present a model which captures the observed movements in business investment, household investment, broad monetary aggregates, and credit in a parsimonious framework without having to resort to these exogenous frictions. It is believed that adding these numerous features will only improve the empirical results of the model, and this is left for future work.

Appendices

VAR Analysis

Impulse responses were calculated by replicating the VAR estimation exercise of Christiano et al. (1999 and 2005). The variables were ordered in the VAR as Y_t, P_t, $PCOM_t$, HI_t, BI_t, $HCRED_t$, FF_t, TR_t, NBR_t, and M_t and denote the log of real GDP, the log of the implicit GDP deflator, the smoothed change in an index of sensitive commodity prices, the log of real household investment, the log of real business investment, the log of the change in household credit outstanding, the Federal Funds rate, the log of total reserves, the log of nonborrowed reserves, and the log of M1, respectively. All data definitions and construction are reported in the following appendix. The VAR includes four lagged values of each variable and assumes a standard, recursive identification scheme. The 90 percent confidence intervals displayed in the figures were calculated using the bootstrap method.

Data Appendix

Data used for the VAR analysis described above were defined and constructed as follows. Output was taken to be Gross Domestic Product (series name: GDP.US). Business investment was taken to be the sum of nonresidential, fixed investment on structures (series name: IFNS.US) and nonresidential, fixed investment on equipment and software (series name: IFNES.US). Household investment was taken to be the sum of personal consumption expenditures for durable goods (series name: CD.US) and residential, fixed investment (series name: IFR.US). All nominal data was transformed to real by dividing them by the GDP Implicit Price Deflator (series name: GDPDEF). Household credit was taken to be the change in household credit market debt outstanding (series name: CMDEBT). The commodity price index was taken to be the producer price index of industrial commodities (series name: PPIIDC). The data for the Federal Funds rate, total reserves, nonborrowed reserves, and M1 have series names RFED.US, TRARR, BOGNONBR, and M1.US, respectively. All monthly data was made available by taking quarterly averages. The data sample is from 1959:1 to 2004:4 and is available from either the US Department of Commerce: Bureau of Economic Analysis (BEA) or the Board of Governors from the Federal Reserve System.

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