Macroeconomic and Financial Interactions in Chile: An Estimated DSGE Approach*

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1 Introduction

The financial crisis of 2008 and the world recession that followed, as well as the current turbulence in the euro area, have renewed the interest for analyzing the interaction between macroeconomic and financial variables. The prevailing framework for monetary policy analysis before 2008 (the New Keynesian model) proved to be an incomplete tool, both because it did not include these interactions that ex-post were considered as relevant and also because it was not well suited to analyze the several "unconventional" policies that were implemented in response to the crisis. And while it seems that in many emerging countries the turbulence originated from the crisis have passed, the interest in analyzing the link between macroeconomic and financial variables remains. This is particularly so because of the need to evaluate additional tools to complement the usual implementation of inflation targeting frameworks in a global context of significant capital flows to emerging countries.

The main goal of this paper is to characterize macroeconomic and financial interactions in Chile using a framework that can eventually be used for policy analysis. Assessing the empirical relevance of the several possible channels that should play a role is most important before implementing any policy exercise. To that end, we extend in several dimensions a standard New Keynesian model of a small open economy to incorporate different aspects of the financial system. We estimate different versions of the model to assess how the several financial features contribute to explain both macroeconomic data (such as GDP, inflation, the exchange rate, etc.) and financial variables (spreads, credit, etc.).[1]

We begin with a baseline macro model that is a fairly standard New Keynesian model of a small open economy. In particular, the model features home and foreign goods, staggered prices *à la* Calvo both for domestic producers and importers (i.e. delayed pass-trough), a commodity sector, habits in consumption, investment adjustment costs, an elastic country premium, monetary policy modeled as a Taylor-type rule and Ricardian equivalence (with exogenous government expenditures). This model is a simplification of the DSGE model used for policy analysis and forecasting at the Central Bank of Chile (the MAS model from Medina and Soto, 2007) and similar to other small open economy models as, for instance, in Adolfson *et al.* (2007). We estimate this model using Bayesian techniques with macroeconomic variables such as GDP, consumption, investment, the real exchange rate, inflation and the monetary policy rate, as well as several external variables like foreign inflation, commodity prices, commercial partners' GDP, and world interest rates.

The first extension we consider is to incorporate a financial sector as in Gertler and Karadi (2011), extending it to a small open economy environment. In this framework banks obtain funds from domestic deposits and lend to firms for capital accumulation. The relationship between banks and depositors is subject to a moral hazard problem: the banker can divert a fraction of total assets in every period. As a result, in equilibrium, the spread between the deposit rate and the rate at which banks are willing to lend will depend on the leverage ratio of the banks. For the estimation of this model we will add spreads and a credit aggregate to the dataset.

The Gertler and Karadi framework has become quite popular in the recent macroeconomic literature, particularly for the analysis of "unconventional" monetary policies (see, for instance, Gertler and Kiyotaki, 2011; Gertler and Karadi, 2013; Dedola *et al.*; 2013; Kirchner and van Wijnbergen, 2012; Rannenberg, 2012). However, there are significantly less studies estimating models using this framework, particularly for small open economies. Some examples of estimations in closed-economy models are Villa (2013), Villa and Yang (2013), and Areosa and

[1] This type of model-based analysis will provide new useful tools for monetary policy analysis and forecasting at the Central Bank of Chile. In particular, it can used to complement the forecast usually made with a larger-scale DSGE model (which does not consider financial frictions in an explicit way). Moreover, it can be used to analyze risk scenarios related to the potential shocks affecting financial intermediation. Finally, the model will also have the potential to analyze policy tools that complements the usual implementation of monetary policy (such as reserve requirements and other macro-prudential tools).

Coelho (2013).

On top of the model that incorporates banks *à la* Gertler-Karadi, we consider several other extensions.[2] Two of them have to do with introducing an additional friction in the relationship between banks and borrowers. In one alternative this friction is modeled as the financial accelerator mechanism of Bernanke *et al.* (1999). In the other, we introduce the possibility of strategic default by firms using the framework developed by Dubey *et al.* (2005) (see also Goodhart *et al.*, 2007). In this model, the firm chooses what fraction of its outstanding loans to repay, suffering both pecuniary and non-pecuniary costs if it chooses not to fully repay. This is a tractable way to include a relevant variable that seems to lead the credit cycle in the data: the fraction of defaulted loans. The estimation exercise will shed light on the relevance of the information contained in that variable to explain other financial variables and also macroeconomic variables.

A final extension is to consider the possibility of two different types of firms in the model. In one group there are large firms that face no credit constraints and that can fund themselves both domestically (trough the banking system) and abroad (trough the bond market). The other group of firms is composed by smaller and riskier firms that are subject to financial frictions, and that can only obtain funding from local banks. This distinction has been emphasized by Caballero (2002) as a way to understand how the effects of capital inflows and outflows are transmitted to emerging countries (Chile in particular). The idea is that during inflow episodes large firms find it cheaper to obtain funds abroad, and thus they do not require credit from domestic banks. This and the fact that banks can also obtain cheap funds abroad increase the availability of domestic credit for small and more risky firms, lowering also the spreads faced by these firms. When capital inflows are reversed, large firms turn to the domestic banking system to obtain financing and, given that they are less risky than smaller firms, banks choose to lend to large firms, crowding out the credit to small firms. This mechanism clearly amplifies the effect of capital flows relative to a model with only one type of firm, and it is of interest to investigate the empirical performance of a model with this characteristics.

