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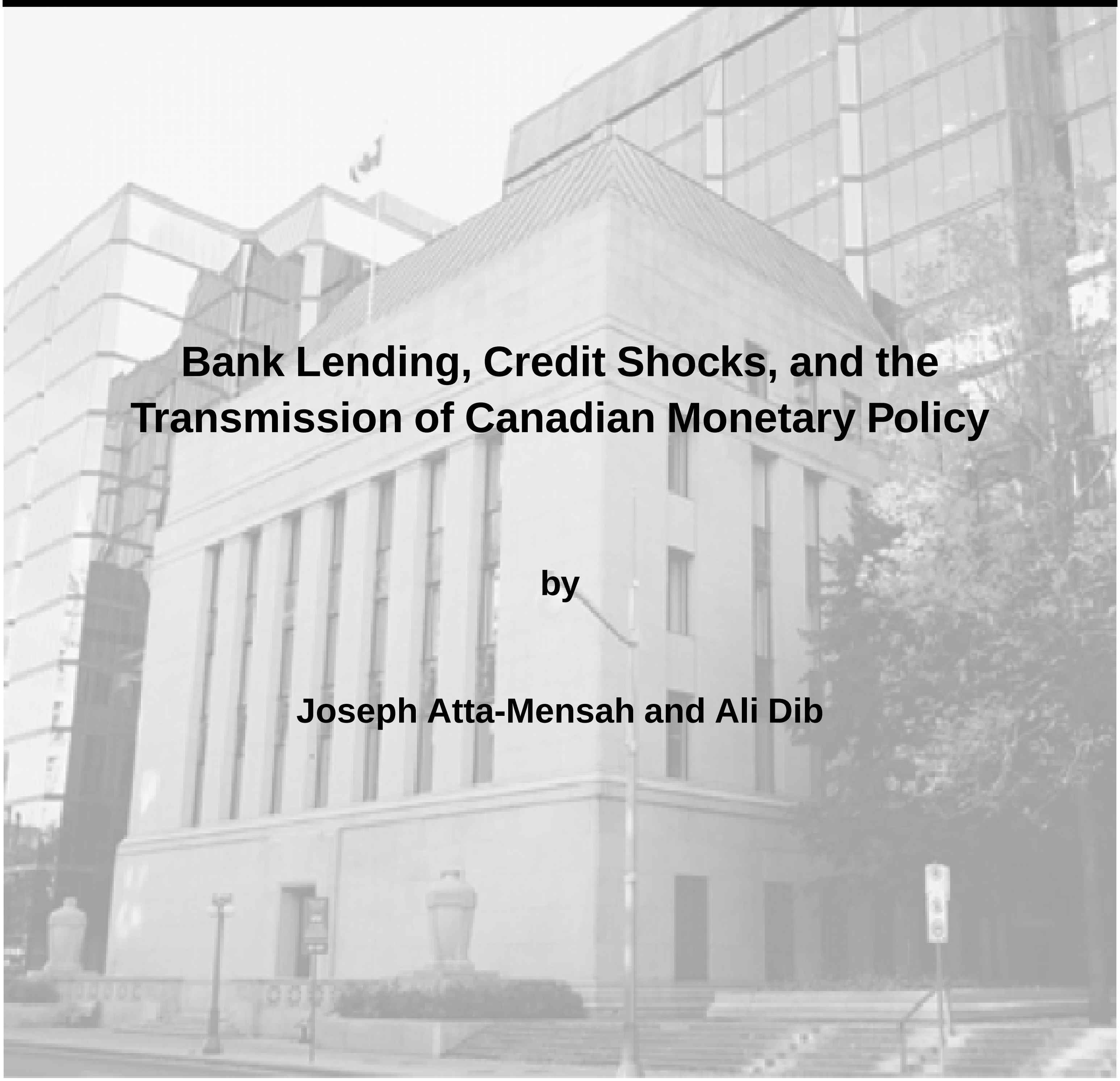

Bank Lending, Credit Shocks, and the Transmission of Canadian Monetary Policy

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Abstract

The authors use a dynamic general-equilibrium model to study the role financial frictions play as a transmission mechanism of Canadian monetary policy, and to evaluate the real effects of exogenous credit shocks. Financial frictions, which are modelled as spreads between deposit and loan interest rates, are assumed to depend on economic activity as well as on credit shocks. A general finding is that almost all of the real response to a monetary policy shock comes from the price rigidity and not the credit frictions. Credit shocks, however, do have substantial real effects on macroeconomic variables. Thus, in this model, imperfections in credit markets are responsible only for a small amplification and propagation of the real effects of monetary policy shocks.

JEL classification: E32, E4, E51
Bank classification: Financial institutions; Monetary policy framework; Transmission of monetary policy

Résumé

Les auteurs utilisent un modèle dynamique d'équilibre général pour étudier le rôle que jouent les frictions financières comme mécanisme de transmission de la politique monétaire canadienne. Ils évaluent aussi les effets réels de chocs exogènes de crédit. Les frictions financières sont modélisées comme l'écart entre les taux d'intérêt des dépôts et ceux des empruts bancaires. Elles dépendent ainsi de l'activité économique et des chocs de crédit. La conclusion générale qui découle de cette étude est que la majeure partie des effets réels des chocs de politique monétaire est due à la rigidité des prix et non aux frictions financières. Cependant, les chocs de crédit affectent significativement les variables macroéconomiques. Par conséquent, l'imperfection des marchés du crédit n'explique dans ce modèle qu'une faible part de l'amplification et de la propagation des effets réels des chocs de politique monétaire.

Classification JEL : E32, E4, E51
Classification de la Banque : Institutions financières; Cadre de la politique monétaire; Transmission de la politique monétaire

1. Introduction

In the literature, it is argued that bank lending plays an important role in the monetary transmission mechanism. Banks, by their very nature, are well-suited to deal with certain types of borrowers, especially small firms, where the problems of asymmetric information can be pronounced. From the perspective of bank lending, monetary policy affects the balance sheet of the banks. For example, an increase in interest rates by the monetary authority implies that banks will have to pay more in the overnight loans market. The rise in the overnight rate in turn leads to adjustments in interest rates and a decrease in the supply of bank credit, as banks shift out of risky loans and into safer assets. Tight monetary policy also leads to a fall in bank deposits, which results in a further fall in bank lending and consequently a fall in investment and output. Ultimately, prices fall. Declines in bank lending induced by a monetary contraction should also cause a decline in household expenditures on durables and housing: increases in interest rates lead to a deterioration in household balance sheets because of the fall in their cash flow.

In this paper, we examine the role of the banking sector in the monetary transmission mechanism and assess the contribution of exogenous credit shocks to the fluctuations in inflation and output.[1] We employ a dynamic general-equilibrium model (DGEM) to examine whether the intermediation process acts as a source of fluctuations or as a propagator of the business cycle. By choosing the DGEM, which is founded on microeconomic principles and identifies the structural links between the various sectors of the economy, we are able to identify shocks and measure their impact on consumption, investment, capital stock, and output. In effect, the richness of the model enables us to analyze the role of bank credit in economic fluctuations.

The DGEM is considered under various scenarios. First, we examine the model when there are credit frictions and price- and capital-adjustment costs. Second, we examine the model when there are credit frictions and capital-adjustment costs. Third, to gauge the impact of credit, we re-examine the model under the first scenario with no credit friction.

This paper is organized as follows. Section 2 briefly describes the transmission mechanism and the special nature of bank lending. Section 3 describes the model's salient features, and section 4 the results of our calibration exercise. Section 6 offers some conclusions.

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1. By exogenous credit shocks we mean the tightening or easing of credit conditions by intermediaries. These intermediaries may change credit conditions as a response to changes in asset markets or technological innovations in the financial sector.

2. The Transmission of Monetary Policy and the "Specialness" of Intermediaries

2.1 The transmission mechanism

Monetary policy is a powerful tool, but one that sometimes has unexpected or unwanted consequences. To succeed in the conduct and implementation of monetary policy, monetary authorities must have an accurate assessment of the timing and effect of their policies on the economy. An understanding is therefore required of the mechanisms through which monetary policy affects the economy.

Traditionally, economists have explained the transmission mechanism through the interest rate and the exchange rate channels. The interest rate channel, a key component of how monetary policy effects are transmitted to the economy, suggests that, when contractionary monetary policy raises the short-term nominal interest rate, the real long-term interest rate rises as well, as a result of sticky prices and rational expectations. These higher real interest rates lead to a decline in business fixed investment, residential housing investment, consumer durable expenditure, and inventory investment, which causes a decline in aggregate output. The decline in output leads to a fall in the output gap and eventually a decline in prices and wages.

