The quantitative effects of bank lending

Iris Claus*

The Treasury and

Victoria University of Wellington

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Abstract

The purpose of this paper is to assess the quantitative importance of the bank lending channel in a small open economy with a floating exchange rate. The framework of the analysis is a general equilibrium model with microeconomic foundations, where agents' decisions are derived from optimising behaviour. A theoretical model with costly financial intermediation is developed and calibrated for New Zealand. The steady states with and without the bank lending channel are derived and the dynamic properties of the model are assessed. The quantitative effects of the bank lending channel are small. This suggests that the degree to which firms borrow from financial intermediaries (banks) or public debt markets is unlikely to affect economic growth.

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1 Introduction and motivation

Following a tightening in monetary policy, borrowing and output by bank dependent firms, which are typically smaller in size, often fall significantly more than borrowing and output by large firms with access to public debt markets.[1] Moreover, the spread between the interest rate on loans paid by bank dependent (small) firms compared to the interest rate paid by (large) firms, who use public debt markets, tends to increase during monetary contractions.[2] These findings have been interpreted as evidence of quantitatively important frictions in the credit market. Small firms tend to have limited access to public capital markets for external finance and are bank dependent because of reduced economies of scale with respect to acquiring information about small firms.

Asymmetric information in credit markets is thought to affect the monetary transmission mechanism in two ways. First, a change in monetary policy can influence banks' willingness to provide loans. This channel is referred to as the bank lending channel. The second channel is the balance sheet channel or financial accelerator effect. It focuses on the potential impact of monetary policy on firms' balance sheets and their ability to borrow.

The credit channel literature has made great strides in recent years, however, significant issues remain unresolved. Much of the literature to date has focused on the United States, which can be adequately modelled as a large closed economy.[3] The credit channel has yet to be incorporated in a model of

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[1] See, for example, Gertler and Gilchrist (1994) for evidence in the manufacturing sector in the United States.

[2] For instance, Kashyap, Stein and Wilcox (1993) find that the spread between the prime bank lending rate and a commercial paper rate increases after the Federal Reserve tightens.

[3] See Bernanke, Gertler and Gilchrist (1998), Fuerst (1995), Carlstrom and Fuerst (1997)

a small open economy with a floating exchange rate.[4]

The purpose of this paper is to assess the quantitative importance of the bank lending channel in a small open economy with a floating exchange rate. The framework of the analysis is a general equilibrium model with microeconomic foundations, where agents' decisions are derived from optimising behaviour.

There are two main features of the bank lending channel. First, the monetary authority must be able to influence the real supply of loanable funds. Second, (some) firms in the economy must depend on bank lending, rather than public debt markets, for (part of their) external finance. In this model, as in Edwards and Végh (1997), firms must borrow from banks to pay households' wages. To model the effects of shocks on the supply of loanable funds, financial intermediation costs are introduced. As in Bernanke and Blinder (1988), banks hold bonds and loans as assets and deposits are liabilities.[5] The provision by banks of deposits and loans is assumed to be costly because of informational asymmetries between borrowers and lenders.

The remainder of the paper proceeds as follows. Section 2 describes the theoretical model, which is then calibrated for New Zealand. Section 3 discusses parameter values and derives the steady states with and without a bank lending channel. Next, the dynamic properties of the model are evaluated. Prices are

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and Fisher (1999) among others.

[4]Edwards and Végh (1997) develop a theoretical model of a small open economy with a "predetermined" exchange rate. In their model, the policy maker sets the exchange rate and stands ready to exchange domestic money for international reserves (or vice versa) at the prevailing exchange rate.

[5]The model in this paper abstracts from reserves and assumes that banks can also issue bonds.

assumed sticky and section 4 derives the price adjustment. The dynamic model is solved in section 5 and its dynamic properties are assessed in section 6. Section 7 contains some concluding remarks.

2 The model

There are five agents in the economy: households, firms, financial intermediaries (banks), a government and a monetary authority. Households, who own the firms and banks, provide labour and consume. Households face a deposit-in-advance constraint on a subset of their purchases and must hold demand deposits, D_t, for consumption of cash goods, C_{1t}.[6] They also purchase credit goods, C_{2t}. Moreover, households hold bonds in the form of domestic, B_t^h, and foreign securities, B_t^{h*}.

Firms are monopolistic competitors and produce output, Y_t, by hiring labour, N_t, and using commodity inputs, IM_t, which they import at the beginning of each period. To pay households' wages, firms need bank credit. Financial intermediaries make loans, L_t, to firms, which they finance with households' demand deposits, D_t, and domestic bond holdings, B_t^h. Firms and financial intermediaries can also borrow (lend) internationally by selling (buying) bonds. The provision of demand deposits and loans is costly because of informational asymmetries between borrowers and lenders.

The government collects taxes from households to purchase goods, G_t, from firms. The monetary authority has an explicit inflation target, Π^T, and acts to achieve this target by adjusting the rate of interest paid on domestic bonds, I_t.

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[6] Capital letters denote "levels" of variables.

Table 1: Chronology of events

Firms take out loans from financial intermediaries, import commodity inputs, $S_t P_t^* IM_t$, and hire labour, N_t, to produce output, Y_t. Firms pay households' wages, $W_t N_t$.

Households withdraw their demand deposits accumulated last period to purchase the cash good, $P_t C_{1t}$. They also purchase the credit good, $P_t C_{2t}$. Firms export to foreigners, $P_t EX_t$, and the government purchases goods, $P_t G_t$.

Households, firms and financial intermediaries receive (make) interest payments on bonds. Firms also re-pay loans taken out at the beginning of the period including interest, $\left(1 + I_t^l\right) L_t$.

Financial intermediaries incur the cost of providing demand deposits and loans.

Firms and financial intermediaries purchase (sell) bonds and households divide their assets into demand deposits, domestic and foreign bonds.

The domestic economy is assumed to be perfectly integrated with the rest of the world in both goods and capital markets and operates under a flexible exchange rate. Perfect capital mobility implies uncovered interest rate parity. Domestic prices are assumed to only adjust gradually. The chronology of events is summarised in Table 1. Table 2 defines the variables and Table 3 the parameters in the model.

2.1 Households

Following Lucas and Stokey (1983), households face a deposit-in-advance constraint on a subset of their consumption goods. As a result, their utility function is defined over two types of good: cash goods and credit goods. More specifi-

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Table 2: Definition of variables

A_t^h	households' financial net wealth
A_t^f	firms' financial net wealth
A_t^{fi}	financial intermediaries' financial net wealth
D_t	demand deposits
L_t	loans
B_t^h	households' domestic bond holdings
B_t^{h*}	households' foreign bond holdings
B_t^f	firms' bond holdings
B_t^{fi}	financial intermediaries' bond holdings
Ω_t^f	firms' dividend payments to households
Ω_t^{fi}	financial intermediaries' dividend payments to households
C_{1t}	households' consumption of the cash good
C_{2t}	households' consumption of the credit good
G_t	government consumption
EX_t	exports
Y_t	output
IM_t	imports of commodity inputs
N_t	labour
W_t	wage rate
I_t	domestic bond rate
I_t^l	lending rate
I_t^d	demand deposit rate
P_t	domestic prices
Π_t	domestic inflation rate
$\frac{\kappa_t}{\xi_t}$	ratio of the price level to aggregate marginal cost
S_t	nominal exchange rate
Q_t	real exchange rate
Z_t	productivity
Y_t^*	foreign demand for domestic country's products
I_t^*	foreign bond rate
P_t^*	foreign prices
Π_t^*	foreign inflation rate
$\epsilon_{i,t}$	monetary policy shock
$\epsilon_{z,t}$	productivity shock
$\epsilon_{y*,t}$	foreign demand shock
$\epsilon_{i*,t}$	foreign interest rate shock
E_t	conditional expectation operator

Note: In the paper, capital letters denote levels, capital letters with " ˆ " denote the real values of nominal variables, capital letters with a " ¯ " are steady state levels. Lower case letters denote logarithmic deviations from steady state.

Table 3: Definition of parameters

Π^T	monetary authority's target inflation rate
α	ratio of credit goods to total consumption
β	discount rate
γ	weight on leisure
ϱ	proportion of households' bonds held in foreign bonds
υ_L	coefficient on loans in financial intermediaries' cost function
υ_D	coefficient on demand deposits in financial intermediaries' cost function
υ_{LD}	coefficient in financial intermediaries' cost function
$\frac{1}{1-\nu}$	elasticity of substitution between labour and commodity inputs in firms' production function
η	coefficient on productivity and employment in firms' production function
θ	price elasticity of demand faced by monopolistic competitive firms
ζ	exponent on the real exchange rate in the export demand equation
ς	exponent on foreign demand in the export demand equation
τ	tax rate
φ	probability that firms can adjust prices
ϑ	coefficient on the output gap in the inflation adjustment equation
μ_1	coefficient on inflation in the monetary authority's reaction function
μ_2	coefficient on the output gap in the monetary authority's reaction function
μ_3	coefficient on past interest rates in the monetary authority's reaction function
ρ_z	autocorrelation of productivity shocks
ρ_{y^*}	autocorrelation of foreign demand shocks
ρ_{i^*}	autocorrelation of foreign interest rate shocks

cally, households value streams of consumption and leisure according to

$$E_t \sum_{i=0}^{\infty} \beta^i \left\{ (1 - \alpha) \log \left(C_{1t+i} \right) + \alpha \log \left(C_{2t+i} \right) + \gamma \log \left(1 - N_{t+i} \right) \right\} \qquad (1)$$

where $\alpha \in [0, 1]$, $\gamma > 0$ and $\beta \in (0, 1)$. E_t is the conditional expectation operator with respect to information available at time t and C_{1t} and C_{2t} denote consumption of the cash and credit good. Time is normalised to one. Labour supply is thus given by N_t and $(1 - N_t)$ denotes leisure.

At the end of each period, households divide their assets into demand deposits and domestic and foreign bonds. Households' financial net wealth in real terms, $\hat{A}_t^h$, is given by

$$\hat{A}_t^h = \hat{D}_t + \hat{B}_t^h + Q_t \hat{B}_t^{h*} \qquad (2)$$

$\hat{D}_t$, $\hat{B}_t^h$ and $\hat{B}_t^{h*}$ denote the real stock of demand deposits and domestic and foreign bonds and Q_t the real exchange rate.[7] The real exchange rate is defined as $Q_t \equiv \frac{S_t P_t^*}{P_t}$, where S_t denotes the nominal exchange rate, P_t is the domestic price level and P_t^* are foreign prices.[8] The proportion of bonds households hold

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[7] A change in variables is introduced as inflation is positive in the steady state (discussed further below) and nominal variables are trending. Let $\frac{W_t}{P_t} = \hat{W}_t$, $\frac{W_{t+1}}{P_{t+1}} = \hat{W}_{t+1}$, $\frac{D_t}{P_t} = \hat{D}_t$, $\frac{D_{t+1}}{P_{t+1}} = \hat{D}_{t+1}$, $\frac{B_t^h}{P_t} = \hat{B}_t^h$, $\frac{B_{t+1}^h}{P_{t+1}} = \hat{B}_{t+1}^h$, $\frac{B_t^{h*}}{P_t^*} = \hat{B}_t^{h*}$, $\frac{B_{t+1}^{h*}}{P_{t+1}^*} = \hat{B}_{t+1}^{h*}$, $\frac{B_t^f}{P_t} = \hat{B}_t^f$ (or $\frac{B_t^f}{P_t^*} = \hat{B}_t^f$ in case of foreign bonds), $\frac{B_{t+1}^f}{P_{t+1}} = \hat{B}_{t+1}^f$ (or $\frac{B_{t+1}^f}{P_{t+1}^*} = \hat{B}_{t+1}^f$), $\frac{B_t^{fi}}{P_t} = \hat{B}_t^{fi}$ (or $\frac{B_t^{fi}}{P_t^*} = \hat{B}_t^{fi}$), $\frac{B_{t+1}^{fi}}{P_{t+1}} = \hat{B}_{t+1}^{fi}$ (or $\frac{B_{t+1}^{fi}}{P_{t+1}^*} = \hat{B}_{t+1}^{fi}$), $\frac{\Omega_t^f}{P_t} = \hat{\Omega}_t^f$ and $\frac{\Omega_t^{fi}}{P_t} = \hat{\Omega}_t^{fi}$. Capital letters with a " ˆ " thus denote the real values of nominal variables.

[8] The nominal exchange rate, S_t, is measured as the price of domestic currency in units of foreign currency, i.e. an increase in S_t indicates a depreciation.

in the form of foreign securities is assumed fixed, i.e.

$$Q_t B_t^{h*} = \varrho \left(B_t^h + Q_t B_t^{h*} \right) \tag{3}$$

with $\varrho \in (0, 1)$.

Households derive income from three sources. First, households earn wage income, $\hat{W}_t N_t$, from supplying labour, N_t, to firms, where $\hat{W}_t$ denotes the real wage rate. Second, they receive interest from holding financial assests. Demand deposits and domestic bonds earn a nominal return (in terms of domestic currency) of I_t^d and I_t. The rate of interest paid on foreign bonds is given by I_t^*. Third, households receive dividends from firms and financial intermediaries, $\hat{\Omega}_t^f$ and $\hat{\Omega}_t^{fi}$.[9] Households pay taxes on their wage, interest and dividend income. For simplicity it is assumed that households' capital gains from exchange rate movement are not taxed. The tax rate imposed by the government is given by τ.

