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Bank Intermediation over the Business Cycle

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Abstract

This paper examines a model in which banks engage in valued asset transformation by converting illiquid assets into highly liquid demand deposit accounts that households use for transactions purposes. Premised on banks playing this role in the economy, the paper illustrates how consumption-smoothing behavior can induce countercyclicality in the degree to which firms rely on bank borrowings to finance their working capital expenses. The countercyclical behavior of this "degree of bank intermediation" with respect to the financing of working capital, measured by the volume of commercial and industrial loans in the banking system relative to output, is consistent with the U.S. data. The model further illustrates the importance of accounting for financial markets that provide alternative sources of short-term funds to firms. Absent these markets, nominal interest rates become nearly perfectly positively correlated with output, which is counterfactual, and monetary shocks (perhaps, artificially) induce large aggregate employment responses. [JEL Codes: E44,E32]

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1 Introduction

Firms rely heavily on short-term debt to finance their working capital expenses. While households represent the ultimate source of those funds to firms, much of this lending in the United States is intermediated through the banking system rather than being channeled through the financial markets, for example, via directly-placed corporate debt. Over the business cycle, working capital expenses are procyclical, as is the volume of bank loans to the business sector. However, the degree to which firms rely on bank loans to finance their working capital expenses, measured as the volume of commercial and industrial loans relative to output, is countercyclical. These statistics imply that bank lending to firms is "smoother" than alternative sources of working capital finance.[1]

This paper develops a theoretical model in which this "degree of bank intermediation" of working capital finance is countercyclical. Banks exist in the model by virtue of engaging in asset transformation by writing relatively illiquid loan contracts with firms that are funded through highly liquid demand deposit account contracts with households.[2] The model is used to illustrate the importance of a direct lending channel in accounting for the nearly acyclical or mildly procyclical behavior of the nominal interest rates that reflects the short-term borrowing costs for firms in economies where bank lending represents a significant source of working capital finance.[3] By restricting the model such that only bank lending is available to firms and only monetary assets are available to households to absorb the effects of aggregate shocks on financing requirements, the model gives a counterfactual prediction that the nominal bank lending rate is nearly perfectly positively correlated with ouptut.[4]

[1] As one example, the standard deviation of commercial and industrial loans is 3.17% versus 11.37% for directly-placed, non-financial commercial paper over the period 1973:1-1994:4 using HP-filtered data.

[2] The model abstracts from private information associated with the riskiness of loan repayment that could provide a market niche for financial intermediaries due to the economies of scale in monitoring, as in Diamond (1984).

[3] The correlations of the bank's prime lending rate and the commercial paper rate with output in the United States are 0.164 and 0.320 over the (quarterly) sample period 1973:1 to 1994:4 using HP-filtered data.

[4] In the liquidity effects models, for example, of Fuerst (1992) and Christiano and Eichenbaum (1995), the "financial intermediary" performs the role of the direct lending market. That is, the demand for bank deposits in those models arises solely from the interest earnings that are paid on the accounts. For this reason, these models were neither designed for nor are they well suited to examine the relative importance of bank intermediation over the business cycle. Chari, Christiano, and Eichenbaum (1995) do include a liquidity demand for bank deposits and no direct lending market. They also find the bank lending rate to be nearly perfectly positively correlated with output unless they impose strong restrictions on the the

In the model, firms issue debt to finance working capital expenses. A portion of the debt is bought by households, thus making up a financial market for direct lending. The remainder of the bond issues is bought by commercial banks, who use funds raised by issuing demand deposit accounts to households. Households value the liquidity services provided by the demand deposit accounts and are thus willing to take a lower rate of interest on their bank deposits than they receive on the firms' bonds. The volume of bonds that the bank purchases is limited by reserve requirements and the amount of deposits that it can attract from households. The government supplies high-powered money in accordance with a policy rule that determines the rate of growth of nominal bank reserves (its policy instrument).

In response to a positive productivity shock, firms increase their demand for labor, which increases their working capital financing requirements and the total volume of bonds outstanding expands. Due to the fact that consumption-smoothing moderates the liquidity needs of households, the increase in financial wealth of the household is disporportionately allocated to bonds. Consequently, there is a greater increase in the direct lending of households to firms than in bank lending to firms, thus inducing a countercyclical behavior in the degree of bank intermediation. This response is mitigated somewhat when the direct lending market is not available to firms as an alternative to the banks for the working capital financing needs. Thus, the employment response to the productivity shock is muted by the higher financing costs associated with higher real interest rates.

In response to a positive reserves shock, bank lending to firms increases. However, this increase is almost exactly offset by a decline in direct lending, with total lending falling by a very slight amount, but with the banks intermediating a larger share of the loans. The slight decline in total lending reflects a very modest increase in the real interest rate that raises the financing cost to firms, who thereby reduce their demand for labor. There is a very mild decline in equilibrium employment and in output, thus inducing a countercyclical element in the degree of bank intermedaition. By contrast, when the direct lending channel is not allowed to respond to the reserves shock, households are unable to make short-term adjustments in their financial asset portfolios, and real interest rates decline. This increases

model. One restriction is that households incur a transactions cost for adjusting their bank deposit position, and the other restriction is a monetary policy reaction function, whereby reserves growth in part adjusts endogenously to productivity shocks. *Both* restrictions are needed to obtain a low positive correlation of nominal interest rates with output.

the firm's demand for labor, and employment and output rise. This response induces a procyclical element into the degree of bank intermediation. However, on balance the real shocks dominate the monetary shocks, and bank intermediation, while less volatile in this latter case, is still countercyclical.

The theoretical model is developed in section 2. The sectoral optimizations are carried out and the equilibrium is defined in section 3. The model is calibrated in section 4. In section 5, the business cycle analysis is presented, in which the second moments of key variables relevant to the behavior of bank intermediation that are obtained from simulations of the model are reported and compared to the U.S. data. Impulse response functions are then used to explain the model's dynamic performance over the business cycle. Conclusions from this paper and suggestions for future research into models in which banks exist by virture of their role in transforming illiquid assets (loans) into highly liquid demand deposit accounts are contained in section 6.

2 Theoretical Model with a Banking Sector

This section develops a model in which commercial banks provide valued liquidity services to households in the form of demand deposit account offerings. Households use those deposits for purchasing a subset of their consumption goods, with the balance of their consumption goods acquired through monetary transactions. After setting aside reserves, banks use the remainder of their deposit funds to finance a portion of the working capital requirements of firms. Households provide an alternative source of working capital finance through a direct lending market. There are two sources of aggregate shocks in the economy: one to the growth rate of bank reserves and the other to total factor productivity.

2.1 The household sector.

The economy is populated by a large number of identical households, who derive utility from leisure, l, and two types of consumption goods, c_1 and c_2, that differ by the medium of exchange needed to acquire them. The c_1 goods are referred to as "cash goods" and are subject to a cash-in-advance constraint; the c_2 goods are referred to as "deposit goods" and are subject to a deposit-in-advance constraint. The household seeks to maximize expected lifetime utility at date $t = 0$ given by:

$$\max_{\{c_{1t},c_{2t},n_t,l_t,M^d_{t+1},X^d_{t+1},B^{dh}_{t+1}\}} \mathrm{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t U[c_{1t}, c_{2t}, l_t] \right\}, \quad \beta \in (0,1) \tag{1}$$

where: $U : \Re^2_+ \times (0,1) \rightarrow \Re$ is the period utility function that is continuous and continuously-differentiable in each of its arguments, with $U_{c1}, U_{c2}, U_l > 0$ and $U_{c1c1}, U_{c2c2}, U_{ll} < 0$, where the subscripts represent partial derivatives; E_0 is the expectations operator conditioned on all current information, including the current period monetary and productivity shocks described below; and β is the subjective discount factor.

The household begins the period with financial holdings of money, M^d_t, deposits, X^d_t, and bonds, B^{dh}_t, and receives: labor income $W_t n_t$, where W_t is the nominal wage rate and n_t is the quantity of labor supplied; interest income on deposits, $r_{dt} X^d_t$, where the deposit rate is given by r_{dt}, and on bonds, $r_{bt} B^{dh}_t$, where r_{bt} is the bond rate; and (*per capita*) dividends Π^f and Π^{cb} (assumed to be paid in cash), reflecting the household's ownership in firms and commercial banks, respectively. These funds are used by the household to make its consumption purchases, $P_t(c_{1t} + c_{2t})$, where P_t is the money price of output goods, and its financial asset portfolio allocation between money, M^d_{t+1}, deposits, X^d_{t+1}, and bonds B^{dh}_{t+1} that are carried over to next period.

$$P_t(c_{1t} + c_{2t}) + M^d_{t+1} + X^d_{t+1} + B^{dh}_{t+1} \leq W_t n_t + M^d_t + (1 + r_{xt}) X^d_t + (1 + r_{bt}) B^{dh}_t + \Pi^f_t + \Pi^{cb}_t \tag{2}$$

The asset markets are assumed to clear at the end of the period, when interest on deposits and bonds are paid by the banks and firms, and the household takes new asset positions in money, deposits, and bonds. Liquid assets are used to make consumption purchases, with the nominal value of the cash goods constrained by the stock of money held at the beginning of the period.

$$P_t c_{1t} \leq M^d_t \tag{3}$$

Similarly, the nominal value of the deposit goods cannot exceed the stock of bank deposits held by the household at the beginning of the period, against which the household issues liabilities (writes a check), that clear at the end of the period.[5]

$$P_t c_{2t} \leq X^d_t \tag{4}$$

[5] A similar liquidity constraint is used by Hartley (1998) and Edwards and Vegh (1997).

The household allocates its time to labor and leisure, with the total time available each period normalized to one.

$$n_t + l_t \leq 1 \tag{5}$$

The household's optimization problem consists of choosing the optimal sequences $\{c_{1t}, c_{2t}, n_t, l_t, M^d_{t+1}, X^d_{t+1}, B^{dh}_{t+1}\}_{t=0}^{\infty}$ that maximize expected lifetime utility (1) given initial wealth holdings: M^d_0, X^d_0, B^{dh}_0, subject to the budget constraint, (2), the payment system constraints, (3) and (4), the time resource constraint, (5) non-negative constraints: $c_{1t}, c_{2t}, n_t, l_t, M^d_t, X^d_t, B^{dh}_t \geq 0, \forall t$, and the usual transversality conditions on the household's financial assets.

2.2 The firm sector.

The production sector consists of a perfectly competitive industry that is modeled by a single aggregate firm. The firm is owned by households and pays nominal dividends each period equal to its net cash flow, which in *per capita* terms is given by Π^f_t.

$$\Pi^f_t = P_t \theta^p_t F(k_t, N_t) - P_t[k_{t+1} - (1-\delta)k_t] - (1 + r_{bt})B_t \tag{6}$$

where: $F : \Re_+ \times (0,1) \to \Re_+$ is the production function, which is continuous and continuously-differentiable in each of arguments, with $F_k, F_N > 0$ and $F_{kk}, F_{NN} < 0$; k_t is the aggregate *per capita* capital stock; N_t is the aggregate *per capita* employment; δ is the depreciation rate on capital; and θ^p_t is a total factor productivity shock, whose logarithm follows an AR1 stochastic process given by:

$$\ln\, \theta^p_{t+1} = \rho_p \ln\, \theta^p_t + \epsilon^p_{t+1}, \quad \rho_p \in (0,1),\ \epsilon_t \sim \text{ iid } (0, \sigma^2_p) \tag{7}$$

The *per capita* supply of bonds that were issued in the previous period is denoted B_t and are retired out of current income. The new bonds that are issued in the current period are denoted B_{t+1} and are used to finance the portion of the firm's working capital expenses consisting of its wage bill $W_t N_t$, or

$$W_t N_t = B_{t+1} \tag{8}$$

Gross investment is financed out of current revenues.[6]

For simplicity, the equity market is not modeled explicitly, since equity prices *per se* are not of interest. Households are assumed to possess equal shares in the firm. As in Christiano (1991), the firm acts in the interest of shareholders and maximizes the present value of the expected dividend stream using the household stochastic discount factor that reflects the fact that dividends are paid in currency, which the household values in terms of its consumption value next period. That is, each unit of currency (dollar) of date t dividends purchases $(1/P_{t+1})$ units of the cash consumption goods next period, where each unit of date $t+1$ consumption is valued by the household at date $t+1$ by its marginal utility, U_{c1t+1}. The total increase in utility next preiod, $[U_{c1t+1}/P_{t+1}]$, must be discounted back one period at β to determine its present value.

$$\max_{\{k_{t+1},N_t,B_{t+1}\}} \mathrm{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^{t+1}[U_{c1t+1}/P_{t+1}]\Pi_t^f \right\} \tag{9}$$

The firm takes as given its initial capital stock, k_0, and bonds outstanding, B_0, and chooses the optimal sequences for investment, employment, and bond issuance: $\{k_{t+1}, N_t, B_{t+1}\}_{t=0}^{\infty}$, subject to its financing constraint, equation (7), the nonnegativity constraints $k_t, N_t, B_t \geq 0, \forall t$, and the usual transversality conditions on bonds and capital.