Because Canada is a small open economy with a flexible exchange rate, monetary policy transmission also operates through exchange rate effects on net exports. This channel involves interest rate effects, because when domestic real interest rates rise, Canadian-dollar deposits become more attractive than deposits denominated in foreign currencies, leading to an appreciation of the Canadian dollar. This appreciation makes domestic goods more expensive than foreign goods, causing a fall in net exports and hence in aggregate output. Consequently, prices fall. An appreciation of the exchange rate will lower imported inflation, since foreign goods become cheaper.

Complementing the interest rate and exchange rate channels of the transmission mechanism is the credit channel, in which bank lending plays an important role. The credit channel is based on the view that banks play a special role in the financial system, because they are well-suited to deal with certain types of borrowers, particularly small firms, where the problems of asymmetric information can be pronounced. (Large firms are deemed to have access to external sources of finance without having to go through banks.) Thus, tight monetary policy that increases interest rates leads to a fall in bank deposits, which leads to a fall in bank lending and, consequently, a fall in investment and output. Ultimately, prices fall.

Strengthening the bank lending channel is the balance-sheet channel, which operates through the net worth of business firms. Lower net worth means that borrowers have less collateral with which to back their loans. Such a decline in net worth raises the adverse-selection problem by raising the percentage of risky firms in the economy, inducing banks to decrease lending to finance investment spending. Lower net worth also increases the moral hazard problem: owners have a lower equity stake in their firms, giving them more incentive to engage in risky investment projects. Since this makes it less likely that lenders will be repaid, a decrease in firms' net worth leads to a decrease in lending and hence in investment spending. Thus, contractionary monetary policy, which causes a decline in equity prices and a reduction in the net worth of firms, leads to a fall in lending, investment, and output. In addition, contractionary monetary policy that raises interest rates reduces the cash flows of firms. The fall in cash flow leads to greater adverse selection and moral hazard problems and, consequently, a fall in lending and a decline in aggregate demand.

2.2 Why intermediaries are special

Bank lending plays an important role in the transmission of monetary policy; it helps satisfy the external financial needs of firms, particularly smaller firms. Financial-contracting theory suggests that, under asymmetric information, smaller firms rely on intermediaries to reduce agency costs. Financial contracts tend to involve tight and detailed loan covenants. The efficiency of intermediaries allows them to monitor and renegotiate these contracts at a lower cost. By frequent monitoring of these contracts, intermediaries become better informed about firms and they develop special relationships with each other.

In explaining the special role of banks, Himmelberg and Morgan (1995) suggest that lenders attempt to control agency problems by imposing restrictive covenants in lending contracts. These covenants require firms to maintain minimum levels of net worth and working capital. Because of the difficulty in determining the true financial health of a firm, the covenants require frequent monitoring of the firm. Diamond (1984) suggests that the set-up of intermediaries makes them perfect monitors. Himmelberg and Morgan (1995) argue that intermediaries are more efficient at monitoring financial contracts for at least two reasons. First, because of their large stake in the projects, intermediaries will conduct frequent monitoring to determine whether a covenant has been violated. Second, intermediaries can renegotiate a covenant more easily and cheaply than dispersed public lenders, such as bondholders.

Asquith, Gertner, and Sharfstein (1994) suggest that another factor that makes banks special is their flexibility in dealing with financially distressed firms. For example, when a firm fails to make a payment or breaks a covenant, banks generally restructure the loan contract. The new contract may waive some elements of the covenant, prolong the maturity of the debt, or require more collateral to be posted. By restructuring the contract, banks reduce the cost of financial distress on firms. Market-based lenders, such as bondholders, who do not have this flexibility in renegotiating with financially distressed firms, generally force those firms into bankruptcy.

In sum, banks or intermediaries are special, especially for small businesses. The intense monitoring of projects, the tight and detailed covenants on loan contracts, and the special relationship between banks and clients make bank credit an imperfect substitute for other forms of credit. The imperfect substitution between bank and non-bank credit contributes to the bank lending channel of the monetary transmission mechanism.

3. The Model

The model we use is very similar to that used by Dib (2002), which is inspired by Ireland (1997, 2000).[2] There are five agents in this economy: a representative household, a representative final-good-producing firm, a continuum of intermediate-good-producing firms indexed by $j \in (0, 1)$, a financial intermediary, and a monetary authority. The representative final-good producer sells its output, y_t, to households at a perfectly competitive price, p_t. Purchases of intermediate-good producers must be financed through borrowing from the financial intermediary. The intermediate-good producer is assumed to produce a distinct, perishable good, y_{jt}, that is sold on a monopolistic-competitive market at price p_{jt}. This intermediate good is sold to other intermediate producers and the final-good producer. Furthermore, the intermediate-good producer is assumed to pay quadratic adjustment costs when it changes its nominal price. Purchases of intermediate goods as inputs to production for other intermediate producers must be financed through borrowing from the financial intermediary.

3.1 The household

Faced with a budget constraint, the representative household chooses consumption, c_t, real money balances, $M_t^c / p_t = (M_t - D_t) / p_t$, and leisure, $(1 - h_t)$, that will maximize a utility function of the form:

2. Dib (2002) constructs and estimates a dynamic, stochastic, general-equilibrium model with price and wage rigidities and capital-adjustment costs.

$$U_0 = E_o \sum_{k=0}^{\infty} \beta^t \left[\frac{\gamma}{\gamma - 1} \log \left(c_t^{\frac{\gamma-1}{\gamma}} + b_t^{\frac{1}{\gamma}} \left(\frac{M_t^c}{p_t} \right)^{\frac{\gamma-1}{\gamma}} \right) + \eta \log(1 - h_t) \right], \tag{1}$$

where $\beta \in (0, 1)$ is the discount factor, γ and η are positive structural parameters, M_t is the total money balance in the economy, D_t is household deposits at the financial intermediaries, and h_t is labour hours. As in Kim (2000), b_t summarizes the money-demand shocks and is assumed to evolve as:

$$\log(b_t) = (1 - \rho_b)\log b + \rho_b \log(b_{t-1}) + \varepsilon_{bt}. \tag{2}$$

Let ε_{bt}, the serially uncorrelated shock, be normally distributed with mean zero and standard deviation σ_b and $\rho_b \in (-1, 1)$.

The household enters period t with k_t units of capital and M_{t-1} units of money. Capital, k_t, and labour, h_t, are supplied by the household to the intermediate-good producers in perfectly competitive markets. The amounts supplied to each individual intermediate firm, j, are given by k_{jt} and h_{jt}. Therefore, aggregate capital and aggregate labour satisfy $k_t = \int_0^1 k_{jt} dj$ and $h_t = \int_0^1 h_{jt} dj$, for all t. The sources of household income are rent from capital, labour income, and profits from intermediate-good-producing firms, $\pi_t^F = \int_0^1 \pi_{jt}^F dj$, as well as from the intermediaries, π_t^I. In addition, at the end of period t, the household receives payments of principal plus interest, $R_t D_t$, from intermediaries, where R_t denotes the current gross return on deposits, D_t.

The household purchases the final good at the price p_t, part of which it consumes, while the remainder is invested. The usual relationship between capital, k_t, and investment, i_t, is assumed:

$$k_{t+1} = (1 - \delta)k_t + i_t, \tag{3}$$

where $\delta \in (0, 1)$ is a constant capital depreciation rate. We assume that each household adjusts its capital stock slowly, at a cost:

$$CAC_t = \frac{\phi_k}{2} \left(\frac{k_{t+1}}{k_t} - 1 \right)^2 k_t, \tag{4}$$

where ϕ_k is a positive capital-adjustment cost parameter. With this specification, both total and marginal capital-adjustment costs are equal to zero in the steady-state equilibrium.

Let r_{kt} be the real rental rate of capital and w_t the real wage. The budget constraint facing the representative household is of the form:

$$c_t + i_t + CAC_t - r_{kt}k_t - w_t h_t \le \frac{M_{t-1} - M_t + (R_t - 1)D_t + \pi_t^F + \pi_t^I}{p_t}. \tag{5}$$