Households' flow constraint in real terms is given by

$$
\begin{aligned}
(1 - \tau) &\left(\hat{W}_t N_t + \hat{\Omega}_t^f + \hat{\Omega}_t^{fi} \right) + \frac{\left(1 + (1-\tau)I_t\right)\left(\hat{D}_t + \hat{B}_t^h\right)}{1 + E_t[\Pi_{t+1}]} \\
&+ \frac{\left(1 + (1-\tau)I_t^*\right)Q_t \hat{B}_t^{h*}}{1 + E_t[\Pi_{t+1}^*]} - C_{1t} - C_{2t} - \frac{(1-\tau)\left(I_t - I_t^d\right)\hat{D}_t}{1 + E_t[\Pi_{t+1}]} \\
&- E_t\left[\hat{D}_{t+1}\right] - E_t\left[\hat{B}_{t+1}^h\right] - Q_t E_t\left[\hat{B}_{t+1}^{h*}\right] = 0
\end{aligned}
\tag{4}
$$

where $\frac{(1-\tau)\left(I_t - I_t^d\right)\hat{D}_t}{1 + E_t[\Pi_{t+1}]}$ denotes the opportunity cost of having to hold demand deposits. Households' flow constraint can be interpreted as follows. Each period, households receive income from supplying labour. They also earn a real return

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[9]For simplicity, equities are assumed non-tradeable.

on their financial assets (demand deposits, domestic and foreign bonds) and receive dividend payments from firms and financial intermediaries. Households then sell all their financial assets to purchase the cash and credit good and new financial assets. The flow constraint is binding and households' expenditure is equal to their income.

Households hold positive demand deposits because of transaction costs. The deposit-in-advance constraint is given by

$$C_{1t} \leq \hat{D}_t \tag{5}$$

and will hold as an equality, at an optimum, if $I_t^d < I_t$. Households' lifetime budget constraint can then be written as follows

$$
\begin{aligned}
&\hat{A}_0^h + E_t \sum_{j=0}^{\infty} \beta^i \{(1-\tau)\left(\hat{W}_{t+j}N_{t+j} + \hat{\Omega}_{t+j}^f + \hat{\Omega}_{t+j}^{fi}\right) \\
&- \left(1 + \frac{(1-\tau)\left(I_{t+j} - I_{t+j}^d\right)}{1+\Pi_{t+j+1}}\right) C_{1t+j} - C_{2t+j}\} = 0
\end{aligned}
\tag{6}
$$

Households' optimisation problem consists of choosing $\{C_{1t}, \ C_{2t}, \ N_t\}$ for all $t \in [0, \infty)$ so as to maximise lifetime utility (equation 1) subject to equation (6), given their initial financial net wealth, $\hat{A}_0^h$, and the time paths of $\hat{W}_t$, $\hat{\Omega}_t^f$, $\hat{\Omega}_t^{fi}$, I_t and I_t^d. Households' first-order conditions are given by

$$\frac{\alpha}{C_{2t}} - \frac{\gamma}{(1-\tau)\hat{W}_t(1-N_t)} = 0 \tag{7}$$

$$\frac{1-\alpha}{C_{1t}} - \frac{\alpha}{C_{2t}}\left(1 + \frac{(1-\tau)\left(I_t - I_t^d\right)}{1+E_t[\Pi_{t+1}]}\right) = 0 \tag{8}$$

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$$\frac{1}{C_{2t}} - \frac{\beta(1+(1-\tau)I_t)}{(1+E_t[\Pi_{t+1}])E_t[C_{2t+1}]} = 0 \qquad (9)$$

Equation (7) indicates that, at an optimum, the marginal rate of substitution between consumption of the credit good and leisure is equal to the after-tax real wage rate. Equation (8) states that the marginal rate of substitution between consumption of the cash good and the credit good is equal to the opportunity cost of holding demand deposits and equation (9) determines the equilibrium after-tax, real rate of interest paid on domestic bonds.

2.2 Firms

Firms are monopolistic competitors and produce output, Y_t, under a constant elasticity of substitution technology by hiring labour, N_t, and using commodity inputs, IM_t, which, as in McCallum and Nelson (1999), they import at the beginning of each period. Firms' production function is given by

$$Y_t = (\eta \, (Z_t N_t)^\nu + (1-\eta) \, (IM_t)^\nu)^{\frac{1}{\nu}} \qquad (10)$$

where $\eta \in (0,1]$ and $\nu \in (-\infty, \infty)$. Z_t denotes productivity (discussed further in section 6). Firms treat the price in domestic currency, $P_t(i)$, of the good i they produce as a choice variable, while taking the domestic aggregate price level, P_t, the nominal exchange rate, S_t, and the foreign price level, P_t^*, as given. Having chosen $P_t(i)$, firms produce the quantity of output demanded at that price. They sell the good, Y_t, to domestic households for consumption, C_{1t} and C_{2t}, and the government, G_t. Firms also export, EX_t, to the rest of the

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world. Firms cannot price-discriminate and the price they receive from foreign

purchasers is given by $P_t(i)$.[10]

Households' and the government demand functions are given by

$$C_{1t}(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\theta} C_{1t} \tag{11}$$

$$C_{2t}(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\theta} C_{2t} \tag{12}$$

and

$$G_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\theta} G_t \tag{13}$$

where $C_{1t}(i)$, $C_{2t}(i)$ and $G_t(i)$ denote the total quantity demanded by house-

holds and the government of firm i's output and C_{1t}, C_{2t} and G_t are aggregate

household and government consumption. The aggregate price level, P_t, is an in-

dex given by $P_t = \left[\int_0^1 P_t(i)^{1-\theta}\, di\right]^{\frac{1}{1-\theta}}$, where θ is the price elasticity of demand

faced by each monopolistic competitive firm.

Similarly, foreigners' demand for firm i's output is given by

$$EX_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\theta} EX_t \tag{14}$$

where EX_t denotes aggregate exports, which are assumed to be given by

$$EX_t = \left(\frac{S_t P_t^*}{P_t}\right)^{\zeta} (Y_t^*)^{\varsigma} \tag{15}$$

with $\zeta > 0$ and $\varsigma > 0$. Aggregate export demand is thus a function of the

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[10]Foreign producers also cannot price-discriminate.

real exchange rate, $Q_t \equiv \frac{S_t P_t^*}{P_t}$, and foreign demand for the domestic country's products, Y_t^*.

To pay households' wages, firms must use bank credit, i.e.

$$\hat{L}_t = \hat{W}_t N_t \tag{16}$$

In addition to bank credit, which is a liability, firms may hold bonds, $\hat{B}_t^f$, i.e. firms can borrow at rate I_t. Firms' financial net wealth in real terms, $\hat{A}_t^f$, is thus given by

$$\hat{A}_t^f = \hat{B}_t^f - \hat{L}_t \tag{17}$$

Since firms must pay the lending rate, I_t^l, for bank credit, their flow constraint is given by

$$
\begin{aligned}
&\left(\frac{P_t(i)}{P_t}\right) Y_t + \frac{(1+I_t)\hat{A}_t^f}{1+E_t[\Pi_{t+1}]} - \hat{W}_t N_t - \frac{(I_t^l - I_t)\hat{L}_t}{1+E_t[\Pi_{t+1}]} - Q_t IM_t \\
&- \hat{\Omega}_t^f - E_t\left[\hat{A}_{t+1}^h\right] = 0
\end{aligned}
\tag{18}
$$

where $\frac{(I_t^l - I_t)\hat{L}_t}{1+E_t[\Pi_{t+1}]}$ represents firms' financial cost, in real terms, for having to use bank credit to pay households' wages.

The present discounted value of firms' dividends can be written as

$$
\begin{aligned}
E_t \sum_{j=0}^{\infty} \beta^j \hat{\Omega}_{t+i}^f = \hat{A}_0^f + E_t \sum_{j=0}^{\infty} \beta^j \{ \left(\frac{P_{t+j}(i)}{P_{t+j}}\right) Y_{t+j} \\
- \left(1 + \frac{I_{t+j}^l - I_{t+j}}{1+\Pi_{t+j+1}}\right) \hat{W}_{t+j} N_{t+j} - Q_{t+j} IM_{t+j} \} = 0
\end{aligned}
\tag{19}
$$

Firms' objective is to choose $\{IM_t,\ N_t\}$ to maximise the present discounted value of dividends for given paths of $\hat{W}_t$, Q_t, I_t^l and I_t and an initial stock of

net assets, $\hat{A}_0^f$. Firms' first-order conditions are given by

$$\left(\frac{\kappa_t}{\xi_t} \left(1 + \frac{I_t^l - I_t}{1 + E[\Pi_{t+1}]} \right) \hat{W}_t \right)^{\frac{1}{1-\nu}} = \frac{\eta^{\frac{1}{1-\nu}} (Z_t)^{\frac{\nu}{1-\nu}} Y_t}{N_t} \tag{20}$$

$$\left(\frac{\kappa_t}{\xi_t} Q_t \right)^{\frac{1}{1-\nu}} = \frac{(1-\eta)^{\frac{1}{1-\nu}} Y_t}{IM_t} \tag{21}$$

where ξ_t is the Lagrange multiplier on constraint (10) and κ_t the multiplier on (19). Equations (20) and (21) indicate that, in a symmetric equilibrium, the aggregate mark-up, i.e. the ratio of the price level to aggregate marginal cost, is given by $\frac{\kappa_t}{\xi_t}$. Under price flexibility the mark-up $\frac{\kappa_t}{\xi_t}$ is constant and equal to $\frac{\theta}{\theta - 1}$.

Equations (20) and (21) show that the real allocation of resources is independent of the time path of dividends. This is because households only care about the present discounted value of dividends. For simplicity, firms are assumed to finance their operations out of retained earnings, i.e. they do not accumulate or decumulate net assets or issue new equity, and initial net assets, $\hat{A}_0^f$, are zero. Firms' dividends, in real terms, are then given by

$$\hat{\Omega}_t^f = \left(\frac{P_t(i)}{P_t} \right) Y_t - \left(1 + \frac{I_t^l - I_t}{1 + E_t[\Pi_{t+1}]} \right) \hat{W}_t N_t - Q_t IM_t = 0 \tag{22}$$

2.3 Financial intermediaries

Financial intermediaries provide loans, $\hat{L}_t$, to firms, which they finance with households' demand deposits, $\hat{D}_t$, and domestic bonds, $\hat{B}_t^h$. They can also issue internationally traded bonds, $\hat{B}_t^{fi}$. Financial intermediaries thus exist because

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of households' demand for deposit liabilities as a medium of exchange, and to provide loans to firms. Financial intermediaries' total net wealth in real terms, $\hat{A}_t^{fi}$, is given by

$$\hat{A}_t^{fi} = \hat{B}_t^{fi} + \hat{L}_t - \hat{D}_t - \hat{B}_t^h \tag{23}$$

Following Edwards and Végh (1997), the provision of demand deposits and loans is costly and financial intermediaries use tradeable resources to jointly produce demand deposits and loans. Costs are assumed to be given by the generalised Leontief function

$$\xi\left(\hat{L}_t, \hat{D}_t\right) = \upsilon_L \hat{L}_t + \upsilon_D \hat{D}_t - \upsilon_{LD}\left(\hat{L}_t\right)^{\frac{1}{2}}\left(\hat{D}_t\right)^{\frac{1}{2}} \tag{24}$$

where υ_L, υ_D and $\upsilon_{LD} > 0$. The function $\xi\left(.\right)$ is strictly increasing, convex and linearly homogenous; that is, for $\hat{L}_t > 0$ and $\hat{D}_t > 0$ it satisfies:

$$\xi\left(.\right) > 0,\ \frac{\partial \xi}{\partial \hat{L}} > 0,\ \frac{\partial \xi}{\partial \hat{D}} > 0,\ \frac{\partial^2 \xi}{\partial^2 \hat{L}} > 0,\ \frac{\partial^2 \xi}{\partial^2 \hat{D}} > 0 \text{ and } \frac{\partial^2 \xi}{\partial \hat{L}\partial \hat{D}} < 0$$

Financial intermediaries' flow budget constraint is given by

$$\begin{aligned}
&\frac{(1+I_t)\hat{A}_t^{fi}}{1+E_t[\Pi_{t+1}]} + \frac{\left(I_t^l - I_t\right)\hat{L}_t}{1+E_t[\Pi_{t+1}]} + \frac{\left(I_t - I_t^d\right)\hat{D}_t}{1+E_t[\Pi_{t+1}]} \\
&- \left(\upsilon_L \hat{L}_t + \upsilon_D \hat{D}_t - \upsilon_{LD}\left(\hat{L}_t\right)^{\frac{1}{2}}\left(\hat{D}_t\right)^{\frac{1}{2}}\right) \\
&- \hat{\Omega}_t^{fi} - E_t\left[\hat{A}_{t+1}^{fi}\right] = 0
\end{aligned} \tag{25}$$

Since financial intermediaries could always lend to the rest of the world (by buying bonds) at the rate I_t, $I_t^l - I_t$ is the spread earned from lending domestically. Since financial intermediaries could always borrow from the rest of the

world (by issuing bonds) at the rate I_t, $I_t - I_t^d$ is the spread earned by financial intermediaries from borrowing domestically at a lower cost.