The rest of this paper is organized as follows. Section 2 presents the baseline model and the extension with banks *à la* Gertler and Karadi (2011). Section 3 presents the data, the estimation strategy and the goodness-of-fit analysis. Section 4 describes variance decompositions and impulse responses obtained with the different versions of the model. Finally, Section 4 summarizes the results so far and describes the steps to follow.

2 Models

We first describe the baseline model (with no financial frictions) and the extension that incorporates banks as in Gertler and Karadi (2011). Thereafter, we describe the second extension modifying the entrepreneurs' problem along the lines of Bernanke *et al.* (1999). In the main part of the paper, we just describe and set up the problems faced by each agent, leaving for the appendix the list of the relevant equilibrium conditions and the computation of the steady state.

2.1 Baseline Model

The baseline model is a small open economy model with nominal and real rigidities. Domestic goods are produced with capital and labor, there is habit formation in consumption, there are adjustment costs in investment, firms face a Calvo-pricing problem with partial indexation and there is imperfect exchange rate pass-through into import

[2] We are in the process of implementing those extensions, so this document does not include result from all other models.

prices in the short run due to local currency price stickiness. In addition, households face a Calvo-type problem in setting wages, assuming also partial indexation to past inflation. The economy also exports an exogenous endowment of a commodity good. There are several exogenous sources of fluctuations: shocks to preferences, technology (neutral and investment-specific), commodity production, government expenditures, monetary policy, foreign demand, foreign inflation, foreign interest rates and the international price of the commodity good.

2.1.1 Households

There is a continuum of infinitely lived households of mass one that have identical asset endowments and identical preferences that depend on consumption of a final good (C_t) and hours worked (h_t) in each period ($t = 0, 1, 2, \ldots$).[3] Households save and borrow by purchasing domestic currency denominated government bonds (B_t) and by trading foreign currency bonds (B_t^*) with foreign agents, both being non-state-contingent assets. They also make state-contingent loans (L_t) to goods producing firms. Expected discounted utility of a representative household is given by

$$E_t \sum_{s=0}^{\infty} \beta^s v_{t+s} \left[\log\left(C_{t+s} - \varsigma C_{t+s-1}\right) - \kappa \frac{h_{t+s}^{1+\phi}}{1+\phi} \right], \tag{1}$$

where v_t is an exogenous preference shock.

Following Schmitt-Grohé and Uribe (2006a, 2006b), labor decisions are made by a central authority, a union, which supplies labor monopolistically to a continuum of labor markets indexed by $i \in [0, 1]$. Households are indifferent between working in any of these markets. In each market, the union faces a demand for labor given by $h_t(i) = \left[W_t^n(i)/W_t^n\right]^{-\epsilon_W} h_t^d$, where $W_t^n(i)$ denotes the nominal wage charged by the union in market i, W_t^n is an aggregate hourly wage index that satisfies $(W_t^n)^{1-\epsilon_W} = \int_0^1 W_t^n(i)^{1-\epsilon_W} di$, and h_t^d denotes aggregate labor demand by firms. The union takes W_t^n and h_t^d as given and, once wages are set, it satisfies all labor demand. Wage setting is subject to a Calvo-type problem, whereby each period the household (or union) can set its nominal wage optimally in a fraction $1 - \theta_W$ of randomly chosen labor markets, and in the remaining markets, the past wage rate is indexed to a weighted product of past and steady state inflation with weights $\vartheta_W \in [0, 1]$ and $1 - \vartheta_W$.

Let r_t, r_t^* and r_t^L denote the gross real returns on B_{t-1}, B_{t-1}^* and L_{t-1}, respectively. Further, let W_t denote the real hourly wage rate, let rer_t be the real exchange rate (i.e. the price of foreign consumption goods in terms of domestic consumption goods), let T_t denote real lump-sum tax payments to the government and let Σ_t collect real dividend income from the ownership of firms. The period-by-period budget constraint of the household is then given by

$$C_t + B_t + rer_t B_t^* + L_t + T_t = \int_0^1 W_t(i) h_t(i) di + r_t B_{t-1} + rer_t r_t^* B_{t-1}^* + r_t^L L_{t-1} + \Sigma_t. \tag{2}$$

The household chooses C_t, h_t, $W_t^n(i)$, B_t, B_t^* and L_t to maximize (1) subject to (2) and labor demand by firms,

[3] Throughout, uppercase letters denote variables containing a unit root in equilibrium (either due to technology or to long-run inflation) while lowercase letters indicate variables with no unit root. Real variables are constructed using the domestic consumption good as the numeraire. In the appendix we describe how each variable is transformed to achieve stationarity in equilibrium. Variables without time subscript denote non-stochastic steady state values in the stationary model.