Faced with the above budget constraint and equations (3) and (4), the household chooses, in each period, $\{c_t, M_t, D_t, h_t, k_{t+1}\}$, $t = 0, 1, 2, \ldots$, to maximize the utility function given by equation (1). The optimal decision facing the household can be expressed in the following Bellman equation:

$$V(k_t, M_{t-1}, \Omega_t) = \max_{\{c_t, M_t, D_t, h_t, k_{t+1}\}} [u(c_t, M_t^c/p_t, h_t) +$$

$$\beta E_t V(k_{t+1}, M_t, \Omega_{t+1})],$$

under constraints (3)-(5); $M_t^c = M_t - D_t$. Ω_t is the information set upon which expectations formed in period t are conditioned. Note that, in contrast to the limited-participation models utilized by Christiano, Eichenbaum, and Evans (1997) and others, households are free to adjust their deposits at banks after the current period's shocks are revealed. The real effects of monetary policy come from price and credit frictions in this model. Given λ_t, as the Lagrangian multiplier, the first-order conditions for the household are:

$$\frac{c_t^{-\frac{1}{\gamma}}}{c_t^{\frac{\gamma-1}{\gamma}} + b_t^{\frac{1}{\gamma}}(M_t^c/p_t)^{\frac{\gamma-1}{\gamma}}} - \lambda_t = 0, \tag{6}$$

$$\frac{\eta}{1-h_t} - \lambda_t w_t = 0, \tag{7}$$

$$\frac{b_t^{\frac{1}{\gamma}}(M_t^c/p_t)^{\frac{-1}{\gamma}}}{c_t^{\frac{\gamma-1}{\gamma}} + b_t^{\frac{1}{\gamma}}(M_t^c/p_t)^{\frac{\gamma-1}{\gamma}}} - \lambda_t + \beta E_t\left(\frac{p_t\lambda_{t+1}}{p_{t+1}}\right) = 0, \tag{8}$$

$$\frac{b_t^{\frac{1}{\gamma}}(M_t^c/p_t)^{\frac{-1}{\gamma}}}{c_t^{\frac{\gamma-1}{\gamma}} + b_t^{\frac{1}{\gamma}}(M_t^c/p_t)^{\frac{\gamma-1}{\gamma}}} = \lambda_t(R_t - 1), \tag{9}$$

$$\beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\left(r_{kt+1} + (1-\delta) + \phi_k\left(\frac{k_{t+2}}{k_{t+1}} - 1\right)\frac{k_{t+2}}{k_{t+1}}\right)\right] - \phi_k\left(\frac{k_{t+1}}{k_t} - 1\right) - 1 = 0. \tag{10}$$

Equations (6) and (7) suggest that the marginal rate of substitution between consumption and labour is equal to the real wage. Equation (8) shows that the marginal utility of real money balances is equal to the difference between the current marginal utility of consumption and the expected future marginal utility of consumption adjusted for the expected rate of inflation. Equation (9) indicates that the marginal cost of one dollar used as deposits, in terms of the marginal utility of real money balances, is equal to the net return, $R_t - 1$, of this dollar discounted by the marginal utility of consumption, λ_t. Furthermore, equations (8) and (9) imply that the net nominal interest rate between t and t+1, $r_t = R_t - 1$, is equal to $1 - \beta E_t[\lambda_{t+1}p_t/\lambda_t p_{t+1}]$. Equation (10) indicates the optimal intertemporal wealth allocation.

Following Ireland (1997) and Kim (2000), equations (6) and (8) can be used to approximate a real money-demand function of the form:

$$\log(M_t^c/p_t) = \log(c_t) - \gamma\log(r_t) + \log(b_t). \tag{11}$$

where γ is the interest elasticity of money demand. Note that in equation (11), b_t represents a serially correlated money-demand shock.

3.2 The final-good-producing firm

We assume that a continuum of the intermediate goods is used in the production of the final good. Let y_t be the output of a final-good firm. Then, assuming that all intermediate goods are imperfect substitutes with constant elasticity of substitution, θ, we can use the Dixit and Stiglitz (1977) aggregator function to express the aggregate output, y_t, of all final-goods firms as:

$$y_t \le \left[\int_0^1 y_{jt}^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}}, \tag{12}$$

where $\theta > 1$. The final good, y_t, is divided between consumption, investment, and inputs used in the production of each intermediate good.

Given the price p_{jt}, the final-good firm chooses the quantity of intermediate output, y_{jt}, that maximizes its profits. The profit-maximization problem is:

$$\max_{y_{jt}} \left[p_t \left(\int_0^1 y_{jt}^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}} - \int_0^1 p_{jt} y_{jt} dj \right]. \tag{13}$$

The first-order conditions imply that the demand function facing each intermediate-good-producing firm is given as:

$$y_{jt} = \left(\frac{p_{jt}}{p_t} \right)^{-\theta} y_t. \tag{14}$$

The implied final-good price index satisfies:

$$p_t = \left[\int_0^1 p_{jt}^{(1-\theta)} dj \right]^{\frac{1}{1-\theta}}. \tag{15}$$

3.3 The intermediate-good-producing firm

Good y_{jt} is produced using an intermediate-good input, χ_{jt}, which is a quantity of the final output, a capital stock, k_{jt}, and labour, h_{jt}, according to the following constant-returns-to scale technology:

$$y_{jt} \le \chi_{jt}^{\psi} [k_{jt}^{\alpha} (A_t h_{jt})^{1-\alpha}]^{1-\psi}, \tag{16}$$

where $\psi \in [0, 1]$ is the share of intermediate goods in production, and $\alpha \in (0, 1)$ is the share of capital in value-added. Huang, Liu, and Phaneuf (2000) also introduce intermediate-goods inputs in their model to generate more dynamics. A_t is a technology shock that is common to all intermediate-good-producing firms and follows an autoregressive process:

$$\log(A_t) = (1-\rho_A)\log A + \rho_A \log(A_{t-1}) + \varepsilon_{At}. \tag{17}$$

The serially uncorrelated shock, ε_{At}, is assumed to be normally distributed with mean zero and standard deviation σ_A and $\rho_A \in (-1, 1)$.

Each intermediate-goods-producing firm, j, must borrow funds, L_{jt}, from financial intermediaries to pay for its intermediate-good inputs. We assume that firms borrow to pay for intermediate-goods inputs as opposed to wages or capital because it is equivalent to using the loan as a variable in the production function and it generates more dynamics in the model.[3] Therefore, the firm faces the financing constraint

$$L_{jt} \geq p_t \chi_{jt},$$

for all t=0,1,2, ... Since these funds are borrowed at the gross rate, R_t^l, the firm must repay principal plus interest, $R_t^l L_{jt}$, at the end of the period.

Next, we follow Rotemberg (1982) by introducing a nominal rigidity into the model. This is done by assuming that the intermediate-good producer incurs a cost for adjusting its nominal price. The cost is of the form:

$$PAC_{jt} = \frac{\phi_p}{2}\left(\frac{p_{jt}}{\pi p_{jt-1}} - 1\right)^2 y_t, \tag{18}$$

where $\phi_p \geq 0$ is the price-adjustment cost parameter. The adjustment cost, which is measured in terms of the final good, is explained by Rotemberg as capturing the negative effects of price changes on the relationship between the firm and the consumer. Equation (18) shows that this cost increases in magnitude with the size of the price change and with the overall size of economic activity (proxied by the total output of the final good produced). Note that the price markup is constant under complete price flexibility ($\phi_p = 0$), but endogenous when prices are rigid.

Constrained by equation (16) and given the price-adjustment costs, the representative intermediate-good-producer chooses h_{jt}, k_{jt}, χ_{jt}, and p_{jt}, $t \geq 0$, to maximize the expected discounted flow of its profits:

$$\underset{\{k_{jt}, h_{jt}, \chi_{jt}, p_{jt}\}}{max} E_o\left[\sum_{t=0}^{\infty} \beta^t \lambda_t \pi_{jt}^F / p_t\right].$$

The instantaneous profit function is of the form:

$$\pi_{jt}^F = p_{jt} y_{jt} - p_t r_{kt} k_{jt} - p_t w_t h_{jt} - p_t PAC_{jt} - R_t^l p_t \chi_{jt}, \tag{19}$$

3. It is equivalent to assuming that small firms borrow to finance their purchases of raw material used in the production process.

where $\beta^t\lambda_t$ and λ_t, which represent the pricing kernel for contingent claims, are the firm's stochastic discount factor and marginal utility of consumption, respectively. Transforming the maximization problem into a Bellman equation, we have:

$$V(p_{jt-1}, \Omega_t) = \max_{\{k_{jt}, h_{jt}, p_{jt}, \chi_{jt}\}} [\lambda_t \pi^F_{jt} / p_t + \beta E_t V(p_{jt}, \Omega_{t+1})],$$

subject to equations (14) and (16). Ω_t is the information set upon which expectations are conditioned in period *t*. With $\xi_t > 0$ denoting the Lagrangian multiplier, the first-order conditions for the maximization problem with respect to k_{jt}, h_{jt}, χ_{jt}, p_{jt}, and ξ_t are:

$$(1-\psi)\alpha\frac{y_{jt}}{k_{jt}}\frac{\xi_t}{\lambda_t} - r_{kt} = 0, \tag{20}$$

$$(1-\psi)(1-\alpha)\frac{y_{jt}}{h_{jt}}\frac{\xi_t}{\lambda_t} - w_t = 0, \tag{21}$$

$$\psi\frac{y_{jt}}{\chi_{jt}}\frac{\xi_t}{\lambda_t} - R^l_t = 0, \tag{22}$$

$$\begin{aligned}&\frac{\xi_t}{\lambda_t} - \frac{\theta-1}{\theta}\frac{p_{jt}}{p_t} - \frac{\phi_p}{\theta}\left(\frac{p_{jt}}{\pi p_{jt-1}} - 1\right)\frac{p_{jt}}{\pi p_{jt-1}}\frac{y_t}{y_{jt}} \\ &+ \frac{\beta\phi_p}{\theta}E_t\left[\left(\frac{p_{jt+1}}{\pi p_{jt}} - 1\right)\frac{p_{jt+1}}{\pi p_{jt}}\frac{\lambda_{t+1}}{\lambda_t}\frac{y_{t+1}}{y_{jt}}\right] = 0,\end{aligned} \tag{23}$$

$$\chi^{\psi}_{jt}[k^{\alpha}_{jt}(A_t h_{jt})^{1-\alpha}]^{1-\psi} - \left(\frac{p_{jt}}{p_t}\right)^{-\theta} y_t = 0. \tag{24}$$

Equations (20) - (22) equate the marginal productivity of capital, labour, and intermediate goods to their relative prices. Equation (23) summarizes the adjustment process of the nominal price of y_{jt}.