Financial intermediaries choose $\left\{ \hat{D}_t, \hat{L}_t \right\}$ to maximise the present discounted value of dividends

$$
\begin{aligned}
E_t \sum_{j=0}^{\infty} \beta^j \hat{\Omega}_{t+i}^{fi} &= \hat{A}_0^{fi} + E_t \sum_{j=0}^{\infty} \beta^j \{ \tfrac{(I_{t+j}^l - I_{t+j})\hat{L}_{t+j}}{1 + E_t[\Pi_{t+j+1}]} \\
&+ \tfrac{(I_{t+j} - I_{t+j}^d)\hat{D}_{t+j}}{1 + E_t[\Pi_{t+j+1}]} - \left(\upsilon_L \hat{L}_{t+j} + \upsilon_D \hat{D}_{t+j} - \upsilon_{LD} \left(\hat{L}_{t+j} \right)^{\frac{1}{2}} \left(\hat{D}_{t+j} \right)^{\frac{1}{2}} \right) \} = 0
\end{aligned}
\tag{26}
$$

taken as given the path of I_t, I_t^d and I_t^l and the cost function, $\xi \left(\hat{L}_t, \hat{D}_t \right) = \upsilon_L \hat{L}_t + \upsilon_D \hat{D}_t - \upsilon_{LD} \left(\hat{L}_t \right)^{\frac{1}{2}} \left(\hat{D}_t \right)^{\frac{1}{2}}$. Financial intermediaries' first-order conditions are given by

$$
\frac{I_t - I_t^d}{1 + E_t[\Pi_{t+1}]} - \frac{2\upsilon_D (\hat{D}_t)^{\frac{1}{2}} - \upsilon_{LD}(\hat{L}_t)^{\frac{1}{2}}}{2(\hat{D}_t)^{\frac{1}{2}}} = 0
\tag{27}
$$

$$
\frac{I_t^l - I_t}{1 + E_t[\Pi_{t+1}]} - \frac{2\upsilon_L (\hat{L}_t)^{\frac{1}{2}} - \upsilon_{LD}(\hat{D}_t)^{\frac{1}{2}}}{2(\hat{L}_t)^{\frac{1}{2}}} = 0
\tag{28}
$$

In the case of costless banking, $\xi \left(\hat{L}_t, \hat{D}_t \right) = 0$ and equations (27) and (28) reduce to

$$
I_t - I_t^d = 0
\tag{29}
$$

$$
I_t^l - I_t = 0
\tag{30}
$$

In a competitive equilibrium with costless banking, financial intermediaries would charge borrowers the opportunity cost of funds (and pay depositors the cost of funds), i.e. firms' cost of borrowing from banks would be the same as accessing capital markets directly for external finance.

In the case of costly banking, the level of deposits and loans affects the cost of extending credit. For example, negative shocks that affect deposits are transmitted to the supply-side through a rise in lending rates and a credit contraction.

As in the case of firms, the time path of financial intermediaries' dividend payments is irrelevant as household only care about the present discounted value of dividends. For simplicity, financial intermediaries are assumed to finance their operations from retained earnings and their initial net assets, $\hat{A}_0^{fi}$, are zero. Loan market clearing (equation 23) then implies

$$\hat{L}_t = \hat{D}_t + \hat{B}_t^h - \hat{B}_t^{fi} \tag{31}$$

and dividends are given by

$$
\begin{aligned}
\hat{\Omega}_t^{fi} = &\frac{\left(I_t^l - I_t\right)\hat{L}_t}{1 + E_t[\Pi_{t+1}]} + \frac{\left(I_t - I_t^d\right)\hat{D}_t}{1 + E_t[\Pi_{t+1}]} \\
&- \left(\upsilon_L \hat{L}_t + \upsilon_D \hat{D}_t - \upsilon_{LD} \left(\hat{L}_t\right)^{\frac{1}{2}} \left(\hat{D}_t\right)^{\frac{1}{2}}\right) = 0
\end{aligned}
\tag{32}
$$

2.4 Government

The government collects taxes on households' wage, interest and dividend income. It uses the tax revenue to purchase goods, G_t, from firms. The government's budget constraint is assumed to balance in each period, i.e. there is no debt financing

$$
\begin{aligned}
&\tau \left(\hat{W}_t N_t + \hat{\Omega}_t^f + \hat{\Omega}_t^{fi} + \frac{I_t^d \hat{D}_t}{1 + E_t[\Pi_{t+1}]} + \frac{I_t \hat{B}_t^h}{1 + E_t[\Pi_{t+1}]} + \frac{I_t^* Q_t \hat{B}_t^{h*}}{1 + E_t[\Pi_{t+1}^*]}\right) \\
&- G_t = 0
\end{aligned}
\tag{33}
$$

2.5 Monetary authority

The monetary authority is assumed to set the nominal rate of interest paid on domestic bonds, I_t, to achieve an explicit inflation target, Π^T. Its reaction function depends on deviations of inflation from target, $\Pi_t - \Pi^T$, deviations of output, Y_t, from flexible price (capacity) output, $\bar{Y}_t$ (discussed further in section 4), and last period's interest rate, I_{t-1}, i.e.

$$1 + I_t = \mu_1 \left(\Pi_t - \Pi^T \right) + \mu_2 \left(Y_t - \bar{Y}_t \right) + \mu_3 \left(1 + I_{t-1} \right) \tag{34}$$

where μ_1, μ_2 and $\mu_3 > 0$.

2.6 Market clearing and equilibrium conditions

In equilibrium, all markets clear. The economy's resource constraint is given by

$$
\begin{aligned}
& Y_t - C_{1t} - C_{2t} - G_t - EX_t \\
& - \left(\upsilon_L \hat{L}_t + \upsilon_D \hat{D}_t - \upsilon_{LD} \left(\hat{L}_t \right)^{\frac{1}{2}} \left(\hat{D}_t \right)^{\frac{1}{2}} \right) = 0
\end{aligned}
\tag{35}
$$

where $\upsilon_L \hat{L}_t + \upsilon_D \hat{D}_t - \upsilon_{LD} \left(\hat{L}_t \right)^{\frac{1}{2}} \left(\hat{D}_t \right)^{\frac{1}{2}}$ denotes the resources used by financial intermediaries to produce demand deposits and loans.[11]

Uncovered interest rate parity holds

$$1 + (1 - \tau) I_t = (1 + (1 - \tau) I_t^*) \frac{E_t[S_{t+1}]}{S_t} \tag{36}$$

Firms' and financial intermediaries' bond holdings, $\hat{B}_t^f$ and $\hat{B}_t^{fi}$, are assumed

---

[11] All imports are intermediate inputs and therefore do not enter the resource constraint.

to be in the form of foreign securities and the foreign sector is determined by

$$\frac{(1+I_t^*)Q_t\left(\hat{B}_t^{h*}+\hat{B}_t^f+\hat{B}_t^{fi}\right)}{1+E_t\left[\Pi_{t+1}^*\right]} + EX_t - Q_t IM_t$$
$$-Q_t\left(E_t\left[\hat{B}_{t+1}^{h*}\right] + E_t\left[\hat{B}_{t+1}^f\right] + E_t\left[\hat{B}_{t+1}^{fi}\right]\right) = 0 \tag{37}$$

The sequence of foreign interest rates, prices, inflation and foreign demand $\{I_t^*,\ P_t^*,\ \Pi_t^*,\ Y_t^*\}$ is given to the small open economy.

3 Parameter values and the steady state

Next, the steady state of the model is derived. Parameter values are chosen so that the steady state is broadly consistent with New Zealand data and/or assumptions in the Reserve Bank of New Zealand's macroeconomic model.[12] To calibrate the model for New Zealand and derive the steady state, the following parameters need to be identified:

Households:	$\alpha,\ \beta,\ \gamma,\ \varrho$
Firms:	$\bar{Z},\ \nu,\ \eta,\ \theta$
Financial intermediaries:	$\upsilon_L,\ \upsilon_D,\ \upsilon_{LD}$
Government/monetary authority:	$\tau,\ \Pi^T$
Foreign sector:	$\bar{\Pi}^*,\ \bar{I}^*,\ \bar{Q},\ \zeta,\ \varsigma,\ \bar{Y}^*$

A period in the model is assumed to correspond to one quarter and the following parameters are chosen.

Households

The share of consumption of the credit good in households' total consumption, α, is set to 0.8. This is in line with the current ratio of advances out-

---

[12] See Black, Cassino, Drew, Hansen, Hunt, Rose and Scott (1997) for details.

standing on personal credit cards to retail sales. The discount rate, β, equals 0.992036 and leads to an annual steady state, pre-tax real domestic interest rate of 3.25 percent. This is lower than the current assumption in the Reserve Bank of New Zealand's model of 4 percent. The coefficient on leisure, γ, is set to 2, such that work effort accounts for approximately a third of the time endowment in steady state. The proportion of households' portfolios held in foreign bonds, ϱ, is set to 0.5, in line with New Zealand households' equity holdings abroad (see Thorp and Ung 2000 and 2001).

Firms

Labour-augmenting productivity, $\bar{Z}$, is normalised to 1 in steady state. The elasticity of substitution between labour and commodity inputs, $\frac{1}{1-\nu}$, is set to $\frac{1}{3}$, the same as in McCallum and Nelson (1999). With an assumption of $\nu = -2$, the coefficient η in firms' production function is set to 0.98. This yields a ratio of imports to output of about 0.27. Firms' mark-up in steady state, $\frac{\theta}{\theta-1}$, is 20 percent, i.e. $\theta = 6$, the same as in McCallum and Nelson (1999).

Financial intermediaries

The parameters in financial intermediaries' cost function are $\upsilon_L = 0.01$, $\upsilon_L = 0.006$ and $\upsilon_{LD} = 0.001$.[13] This leads to a spread between the demand deposit rate and the domestic bond rate of around 2 percent per annum, which is about the average (1991 to 2000) spread between the call deposit rate and the New Zealand overnight interbank cash rate.[14] The spread between the loan rate and domestic bond rate is approximately 4 percent per annum, which is

---

[13] The parameter υ_{LD} must be less than υ_L and υ_D to ensure that $\frac{\partial \xi}{\partial L} > 0$ and $\frac{\partial \xi}{\partial D} > 0$.

[14] The overnight interbank cash rate is the interest rate used by the Reserve Bank of New Zealand to change the stance of monetary policy.

about the average (1991 to 2000) spread between the base lending rate and overnight interbank cash rate.

Government/monetary authority

The annual domestic steady state inflation rate is equal to the Reserve Bank of New Zealand's inflation target rate, Π^T, of 2 percent. The tax rate, τ, equals 20 percent.

Foreign sector

As in the Reserve Bank of New Zealand's model, the steady state foreign inflation rate, $\bar{\Pi}^*$, is higher than the domestic target inflation rate and set to 2.5 percent. The steady state foreign nominal bond rate is assumed to be 5.5 percent. The steady state real exchange rate, $\bar{Q}$, is normalised to 1. The exponent on the real exchange rate, ζ, in the export demand equation is equal to 1, the same as in McCallum and Nelson (2001). The exponent on foreign output, ς, is 10, which, with an assumption of a steady state current account deficit of 2.6 percent, about the same as in the Reserve Bank model, implies foreign demand for the domestic country's products that is almost three times larger than domestic output.

With the above assumptions, the steady state of the model can be solved for numerically.[15] The values for $[D_t, B_t^h, B_t^{h*}, B_t^f, B_t^{fi}, C_{1t}, C_{2t}, G_t, Y_t, EX_t, IM_t, N_t, W_t, I_t, I_t^l, I_t^d, \Delta S_t]$ are summarised in Table 4, column (1).

The ratio of household consumption to output in steady state is about 0.595, which is lower than in the Reserve Bank of New Zealand's model (0.665). The ratios of government consumption and exports to output, at 0.153 and 0.245,

---

[15]The exact equations are contained in Appendix A.

Table 4: Numerical steady state

		costly financial intermediation	no financial intermediation costs	difference (in percent)
		(1)	(2)	(3)
$\bar{D}$	demand deposits	0.1336	0.1354	1.35
$\bar{B}^h$	households' domestic bonds	1.5277	1.5269	-0.05
$\bar{B}^{h*}$	households' foreign bonds	1.5277	1.5269	-0.05
$\bar{B}^f$	firms' bonds	1.7377	1.7464	0.50
$\bar{B}^{fi}$	financial intermediaries' bonds	0.8487	0.8416	-0.84
$\bar{C}_1$	consumption of the cash good	0.1336	0.1354	1.35
$\bar{C}_2$	consumption of the credit good	0.5363	0.5415	0.97
$\bar{G}$	government consumption	0.1719	0.1736	1.02
$\bar{EX}$	exports	0.2759	0.2760	0.02
$\bar{Y}$	output	1.1262	1.1264	0.02
$\bar{IM}$	imports	0.3057	0.3058	0.02
$\bar{N}$	labour	0.3265	0.3266	0.02
$\bar{W}$	wage rate	2.4883	2.5127	0.98
$\bar{I}$	domestic bond rate	6.6762	6.6762	0.00
$\bar{I}^l$	lending rate	10.8706	6.6762	-4.19
$\bar{I}^d$	demand deposit rate	4.6790	6.6762	2.00
$\bar{\Delta S}$	change in exchange rate	0.8936	0.8936	0.00
	residual	$8 \cdot 10^{-19}$		

Note: All variables are reported at annual rates. Deviations of interest rates and exchange rate changes are reported as percentage points differences. All other deviations are percentage changes.

are also lower than the values in the Reserve Bank's model (0.175 and 0.33).
This is because, in this model, all imports are intermediate goods whereas in
the Reserve Bank's model a proportion of imports are for final demand.

The ratio of imports to output is 0.271 compared to 0.354 in the Reserve
Bank's model, with a current account deficit about the same at around -2.6
percent of output. The steady state ratio of demand deposits to output (0.119)
is less than half the current ratio of households' assets with deposit-taking insti-
tutions to output. The cost of financial intermediation makes up approximately
0.8 percent of output and the ratio of loans to output is about 0.721.

To assess the long-run real effects of costly financial intermediation, the
steady state model is solved without financial intermediation costs, i.e. $\xi\left(\hat{L}_t, \hat{D}_t\right)$
$= 0$. The results are reported in Table 4, columns (2) and (3). With no finan-
cial intermediation cost the lending rate banks charge is the same as the rate
of interest firms would pay if borrowing directly in public debt markets.

The decline in firms' cost of borrowing leads to a rise in households' wages
and a small increase in steady state output, employment and imports. House-
holds' consumption rises with higher wages. Consumption of the cash good
increases by more than consumption of the credit good. This is because re-
moving financial intermediation cost raises the rate of interest banks pay on
demand deposits and lowers the opportunity cost of having to hold demand de-
posits. Government consumption also rises because of higher tax revenue from
households' labour income.

Households' saving in the form of domestic and foreign bonds declines. The
decline in domestic bond holdings is more than offset by an increase in demand

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deposits (due to higher consumption of the cash good). But the increase in households' demand deposits is insufficient to meet higher demand for loans and financial intermediaries' stock of foreign bonds declines. Firms' foreign bond holdings rise. The current account deficit remains virtually unchanged with an increase in steady state exports offsetting higher imports.