2.3 The commercial banking sector.

The commercial banking sector is modeled as a single firm standing in for a perfectly competitive industry. The bank's liabilities consist of interest-bearing demand deposit accounts (*per capita*), X_t, and its assets consist of reserves (*per capita*), Z_t, and bonds (*per capita*), B_t^{db}, that it purchases from firms. Its net cash flow (*per capita*), Π_t^{cb}, is given below as the principal and interest received on the maturing bonds, less repayment of principal and interest to the depositors, after holding out reserves, and paying the cost of servicing the demand deposit accounts, ξX_t, where this expense is assumed to be proportional to the size of the bank's deposits, and is financed out of current revenue.

$$\Pi_t^{cb} = (1+r_{bt})B_t^{bd} - (1+r_{dt})X_t + Z_t - \xi X_t, \quad \xi > 0 \tag{10}$$

[6] A version of the model was examined where gross investment was also subject to the financing constraint, equation (8), but this modification had very little effect on the cyclical properties of bank intermediation and was thus dropped from the basic model. Results are available from the authors.

Each period the bank's net cash flow is paid out as cash dividends. The bank seeks to maximize the expected discounted value of the stream of dividends in accordance with household valuation.

$$\max_{\{Z_{t+1}, B^{bd}_{t+1}, X_{t+1}\}} \mathrm{E}_0\{ \sum_{t=0}^{\infty} \beta^{t+1}[U_{c1t+1}/P_t]\Pi^{cb}_t \} \tag{11}$$

The bank chooses a sequence of balance sheet positions $\{Z_{t+1}, B^{bd}_{t+1}, X_{t+1}\}^{\infty}_{t=0}$ given its initial balance sheet, Z_0, B^{bd}_0, X_0, subject to: a balance sheet constraint:

$$B^{bd}_t + Z_t = X_t; \tag{12}$$

its reserve requirements:

$$Z_t = \zeta X_t, \quad \zeta \in (0,1), \tag{13}$$

where ζ is the reserve requirement ratio; and the nonnegativity constraints: $X_t, B^{bd}_t, X_t \geq 0, \forall t$.

2.4 The government sector.

The only role played by government is to supply high-powered money. We assume that the policy instrument of the monetary authorities is nominal bank reserves, and examine a simple policy rule, under which the logarithm of the growth rate of the *per capita* bank reserves follows an AR1 stochastic process.

$$\ln \theta^z_t = \mu + \rho_z \ln \theta^z_{t-1} + \epsilon^z_t, \quad \mu > 0, \ \rho_z \in (0,1), \ \epsilon^z_t \sim (0, \sigma^2_z) \tag{14}$$

where $\theta^z_t \equiv Z_{t+1}/Z_t$ is observed by firms and households. Under this rule, with a reserves policy instrument, currency, M, is supplied passively to households on demand.

3 A Recursive Representation of the Economy

This section sets up the sectoral optimizations as dynamic programs, and defines the equilibrium. Suppressing time subscripts, the model can be rendered stationary by normalizing all nominal variables by the the stock of reserves, Z. Define: $m^d = M^d/Z; x^d = X^d/Z; b^{dh} =$

$B^{dh}/Z; p = P/Z; \pi^f = \Pi^f/Z; \pi^{cb} = \Pi^{cb}/Z; w = W/Z; b = B/Z; b^{bd} = B^{bd}/Z; x = X/Z$ and $m = M/Z$, and the aggregate state vector by: $\mathbf{S} = [m, x, b, b^{bd}, k; \theta^z, \theta^p]$.

3.1 The household's optimization.

Let $\mathbf{s^h} = [x^d, m^d, b^{dh}; \mathbf{S}]$ be the household's state vector and lifetime utility be represented by the value function, $v^h(\mathbf{s^h})$. Using the prime ($'$) notation to denote next period's values, the household's dynamic program becomes:

$$v^h(\mathbf{s^h}) = \sup_{\lambda^h(\mathbf{s^h}) \in \Gamma^h(\mathbf{s^h})} \{u[c_1(\mathbf{s^h}), c_2(\mathbf{s^h}), l(\mathbf{s^h})] + \beta \mathrm{E}[v^h(\mathbf{s^{h'}})]\} \tag{15}$$

where $\lambda^h(\mathbf{s^h}) = [c_1(\mathbf{s^h}), c_2(\mathbf{s^h}), l(\mathbf{s^h}), n(\mathbf{s^h}), x^{d'}(\mathbf{s^h}), m^{d'}(\mathbf{s^h}), b^{dh'}(\mathbf{s^h})]$ is the household's vector of decision rules which are drawn from the feasible set of correspondences, $\Gamma^h(\mathbf{s^h})$, given by the normalized set of constraints from equations (2)-(5):

$$p(\mathbf{S})[c_1(\mathbf{s^h}) + c_2(\mathbf{s^h})] + [m^{d'}(\mathbf{s^h}) + x^{d'}(\mathbf{s^h}) + b^{dh'}(\mathbf{s^h})]\theta^z$$

$$\leq w(\mathbf{S})n(\mathbf{s^h}) + m^d + [1 + r_x(\mathbf{S})]x^d + [1 + r_b(\mathbf{S})]b^{dh} + \pi^f + \pi^{cb} \tag{16}$$

$$p(\mathbf{S})c_1(\mathbf{s^h}) \leq m^d \tag{17}$$

$$p(\mathbf{S})c_2(\mathbf{s^h}) \leq x^d \tag{18}$$

$$n(\mathbf{s^h}) + l(\mathbf{s^h}) \leq 1 \tag{19}$$

Using the Benveniste-Scheinkman conditions, the Euler equations become (dropping the functional notation):

$$\mathrm{E}\{\beta(u'_{c1}/p') - \theta_z(u_l/w)\} = 0 \tag{20}$$

$$\mathrm{E}\{\beta[r'_x(u'_l/w') + (u'_{c2}/p')] - \theta_z(u_l/w)\} = 0 \tag{21}$$

$$\mathrm{E}\{\beta(1+r_b')(u_l'/w') - \theta_z(u_l/w)\} = 0 \tag{22}$$

Equations (20)-(22) are constrained-optimal decisions of the household in which efficient resource allocation decisions require that all constraints (16)-(19) bind. These expresssions have interpretations of equating, say, the utility loss associated with a marginal unit of time reduction in leisure, with the corresponding utility gain resulting from the increase in labor income that is carried forward one period in the form of cash, deposits, and bonds, respectively.

3.2 The firm's optimization.

Noting that the firm's state vector is given by the aggregate state vector, $\mathbf{S}$, the present value of the flow of dividends is given by the firm's value function by $v^f(\mathbf{S})$. With the normalized cash flow given by:

$$\pi^f = p(\mathbf{S})\theta^p F[k, N(\mathbf{S})] - p(\mathbf{S})[k'(\mathbf{S}) - (1-\delta)k] - [1 + r_b(\mathbf{S})]b, \tag{23}$$

the firm's dynamic program becomes:

$$v^f(\mathbf{S}) = \sup_{\lambda^f(\mathbf{S}) \in \Gamma^f(\mathbf{S})} \beta \mathrm{E}\{(U_{c1}'/p')(1/\theta^z)\pi^f + [v^f(\mathbf{S}')]\} \tag{24}$$

where $\lambda^f(\mathbf{S}) = [k'(\mathbf{S}), N(\mathbf{S}), b'(\mathbf{S})]$ is the firm's vector of decision rules, and $\Gamma^f(\mathbf{S})$ is the set of feasible correspondences defined by the financing contraint, equation (8), normalized to be:

$$w(\mathbf{S})N(\mathbf{S}) = b'(\mathbf{S})\theta^z \tag{25}$$

Imposing the Benveniste-Scheinkman conditions, the Euler equations can be written as (dropping the functional notation, with double primes ($''$) denoting values two periods ahead):

$$\mathrm{E}\ \{\beta[u_{c1}''/(\theta_z' p'')][F_K' + (1-\delta)]p' - [(u_{c1}'/p')p/\theta_z]\} = 0 \tag{26}$$

$$\mathrm{E}\ \{\beta[u_{c1}''/(\theta_z' p'')](1 + r_b') - (u_{c1}'/p')(pF_N/w)\} = 0 \tag{27}$$

Equation (26) has an interpretation as the optimal decision between the marginal dividend payout versus investing in physical capital. Equation (27) can be interpreted as the marginal decision to issue bonds and use the proceeds to hire additional units of labor.

3.3 The commercial bank optimization.

The dynamic optimization problem in the commercial banking sector given by equation (8) can be equivalently expressed as a period-by-period profit-maximization:

$$\max_{\{x'(\mathbf{S}),b^{bd'}(\mathbf{S})\}} \pi^c b' \tag{28}$$

subject to its (normalized) balance sheet constraint, and to meeting its reserve requirements.

$$1 + b^{bd'}(\mathbf{S}) = x'(\mathbf{S}) \tag{29}$$

$$1 = \zeta x'(\mathbf{S}) \tag{30}$$

where normalized profits are given by the net cash flow:

$$\pi^{cb'} = [1 + r_b'(\mathbf{S})]b^{bd'}(\mathbf{S}) + 1 - [1 + r_x'(\mathbf{S})]x'(\mathbf{S}) - \xi x'(\mathbf{S}) \tag{31}$$

The first-order conditions fix the spread between the bond rate, r_b, and the deposit rate, r_x (dropping the functional notation).

$$(1 + r_x') = (1 - \zeta)(1 + r_b') + \zeta - \xi \tag{32}$$

3.4 Equilibrium.

To define the equilibrium for this economy, let the set of aggregate decision rules $\Lambda(\mathbf{S}) = [C_1(\mathbf{S}), C_2(\mathbf{S}), N(\mathbf{S}), \tilde{m}^{d'}(\mathbf{S}), \tilde{x}^{d'}(\mathbf{S}), \tilde{b}^{dh'}(\mathbf{S})]$ where the variables in the vector are aggregate *per capita* values.

The *competitive equilibrium* can be defined as: the set of household decision rules $\lambda^h(\mathbf{s^f})$; the set of aggregate decision rules $\Lambda(\mathbf{S})$; the aggregate laws of motion $[k'(\mathbf{S}), b'(\mathbf{S}), b^{bd'}(\mathbf{S}), x'(\mathbf{S})]$

that govern the evolution of the endogenous state variables; the stochastic processes, equations (7) and (14), that govern evolution of the exogenous aggregates state variables, θ^z and θ^p; the set of pricing functions $r_x(\mathbf{S}), r_b(\mathbf{S}), w(\mathbf{S}), p(\mathbf{S})$; and the value functions $v^h(\mathbf{s^h})$ and $v^f(\mathbf{S})$, that satisfy:

(i) *household optimization*: equations (20)-(22), given the liquidity constraints, equations (17)-(18), and the time resource constraint, equation (19);

(ii) *firm optimization*: equations (26)-(27), given the financing constraint, equation (25);

(iii) *bank optimization*: equation (32), given the balance sheet constraint, (29), and satisfaction of the bank's reserve requirements, equation (30);

(iv) *aggregate consistency conditions*: $\lambda^h(\mathbf{s^f}) = \Lambda(\mathbf{S})$; and

(v) *equilibrium conditions*: $\tilde{m}^d(\mathbf{S}) = m(\mathbf{S}), \tilde{x}^d(\mathbf{S}) = x(\mathbf{S}),\ b^{dh}(\mathbf{S}) + b^{bd}(\mathbf{S}) = b(\mathbf{S})$, and $C_1(\mathbf{S}) + C_2(\mathbf{S}) + k'(\mathbf{S}) - (1-\delta)k = \theta^p F[k, N(\mathbf{S})]$.