From equations (20) and (21), the gross price markup over the marginal cost is $q_t = \lambda_t / \xi_t$. This markup is equal to $\theta/(\theta-1)$ when there are no price-adjustment costs ($\phi_p = 0$). Thus, in the absence of price-adjustment costs, marginal cost does not adjust in response to demand and monetary policy shocks.

In the presence of nominal price rigidities, however, the markup does adjust to demand and monetary policy shocks. For instance, following a positive technology shock, the marginal cost curve shifts downward, and, since the intermediate-good-producing firm does not fully adjust its price, both the markup and output increase. On the other hand, a positive aggregate-demand shock shifts the marginal revenue curve upward, and, given that prices are sticky, the markup decreases, while labour demand and output increase.

3.4 The monetary authority

As in Dib (2002), we assume that the monetary authority adjusts the short-term interest rate, R_t (and/or the money supply, M_t), in response to deviations of output, y_t, inflation, and money-supply growth. The process governing the evolution of monetary policy is therefore similar to a Taylor rule:

$$\log\left(\frac{R_t}{R}\right) = \rho_y \log\left(\frac{y_t}{y}\right) + \rho_\pi \log\left(\frac{\pi_t}{\pi}\right) + \rho_\mu \log\left(\frac{\mu_t}{\mu}\right) + \varepsilon_{Rt}, \tag{25}$$

where $\mu_t = M_t / M_{t-1}$ is the gross growth rate of money in period t, $\pi_t = p_t / p_{t-1}$ is the inflation rate, and ε_{Rt} is a serially uncorrelated and normally distributed interest rate shock with mean zero and standard deviation σ_R.

3.5 The intermediary

At the beginning of each period t, households are assumed to make regular deposits, D_t, with a representative financial intermediary. In addition, at the beginning of each period, this intermediary receives a lump-sum nominal transfer, X_t, from the monetary authority (the central bank). From the household deposits and transfers, the intermediary can lend L_{jt} to each intermediate-good-producing firm to finance the intermediate goods used as inputs in production. Since the loan is taken by the intermediate-goods-producing firm to cover expenditure on intermediate-good inputs, equilibrium requires that:

$$L_t = \int_0^1 p_t \chi_{jt} dj. \tag{26}$$

where $L_t = \int_0^1 L_{jt} dj$ is total loans made in period t. As long as the net nominal interest rate is positive, all available funds will be lent to firms and equation (26) will hold with equality. Next, we postulate an intermediation technology for the production of loans of the following form:

$$L_t \leq \zeta_t(D_t + X_t). \tag{27}$$

The variable $\zeta_t \in [0, 1]$ represents the fraction of total deposits lent out to the intermediate-good-producing firms. The remaining portion of deposits, $(1 - \zeta_t)$, is held as reserves that earn no return.

Next, assume that ζ_t is partly endogenous and depends on the state of the economy. The willingness of intermediaries to lend is assumed to be procyclical. This can be motivated by the fact that, in good times, the cash flow and net worth of firms are relatively high. This improves the creditworthiness of borrowers and increases the willingness of intermediaries to lend. In particular, ζ_t is assumed to have the following form:

$$\zeta_t = (y_t/y)^{\tau} z_t. \tag{28}$$

The state of the economy is given by y_t/y, the deviation of the output from its steady-state equilibrium value.[4] The elasticity with respect to the state of the economy is given by $\tau > 0$, and z_t represents shocks to the intermediation process. The process for z_t is given by:

$$\log(z_t) = (1 - \rho_z)\log(z) + \rho_z \log(z_{t-1}) + \varepsilon_{zt}, \tag{29}$$

where $\rho_z \in (-1, 1)$ and ε_{zt} is a serially uncorrelated shock that is normally distributed with mean zero and standard deviation σ_z.[5]

In equation (28), y_t/y captures the endogenous component of banks' willingness to lend; z_t represents the exogenous effects, approximates perceived changes in cash flow or net worth (i.e., creditworthiness) not measured by y_t, and represents exogenous changes in the confidence level of intermediaries with respect to the credit risks of their borrowers and the health of the economy. Government regulation of intermediaries (for example, reserve requirements) is one possible source of fluctuations in the intermediation process.[6] Technological advances in the intermediation process can be considered another source of variation in z_t. The process of loan evaluation certainly has evolved over time, through stochastic technological advances in

4. The spirit of equation (28) is similar to Cook (1999), where intermediation costs depend on the lagged level of economic activity.
5. In Cooper and Ejarque (2000), the intermediation process is completely exogenous and follows an AR(1).
6. In Canada, since 1993, the financial intermediaries have not been required to keep reserves. This may be interpreted as a shock that affects the intermediation process.

information services. These variations may represent changes in total factor productivity in the intermediation process.

At the end of period t, the representative intermediary collects $R_t^l L_t$ in principal and interest from all intermediate-good-producing firms; hence, R_t^l is the gross nominal interest rate on loans. The intermediary owes $R_t D_t$ to its depositors and earns a zero net return on its reserves. As such, the intermediary profit function is given by

$$\pi_t^I = R_t^l L_t + D_t + X_t - L_t - R_t D_t. \tag{30}$$

Competition among intermediaries for loans and deposits guarantees that

$$\zeta_t (R_t^l - 1) = R_t - 1, \tag{31}$$

for all t. With competitive intermediaries, fluctuations in the reserve levels of banks would be reflected in the gap between loan and deposit interest rates. Since $\zeta_t < 1$, we have $R_t^l - R_t > 0$. This intermediation spread decreases as ζ_t increases, so that as intermediaries become more willing to lend, the supply of funds increases and their profit is squeezed. The maximum nominal profits of the intermediary, under this condition, are $\pi_t^I = R_t X_t$.

3.6 Symmetric equilibrium and resolution

In a symmetric equilibrium, all intermediate-good-producing firms are identical. They make the same decisions, so that $k_{jt} = k_t$, $h_{jt} = h_t$, $p_{jt} = p_{it} = p_t$, $y_{jt} = y_t$, $\chi_{jt} = \chi_t$, and $\pi_{jt}^F = \pi_t^F$, $\forall\, j, i$. Let $\pi_t = p_t / p_{t-1}$ denote the inflation rate in period t, $m_t = M_t / p$, and $m_t^c = M_t^c / p$. The symmetric equilibrium is composed of an allocation, $\{y_t, c_t, m_t, m_t^c, c_t, h_t, k_t, \chi_t\}_{t=0}^{\infty}$, and a sequence of prices and co-state variables, $\{R_t, R_t^l, w_t, r_{kt}, \pi_t, \lambda_t, q_t\}_{t=0}^{\infty}$, that satisfy the household's first-order conditions, equations (6) to (10); the intermediate-good-producing firm's first-order conditions, equations (20) to (24); the aggregate resource constraint;[7] the monetary policy rule, equation (25); the loan market equilibrium condition, equation (26); the financial intermediary technology and first-order conditions, equations (28) and (31); and the stochastic processes of money demand, technology, and credit shocks, equations (2), (17), and (29), respectively.