4   Price adjustment

The remainder of the paper assesses the dynamic properties of the model. Analysing the dynamics of the model requires specifying a price setting strategy for firms. It is convenient to derive firms' price adjustment in terms of logarithmic deviations from steady state.[16], [17]

As in Calvo (1983), firms' opportunity to adjust prices is assumed to follow an exogenous Poisson process. Each period, there is a constant probability φ that firms can adjust their prices. The expected time between adjustments is thus given by $\frac{1}{\varphi}$. Following Rotemberg (1987), the representative firm i sets its price to minimise a quadratic loss function that depends on the difference between the firm's actual price in period t, denoted by $p_t(i)$, and its target price, $p_t^T(i)$, where $p_t^T(i)$ denotes firm i's profit-maximising price in the absence of any restrictions or costs of adjusting prices. If firm i can adjust at time t, then it will set its price to minimise

$$\frac{1}{2} E_t \sum_{j=0}^{\infty} \beta^j \left(p_{t+j}(i) - p_{t+j}^T(i) \right)^2 \tag{38}$$

---

[16]Logarithmic deviations from steady state are denoted by lower case letters.
[17]The derivation of the price adjustment largely follows Walsh (1998).

subject to the assumed process for determining when the firm will be able to adjust its price next.

Equation (38) can be written as follows

$$\frac{1}{2}E_t[\left(p_t\left(i\right)-p_t^T\left(i\right)\right)^2+\left(1-\varphi\right)\beta\left(p_t\left(i\right)-p_{t+1}^T\left(i\right)\right)^2$$
$$+\left(1-\varphi\right)^2\beta^2\left(p_t\left(i\right)-p_{t+2}^T\left(i\right)\right)^2+...]$$

(39)

since $1-\varphi$ is the probability that the firm cannot adjust its price, so that the price set at time t still holds in $t+1$. Equation (39) can be simplified to

$$\frac{1}{2}\sum_{j=0}^{\infty}\left(1-\varphi\right)^j\beta^j E_t\left[p_t\left(i\right)-p_{t+j}^T\left(i\right)\right]^2$$

(40)

The first order condition of equation (40) with respect to $p_t\left(i\right)$ is given by[18]

$$p_t\left(i\right)\sum_{j=0}^{\infty}\left(1-\varphi\right)^j\beta^j-\sum_{j=0}^{\infty}\left(1-\varphi\right)^j\beta^j E_t\left[p_{t+j}^T\left(i\right)\right]=0$$

(41)

and solving for $p_t\left(i\right)$ yields

$$p_t\left(i\right)=\left(1-\left(1-\varphi\right)\beta\right)\sum_{j=0}^{\infty}\left(1-\varphi\right)^j\beta^j E_t\left[p_{t+j}^T\left(i\right)\right]$$

(42)

Thus, the price set by firm i is a weighted average of current and expected future values of the target price $p_t^T\left(i\right)$. If φ is large, then the expected time until the firm can adjust its price next is small and the smaller the weight on future $p_t^T\left(i\right)$'s.

---

[18]Note that $\sum_{j=0}^{\infty}\left(1-\varphi\right)^j\beta^j=\frac{1}{1-\left(1-\varphi\right)\beta}$ for $\left(1-\varphi\right)\beta<0$.

25

Equation (42) can be written as

$$
\begin{aligned}
p_t\left(i\right) &= \left(1 - \left(1 - \varphi\right)\beta\right)\left(p_t^T\left(i\right) + \left(1 - \varphi\right)\beta E_t\left[p_{t+1}^T\left(i\right)\right]\right. \\
&\left. + \left(1 - \varphi\right)^2\beta^2 E_t\left[p_{t+2}^T\left(i\right)\right] + ...\right) \\
&= \left(1 - \left(1 - \varphi\right)\beta\right)p_t^T\left(i\right) + \left(1 - \varphi\right)\beta E_t\left[p_{t+1}\left(i\right)\right]
\end{aligned}
\tag{43}
$$

Since firms are assumed to face a downward sloping demand curve, firm i's target price can be written as a function of the aggregate price level, p_t, and deviations of output from flexible price output, $y_t - \bar{y}_t$,

$$
p_t^T\left(i\right) = p_t + \tfrac{1}{\theta}\left(y_t - \bar{y}_t\right)
\tag{44}
$$

Flexible price output, which is defined further below, is the total domestic output that would be produced under price flexibility, i.e. in the absence of any restrictions or costs of adjusting prices.

If the number of firms is large, a fraction φ will actually adjust their price each period. The aggregate price level can thus be expressed as

$$
p_t = \varphi p_t\left(i\right) + \left(1 - \varphi\right)p_{t-1}
\tag{45}
$$

To obtain an expression for the adjustment of the aggregate price, equation (45) is first updated by one period and expectations are taken to obtain

$$
E_t\left[p_{t+1}\right] = \varphi E_t\left[p_{t+1}\left(i\right)\right] + \left(1 - \varphi\right)p_t
\tag{46}
$$

or

$$E_t \left[p_{t+1} \left(i \right) \right] = \tfrac{1}{\varphi} \left(E_t \left[p_{t+1} \right] - p_t \right) + p_t \tag{47}$$

Equation (47) can then be used to eliminate $E_t \left[p_{t+1} \left(i \right) \right]$ from equation (43)

$$p_t \left(i \right) = \left(1 - \left(1 - \varphi \right) \beta \right) p_t^T \left(i \right) + \tfrac{\left(1 - \varphi \right) \beta}{\varphi} \left(E_t \left[p_{t+1} \right] - p_t \right) + \left(1 - \varphi \right) \beta p_t \tag{48}$$

and equation (48) can be used to eliminate $p_t \left(i \right)$ from equation (45)

$$p_t = \varphi \left(1 - \left(1 - \varphi \right) \beta \right) p_t^T \left(i \right) + \left(1 - \varphi \right) \beta \left(E_t \left[p_{t+1} \right] - p_t \right)$$
$$+ \varphi \left(1 - \varphi \right) \beta p_t + \left(1 - \varphi \right) p_{t-1} \tag{49}$$

Replacing $p_t^T \left(i \right)$ with equation (44) yields

$$p_t = \varphi \left(1 - \left(1 - \varphi \right) \beta \right) \left(p_t + \tfrac{1}{\theta} \left(y_t - \bar{y}_t \right) \right) + \left(1 - \varphi \right) \beta \left(E_t \left[p_{t+1} \right] - p_t \right)$$
$$+ \varphi \left(1 - \varphi \right) \beta p_t + \left(1 - \varphi \right) p_{t-1} \tag{50}$$

Collecting terms, the aggregate price adjustment equation can be written as

$$\pi_t = \beta E_t \left[\pi_{t+1} \right] + \vartheta \left(y_t - \bar{y}_t \right) \tag{51}$$

where $\pi_t = p_t - p_{t-1}$ and $\vartheta = \frac{\varphi \left(1 - \left(1 - \varphi \right) \beta \right)}{\left(1 - \varphi \right) \theta}$.

The derivation of the log level of flexible price output, $\bar{y}_t$, follows McCallum and Nelson (1999). Under price flexibility, labour supply is equal to labour demand, i.e. employment is at $\bar{N}$. The flexible price level of output is therefore

given by

$$\bar{Y}_t = \left(\eta \left(Z_t \bar{N} \right)^\nu + (1 - \eta) \left(I\bar{M}_t \right)^\nu \right)^{\frac{1}{\nu}} \tag{52}$$

where $\bar{Y}_t$ and $I\bar{M}_t$ denote the flexible price level of output and imports. Log-linearising equation (52) yields

$$\bar{y}_t = \frac{\eta \left(\bar{Z}\bar{N} \right)^\nu}{\bar{Y}^\nu} z_t + \left(1 - \frac{\eta \left(\bar{Z}\bar{N} \right)^\nu}{\bar{Y}^\nu} \right) i\bar{m}_t \tag{53}$$

The log level of flexible price imports can be derived from firms' first-order condition (equation 21)

$$i\bar{m}_t = \bar{y}_t - \frac{1}{1-\nu} q_t \tag{54}$$

where the mark-up $\frac{\kappa_t}{\xi_t}$ is constant and equal to $\frac{\theta}{\theta - 1}$. Substituting (54) into (53) yields

$$\bar{y}_t = z_t - \frac{\bar{Y}^\nu - \eta \left(\bar{Z}\bar{N} \right)^\nu}{\eta (1 - \nu) \left(\bar{Z}\bar{N} \right)^\nu} q_t \tag{55}$$

The flexible price level of log output, $\bar{y}_t$, is thus a function of labour-augmenting productivity, z_t, and the real exchange rate, q_t.

5   Log-linearisation and solution of the dynamic model

This section derives the solution of the dynamic model. The dynamic model can be solved by log-linearising the necessary equations characterising the equilibrium and applying the method of undetermined coefficients.[19]   The log-linearised model is given by the following deterministic and expectational equa-

---

[19] Log-linearising the non-linear equations makes them approximately linear in the logarithmic deviations from the steady state.

tions.[20]

The deposit-in-advance constraint holds

$$d_t - c_{1t} = 0 \tag{56}$$

and households' first-order condition is given by

$$w_t - n_t - c_{2t} = 0 \tag{57}$$

Deviations from steady state of households' domestic bond holdings are equal to changes in foreign bonds and real exchange rate movements

$$b_t^{h*} + q_t - b_t^h = 0 \tag{58}$$

Exports are a function of the real exchange rate and foreign demand

$$ex_t - \zeta q_t - \varsigma y_t^* = 0 \tag{59}$$

Firms' production function is given by

$$y_t - \eta \left(\frac{\bar{Z}\bar{N}}{\bar{Y}}\right)^\nu n_t - (1-\eta) \left(\frac{I\bar{M}}{\bar{Y}}\right)^\nu im_t - \eta \left(\frac{\bar{Z}\bar{N}}{\bar{Y}}\right)^\nu z_t = 0 \tag{60}$$

---

[20] Details of the log-linerisation are available upon request.

The loan market clears

$$\bar{W}\bar{N}w_t + \bar{W}\bar{N}n_t - \bar{D}d_t - \bar{B}^h b_t^h + \bar{B}^{fi}b_t^{fi} = 0 \tag{61}$$

and the resource constraint holds

$$\bar{Y}y_t - \bar{C}_1 c_{1t} - \bar{C}_2 c_{2t} - \bar{G}g_t - \bar{EX}ex_t - \left(v_L \bar{W}\bar{N} - \frac{v_{LD}(\bar{W}\bar{N})^{\frac{1}{2}}(\bar{D})^{\frac{1}{2}}}{2}\right)w_t$$
$$- \left(v_L \bar{W}\bar{N} - \frac{v_{LD}(\bar{W}\bar{N})^{\frac{1}{2}}(\bar{D})^{\frac{1}{2}}}{2}\right)n_t - \left(v_D \bar{D} - \frac{v_{LD}(\bar{W}\bar{N})^{\frac{1}{2}}(\bar{D})^{\frac{1}{2}}}{2}\right)d_t = 0 \tag{62}$$

The monetary authority adjusts interest rates according to the following policy rule

$$i_t - \frac{\mu_1 \bar{\Pi}}{1+I}\pi_t - \frac{\mu_2 \bar{Y}}{1+I}\left(y_t - \bar{y}_t\right) - \mu_3 i_{t-1} = 0 \tag{63}$$

where $\frac{\mu_1 \bar{\Pi}}{1+I} = 1.5$, $\frac{\mu_2 \bar{Y}}{1+I} = 0.5$ and $\mu_3 = 0.8$. The choice for μ_1 and μ_2 is based on the parameter values in a Taylor rule (Taylor 1993).[21] The value for μ_3 is the same as in McCallum and Nelson (1999) and in line with estimates for New Zealand by Huang, Margaritis and Mayes (2001), who find strong evidence of interest rate smoothing. The log level of flexible price output is given by (55).

---

[21] The original Taylor rule does not include lagged interest rates.