4 Calibration.

This section describes how the model was calibrated to quarterly data for the U.S. economy. In addition, we subsequently report results for two modifications to the model presented above. In one version of the model, we freeze direct lending at its steady-state value to examine the significance of that market for affecting business cycle dynamics.[7] In another version, stochastic bank capital requirements are introduced to examine their potential importance in the volatility of bank intermediation. Descriptions of how these modifications affect the calibration are also given below.

For the period utility function, we assume a log-linear form.

$$u(c_1, c_2, l) = \ln c_1 + \eta_1 \ln c_2 + \eta_2 \ln l, \quad \eta_1,\ \eta_2 > 0 \tag{33}$$

The production function, F, is assumed to be Cobb-Douglas.

$$F(K, N, \theta^p) = \theta^p K^\alpha N^{1-\alpha}, \quad \alpha \in (0,1) \tag{34}$$

[7] We chose to freeze direct lending at its steady-state value rather than setting it to zero, which would have called for a recalibration of the model with a different deposit/currency ratio.

In calibrating the model, we follow a standard strategy employed in such exercises. A subset of the parameters is determined on the basis of *a priori* information, such as micro data and other empirical studies. The remaining parameters are chosen to match the first moments of the model with the post-War U.S. data.

Based on U.S. data from 1960-1994, we obtain average estimates of: $\alpha = 0.34$, an investment to output ratio, I/Y, of 0.209, a physical capital to quarterly output ratio, K/Y, of 12.022. We note that both the series on investment and the stock of capital include consumer durables.

From the steady-state version of the model, the above values of I/Y and K/Y yield $\delta = 0.0174$. Given the values of α, K/Y, and δ, equation (26) yields $\beta = 0.9892$. To determine η_1 we use the deposit over currency ratio of 2.941. We set η_2, the parameter on leisure in the utility function, to 6.85, which yields the steady-state value of hours worked of 0.32. This is consistent with the U.S. average for men and women in 1981, obtained from diary-based estimates. See Juster and Stafford (1991).

For the autocorrelation coefficient, ρ_p, in (14) we use the value 0.95, the one used by Kydland and Prescott (1982) and many others in the RBC literature. The implied value of σ_p, matching the percent standard deviation of output in the model with the 1960-94 U.S. data is 0.0090. For the version of the model where direct lending is frozen at its steady-state value, a higher σ_p of 0.0107 is required.

In the banking sector, the reserve ratio, ζ, is set at 0.10, which is the current U.S. value for transaction deposits. In accordance with the average spread between the commercial paper and the deposit rate on other checkable deposit accounts (OCDs) of 1.73% (quarterly), we set ξ to 0.0151.[8] The autocorrelation coefficient in the rule for reserves growth, ρ_z, is set to 0.53, obtained from regressing (the log of) total reserves on its lagged values, using data from 1960:1-1994:4. The parameters μ and σ_z are calibrated to obtain a quarterly CPI inflation rate mean and percent standard deviation of 0.0117 and 0.80 consistent with the sample averages from 1960:1-1994:4. This produces values of $\mu = 0.0055$ and $\sigma_z = 0.007$.

In the version of the model where we add stochastic bank capital requirements to the model, three equations are modified in obvious ways: the bank's period cash flow and

[8] The average spread was calculated by approximating the average deposit rate with an average of zero prior to 1987 and the (weekly, annualized) averages from 1987 through 1994, and subtracting this number, 0.864%, from the (monthly, annualized) commercial paper rate of 7.986 % over the same period.

its balance sheet constraint. In this version the parameter ξ needs an adjustment (set at 0.0167) in order to maintain the same interest rate spread as above. In addition, a stochastic process is required for the evolution of the bank capital. From U.S. data during 1973:1-1994:4, we calculate the average ratio of bank capital to banks total assets to be 7.4 %. Assuming this ratio to follow an AR(1) process, the estimated autocorrelation coefficient is 0.91, and the standard error of the process is 3.6 %.

5 Simulation Results

In this section, we report the simulation results for three versions of the model.[9] In Table 1, the results for the model developed in the paper are reported under the label "Model w/ d.l. nonstochastic b.c." reflecting: (i) the availability of the direct lending channel for absorbing macroeconomic shocks that affect the firm's demand for working capital, and (ii) the absence of bank capital requirements. In order to examine the significance of the direct lending market for the cyclical behavior of both the degree of bank intermediation and the bank lending rate, a version of this model, where the quantity of direct lending from households to firms is frozen at its steady-state level, was simulated. In Table 1, those results are reported under the label "Model w/o d.l. nonstochastic b.c." Finally, to examine the potential for stochastic fluctuations in bank capital to have a significant effect on the degree of bank intermediation, a version of the model where bank capital requirements are stochastic was simulated. Those results are reported in Table 1, under the label "Model w/ d.l. stochastic b.c."

We begin by identifying the key second moments from the simulations of the various models that bear on the role of bank intermediation in financing the working capital expenditures of firms and compare those results with the U.S. data. Impulse response functions are then analyzed to describe the mechanisms in the models that are responsible for generating those results.

[9] The model was solved using the parameterized expectations algorithm (PEA) proposed by Marcet (1988) and DenHaan and Marcet (1990). See Appendix for further details.

5.1 Second moments.

A key prediction of the model developed in this paper is the countercyclical behavior of the degree of bank intermediation. This variable is measured in the model by the volume of bank loans to output, $\hat{b_B}$ in Table 1, and compared to the statistic from the U.S. data constructed as the ratio of commercial and industrial loans in the banking system to output. Referring to Table 1, the degree of bank intermediation is seen to be mildly countercyclical, with a correlation between bank intermediation and output of -0.321. The degree of bank intermediation in the model developed in the text (Model w/ d.l. nonstochastic b.c.) is also countercyclical, but with a correlation with output of -0.858, which is too high in absolute value. The principal reason for the model's prediction of the countercyclicality of bank intermediation is that banks use deposit funds to make working capital loans, but households use their bank deposits for consumption purchases. With households smoothing consumption, the ability of banks to respond, say, to an increase in the demand for bank loans from firms is limited. Consequently, firms will turn to the direct lending market, where the supply of funds by households is more responsive to income shocks, again due to consumption-smoothing. Given that the total volume of working capital loans, or bonds issued, is held in fixed proportion to output over the business cycle due to the Cobb-Douglas production technology, the share of those loans created in the direct lending market increases, and the degree of bank intermediation in working capital loans falls. Table 1 also includes statistics on the *level* of bank lending in real terms, B_B'/P, which show a weak positive correlation with output, 0.203. The models all predict a positive correlation. Quantitively, however, a direct lending market makes a substantial difference, yielding a lower positive correlation between real bank lending and output (0.518 and 0.449 v. 0.934), bringing it closer to the data.

All three versions of the model have similar predictions on the countercyclical behavior of bank intermediation. However, when the direct lending market is unavailable to absorb fluctuations in the firm's demand for working capital, the "Model w/o d.l." in Table 1 indicates that the volatility of bank intermediation falls nearly by one-half when measured by the percent standard deviation, i.e., it drops from 1.51 to 0.85. This takes the model's predictions further from the data, where the degree of bank intermediation is seen to be about twice as volatile as output, with a percent standard deviation of 3.24. This result is also attributable to the inability of the firm to substitute direct lending for bank loans.[10] We then asked whether stochastic movements in bank capital could explain some of this excess volatility in bank intermediation. However, as shown in Table 1 for the "Model w/ d.l." and "stochastic b.c." we discovered that the contribution appears to be small. The percent standard deviation of the degree of bank intermediation increased to just 1.60, which is still about one-half of that observed in the data.

A striking feature of the version of model in which there is not a direct lending market available to absorb the macroeconomic shocks that affect the firm's demand for working capital loans is the prediction for nominal interest rate behavior. From Table 1, nominal interest rates are predicted to be nearly perfectly positively correlated with output, with a correlation coefficient of 0.922; whereas in the U.S. data, the prime rate is nearly acyclical, with a correlation coefficient between the prime rate and output of 0.164, while the commercial paper rate is mildly procyclical, with a correlation coefficient of 0.320. By contrast, when a direct lending channel is available to absorb the fluctuations in the demand for working capital loans, as in the other two versions of the model reported in Table 1, nominal interest rates become acyclical. All three versions of the model yield predictions for interest rate volatility that exceed those observed in the U.S. data, where the percent standard deviation of the U.S. prime lending rate is seen to be 0.42 and for the commercial paper rate is 0.38.

[Insert Table 1.]

5.2 Response of the degree of bank intermediation to productivity, reserves, and bank capital shocks.

[11]

A positive productivity shock increases the demand for labor in the current period, and in future periods due to its persistence. The demand for working capital loans (or the

[10] Obviously, had we recalibrated the model by setting the volume of direct lending to zero, the degree of bank intermediation would be perfectly acyclical, since all lending must be intermediated by the bank and the volume of total loans to output is constant.

[11] The impulse response functions (IRFs) reported in this section are taken from the version of the model with stochastic bank capital. The IRFs resulting from productivity and reserves shocks are nearly identical in the two versions of the model that contain a direct lending channel for absorbing shocks, that is, with and without bank capital requirements.

supply of bonds) therefore increases. This is displayed in Figure 1, by the impulse response function of total lending to a one standard deviation shock. Firms turn to both households and the banks for loans. However, because of the effect of consumption-smoothing on the banks' ability to attract deposit funds as described above, there is a greater increase in direct lending from households to firms than there is in the creation of new bank loans to firms. Figures 2 and 3 display the impulse response functions of direct lending and bank loans, respectively, to a one standard deviation shock. As a consequence, the share of total lending to firms from the banks falls, and the degree of bank intermediation declines, tending to produce the countercyclical behavior observed in the data. This is illustrated by the impulse response function of the degree of bank intermediation to the one standard deviation shock in Figure 4.

[Insert Figures 1-4.]

A positive shock to the growth rate of bank reserves tends to raise the borrowing costs of firms due to the implied inflation tax. This is described in more detail below. As a consequence, the demand for labor falls, and total lending declines in response to the drop off in loan demand (or bond supply), albeit very modestly. This is shown in Figure 1 by the impulse response function of total lending to a one standard deviation shock to reserves growth. However, because the reserves injection increases the banks' ability to make loans without having to rely on deposit funds, bank lending to firms actually increases. This increase is accompanied by a decline in direct lending, which dominates. Refer to the impulse response functions in Figures 3 and 2, respectively. Therefore, the share of total working capital loans to firms that originate with the banks increases, tending to cause the degree of bank intermediation to become countercyclical. Figure 4 displays this response.

As illustrated in Figures 1 to 4, in response to a positive, one standard deviation shock to bank capital, both bank lending and the direct lending from households to firms mirror their responses to a reserves shock. Bank lending expands and direct lending contracts, at a time when the economy slows, rendering the degree of bank intermediation countercyclical. However, the magnitudes of these responses are smaller, and the effects on employment and output are almost negligible.

5.3 Interest rate and employment response to productivity shocks.

[12]

Consider the version of the model in which direct lending is frozen at its steady-state level. In this model, a positive productivity shock increases the demand for labor by firms in both current and future periods due to its persistence. Consequently the supply of bonds rises, and banks see this as an increase in the demand for working capital loans. The higher productivity is also reflected in household's income. However, nominal consumption expenditures are predetermined by the liquidity constraints. Therefore, all of the additional income must go into cash and deposit holdings, and consumption-smoothing by households would cause households to allocate the additional income somewhat evenly across those two liquid assets. To entice a greater share of this allocation into bank deposits, the bank will raise the deposit rate. To maintain the bank's profit margin, the nominal bank lending (or bond) rate also rises. Consequently, productivity shocks induce the highly procyclical, and volatile movements in the nominal interest rate reported in Table 1. This effect is illustrated in Figure 5, by the impulse response of the nominal interest rate to a positive one standard deviation productivity shock.

[Insert Figure 5.]

By contrast, when the direct lending market is available to help absorb the productivity shock, the household can modify its financial asset portfolio allocation by purchasing a share of the additional bond issue of firms. In so doing, the demand for bank loans is reduced. Under our calibration, the increase in bond supply is almost exactly offset by the increase in directly lending, such that there is essentially no effect on the nominal interest rate, as can be seen from the impulse response function in Figure 5.