7. The aggregate resource constraint in this economy is $y_t = c_t + k_{t+1} - (1-\delta) k_t + \chi_t$.

This system is composed of 15 equations and 15 variables. All variables in the model are stationary. Taking these definitions into account, and given the initial values of k_t, m_t, and $\{A_t, b_t, \varepsilon_{Rt}, z_t\}_{t=0}^{\infty}$, we can obtain equilibrium conditions for the allocation $\{y_t, c_t, \pi_t, h_t, m_t^c, \mu_t, \chi_t\}_{t=0}^{\infty}$ and the sequence of prices and co-state variables $\{R_t, r_{kt}, R_t^l, w_t, \lambda_t, q_t\}_{t=0}^{\infty}$. A log-linear approximation of the equilibrium system around steady state is obtained by using the methods described in Blanchard and Kahn (1980). For any stationary variable, x_t, we define $\hat{x}_t = \log(x_t/x)$ as the deviation of x_t from its steady-state value, x.The log-linearized version of the model can thus be written in its state-space form:

$$\hat{s}_{t+1} = \Phi_1 \hat{s}_t + \Phi_2 \varepsilon_{t+1}, \tag{32}$$

$$\hat{d}_t = \Phi_3 \hat{s}_t, \tag{33}$$

where $\hat{s}_t = (\hat{k}_t, \hat{m}_{t-1}, \hat{A}_t, \hat{b}_t, \varepsilon_{Rt}, \hat{z}_t)'$ is a vector of state variables that includes predetermined variables; $\hat{d}_t = (\hat{\lambda}_t, \hat{q}_t, \hat{m}_t, \hat{h}_t, \hat{y}_t, \hat{w}_t, \hat{r}_t, \hat{c}_t, \hat{\pi}_t, \hat{\mu}_t, \hat{R}_t^l, \hat{R}_t, \hat{m}_t^c, \hat{\chi}_t)'$ is a vector of control variables; and the vector $\varepsilon_{t+1} = (\varepsilon_{At+1}, \varepsilon_{bt+1}, \varepsilon_{Rt+1}, \varepsilon_{zt+1})'$ contains technology, money demand, and monetary policy and credit shocks. The solution is a restricted vector autoregression (VAR) in the sense that the coefficient matrices, Φ_1, Φ_2, and Φ_3 depend on the structural parameters of the model. Thus, the state-space solution in equations (32) and (33) is used to simulate the model.

4. Data and Calibration

To calibrate the parameters that occur in the money demand and credit equations, we use two regressions. In these regressions, we use real per-capita personal spending on non-durable goods and services and monetary aggregate M1 as measures of consumption, c_t, and money balances, m_t^c. The GDP deflator is used as the price index. The deposit and loan interest rates, R_t and R_t^l, are measured by the 3-month treasury-bill rate and the prime business loan rate, respectively. Output, y_t, is measured by the real GDP per capita. The variables measuring c_t, m_t^c, and y_t are linearly detrended. The data run from 1981Q2 to 2000Q4.

As shown in Appendix A, section A.1, the estimate of γ, the elasticity of money demand, is 0.0223, and the estimates of ρ_b and σ_b are 0.8334 and 0.0146, respectively. Since the constant corresponds to ln(b), however, the estimate value for b is 0.1150. Ireland (2001) also uses this procedure to estimate money-demand function parameters.

Section A.2 of Appendix A shows the estimation results for τ in equation (29) and ρ_z in equation (30). The estimated value for τ is 1.4766, while ρ_z is 0.7817 and σ_z is 0.0472. In the steady state, we set R equal to 1.021, the average in the sample. R^l is set equal to 1.025, however, so that the steady-state value of $\zeta = z = 0.842$, as in the data.

Some of parameters are set equal to values commonly used in the literature: $\delta = 0.025$, $\alpha = 0.33$, $\beta = 0.987$, $\pi = 1.0071$, and $\theta = 9$. The setting $\theta = 9$ makes the markup equal to 12.5 per cent. The setting $\eta = 1.48$ implies that the household spends about 0.33 of its time working in the model's steady state.

Following the literature, particularly Basu (1995) and Huang, Liu, and Phaneuf (2000), we consider values of ψ in the empirically plausible range of 0.2 and 0.6. For the exercise reported on in this paper, we choose $\psi = 0.3$.[8]

The calibrated values for the remaining parameters are taken from Dib (2002), who estimates a version of a dynamic, stochastic, general-equilibrium model with price and capital rigidities for Canada. The parameters of the capital and price rigidities, ϕ_k and ϕ_p, are set equal to 8.5824 and 16.861, respectively; the steady-state technology shock, A, is set equal to 1, with serial correlation ρ_A and standard deviation σ_A equal to 0.90 and 0.0071, respectively. Similarly, the parameters of the monetary policy rule are set equal to the estimated values in Dib (2002), where $\rho_\pi = 0.6717$, $\rho_y = 0.072$, $\rho_\mu = 0.3686$, and $\sigma_R = 0.0061$.

5. Evaluating the Model's Performance

Given the endogeneity of most of the inputs into the model, described in section 4, and the interaction between the variables, an appropriate method of analyzing the impact of a shock to a variable in the model is to study the behaviour of the impulse-response functions generated from the variance-covariance matrix of the forecast errors of the model. In this section, we examine these functions in relation to the shocks in the model: monetary policy, credit, money demand, and technology. In addition to studying the impulse-response functions, we compute the forecast-error variance decomposition of detrended output, inflation, and the interest rate at various horizons.

We consider the model within various scenarios. First, we examine the model when there are credit and price frictions (CPF) present; this we denote a CPF model. Second, we consider the model when there are only credit frictions (CF); this we denote a CF model. Third, to gauge the impact of credit, we examine a model with no credit frictions; this we denote a standard sticky-price (SSP) model.

8. We observe that there are no remarkable differences in the results for $\psi = 0.2$ and $\psi = 0.4$. The differences lie in the magnitude of the responses to credit shocks.

To determine the impact of credit, we need to compare models where the credit friction is in operation with those where it is absent. In the case where there are no credit frictions, we set $\tau = 0$, so that $\zeta = z = 1$ and thus, $R_t = R^l_t$.

5.1 Impulse-response functions

Figure 1 shows the impact of a 1 per cent increase in the innovations of monetary policy; i.e., $\varepsilon_{Rt} = 0.01$. This represents a tightening of monetary policy. The figure shows that, for all models, a contractionary monetary policy that raises short-term interest rates causes a fall in output and inflation. Tight monetary policy also causes a decline in credit.

Although all the models generate the expected behaviour of the transmission mechanism, Figure 1 shows that the magnitude of the effect of monetary policy tightening differs for each model. The magnitude of the effect on output is strong in the CPF and SSP models, with CPF yielding the largest impact. The main features of the two models are the same, both having capital and price rigidities. The CPF model, however, with the credit channel "turned on," does not substantially increase the real response of output to the monetary policy shock. The results show that the credit-market frictions do indeed play a role in the transmission of monetary policy, but that this role is minor when compared with the contribution of the price rigidity. The results are further supported by the CF model, which shows that credit-market frictions alone will create only a very small output response to a monetary policy shock. The credit channel operates by reducing the willingness of banks to lend (i.e., ζ_t falls) as output falls. Banks cut back their lending and increase the spread between lending and borrowing rates. This restricts output even further. However, the particular form of the credit frictions we introduce does not significantly augment the effects of policy shocks. Future estimation will investigate the importance of the other variables, such as risk measures, in the banks' production function. In addition, we can increase the contribution of credit frictions to the persistence of the model's responses by assuming that ζ_t is a function of lagged output, as in Cook (1999).

Figure 2 shows the impulse-response functions for an exogenous tightening of credit conditions. The CPF and CF models are examined. The SSP model, which has the credit channel turned off, is not included in the figure because, as expected, it yields no response to the credit shocks. Although the magnitude of the impact differs between the models, the CPF and CF models respond similarly to the tighter credit conditions. As expected, the tightening of credit conditions leads banks to reduce lending and increase the loan rate. Firms react by cutting back on external funds to finance intermediate-good inputs, which causes in a fall in production. The central bank allows the deposit rate to also rise as it injects money (i.e., creates an inflation expectation) to offset the negative consequences of credit shocks. The restriction of credit impacts negatively on aggregate supply, as firms cut back on production, leading to a fall in final output. In an attempt to accommodate the deterioration in credit conditions, the monetary authority reacts by injecting more liquidity into the economy. The rise in liquidity plus the negative shift of the aggregate supply curve combine to push up the inflation rate.

The persistence of credit shocks is estimated to be quite high (i.e., $\rho_z = 0.7817$). The result is that the tighter credit conditions generate persistent movements in all variables. In each case, we find that the variables do not return to their steady-state values even after 10 quarters. The implication of this result is that a worsening of credit conditions can be very persistent and have a lasting impact on economic activity. There could also be a persistent increase in the inflation rate if the monetary authority offsets the credit shock by infusing additional liquidity into the economy.[9]

Figure 3 shows the impulse-response functions for a 1 per cent positive technology shock. As the figure shows, we find that output increases in response to the positive shock to technology. Interestingly, the magnitude of the effects on output is greater for the CPF and CF (models with the credit channel turned on) than for the SSP model (no credit channel), which suggests that credit magnifies and propagates the technology shocks. With the improvement in technology, the deposit and loan rates as well as the inflation rate fall below their steady-state values in the initial quarters before slowly moving back towards their steady-state values. Borrowing is seen to rise for about 4 quarters following the technology shock as banks loosen their credit conditions and firms' demand increases. Money growth responds negatively to the technology shock.

The technology shock is a positive supply-side shock that causes inflation to fall. The disinflation causes the monetary authorities to gradually ease monetary conditions by lowering interest rates. In addition, banks seeing brighter prospects with improved technology respond by easing terms and conditions and increasing the supply of funds it lends out. This causes lending rates to fall. Capital and labour become very productive as a result of the positive technology shock, which leads to increased production and, consequently, rising demand for credit. All these factors accelerate and magnify the rise in economic activity.