The expectational equations are given by households' budget constraint

$$
(1 - \tau) \bar{W} \bar{N} w_t + (1 - \tau) \bar{W} \bar{N} n_t + \frac{\left(\left(1 + (1 - \tau)\bar{I}\right) - (1 - \tau)\left(\bar{I} - \bar{I}^d\right)\right)\bar{D}}{1 + \bar{\Pi}} d_t
$$

$$
+ \frac{(1 - \tau)\left(1 + \bar{I}^d\right)\bar{D}}{1 + \bar{\Pi}} i_t^d + \frac{\left(1 + (1 - \tau)\bar{I}\right)\bar{B}^h}{1 + \bar{\Pi}} b_t^h + \frac{\left(1 + (1 - \tau)\bar{I}\right)\left(\bar{D} + \bar{B}^h\right) - (1 - \tau)\left(1 + \bar{I}\right)\bar{D}}{1 + \bar{\Pi}} i_t
$$

$$
- \frac{\left(1 + (1 - \tau)\bar{I}\right)\left(\bar{D} + \bar{B}^h\right) - (1 - \tau)\left(\bar{I} - \bar{I}^d\right)\bar{D}}{1 + \bar{\Pi}} E_t\left[\pi_{t+1}\right] + \frac{\left(1 + (1 - \tau)\bar{I}^*\right)\bar{Q}\bar{B}^{h*}}{1 + \bar{\Pi}^*} b_t^{h*}
$$

$$
+ \left(\frac{\left(1 + (1 - \tau)\bar{I}^*\right)}{1 + \bar{\Pi}^*} - 1\right)\bar{Q}\bar{B}^{h*} q_t + \frac{\left(1 + (1 - \tau)\bar{I}^*\right)\bar{Q}\bar{B}^{h*}}{1 + \bar{\Pi}^*} i_t^*
$$

$$
- \frac{\left(1 + (1 - \tau)\bar{I}^*\right)\bar{Q}\bar{B}^{h*}}{1 + \bar{\Pi}^*} E_t\left[\pi_{t+1}^*\right] - \bar{C}_1 c_{1t} - \bar{C}_2 c_{2t} - \bar{D} E_t\left[d_{t+1}\right] - \bar{B}^h E_t\left[b_{t+1}^h\right]
$$

$$
- \bar{Q}\bar{B}^{h*} E_t\left[b_{t+1}^{h*}\right] = 0
$$

(64)

households' first-order conditions,

$$
c_{2t} - \frac{(1 - \tau)\left(1 + \bar{I}\right)}{\left(1 + \bar{\Pi}\right) + (1 - \tau)\left(\bar{I} - \bar{I}^d\right)} i_t + \frac{(1 - \tau)\left(1 + \bar{I}^d\right)}{\left(1 + \bar{\Pi}\right) + (1 - \tau)\left(\bar{I} - \bar{I}^d\right)} i_t^d
$$

$$
+ \frac{(1 - \tau)\left(\bar{I} - \bar{I}^d\right)}{\left(1 + \bar{\Pi}\right) + (1 - \tau)\left(\bar{I} - \bar{I}^d\right)} E_t\left[\pi_{t+1}\right] - c_{1t} = 0
$$

(65)

$$
E_t\left[c_{2t+1}\right] - c_{2t} - i_t + E_t\left[\pi_{t+1}\right] = 0
$$

(66)

firms' first-order condition,

$$
(1 - \nu) im_t + q_t - (1 - \nu) n_t - w_t + \nu z_t - \frac{1 + \bar{I}^l}{1 + \bar{\Pi} + \bar{I}^l - \bar{I}} i_t^l
$$

$$
+ \frac{1 + \bar{I}}{1 + \bar{\Pi} + \bar{I}^l - \bar{I}} i_t + \frac{\bar{I}^l - \bar{I}}{1 + \bar{\Pi} + \bar{I}^l - \bar{I}} E\left[\pi_{t+1}\right] = 0
$$

(67)

and the government's budget constraint

$$
\tau \bar{W} \bar{N} w_t + \tau \bar{W} \bar{N} n_t + \frac{\tau \bar{I}^d \bar{D}}{1 + \bar{\Pi}} d_t + \frac{\tau \bar{I}^d \bar{D}}{1 + \bar{\Pi}} i_t^d + \frac{\tau \bar{I} \bar{B}^h}{1 + \bar{\Pi}} b_t^h
$$

$$
+ \frac{\tau \bar{I} \bar{B}^h}{1 + \bar{\Pi}} i_t - \frac{\tau\left(\bar{I}^d \bar{D} + \bar{I} \bar{B}^h\right)}{1 + \bar{\Pi}} E_t\left[\pi_{t+1}\right] + \frac{\tau \bar{I}^* \bar{Q}\bar{B}^{h*}}{1 + \bar{\Pi}^*} q_t
$$

$$
+ \frac{\tau \bar{I}^* \bar{Q}\bar{B}^{h*}}{1 + \bar{\Pi}^*} b_t^{h*} + \frac{\tau \bar{I}^* \bar{Q}\bar{B}^{h*}}{1 + \bar{\Pi}^*} i_t^* - \frac{\tau \bar{I}^* \bar{Q}\bar{B}^{h*}}{1 + \bar{\Pi}^*} E_t\left[\pi_{t+1}^*\right]
$$

$$
- \bar{G} g_t = 0
$$

(68)

Deviations from steady state of the demand deposit and lending rate are given by

$$
\begin{aligned}
&\tfrac{1+\bar{I}^d}{1+\Pi} i_t^d - \tfrac{1+\bar{I}}{1+\Pi} i_t + \tfrac{\bar{I}-\bar{I}^d}{1+\Pi} E_t\left[\pi_{t+1}\right] + \tfrac{v_{LD}}{4}\left(\tfrac{\bar{W}\bar{N}}{\bar{D}}\right)^{\frac{1}{2}} d_t \\
&- \tfrac{v_{LD}}{4}\left(\tfrac{\bar{W}\bar{N}}{\bar{D}}\right)^{\frac{1}{2}} w_t - \tfrac{v_{LD}}{4}\left(\tfrac{\bar{W}\bar{N}}{\bar{D}}\right)^{\frac{1}{2}} n_t = 0
\end{aligned}
\tag{69}
$$

and

$$
\begin{aligned}
&\tfrac{1+\bar{I}^l}{1+\Pi} i_t^l - \tfrac{1+\bar{I}}{1+\Pi} i_t - \tfrac{\bar{I}^l-\bar{I}}{1+\Pi} E_t\left[\pi_{t+1}\right] + \tfrac{v_{LD}}{4}\left(\tfrac{\bar{D}}{\bar{W}\bar{N}}\right)^{\frac{1}{2}} d_t \\
&- \tfrac{v_{LD}}{4}\left(\tfrac{\bar{D}}{\bar{W}\bar{N}}\right)^{\frac{1}{2}} w_t - \tfrac{v_{LD}}{4}\left(\tfrac{\bar{D}}{\bar{W}\bar{N}}\right)^{\frac{1}{2}} n_t = 0
\end{aligned}
\tag{70}
$$

The foreign sector is determined by

$$
\begin{aligned}
&\tfrac{\left(1+\bar{I}^*\right)\bar{B}^{h*}}{1+\bar{\Pi}^*} b_t^{h*} + \tfrac{\left(1+\bar{I}^*\right)\bar{B}^f}{1+\bar{\Pi}^*} b_t^f + \tfrac{\left(1+\bar{I}^*\right)\bar{B}^{fi}}{1+\bar{\Pi}^*} b_t^{fi} \\
&+ \tfrac{\left(1+\bar{I}^*\right)\left(\bar{B}^{h*}+\bar{B}^f+\bar{B}^{fi}\right)}{1+\bar{\Pi}^*} i_t^* - \tfrac{\left(1+\bar{I}^*\right)\left(\bar{B}^{h*}+\bar{B}^f+\bar{B}^{fi}\right)}{1+\bar{\Pi}^*} E_t\left[\pi_{t+1}^*\right] \\
&+ \tfrac{\bar{EX}}{\bar{Q}} ex_t - \tfrac{\bar{EX}}{\bar{Q}} q_t - I\bar{M} im_t - \bar{B}^{h*} E_t\left[b_{t+1}^{h*}\right] - \bar{B}^f E_t\left[b_{t+1}^f\right] \\
&- \bar{B}^{fi} E_t\left[b_{t+1}^{fi}\right] = 0
\end{aligned}
\tag{71}
$$

and uncovered interest rate parity holds

$$
i_t - i_t^* - E_t\left[s_{t+1}\right] + s_t = 0
\tag{72}
$$

The real exchange rate evolves according to

$$
E_t\left[q_{t+1}\right] - q_t - E_t\left[s_{t+1}\right] + s_t + E_t\left[\pi_{t+1}\right] - E_t\left[\pi_{t+1}^*\right] = 0
\tag{73}
$$

with domestic inflation adjusting as described in equation (51). The probability that firms can adjust prices is set to 0.33. This assumes that prices remain unchanged on average for three quarters.

The system of linear equations can be solved with the method of undetermined coefficients, using Uhlig's (1997) procedures for MATLAB. Following Uhlig's (1997) notation, the dynamic stochastic model can be described as follows. The vector of endogenous state variables is given by x_t. Here, x_t contains the domestic bond rate, i_t, the demand deposit and lending rates, i_t^d and i_t^l, the nominal and real exchange rates, s_t and q_t, imports, im_t, inflation, π_t, households' foreign bond holdings, b_t^{h*}, firms' and financial intermediaries' bond holdings, b_t^f and b_t^{fi}, and government consumption, g_t, i.e. $x_t = \left[i_t, i_t^d, i_t^l, s_t, q_t, im_t, \pi_t, b_t^{h*}, b_t^f, b_t^{fi}, g_t \right]'$. The domestic bond rate is a state variable as last period's interest rates enter the monetary authority's reaction function. The other variables are artificially turned into state variables to ensure full rank of C (see equation 74). The vector of endogenous variables is given by y_t and contains households' demand deposits and domestic bonds, d_t and b_t^h, households' consumption of the cash and credit good, c_{1t} and c_{2t}, exports, ex_t, output, y_t, labour, n_t, the wage rate, w_t, flexible price output, $\bar{y}_t$, and the output gap, $y_t - \bar{y}_t$, i.e. $y_t = \left[d_t, b_t^h, c_{1t}, c_{2t}, ex_t, y_t, n_t, w_t, \bar{y}_t, y_t - \bar{y}_t \right]'$. The vector of exogenous state variables is given by z_t and discussed further in the next section. The following equilibrium relationships between these variables are assumed

$$0 = Ax_t + Bx_{t-1} + Cy_t + Dz_t \tag{74}$$

$$0 = E_t \left[Fx_{t+1} + Gx_t + Hx_{t-1} + Jy_{t+1} + Ky_t + Lz_{t+1} + Mz_t \right] \tag{75}$$

$$z_{t+1} = Nz_t + \varepsilon_{t+1}; \ E_t \left[\varepsilon_{t+1} \right] = 0 \tag{76}$$

where C is of size 10×10 and has full rank. F is of size 11×11 and the matrix N is assumed to only have stable eigenvalues.

The next step is to solve for the recursive equilibrium law of motion given by

$$x_t = Px_{t-1} + Qz_t \tag{77}$$

$$y_t = Rx_{t-1} + Sz_t \tag{78}$$

The coefficient matrices P, Q, R and S can be calculated using the method of undermined coefficients. If there exists a recursive equilibrium law of motion that solves equations (74), (75) and (76), then the coefficient matrices, P, Q, R and S, can be found as follows:[22]

1. P satisfies the (matrix) quadratic equations

$$\left(F - JC^{-1}A\right)P^2 - \left(JC^{-1}B - G + KC^{-1}A\right)P$$
$$-KC^{-1}B + H = 0 \tag{79}$$

   The equilibrium described by the recursive equilibrium law of motion (equations 77 and 78) and equation (76) is stable if and only if all eigenvalues of P are smaller than unity in absolute value.

2. R is given by

$$R = -C^{-1}\left(AP + B\right) \tag{80}$$

---

[22] See Uhlig (1997) for details.

3. Q satisfies

$$
(N' \otimes (F - JC^{-1}A)
$$
$$
+ I_k \otimes (JR + FP + G - KC^{-1}A))vec(Q) \tag{81}
$$
$$
= vec((JC^{-1}D - L)N + KC^{-1}D - M)
$$

where I_k is the identity matrix of size $k \times k$ and k is the number of exogenous state variables.

4. S is given by

$$
S = -C^{-1}(AQ + D) \tag{82}
$$

6 Impulse response analysis

The solution to the recursive equilibrium law of motion can be used to evaluate the dynamic properties of the model via impulse response analysis. Four types of aggregate shock are considered: a shock to monetary policy, domestic productivity, foreign demand and foreign interest rates. The response of the endogenous variables to an unanticipated shock in these variables can be traced out using equations (77) and (78), under the assumption that there are no other shocks. If the economy starts out in equilibrium and there are no other shocks, $x_0 = 0$ if the shock occurs in period 1.

All shocks are assumed normally distributed. The standard deviation of the monetary policy shock is 0.8 percent. Productivity, z_t, foreign demand, y_t^*, and foreign interest rates, i_t^*, are univariate exogenous processes and evolve

according to

$$z_t = \rho_z z_{t-1} + \epsilon_{z,t}, \quad \text{where} \quad \epsilon_{z,t} \sim i.i.d. \ N\left(0; \sigma_z^2\right) \tag{83}$$

$$y_t^* = \rho_{y*} y_{t-1}^* + \epsilon_{y*,t}, \quad \text{where} \quad \epsilon_{y*,t} \sim i.i.d. \ N\left(0; \sigma_{y*}^2\right) \tag{84}$$

$$i_t^* = \rho_{i*} i_{t-1}^* + \epsilon_{i*,t}, \quad \text{where} \quad \epsilon_{i*,t} \sim i.i.d. \ N\left(0; \sigma_{i*}^2\right) \tag{85}$$

The parameters ρ_z, ρ_{y*} and ρ_{i*} are set to 0.5 and the innovation variances are assumed to be given by $\sigma_z^2 = (0.007)^2$ and $\sigma_{y*}^2 = \sigma_{i*}^2 = (0.02)^2$.

The impulse responses of the endogenous variables to a shock in domestic interest rates, productivity, foreign demand and foreign interest rates are plotted in Figures 1 to 4 as percent deviations from steady state together with the shocks. The main point to note from Figures 1 to 4 is that, following a shock to the economy, the lending rate and demand deposit rate increase (decrease) by the same amount as the domestic bond rate. This suggests that the presence of financial intermediation costs does not affect business cycle fluctuations.[23] In other words, whether firms borrow from financial intermediaries or public debt markets directly does not affect economic growth. The result of no quantitatively significant effects of the bank lending channel is in line with Fisher's (1999) findings for the United States and it is unlikely that costly banking activity per se "dramatically alter(s) the real effects of macroeconomic disturbances" as projected by Edwards and Végh (1997).

The impulse responses are discussed in more detail below.

---

[23] The result is robust to different specifications of the model and financial intermediation costs.

Monetary policy shock

An increase in domestic interest rates increases firms' cost of borrowing, leading to a fall in output, employment and wages. Households' and government consumption falls and exports are also lower. Exports decline as the unexpected tightening in monetary policy causes an appreciation of the nominal exchange rate. The real exchange rate also appreciates as domestic prices only adjust sluggishly. The real appreciation of the domestic currency increases the price of exports leading to lower foreign demand.

Inflation falls slightly as output temporarily falls below capacity, i.e. the output gap becomes negative. The output gap actually declines more than output as the real appreciation of the domestic currency leads to a small increase in flexible price (capacity) output.

Financial intermediaries' foreign bond holdings increase as loans decline. Households' savings in the form of demand deposists and domestic bonds fall and foreign bond holdings increase due to the appreciation of the exchange rate. Firms' stock of foreign bonds declines.