In both models, the productivity shock lowers the price level. The impulse response functions are displayed in Figure 6. However, the price decline is much sharper with more persistent price declines in the model without directly lending, hence leading to sharper declines in the *ex ante* inflation rate. Nonetheless, real interest rates increase substantially, as is shown in Figure 7. This is also in sharp contrast to the model in which the direct

[12] The impulse response functions (IRFs) reported in this section and the following setion are taken from the versions of the model that exclude bank capital requirements, that is, with and without a direct lending market available to absorb shocks.

lending is available to absorb the shock. In that case, the price decline is mostly a one-time level response, producing little *ex ante* deflation, and rendering the real interest rate little changed.

[Insert Figures 6 and 7.]

While the productivity increase raises the firm's demand for labor, a higher real interest rate would increase the firm's working capital financing costs, and thereby mitigate the greater labor demand somewhat. As can be seen in Figure 8, the equilibrium employment response to the productivity shock is substantially lower when there is no directly lending channel available, which coincides with the sharp increase in the real interest rate.

[Insert Figure 8.]

5.4 Interest rate and employment response to bank reserves shocks

Consider the effect of an unanticipated reserves injection in the form of a one standard deviation increase in the growth rate of nominal bank reserves. In the absence of direct lending, the price level will rise, but by less than the reserves growth. With direct lending, the price level is virtually in tact in the first period. The reasons for these responses, is that with consumption spending predetermined in nominal terms, households increase their demands for monetary assets. With a part of the reserve increase being channelled into currency, a less than one-to-one increase (in percentage terms) in the price level is required to clear the money market in period one. With direct lending available, the reduction in household bond purchases, increases the demand for monetary assets even further, calling for an even lesser response (essentially zero) in the price level, as is evident in Figure 9. However, in both cases, *ex ante* inflation increases. From Figure 10, it is evident that this inflation response is greater in the model with a direct lending market. This anticipated inflation is incorporated into nominal interest rates, and results in a sharper increase in the nominal rate in the model when the direct lending market is available to absorb the shock. In this case, there is only a very slight decline in the real interest rate, as is illustrated in Figure 11. As described above, this result owes to the near perfect offset of the increase in bank lending by the decline in direct lending, with a nearly imperceptible decline in total lending. Given that the real interest rate is little effected, the equilibrium employment response is dominated by the inflation tax, and experiences a very modest decline.

[Insert Figure 9, 10, 11 and 12.]

By contrast, when there is no response in the direct lending market, the increase in bank lending that accompanies the reserves injection tends to lower the real interest rate, since total lending must rise in nominal terms, and with the sluggish price adjustment, as illustrated in Figure 9, induces an increase in total lending in real terms. The lower real interest rate reduces the firm's borrowing costs, and increases their demand for labor. As a consequence equilibrium employment rises significantly, by nearly one percent (on an annual basis), as illustrated in Figure 12. Therefore, arbitrarily shutting down financial markets in models in which banks play an important role in extending working capital loans to firms can artificially induce significant real effects from monetary policy changes.

6 Conclusion

One role that banks play in the economy is to transform illiquid loans into highly liquid demand deposit accounts. This asset transformation enables them to intermediate loans between households and firms by raising deposit funds from households who value the liquidity services that they provide in facilitating transactions, and using the deposit funds to create short-term working capital loans for firms. This paper demonstrates how consumption-smoothing behavior on the part of households can induce a countercyclical response in the degree of bank intermediation in lending to firms, measured as the volume of these bank loans to output, that is observed in the U.S. data.

The model is then used to demonstrate the importance of alternative sources of short-term finance for firms when attempting to match the model's predictions for the cyclical behavior of nominal interest rates with the U.S. data. In the data, and in the model with a direct lending market available to absorb shocks to the firm's demand for working capital loans, the bank lending rate is nearly acyclical. By contrast, when the direct lending market is made unavailable to respond to these shocks, the model yields the counterfactual prediction that the bank lending rate is nearly perfectly positively correlated with output.

The direct lending market also enables monetary policy shocks, or shocks to the growth rate of bank reserves, to be absorbed principally by nominal variables, thus leaving the real side of the economy largely unaffected.[13] Absent the market for absorbing these shocks, a positive reserves shock induces a significant positive employment response, with output also rising. This result suggests the possibility that in a multi-sector model, with a subset of firms that are bank dependent borrowers (as in the literature on the "credit channel" of monetary policy),[14] sectoral reallocations of labor may accompany monetary policy changes that are designed to have only aggregate effects. Examining this issue in the context of an RBC calibration/simulation exercise would be a useful extension of the basic model developed in this paper.

[13] Labadie (1995) also finds little real effects of a stochastic monetary policy that relies on nominal bank reserves as its policy instrument. However, in her (OLG) model, banks perform a delegating monitoring role to deal with private *ex ante* information concerning a state variable in the economy, changes in which can be rendered neutral by writing state-contingent provisions into loan contracts.

[14] This outcome would be consistent with the Bernanke and Gertler (1989) model. However, in their model, banks provide a different service by writing and monitoring risky loan contracts in the presence of private information that could give rise to agency costs which, in turn, alter lending behavior over the business cycle. The empirical literature on the credit channel is not in agreement that the banking sector plays any special role in altering the allocation of loans between, say, small and large firms. See Kashyap, Stein, and Wilcox (1993), Oliner and Rudebusch (1995), and Gilchrist and Zakrajsek (1995). However, data limitations have confined this analysis to the manufacturing sector of the U.S. economy.

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Table 1

Summary of Second Moments

	US Data 1973:1-94:4		Model w/o d.l. nonstochastic b.c.		Model w/ d.l. nonstochastic b.c.		Model w/ d.l. stochastic b.c.	
Variable	stdev	corr w/y	stdev	corr w/y	stdev	corr w/y	stdev	corr w/y
y	1.68	1.000	1.69	1.000	1.73	1.000	1.75	1.000
c	0.85	0.884	0.98	0.776	0.56	0.806	0.55	0.820
c_1			0.82	0.582	0.94	0.477	0.93	0.494
c_2			1.08	0.794	0.50	0.902	0.51	0.882
i	5.85	0.967	5.73	0.909	6.84	0.980	6.83	0.982
n	1.64	0.908	0.52	0.914	0.89	0.987	0.90	0.983
r_B	0.42	0.164	0.72	0.922	0.81	-0.021	0.77	-0.017
$\hat{b_B}$	3.24	-0.321	0.85	-0.908	1.51	-0.858	1.60	-0.817
$B_B{}'/P$	3.14	0.203	0.97	0.934	0.88	0.518	1.02	0.449

Notes: All data are HP-filtered, setting the smoothing parameter to 1600.
The variable $\hat{b_B} = B_B{}'/PY$ measures the degree of bank intermediation.

Appendix: Outline of the PEA used to solve the model.

Write the stochastic parts of the Euler equations (20)-(22), (26), and (27) in a general form as (after imposing the equilibrium and aggregate consistency conditions)[15]

$$\psi_t^i \equiv m^i(\mathbf{S}_t, \lambda(\mathbf{S}_t)), \tag{A1}$$

so that

$$E_t(\psi_t^i) \equiv \int_\Theta \psi_t^i Q(\theta_t, d\theta_{t+1}), \qquad i = 1, ..., 5 \tag{A2}$$

where $\theta_t = (\theta_t^p, \theta_t^z) \in \Theta$, and Q is a transition function.

The *PEA* approximates the conditional expectations in $(A2)$ by seeking vectors of parameters, $\tilde{\mathbf{a}}^i$, that solve

$$\tilde{\mathbf{a}}^i = \arg\min\ (1/T) \sum_{t=1}^{T} |\psi_t^i - P_n^i(\mathbf{S}_t; \mathbf{a}^i)|^2, \qquad i = 1, ..., 5 \tag{A3}$$

where P_n^i is an $n-th$ degree polynomial in the state vector and the parameters, T is sample length, and $|\cdot|$ denotes the Euclidean norm. The solution procedure is initiated with some set of given parameter vectors, $\mathbf{a}_0^i, \quad i = 1, ..., 5$, where the polynomials have been substituted in the Euler equations (20)-(22), (26), and (27). These are used, along with the rest of the model, to generate series for the endogenous variables, which in turn are substituted in $(A3)$ to obtain a new set of estimates for $\mathbf{a}^i$: $\mathbf{a}_1^i$. For the estimation, we use nonlinear least squares. This estimate is then used to generate new data series, and so on iteratively until convergence, that is, until $\mathbf{a}_N^i$ is sufficiently close to $\mathbf{a}_{N-1}^i$, with N being the $N-th$ iteration. We set $T = 2000$ and $n = 1$ in all cases, that is, first degree ordinary polynomials, as these have often been shown to give accurate enough solutions for shocks of the (relatively small) size used in the RBC literature. [See e.g den Haan and Marcet (1990).] Convergence in individual parameter estimates was assumed when $|(a_N^i - a_{N-1}^i)/a_{N-1}^i| < .0001$.

[15] We note that in the model without direct lending, equation (22) becomes redundant.

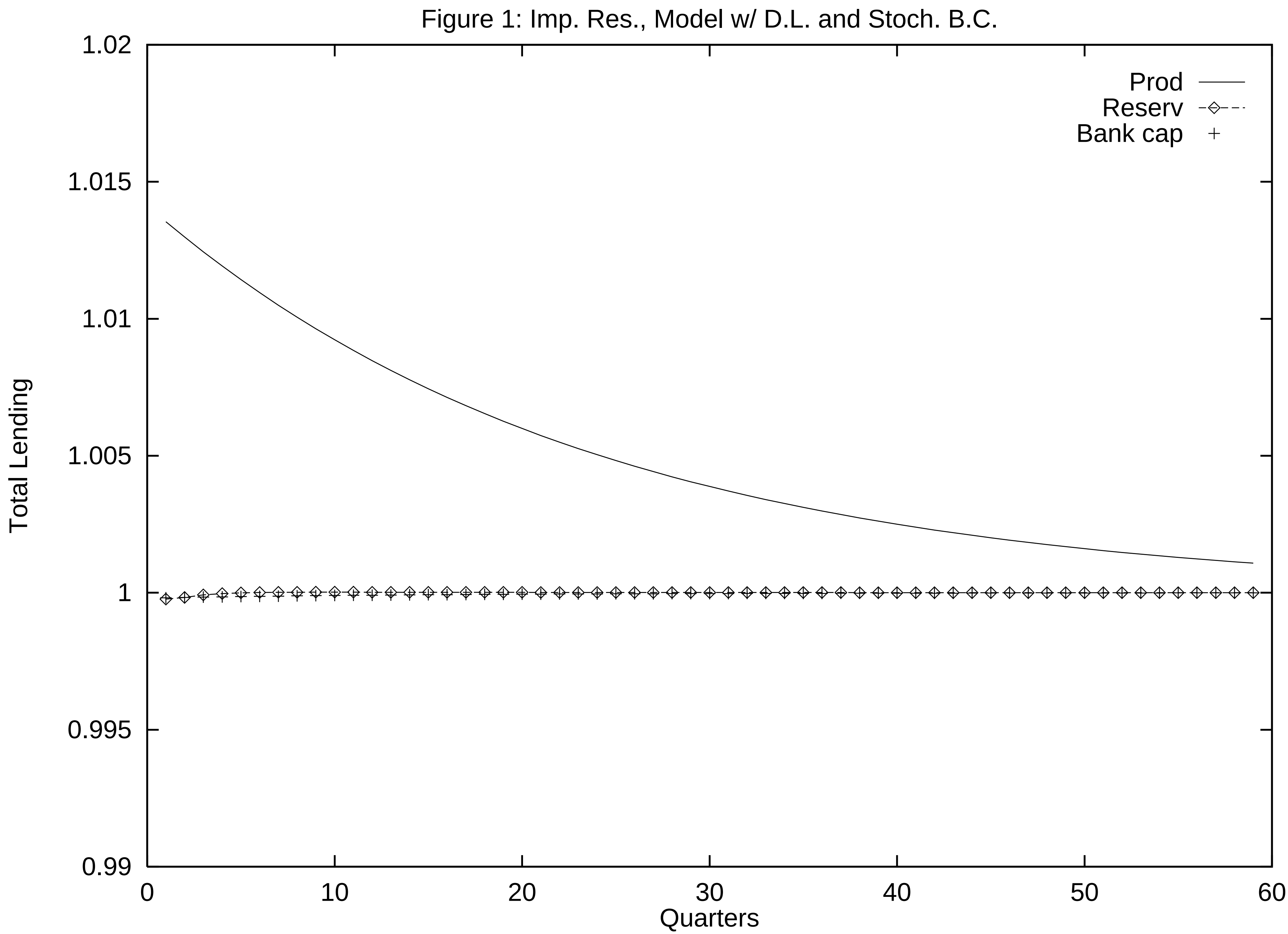


Figure 1: Imp. Res., Model w/ D.L. and Stoch. B.C.
Total Lending
Quarters
Prod
Reserv
Bank cap
1.02
1.015
1.01
1.005
1
0.995
0.99
0
10
20
30
40
50
60