Figure 4 shows impulse-response functions for a positive 1 per cent money-demand shock. The responses of the models to this shock are very similar. The rise in the demand for money is temporarily followed by an increase in the growth rate of money, which in turn exerts upward pressure on inflation. The monetary authority responds by gradually but persistently increasing nominal interest rates. The loan rate rises, forcing firms to borrow less. The combination of these factors results in economic activity slowing down in the first 4 quarters of the money-demand shock. Although the responses are very persistent, all the variables begin a slow return to their steady-state values after 4 quarters.

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9. When $\rho_z = 0$, the effects of credit shocks on inflation are moderately persistent.

5.2 Variance decomposition

To complement our analysis of the impulse-response functions, we examine the forecast error variance decomposition. The decomposition enables us to understand the proportion of the volatility in a series explained by each of the model's shocks. The results of the decompositions are reported in Tables 1 to 3.

The results indicate that, for models with the credit channel turned on, credit is important in explaining the variations in output. We observe that, in the first 4 quarters, credit explains between 10 and 17 per cent of the fluctuations in output. Although the contribution of credit falls with the lengthening of the forecasting horizon, it still accounts for about 5 per cent of the variation in output after four years. In addition, we find that credit shocks substitute for monetary policy shocks as sources of output variation.

The variance decomposition results also show that, in the credit models, the contribution of credit shocks to fluctuations in inflation occurs more at longer horizons, where it accounts for about 10 per cent of the variation. The main sources of the fluctuations in inflation come from technology and monetary policy shocks. As expected, monetary policy shocks contribute to the fluctuations in inflation because the deviation of inflation from its steady state is a major component of the rule used by the monetary authority to set the interest rate. The contribution of technology to the fluctuations in inflation comes from its strong correlation with aggregate supply.

The results also suggest that credit shocks play a significant role in explaining the fluctuations of the short-term lending rate. More of the volatility is explained by credit shocks than it is by monetary policy shocks. This supports conventional thinking that worsening credit conditions push up interest rates because of increased risk premiums. In all cases, we find technology shocks to be responsible for most of the variation in the short-term lending rate.

For the model with the credit frictions turned off, the results in Table 3 are very similar to those found in the literature for standard real business cycle models (Dib 2002), where technology shocks are responsible for the greatest part of the fluctuations in output, inflation, and interest rates. As expected, in the SSP model, the contribution of monetary policy shocks to fluctuations in output is significant. We also find that, in addition to technology shocks, monetary shocks play an important role in the fluctuation of inflation in this non-credit model. In all models, however, money-demand shocks account for a very small fraction of the variations in output and inflation, and a significant fraction of the short-term interest rate. Overall, credit shocks contribute substantially to the volatility of output and the interest rate.

6. Conclusion

In this paper, we have re-examined the role of bank lending in the Canadian monetary transmission mechanism. We used a dynamic general-equilibrium model with price- and capital-adjustment costs to study the interaction between financial factors and real economic activity. An advantage of taking this approach is that financial effects are given explicit micro-foundations, which has allowed us to study conditions under which interactions between real and financial factors are likely to matter.

A general finding of our study is that the response of output to monetary policy shocks is magnified slightly when the model incorporates credit frictions. Credit shocks are also observed to have a significant impact on output, inflation, and the short-term interest rate. The results show that the bank lending channel is an important facet of the dynamics of the economy. Imperfections in the credit markets are partly responsible for the amplification and propagation of the effects of real or monetary policy shocks.

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Table 1: Variance Decomposition in the CPF Model

		Percentage owing to the following shocks:			
Quarters	Variance	Monetary policy	Technology	Money demand	Credit
Detrended output					
1	0.000091	49.949	27.584	5.585	16.881
2	0.000127	35.702	44.704	4.930	14.663
3	0.000160	28.361	55.378	4.122	12.139
4	0.000190	23.960	62.136	3.539	10.365
5	0.000216	21.095	66.617	3.135	9.154
10	0.000301	15.139	76.029	2.259	6.572
50	0.000395	11.566	81.701	1.724	5.009
Inflation					
1	0.000036	24.717	74.621	0.038	0.624
2	0.000054	16.702	76.923	1.374	5.001
3	0.000067	13.346	75.504	2.674	8.476
4	0.000078	11.530	74.400	3.574	10.495
5	0.000086	10.419	73.959	4.130	11.492
10	0.000110	8.211	75.603	4.687	11.499
50	0.000137	6.618	80.071	3.944	9.366
Deposit interest rate					
1	0.000021	18.707	49.809	7.396	24.088
2	0.000035	11.498	54.537	8.353	25.612
3	0.000045	8.859	57.228	8.647	25.265
4	0.000053	7.509	59.442	8.671	24.379
5	0.000060	6.694	61.386	8.563	23.356
10	0.000060	5.063	68.003	7.618	19.315
50	0.000104	3.908	75.372	5.932	14.787

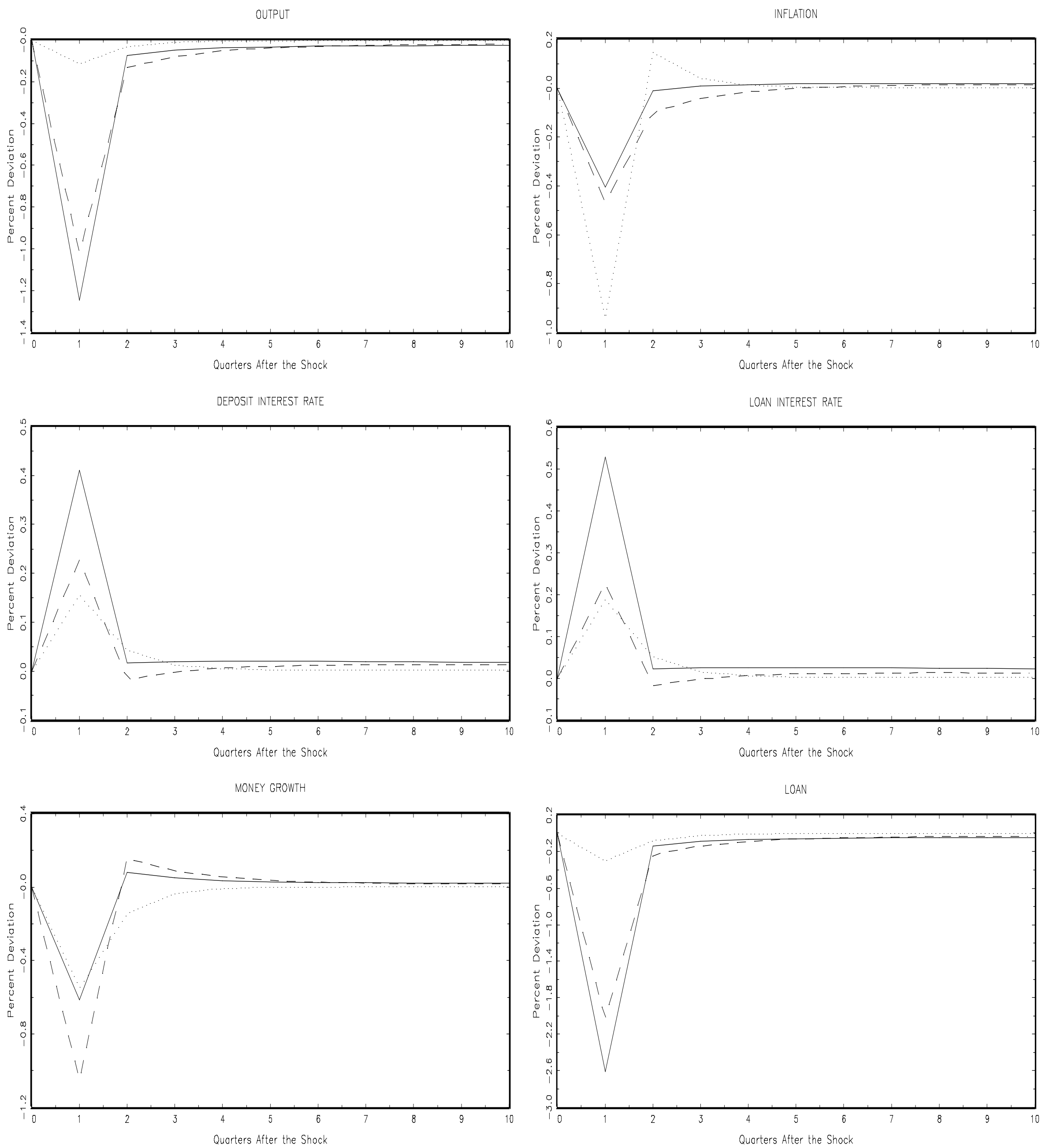
Table 2: Variance Decomposition in the CF Model