Productivity shock

A positive labour-augmenting productivity shock leads to a decline in employment, but an increase in output and wages. In part, firms are able to produce more output because their cost of borrowing falls as the monetary authority accommodates the productivity shock and cuts interest rates. Financial intermediaries are able to increase lending to firms (and increase their foreign bond holdings) as households' saving in the form of demand deposits and domestic bonds rises. Firms' foreign bond holdings decline.

Figure 1: Impulse responses to a monetary policy shock

Households' demand deposits and consumption of the cash good
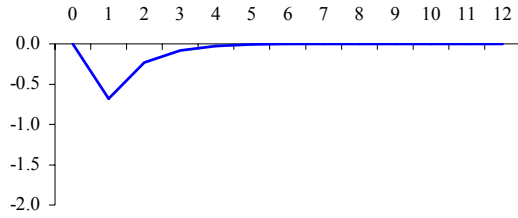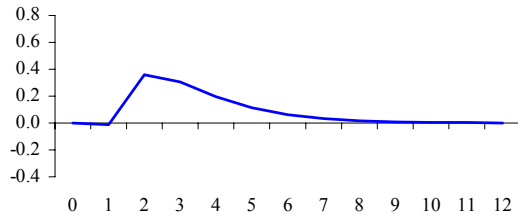
Households' domestic bonds
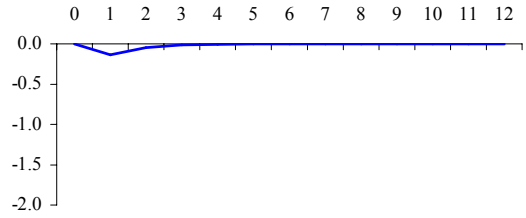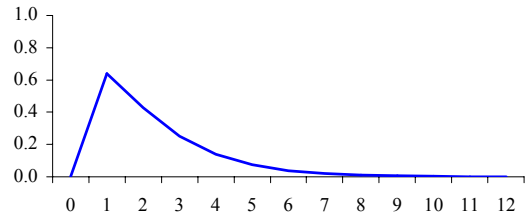
Households' foreign bonds
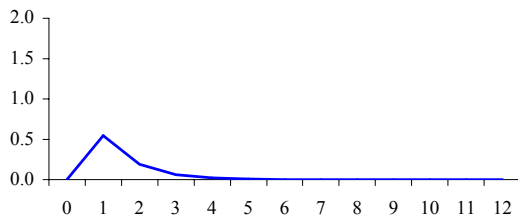
Households' consumption of the cash good
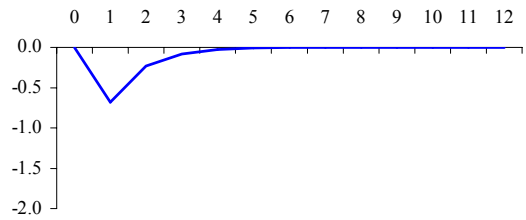
Government consumption
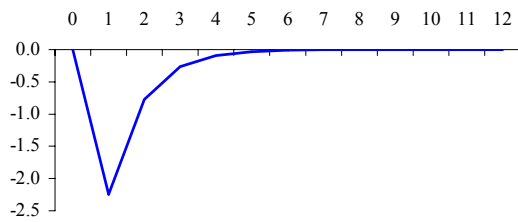
Exports
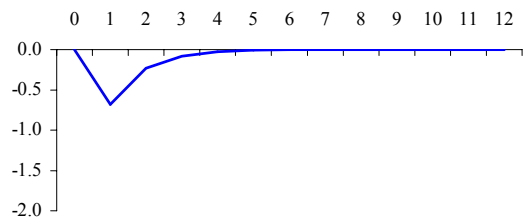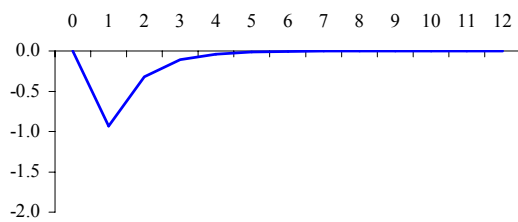
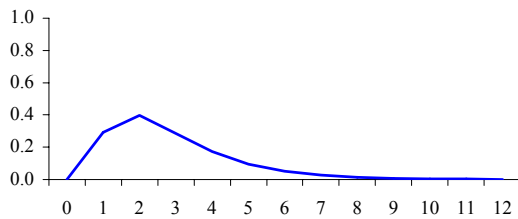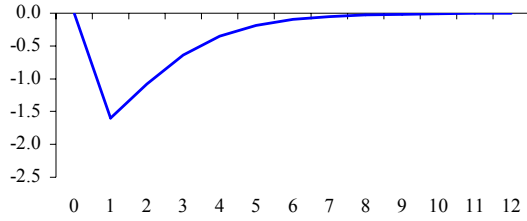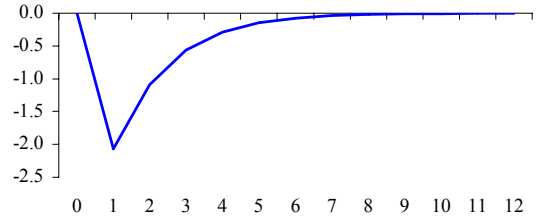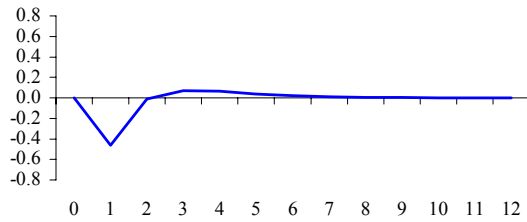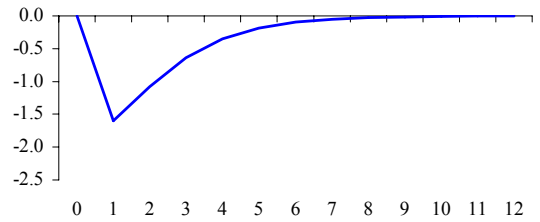**Output**

Labour
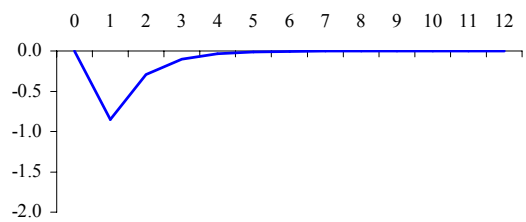
Wages
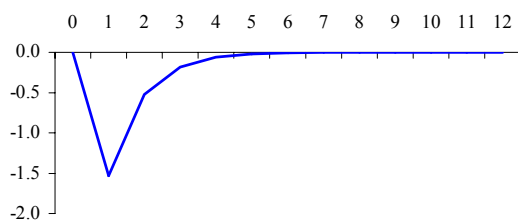
Imports

Figure 1: Impulse responses to a monetary policy shock (cont.)

Firms' bonds

Financial intermediaries' bonds

Domestic bond, demand deposit and lending rate

Inflation

Nominal exchange rate

Real exchange rate

Flexible price output
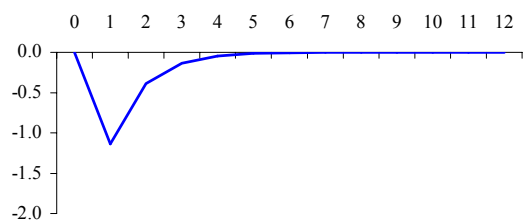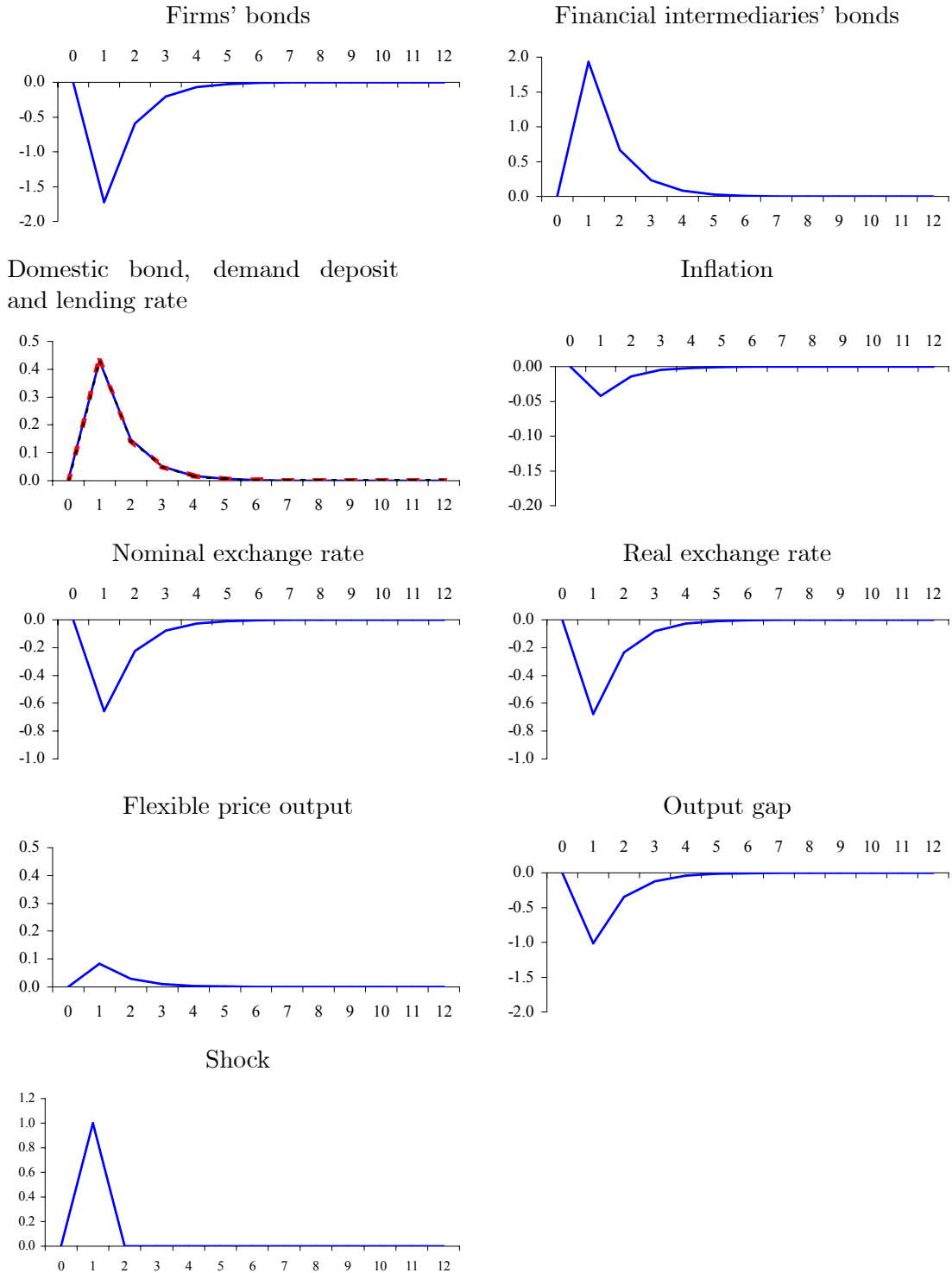
Output gap

Shock

The central bank is able to lower interest rates as the productivity shock leads to an increase in capacity output and a negative output gap, which puts downward pressure on inflation. The decline in interest rates leads to a (real) depreciation of the exchange and increased foreign demand for exports. Households' consumption increases. Government consumption also rises but with a lag. This is because the decline in employment initially offsets the increase in wages.

Foreign demand shock

A positive shock to foreign output increases exports, output and employment. Imports increase by more than employment as a (real) appreciation of the exchange rate, and subsequent decline in the cost of imports, leads to a substitution from labour to commodity inputs. The increase in imports is more than offset by the rise in exports, leading to an outflow of foreign capital and decline in the stock of foreign bonds held by households, firms and financial intermediaries.

Higher employment leads to a fall in households' wages and consumption. Government consumption also fall, but with a lag. This is because employment rises faster than wages fall.

The increase in output opens a positive output gap, despite a small increase in capacity output due to the appreciation of the real exchange rate, and puts upward pressure on inflation. The monetary authority tightens and domestic interest rates rise.