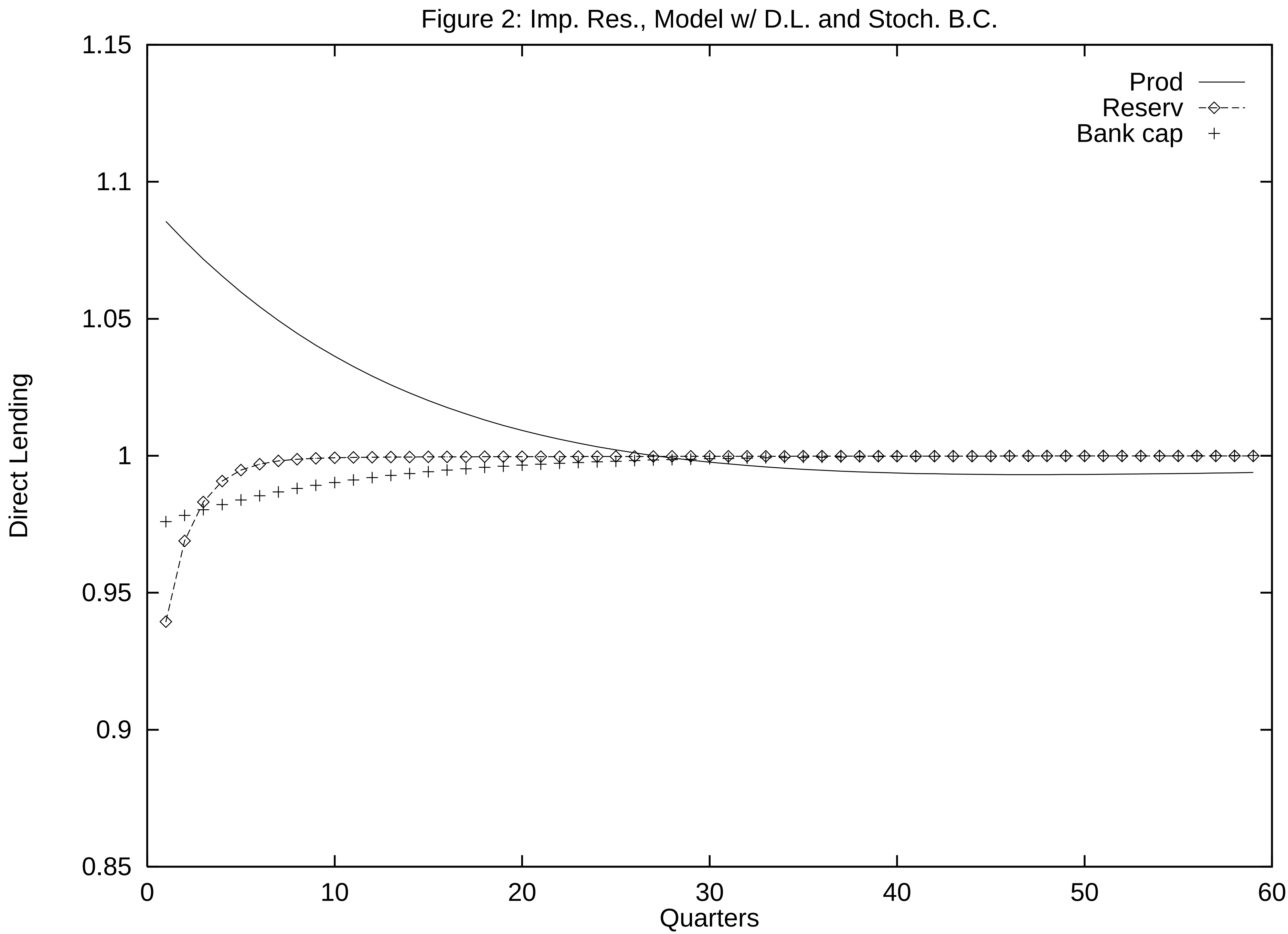


Figure 2: Imp. Res., Model w/ D.L. and Stoch. B.C.
Prod
Reserv
Bank cap
Direct Lending
Quarters
1.15
1.1
1.05
1
0.95
0.9
0.85
0
10
20
30
40
50
60

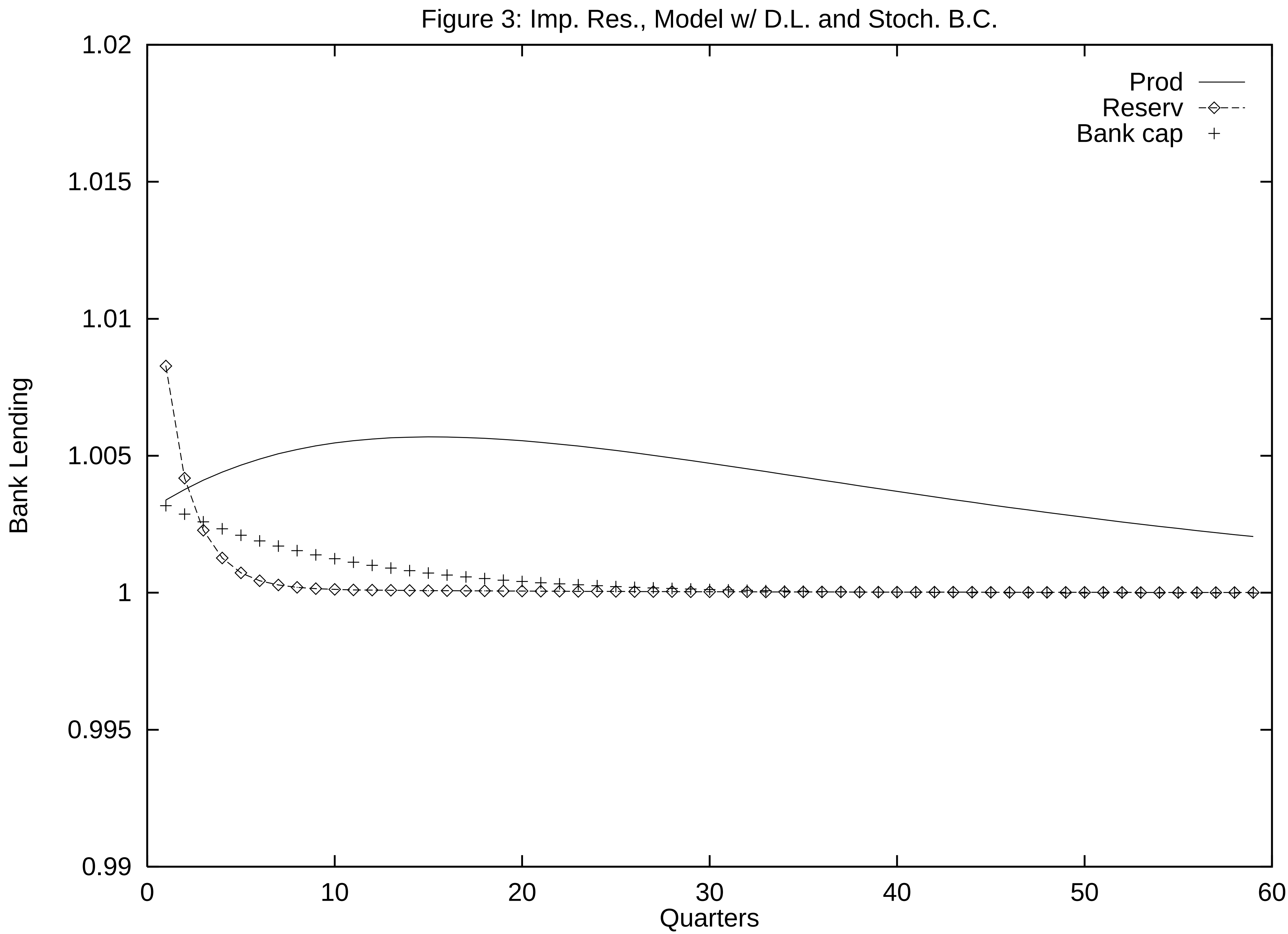


Figure 3: Imp. Res., Model w/ D.L. and Stoch. B.C.
Prod
Reserv
Bank cap
Bank Lending
Quarters
1.02
1.015
1.01
1.005
1
0.995
0.99
0
10
20
30
40
50
60

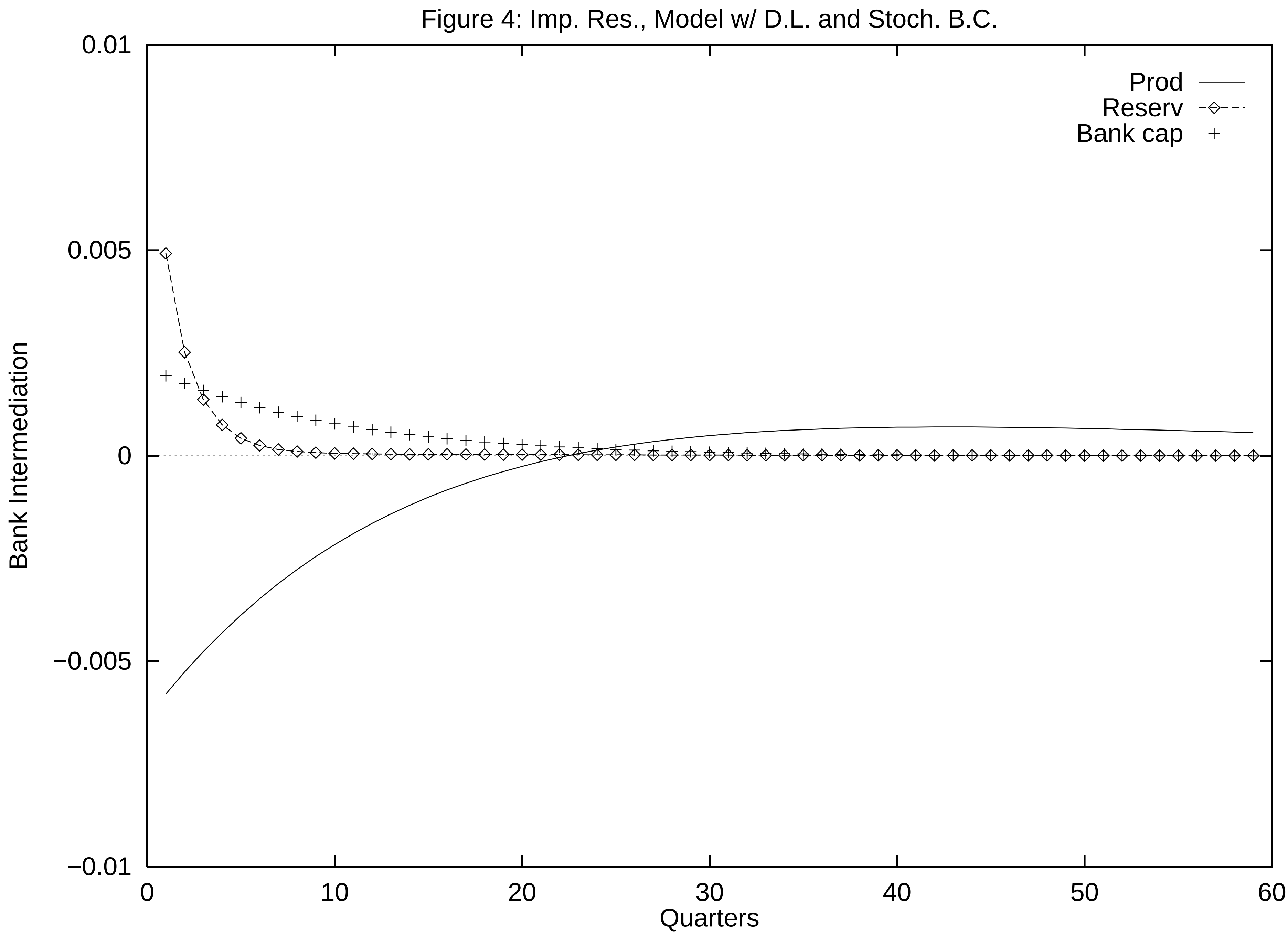


Figure 4: Imp. Res., Model w/ D.L. and Stoch. B.C.
Prod
Reserv
Bank cap
0.01
0.005
0
−0.005
−0.01
0
10
20
30
40
50
60
Bank Intermediation
Quarters