		Percentage owing to the following shocks:			
Quarters	Variance	Monetary policy	Technology	Money demand	Credit
Detrended output					
1	0.000077	0.276	95.401	0.686	3.637
2	0.000137	0.165	94.900	0.884	4.050
3	0.000187	0.122	94.914	0.948	4.016
4	0.000229	0.100	95.117	0.952	3.832
5	0.000264	0.086	95.367	0.932	3.614
10	0.000380	0.060	96.327	0.790	2.823
50	0.000524	0.043	97.288	0.592	2.077
Inflation					
1	0.000089	39.857	59.639	0.300	0.207
2	0.000114	31.899	63.130	1.244	3.727
3	0.000132	27.604	63.136	2.347	6.913
4	0.000145	24.982	63.208	3.089	8.722
5	0.000156	23.240	63.619	3.533	9.608
10	0.000188	19.293	66.882	3.995	9.830
50	0.000232	15.624	72.864	3.397	8.115
Deposit interest rate					
1	0.000024	2.426	77.178	4.425	15.971
2	0.000041	1.497	72.430	6.168	19.905
3	0.000055	1.132	71.085	6.909	20.874
4	0.000065	0.946	71.243	7.163	20.648
5	0.000074	0.834	71.996	7.184	19.986
10	0.000101	0.610	76.414	6.457	16.519
50	0.000142	0.436	82.828	4.779	11.957

Table 3: Variance Decomposition in the SSP Model

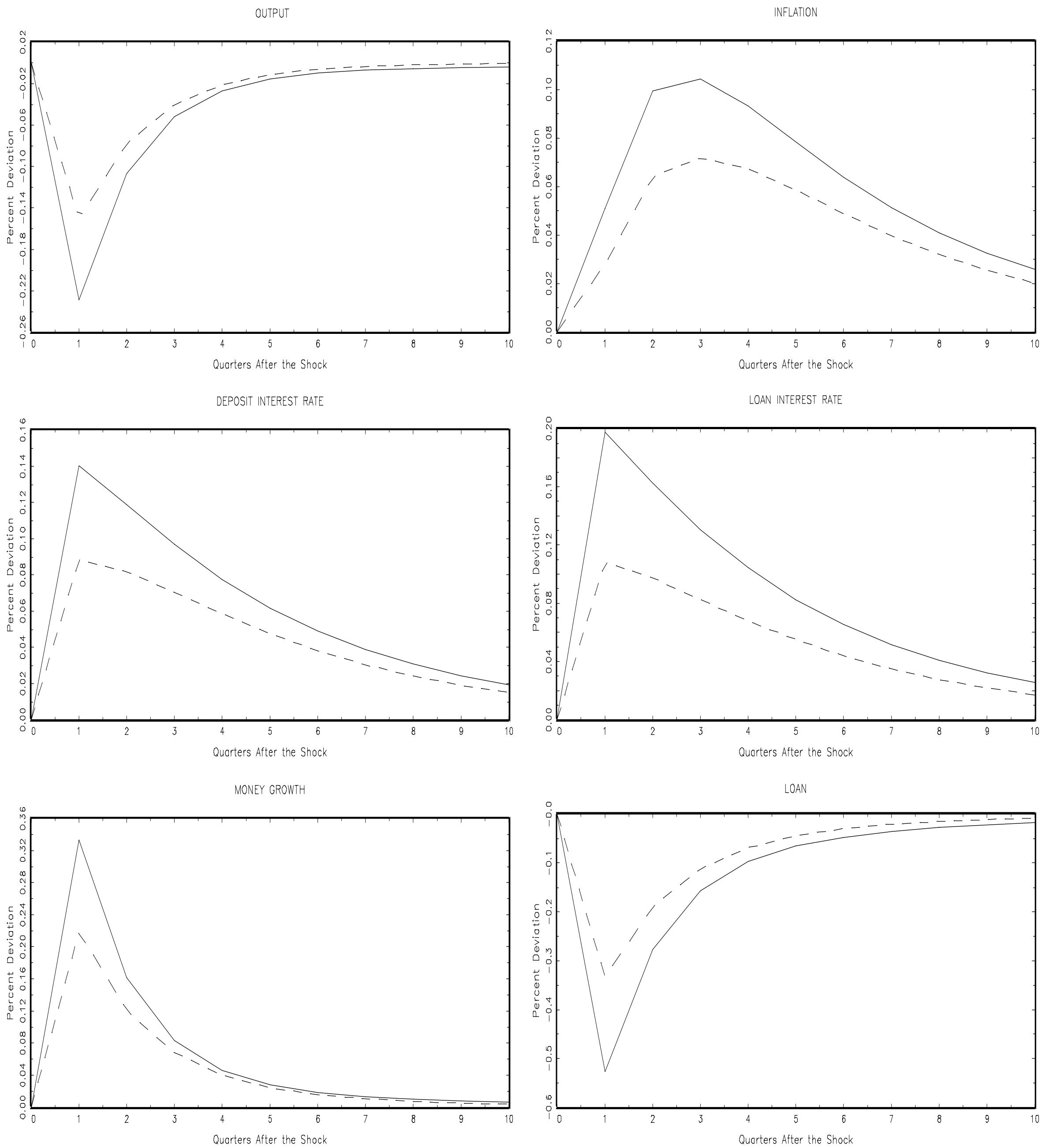
		Percentage owing to the following shocks:			
Quarters	Variance	Monetary policy	Technology	Money demand	Credit
Detrended output					
1	0.000061	62.532	29.689	7.778	0.000
2	0.000087	43.874	49.340	6.786	0.000
3	0.000114	33.746	60.756	5.499	0.000
4	0.000138	27.804	67.596	4.601	0.000
5	0.000160	24.045	71.955	4.000	0.000
10	0.000231	16.623	80.606	2.771	0.000
50	0.000306	12.581	85.322	2.097	0.000
Inflation					
1	0.000035	27.729	72.265	0.006	0.000
2	0.000047	20.591	78.053	1.356	0.000
3	0.000055	17.613	79.378	3.009	0.000
4	0.000061	15.908	79.748	4.345	0.000
5	0.000066	14.785	79.948	5.267	0.000
10	0.000080	12.235	81.285	6.480	0.000
50	0.000097	10.123	84.243	5.634	0.000
Deposit interest rate					
1	0.000012	20.877	67.496	11.628	0.000
2	0.000019	13.111	72.940	13.949	0.000
3	0.000025	10.139	75.020	14.840	0.000
4	0.000030	8.567	76.379	15.053	0.000
5	0.000034	7.595	77.485	14.920	0.000
10	0.000046	5.598	81.284	13.118	0.000
50	0.000062	4.218	85.811	9.971	0.000

Figure 1: The Effects of Monetary Policy Shocks in the Models



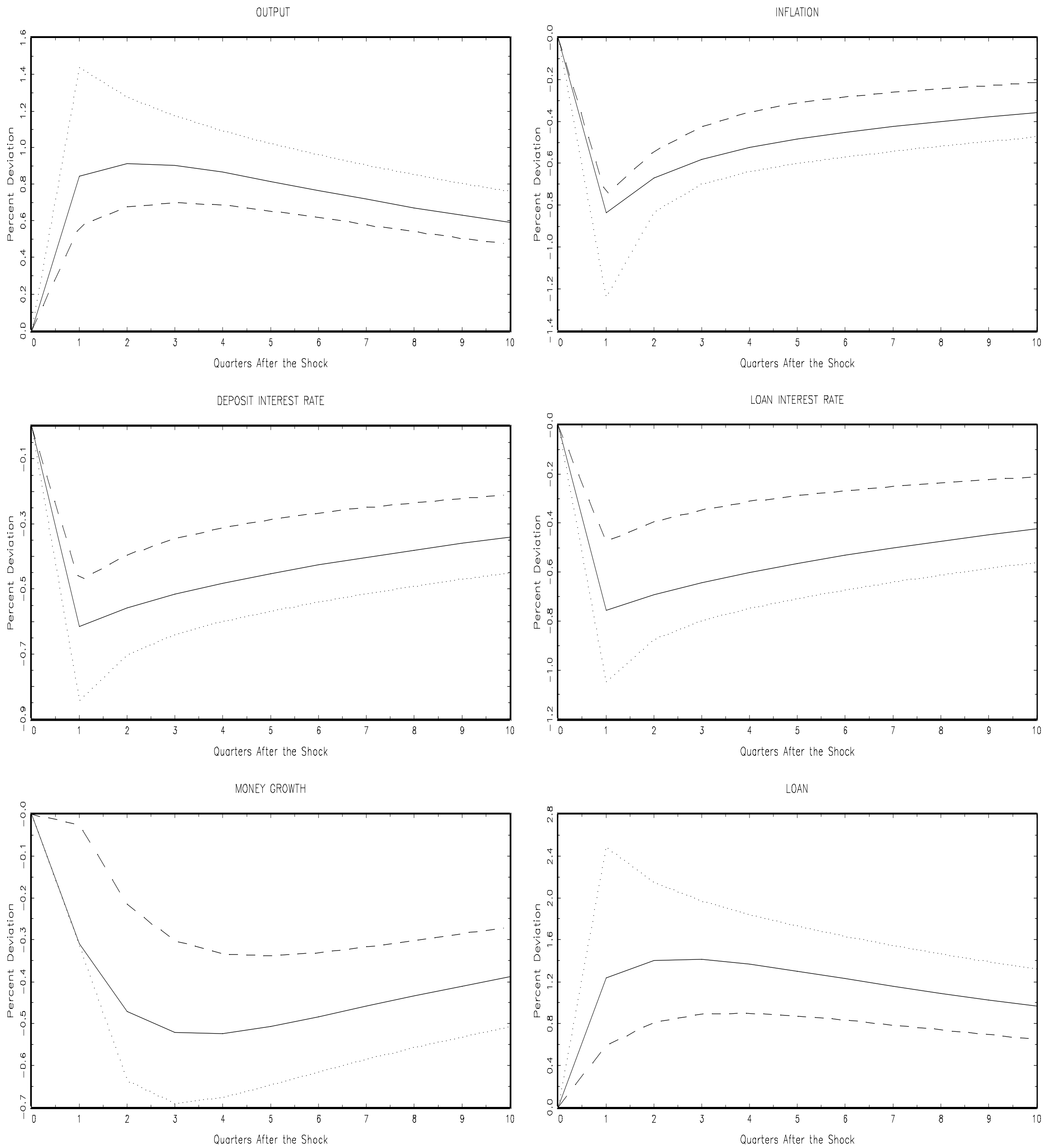
For the impulse-response functions, the solid line represents the CPF model, the dashed line the SSP model, and the dotted line the CF model.