Foreign interest rate shock

An unexpected increase in foreign interest rates leads to a nominal and real

Figure 2: Impulse responses to a productivity shock

Households' demand deposits and consumption of the cash good
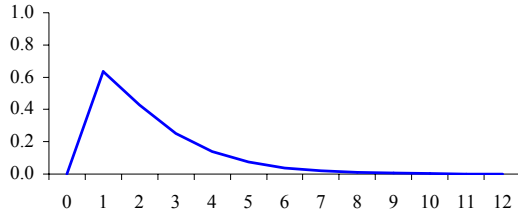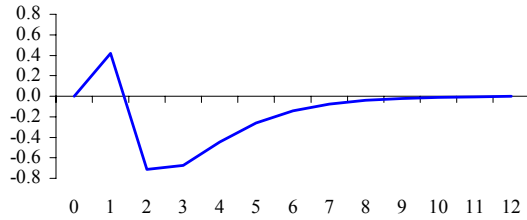

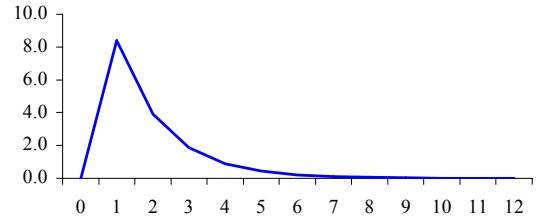Households' domestic bonds
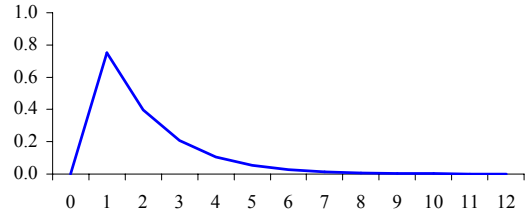
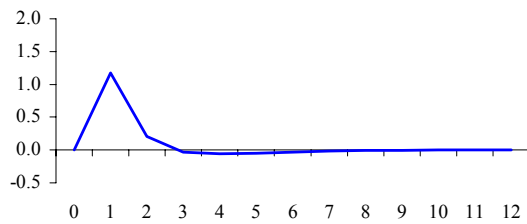Households' foreign bonds
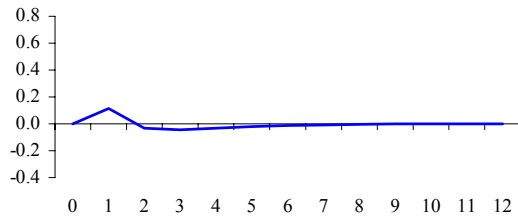
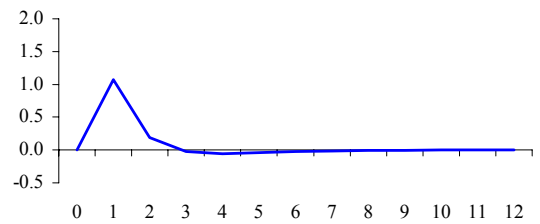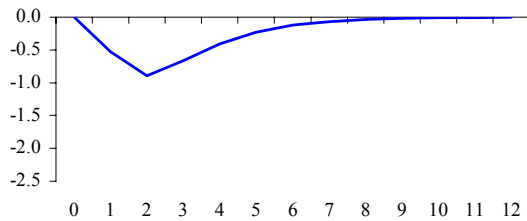Households' consumption of the cash good
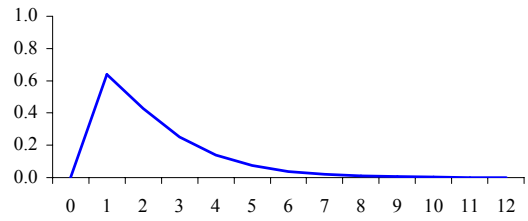
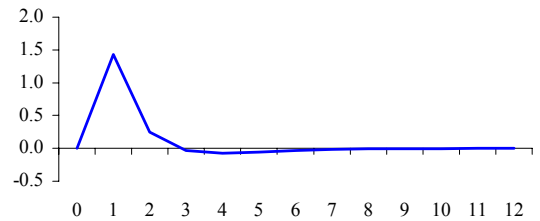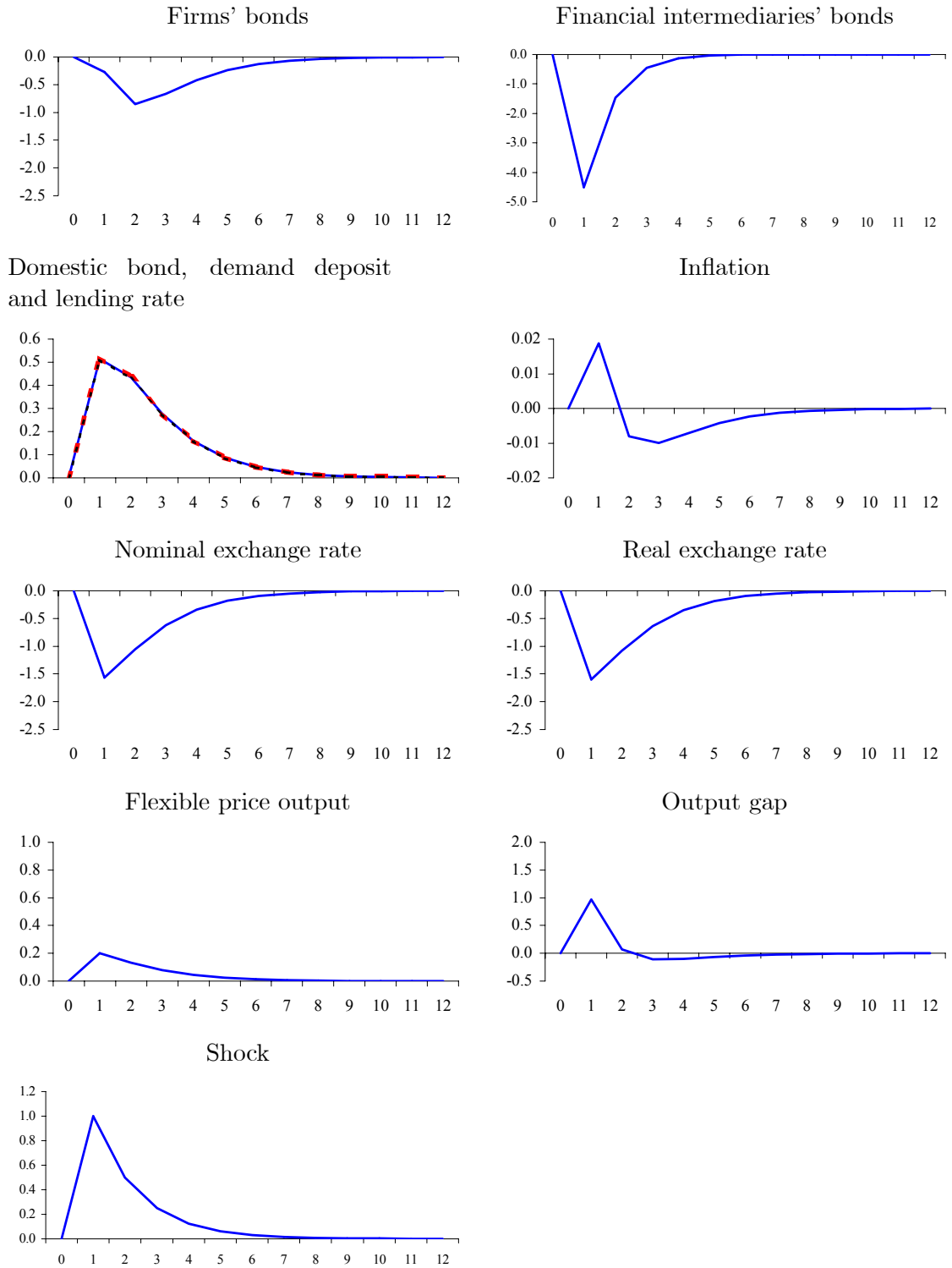Government consumption

Exports

Output
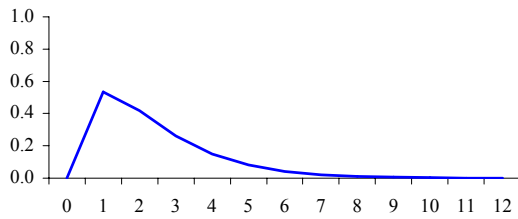
Labour
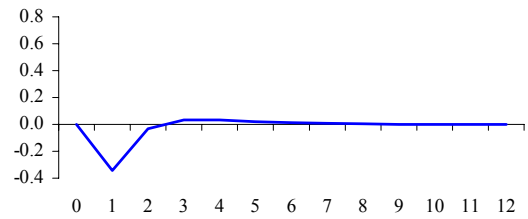
Wages

Imports
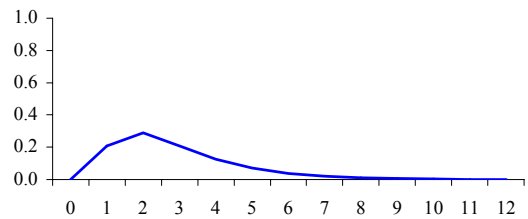
Figure 2: Impulse responses to a productivity shock (cont.)

Firms' bonds

Financial intermediaries' bonds

Domestic bond, demand deposit
and lending rate

Inflation

Nominal exchange rate

Real exchange rate

Flexible price output

Output gap
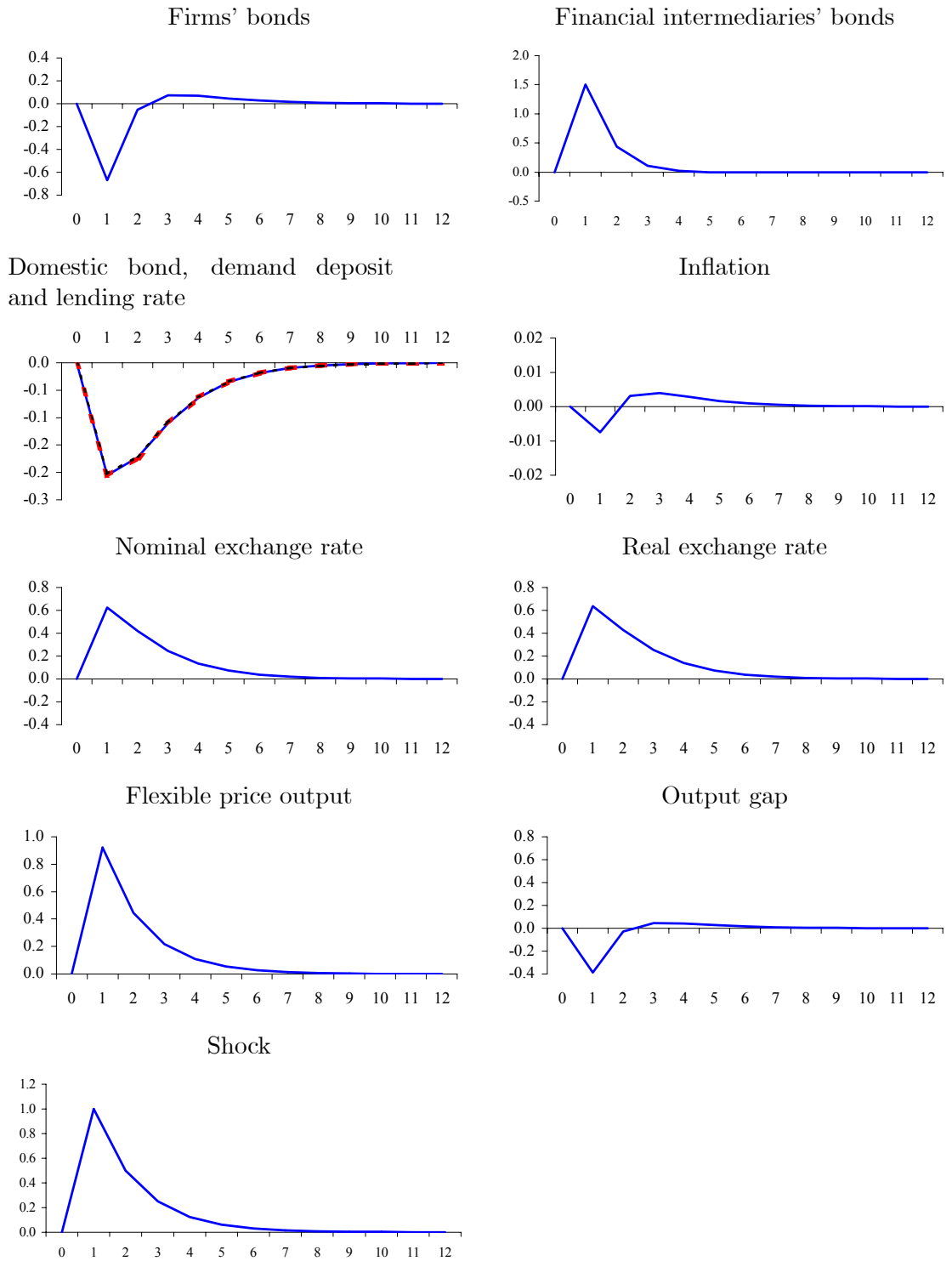
Shock

Figure 3: Impulse responses to a foreign demand shock

Households' demand deposits and consumption of the cash good

Households' domestic bonds

Households' foreign bonds

Households' consumption of the cash good

Government consumption

Exports

Output

Labour

Wages

Imports

Figure 3: Impulse responses to a foreign demand shock (cont.)

Firms' bonds

Financial intermediaries' bonds

Domestic bond, demand deposit and lending rate

Inflation

Nominal exchange rate

Real exchange rate

Flexible price output

Output gap

Shock

depreciation of the domestic currency that lowers the price of exports and increases the cost of imports. The decline in the price of exports increases export demand. The (real) depreciation of the exchange rate and increase in the cost of imports leads to a substitution from imports to labour. It also opens a positive output gap as flexible price output falls, leading to a tightening in monetary policy and higher domestic interest rates. Higher cost of borrowing puts downward pressure on wages and households' consumption falls as wage earnings decline. Government consumption also falls as tax revenue from households' labour income declines. The fall in household and government consumption offset the increase in exports, leaving output virtually unchanged.

Households' foreign bond holdings fall by more than domestic bonds due to the depreciation of the exchange rate. Firms' and financial intermediaries' foreign bond holdings also decline.

7 Concluding remarks

This paper has developed a theoretical model of a small open economy with a floating exchange rate to assess the quantitative effects of the bank lending channel. The model was calibrated for New Zealand. The steady states with and without a bank lending channel were derived and the dynamic properties of the model were assessed.