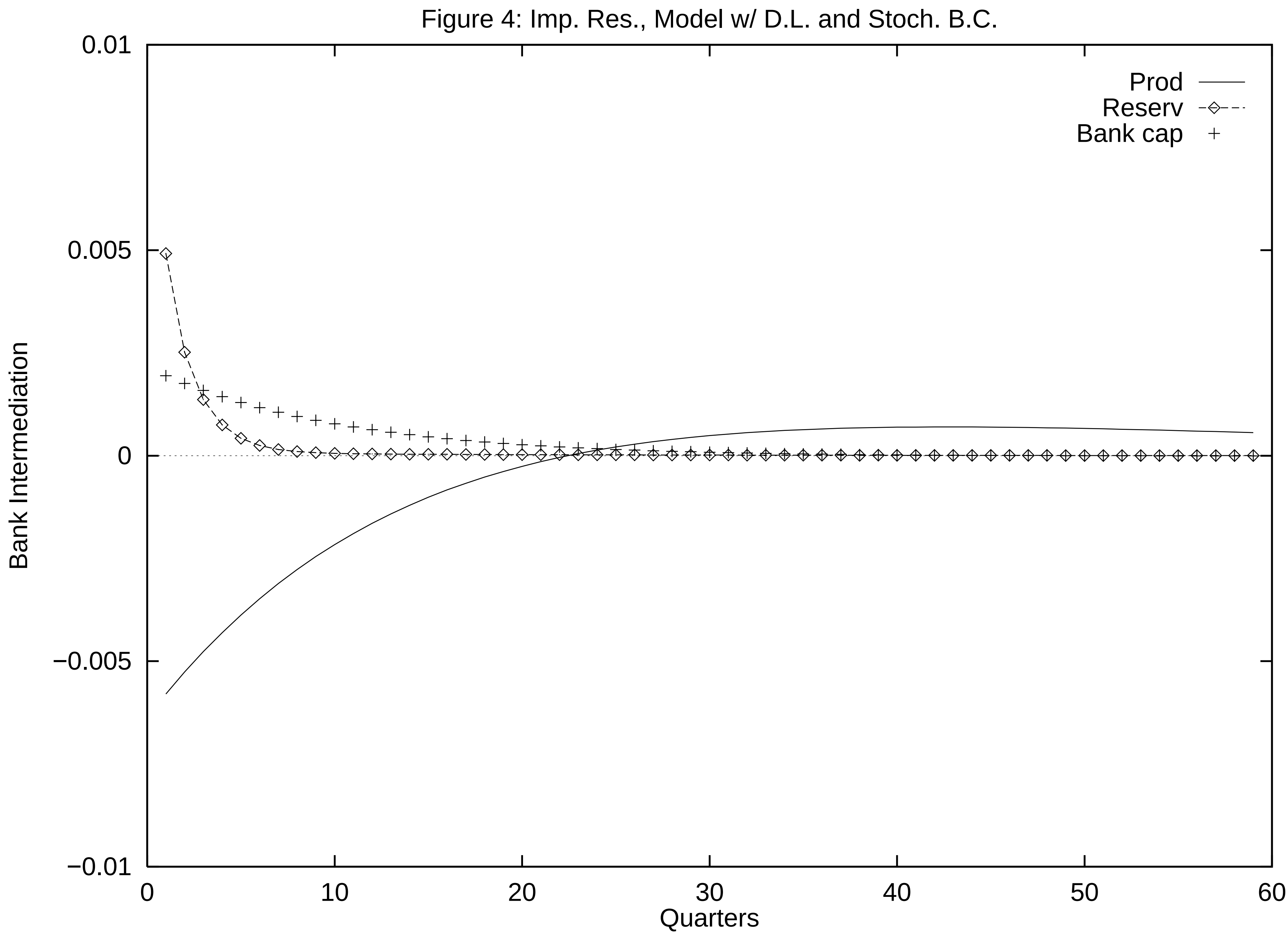
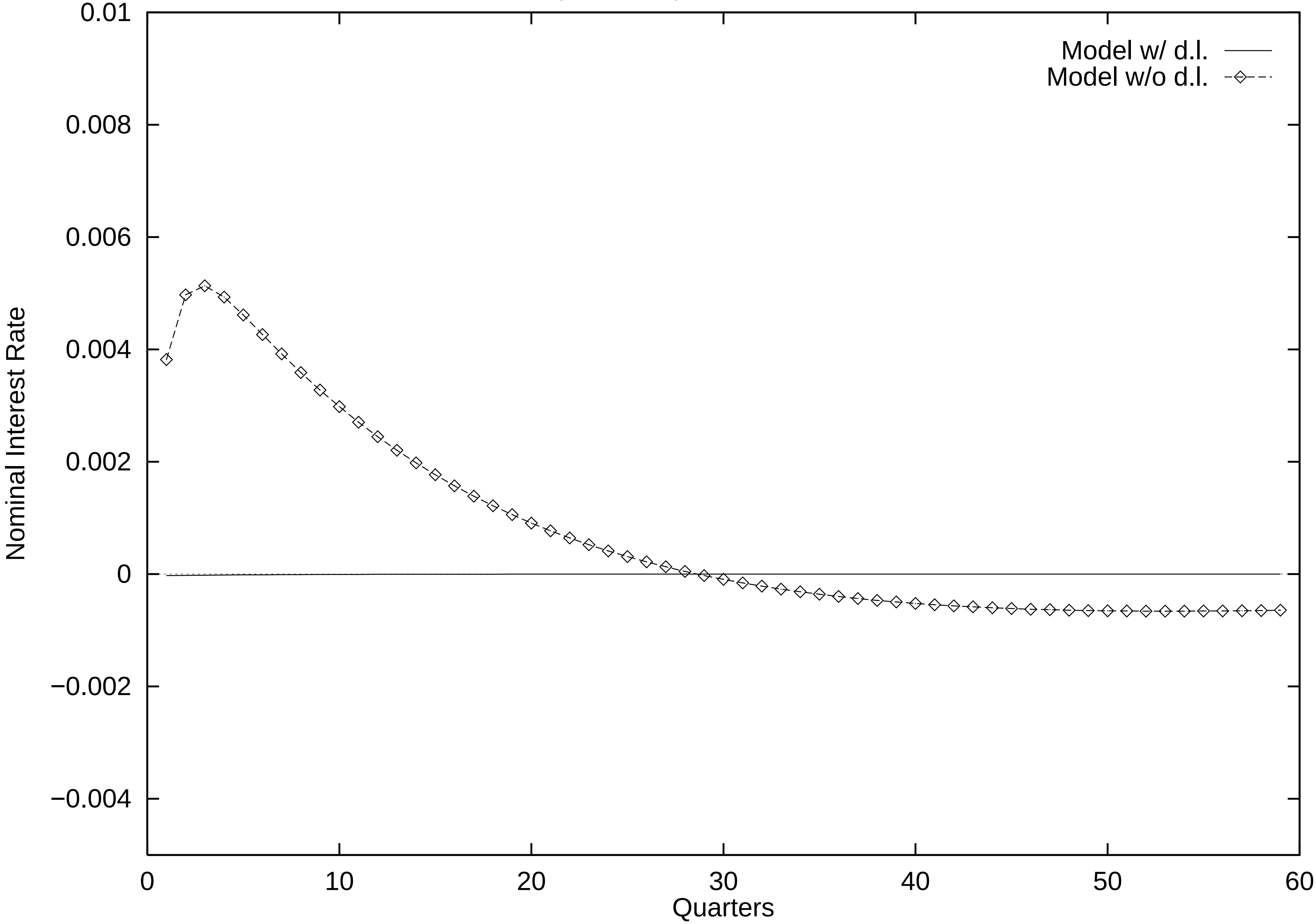


Figure 4: Imp. Res., Model w/ D.L. and Stoch. B.C.
Prod
Reserv
Bank cap
0.01
0.005
0
−0.005
−0.01
Bank Intermediation
0
10
20
30
40
50
60
Quarters

Figure 5: Imp. Res., Prod. Shock



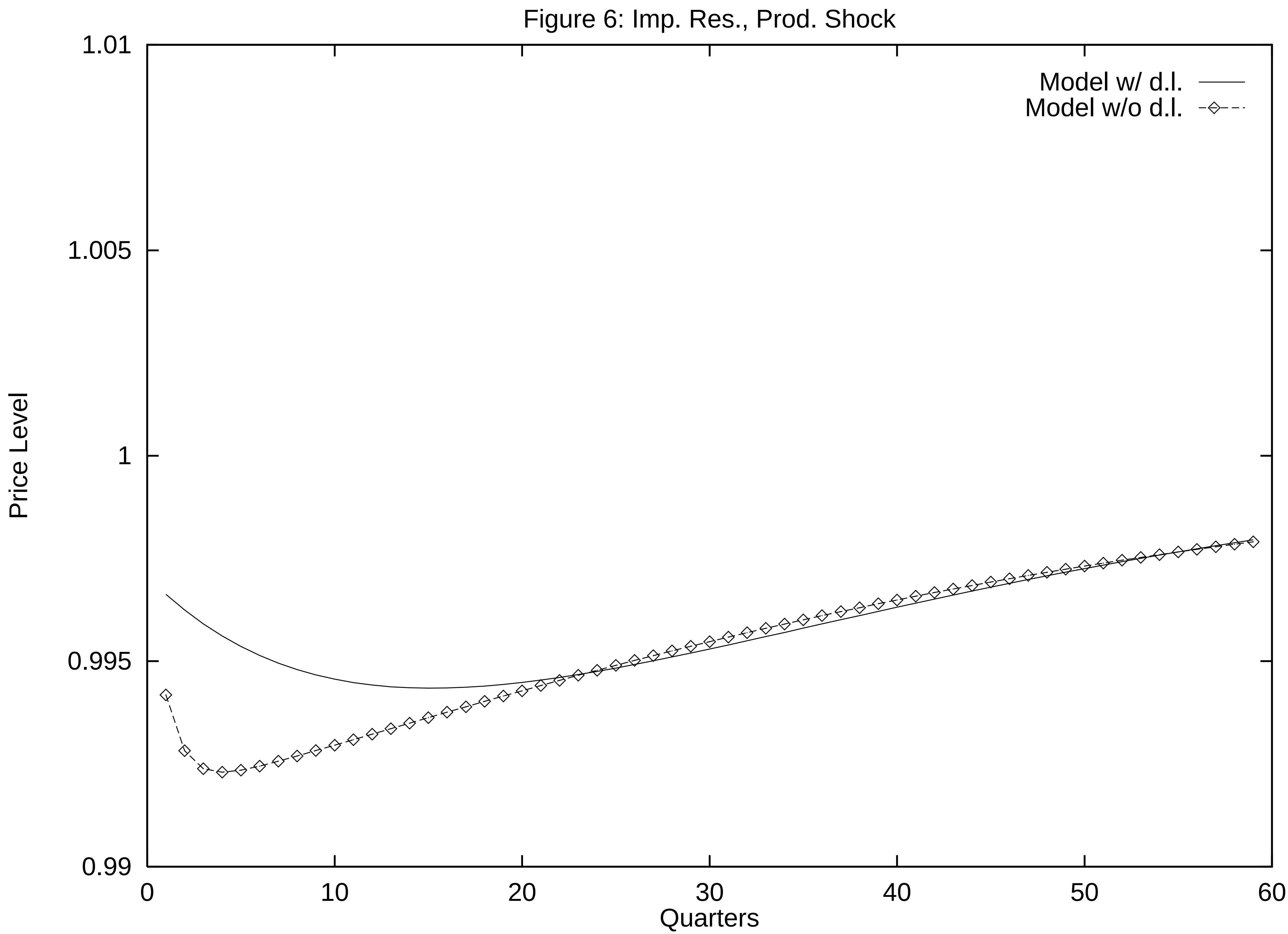


Figure 6: Imp. Res., Prod. Shock
Model w/ d.l.
Model w/o d.l.
Price Level
Quarters
1.01
1.005
1
0.995
0.99
0
10
20
30
40
50
60