Figure 2: The Effects of Credit Shocks in the Models



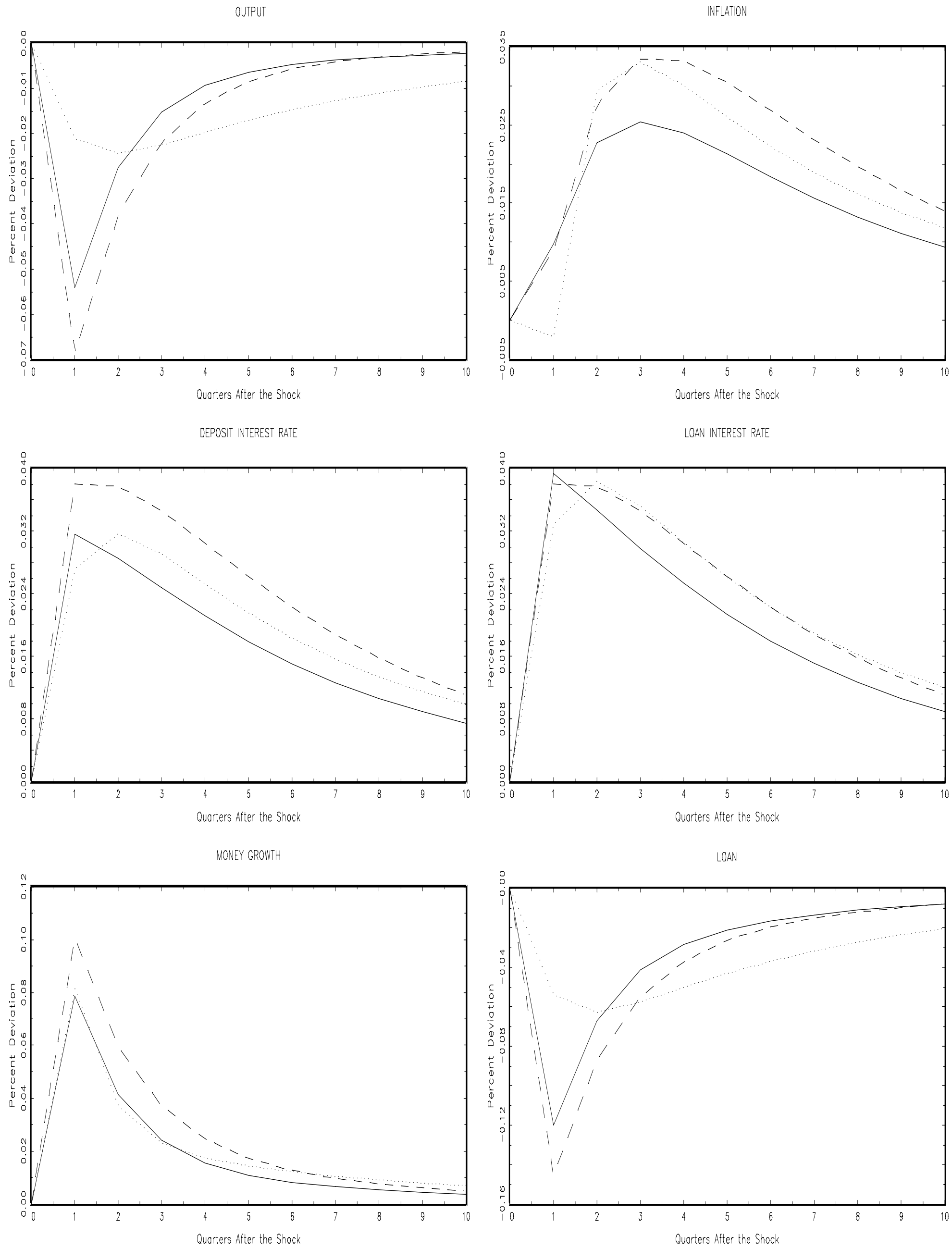
For the impulse-response functions, the solid line represents the CPF model, and the dashed line the CF model.

Figure 3: The Effects of Technology Shocks in the Models



For the impulse-response functions, the solid line represents the CPF model, the dashed line the SSP model, and the dotted line the CF model.

Figure 4: The Effects of Money-Demand Shocks in the Models



For the impulse-response functions, the solid line represents the CPF model, the dashed line the SSP model, and the dotted line the CF model.

Appendix A

A.1 Money Demand Equation

In performing our examination of the bank lending channel, we must estimate the demand for real money balances. The monetary aggregate used is M1, which we deflate by the GDP deflator. Our estimated equation is:

$$\log\left(\frac{M_t^c / p_t}{c_t}\right) = \underset{(0.0430)}{-2.1635} - \underset{(0.0114)}{0.0223} \log(r_t) + \bar{u}_{bt},$$

with

$$\bar{u}_{bt} = \underset{(0.0521)}{0.8334} \bar{u}_{bt-1} + \varepsilon_{bt}, \quad \text{with } \sigma_b = 0.0146, \tag{A1}$$

where $r_t = R_t - 1$ is the net deposit interest rate and $\bar{u}_{bt} = \log(b_t) - \log(b)$. Standard errors are in parentheses.

A.2 The Loan Equation

Next, we estimate the parameters for the intermediary technology. From the first-order conditions, we have:

$$\zeta_t = \frac{R_t - 1}{R_t^l - 1} . \tag{A2}$$

From our main text, we also have:

$$\zeta_t = (y_t / y)^{\tau} z_t . \tag{A3}$$

We also assume that, in the steady-state equilibrium, $\zeta = z$. Hence,

$$\log(\zeta_t) = \log((R_t - 1)/(R_t^l - 1)) = \tau \log(y_t / y) + \log(z_t) , \tag{A4}$$

where

$$\log(z_t) = (1 - \rho_z)\log(z) + \rho_z \log(z_{t-1}) + \varepsilon_{zt} . \tag{A5}$$

Using the equilibrium condition of $\zeta = z$, we can rewrite equation (A5) as:

$$\log(\zeta_t/\zeta) = \tau\log(y_t/y) + \log(z_t/z)\ . \tag{A6}$$

Since $\log(z_t/z) = \rho_z\log(z_{t-1}/z) + \varepsilon_{zt}$ and $E(\log((y_t/y), \varepsilon_{zt})) \neq 0$, we use the Cochrane-Orcutt and instrumental-variables techniques to estimate equation (A7). The estimated equation is given as:

$$\log(\zeta_t/\zeta) = \underset{(0.6886)}{1.4766}\ \log(y_t/y) + \log(z_t/z)\,, \tag{A7}$$

and

$$\log(z_t/z) = \underset{(0.0703)}{0.7817}\ \log(z_{t-1}/z) + \varepsilon_{zt}, \qquad \text{with } \sigma_z = 0.0472\,. \tag{A8}$$

Standard errors are in parentheses.

From the regression summarized by equations (A7) and (A8), we have:

$$\tau = 1.4766 \quad \text{and} \quad \rho_z = 0.7817\,.$$

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