The main findings can be summarised as follows. The dependence on bank credit for external finance increases firms' cost of borrowing. Borrowing in public debt markets directly would lower the cost of borrowing, increase firms' demand for loans and lead to a small increase in the long-run level of steady

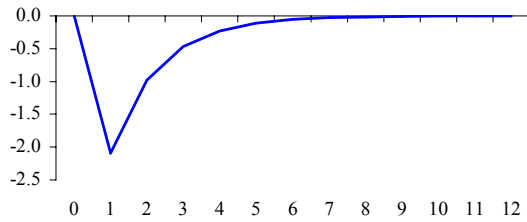Figure 4: Impulse responses to a foreign interest rate shock

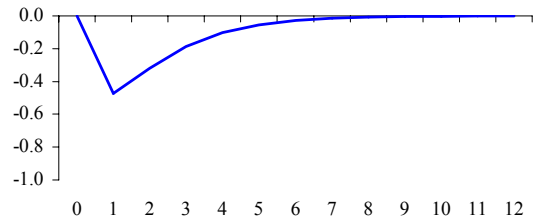Households' demand deposits and consumption of the cash good
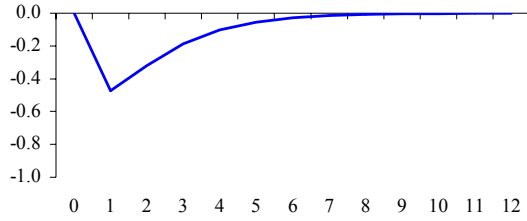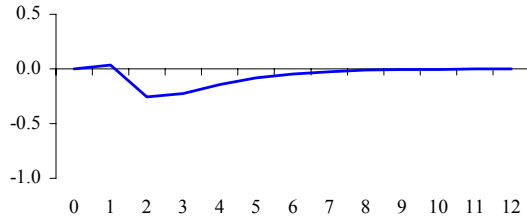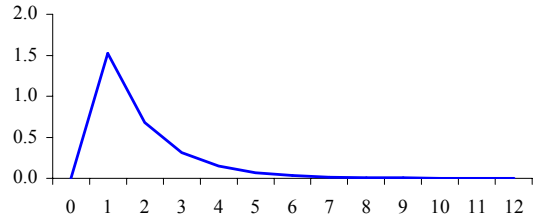
Households' domestic bonds
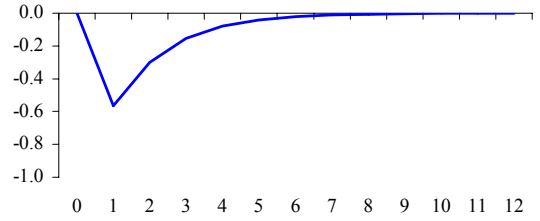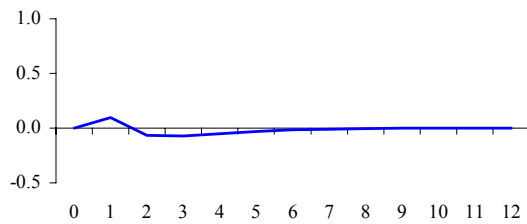
Households' foreign bonds
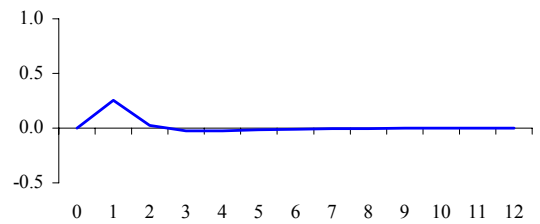
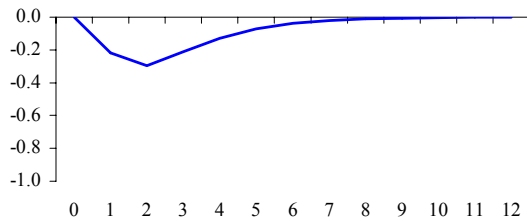Households' consumption of the cash good
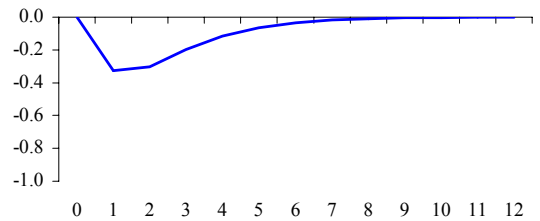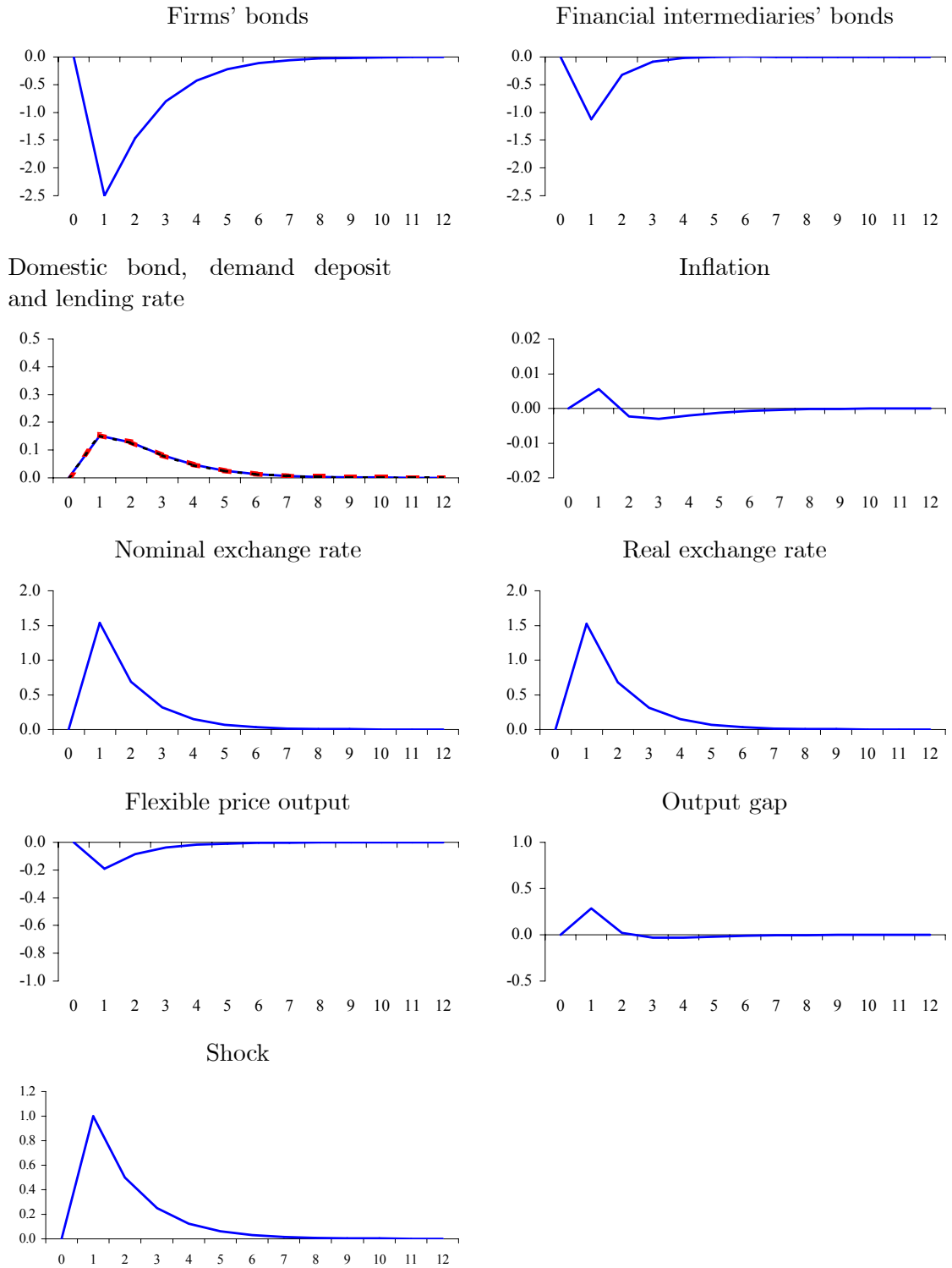
Government consumption

Exports

Output

Labour

Wages

Imports

Figure 4: Impulse responses to a foreign interest rate shock (cont.)

Firms' bonds

Financial intermediaries' bonds

Domestic bond, demand deposit and lending rate

Inflation

Nominal exchange rate

Real exchange rate

Flexible price output

Output gap

Shock

state output. Following a shock to the economy, the lending rate and demand deposit rate increase/decrease by the same amount as the domestic bond rate. This implies that the presence of financial intermediation costs *per se* does not affect the business cycle and is in line with Fisher's (1999) results for the United States.

The finding that the quantitative effects of bank lending are small suggests that the financial structure, or degree to which a country's financial system is intermediary or market based, does not matter for economic growth. In other words, whether firms borrow from financial intermediaries or public debt markets directly does not affect growth. The implication of this finding is that it is therefore unlikely that a "deepening of capital markets" in New Zealand would lead to faster economic growth.

This paper has investigated the quantitative effects of the bank lending channel. Further research is needed to examine the effects of the balance sheet channel or financial accelerator effect.

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A   Steady state equations

Households' budget constraint

$$(1-\tau)\,\bar{W}\bar{N} + \frac{\left(1+(1-\tau)\bar{I}\right)\left(\bar{D}+\bar{B}^h\right)}{1+\bar{\Pi}} + \frac{\left(1+(1-\tau)\bar{I}^*\right)\bar{Q}\bar{B}^{h*}}{1+\bar{\Pi}^*}$$

$$-\bar{C}_1 - \bar{C}_2 - \frac{(1-\tau)\left(\bar{I}-\bar{I}^d\right)\bar{D}}{1+\bar{\Pi}} - \bar{D} - \bar{B}^h - \bar{B}^{h*} = 0 \tag{86}$$

Households' deposit-in-advance constraint

$$\bar{D} - \bar{C}_1 = 0 \tag{87}$$

Households' foreign bond holding

$$\bar{Q}\bar{B}^{h*} - \varrho\left(\bar{B}^h + \bar{Q}\bar{B}^{h*}\right) = 0 \tag{88}$$

Households' first-order conditions

$$\frac{1-\alpha}{\bar{C}_1} - \frac{\alpha}{\bar{C}_2}\left(1 + \frac{(1-\tau)\left(\bar{I}-\bar{I}^d\right)}{1+\bar{\Pi}}\right) = 0 \tag{89}$$

$$\frac{\alpha}{\bar{C}_2} - \frac{\gamma}{(1-\tau)\bar{W}\left(1-\bar{N}\right)} = 0 \tag{90}$$

$$\frac{1+(1-\tau)\bar{I}}{1+\bar{\Pi}} - \frac{1}{\beta} = 0 \tag{91}$$

Firms' production function

$$\left(\eta\left(\bar{Z}\bar{N}\right)^\nu + (1-\eta)\,I\bar{M}^\nu\right)^{\frac{1}{\nu}} - \bar{Y} = 0 \tag{92}$$

Firms' profits from operation

$$\bar{Y} - \left(1 + \frac{\bar{I}^l - \bar{I}}{1 + \bar{\Pi}}\right) \bar{W}\bar{N} - \bar{Q}I\bar{M} = 0 \tag{93}$$

Firms' first-order condition

$$\frac{\left(\left(1 + \frac{\bar{I}^l - \bar{I}}{1 + \bar{\Pi}}\right)\bar{W}\right)^{\frac{1}{1-\nu}}\bar{N}}{\bar{Z}^{\frac{\nu}{1-\nu}}\eta^{\frac{1}{1-\nu}}} - \frac{\bar{Q}^{\frac{1}{1-\nu}}I\bar{M}}{(1-\eta)^{\frac{1}{1-\nu}}} = 0 \tag{94}$$

Financial intermediaries' first-order conditions

$$\frac{\bar{I} - \bar{I}^d}{1 + \bar{\Pi}} - \frac{2\upsilon_D \bar{D}^{\frac{1}{2}} - \upsilon_{LD}\left(\bar{W}\bar{N}\right)^{\frac{1}{2}}}{2\bar{D}^{\frac{1}{2}}} = 0 \tag{95}$$

$$\frac{\bar{I}^l - \bar{I}}{1 + \bar{\Pi}} - \frac{2\upsilon_L \left(\bar{W}\bar{N}\right)^{\frac{1}{2}} - \upsilon_{LD}\bar{D}^{\frac{1}{2}}}{2\left(\bar{W}\bar{N}\right)^{\frac{1}{2}}} = 0 \tag{96}$$

Loan market clearing

$$\bar{W}\bar{N} - \bar{D} - \bar{B}^h + \bar{B}^{fi} = 0 \tag{97}$$

Exports

$$\bar{E}X - \bar{Q}^\zeta \left(\bar{Y}^*\right)^\varsigma = 0 \tag{98}$$

Government budget constraint

$$\tau \left(\bar{W}\bar{N} + \frac{\bar{I}^d \bar{D}}{1 + \bar{\Pi}} + \frac{\bar{I}\bar{B}^h}{1 + \bar{\Pi}} + \frac{\bar{I}^* \bar{Q}\bar{B}^{h*}}{1 + \bar{\Pi}^*}\right) - \bar{G} = 0 \tag{99}$$

Economy's resource constraint

$$\bar{Y} - \bar{C}_1 - \bar{C}_2 - \bar{G} - \bar{E}X - \left(\upsilon_L \bar{W}\bar{N} + \upsilon_D \bar{D} - \upsilon_{LD} \left(\bar{W}\bar{N} \right)^{\frac{1}{2}} \bar{D}^{\frac{1}{2}} \right) = 0 \quad (100)$$

Foreign sector

$$\frac{\bar{Q}\left(1+\bar{I}^*\right)\left(\bar{B}^{h*}+\bar{B}^f+\bar{B}^{fi}\right)}{1+\bar{\Pi}^*} + \bar{E}X - \bar{Q}I\bar{M} + \bar{Q}\left(\bar{B}^{h*} + \bar{B}^f + \bar{B}^{fi}\right) = 0 \qquad (101)$$

Uncovered interest rate parity

$$1 + (1-\tau)\,\bar{I} - \left(1 + (1-\tau)\,\bar{I}^*\right)\left(1 + \bar{\Delta S}\right) = 0 \qquad (102)$$

Residual

$$\frac{\left(\bar{I}^l - \bar{I}\right)\bar{W}\bar{N}}{1+\bar{\Pi}} + \frac{\left(\bar{I} - \bar{I}^d\right)\bar{D}}{1+\bar{\Pi}} - \left(\upsilon_L \bar{W}\bar{N} + \upsilon_D \bar{D} - \upsilon_{LD} \left(\bar{W}\bar{N}\right)^{\frac{1}{2}} \bar{D}^{\frac{1}{2}} \right)$$
$$+ residual = 0 \qquad (103)$$

The steady state model is solved with "FindRoot" in Mathematica, which uses Newton's method.