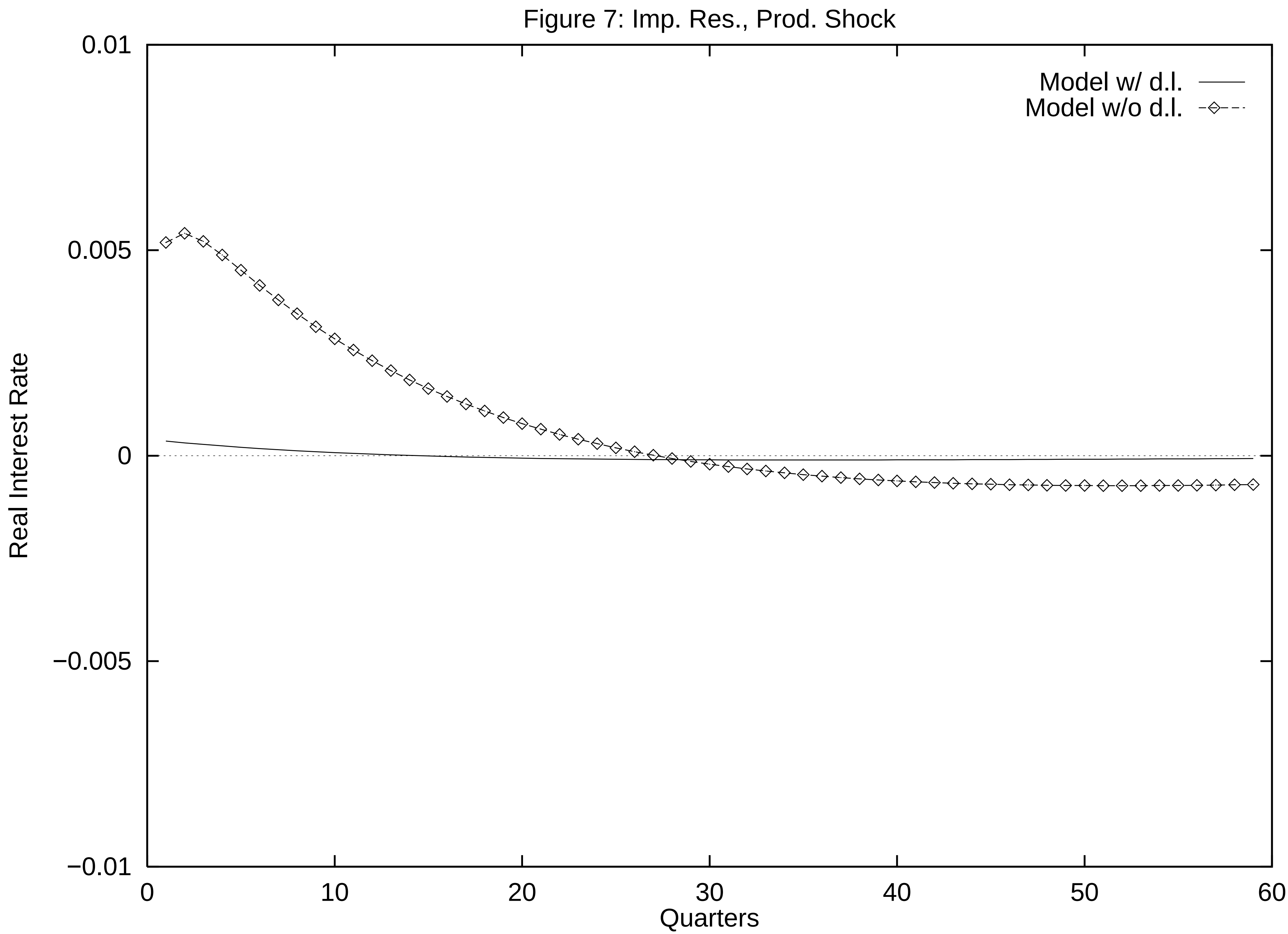


Figure 7: Imp. Res., Prod. Shock
Model w/ d.l.
Model w/o d.l.
0.01
0.005
0
−0.005
−0.01
Real Interest Rate
0
10
20
30
40
50
60
Quarters

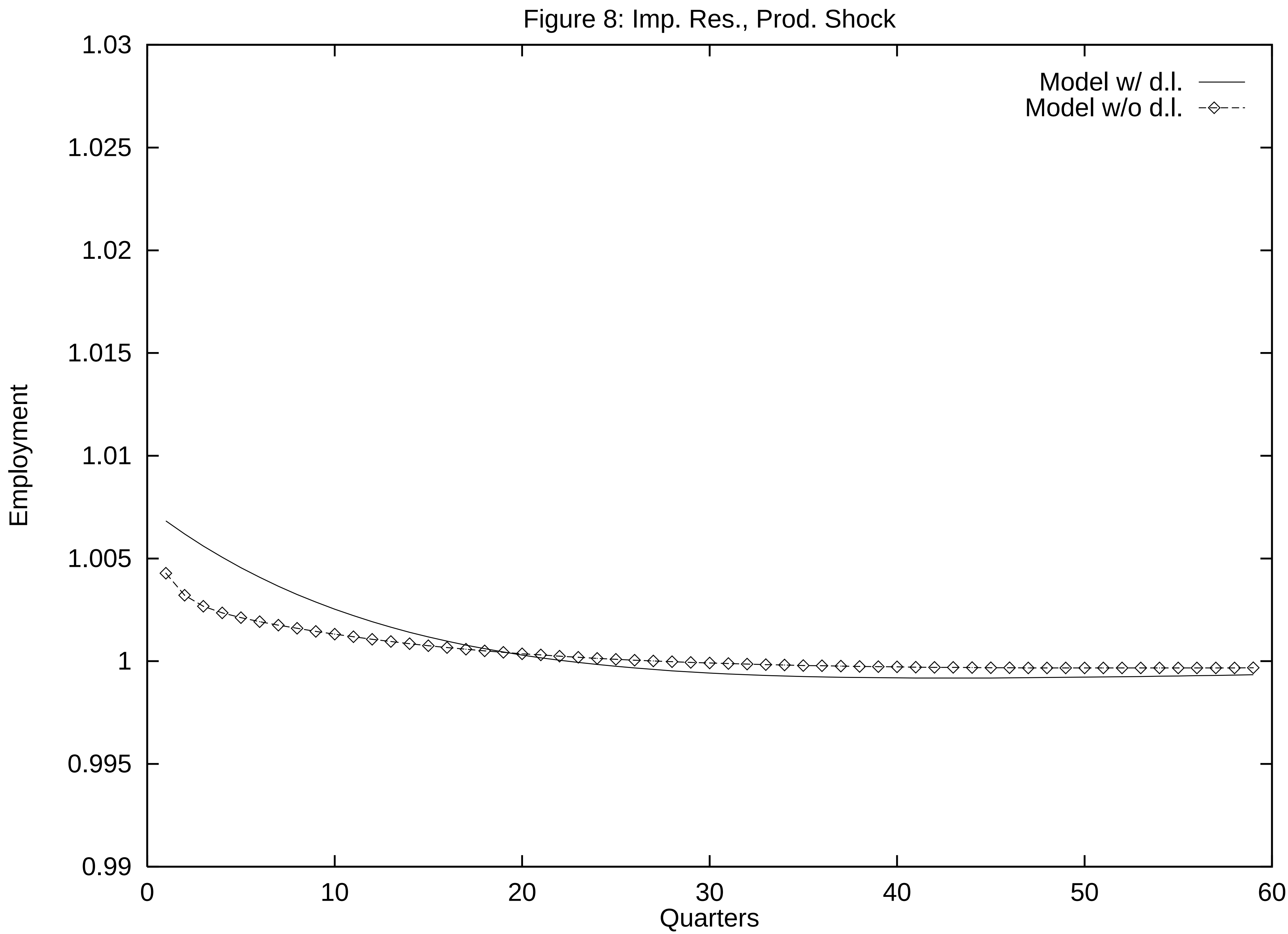
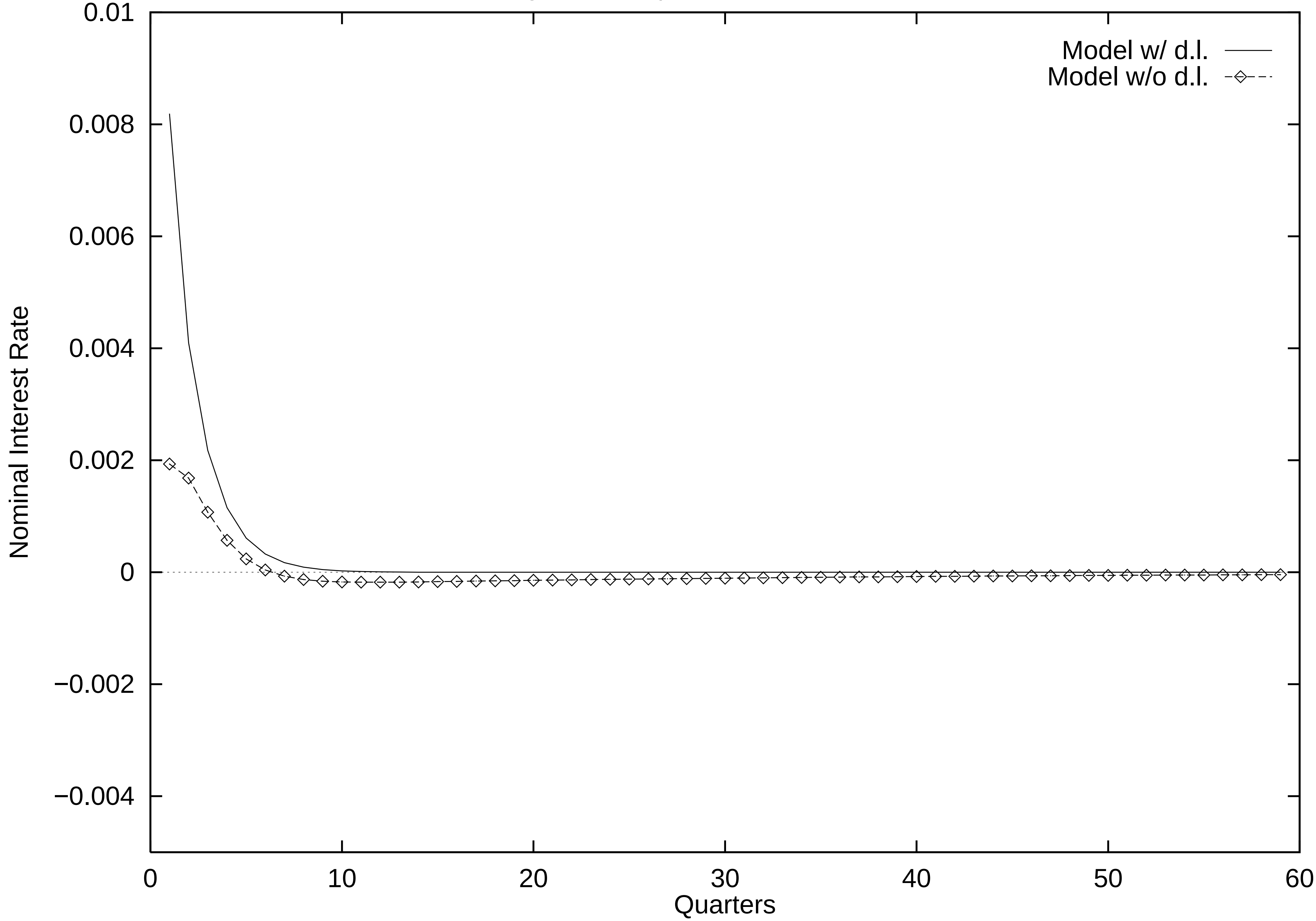


Figure 8: Imp. Res., Prod. Shock
Model w/ d.l.
Model w/o d.l.
Employment
1.03
1.025
1.02
1.015
1.01
1.005
1
0.995
0.99
0
10
20
30
40
50
60
Quarters

Figure 10: Imp. Res., Reserves Shock



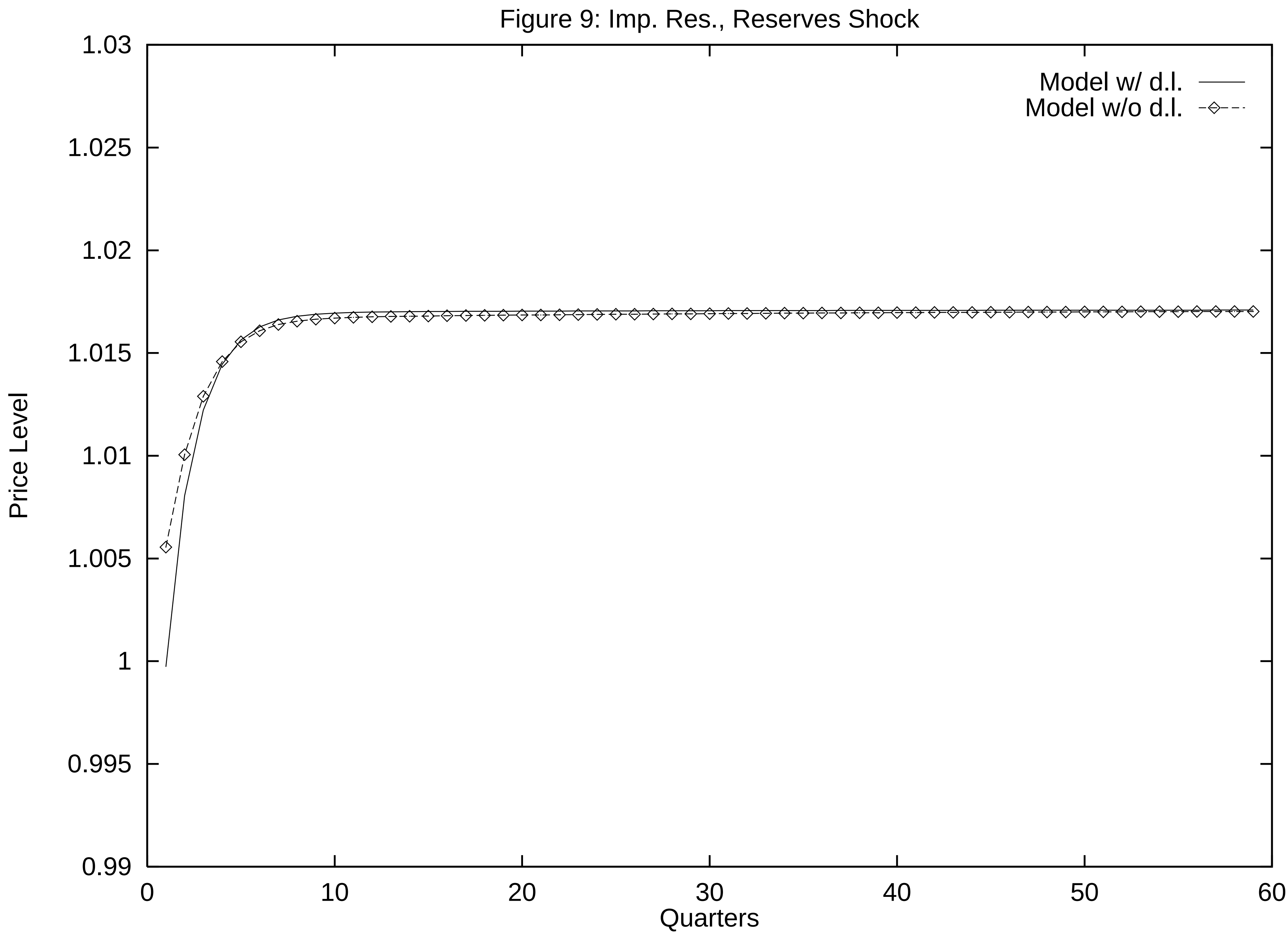


Figure 9: Imp. Res., Reserves Shock
Model w/ d.l.
Model w/o d.l.
Price Level
Quarters
1.03
1.025
1.02
1.015
1.01
1.005
1
0.995
0.99
0
10
20
30
40
50
60

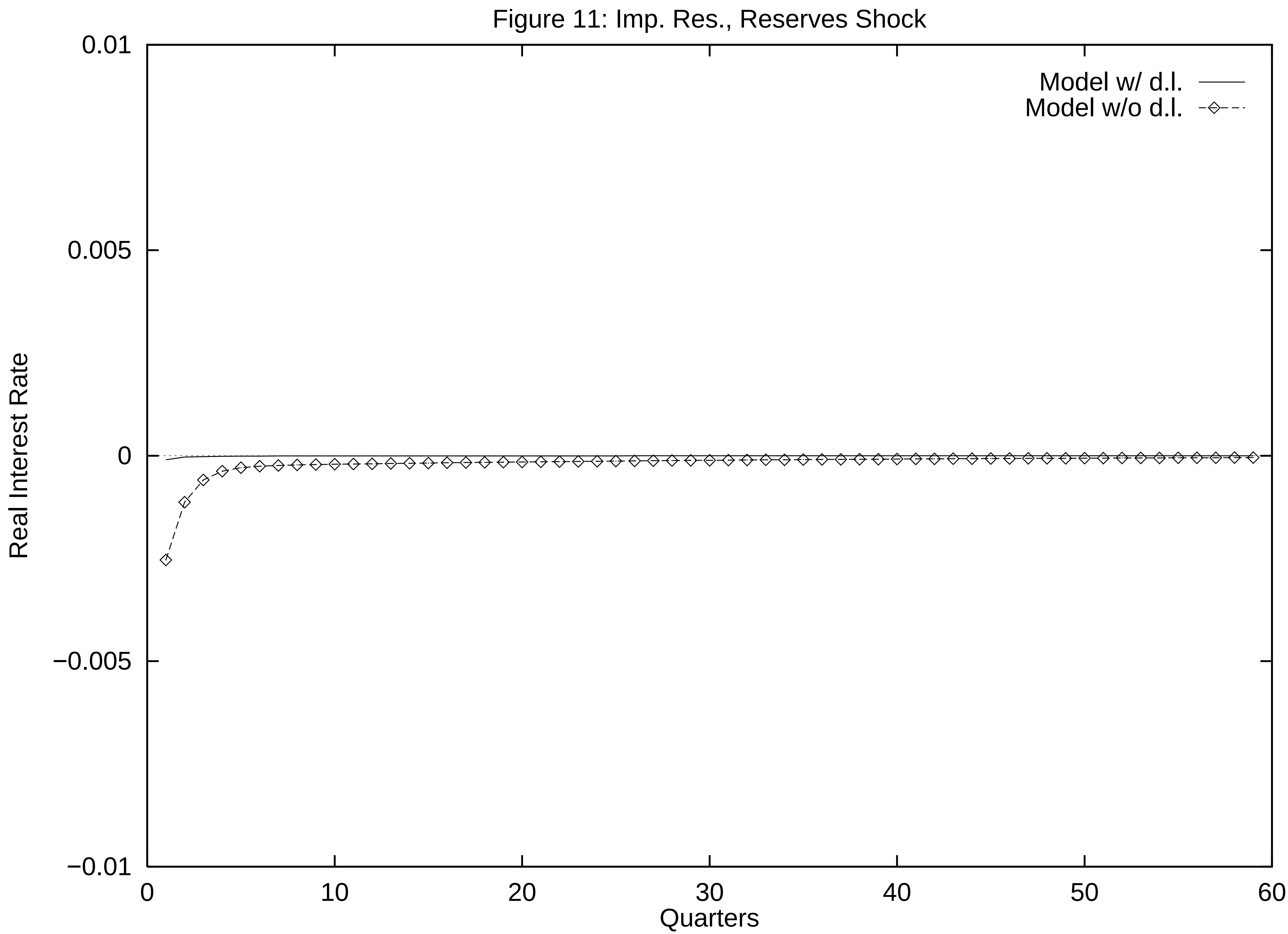
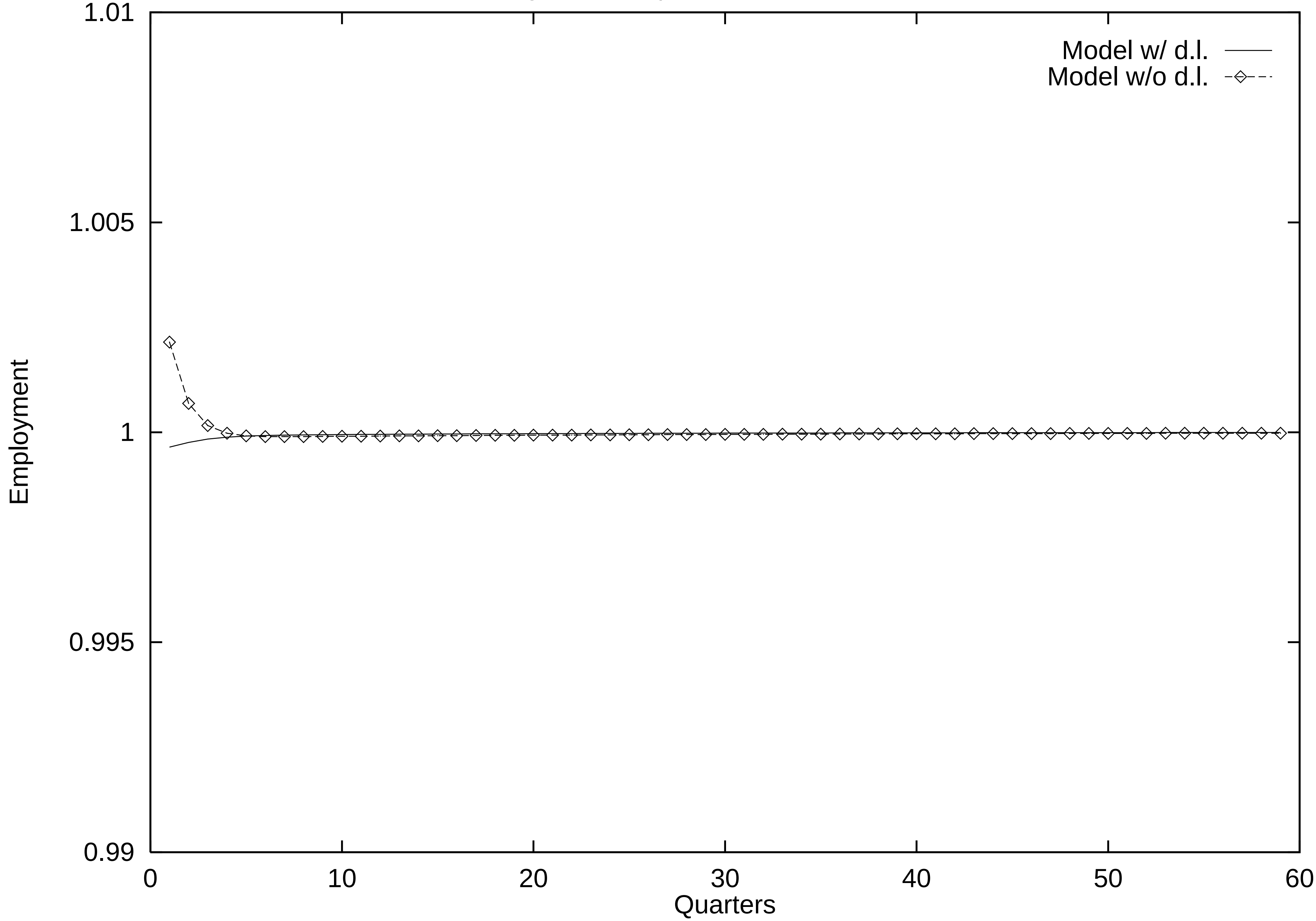


Figure 11: Imp. Res., Reserves Shock
Model w/ d.l.
Model w/o d.l.
Real Interest Rate
Quarters
0.01
0.005
0
−0.005
−0.01
0
10
20
30
40
50
60

Figure 12: Imp. Res., Reserves Shock



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