taking prices, interest rates and aggregate variables as given. The nominal interest rates are implicitly defined as

$$\begin{aligned} r_t &= R_{t-1}\pi_t^{-1}, \\ r_t^* &= R_{t-1}^*\xi_{t-1}\left(\pi_t^*\right)^{-1}, \\ r_t^L &= R_t^L\pi_t^{-1}, \end{aligned}$$

where $\pi_t = P_t/P_{t-1}$ and $\pi_t^* = P_t^*/P_{t-1}^*$ denote the gross inflation rates of the domestic and foreign consumption-based price indices P_t and P_t^*, respectively.[4] The variable ξ_t denotes a country premium given by[5]

$$\xi_t = \bar{\xi}\exp\left[-\psi\frac{rer_t B_t^*/A_{t-1} - rer \times b^*}{rer \times b^*} + \frac{\zeta_t - \zeta}{\zeta}\right],$$

where ζ_t is an exogenous shock to the country premium. The foreign nominal interest rate R_t^* evolves exogenously, and the domestic central bank sets R_t.[6]

2.1.2 Production and Pricing

The supply side of the economy is composed by different types of firms that are all owned by the households. There is a set of perfectly competitive entrepreneurs that manage the economy's stock of capital, a set of competitive capital goods producing firms, a set of monopolistically competitive firms producing different varieties of a home good with labor and capital as inputs, a set of monopolistically competitive importing firms, and three groups of perfectly competitive aggregators: one packing different varieties of the home good into a composite home good, one packing imported varieties into a composite foreign good, and another one that bundles the composite home and foreign goods to create a final good. This final good is purchased by households (C_t), capital goods producers (I_t) and the government (G_t). In addition, there is a set of competitive firms producing a homogeneous commodity good that is exported abroad. A proportion of those commodity-exporting firms is owned by the government and the remaining proportion is owned by foreign agents. The total mass of firms in each sector is normalized to one. Throughout, we denote productions/supply with the letter y and inputs/demand with x.

Entrepreneurs. Entrepreneurs manage the economy's stock of capital (K_t). In each period, they rent the capital to home goods producing firms and after depreciation they sell the capital to capital goods producers. Afterwards, they purchase new capital for the next period and transfer their profits to the households. We assume that the entrepreneurs need to finance a fraction α_L^K of their capital purchases by loans, L_t^K. That is, the constraint $L_t^K = \alpha_L^K q_t K_t$ holds in each period. Let r_t^K denote the real rental rate of capital and let q_t be the relative price of capital. The real profits of a representative entrepreneur in period t are equal to $\Pi_t^E = r_t^K K_{t-1} + q_t(1-\delta)K_{t-1} + L_t^K - q_t K_t - r_t^L L_{t-1}^K$. Perfect competition implies that the entrepreneurs earns zero profits in each period, and the state-contingent return r_t^L therefore satisfies

$$r_t^L = \frac{r_t^K + q_t(1-\delta)}{\alpha_L^K q_{t-1}} - \frac{\left(1-\alpha_L^K\right)q_t K_t}{\alpha_L^K q_{t-1} K_{t-1}}.$$

[4] Notice the difference with r_t^L, which is due to the state-contingent nature of these loans.
[5] See, for instance, Schmitt-Grohé and Uribe (2003) and Adolfson *et al.* (2007).
[6] The variable A_t (with $a_t \equiv A_t/A_{t-1}$) is a non-stationary technology disturbance, see below.

Capital Goods. Capital goods producers operate the technology that allows them to increase the economy-wide stock of capital. In each period, they purchase the stock of depreciated capital from entrepreneurs and combine it with investment goods to produce new productive capital. The newly produced capital is then sold back to the entrepreneurs and any profits are transferred to the households. A representative capital producer's technology is given by

$$K_t = (1-\delta)K_{t-1} + [1 - \Gamma(I_t/I_{t-1})]u_t I_t,$$

where I_t denotes investment expenditures in terms of the final good as a materials input and

$$\Gamma\left(\frac{I_t}{I_{t-1}}\right) = \frac{\gamma}{2}\left(\frac{I_t}{I_{t-1}} - \bar{a}\right)^2$$

are convex investment adjustment costs. The variable u_t is an investment shock that captures changes in the efficiency of the investment process (see, for instance, Justiniano *et al.*, 2011).

Final Goods. A representative final goods firm demands composite home and foreign goods in the amounts X_t^H and X_t^F, respectively, and combines them according to the technology

$$Y_t^C = \left[(1-o)^{\frac{1}{\eta}}\left(X_t^H\right)^{\frac{\eta-1}{\eta}} + o^{\frac{1}{\eta}}\left(X_t^F\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}. \tag{3}$$

Let p_t^H and p_t^F denote the relative prices of X_t^H and X_t^F in terms of the final good. Subject to the technology constraint (3), the firm maximizes its profits $\Pi_t^C = Y_t^C - p_t^H X_t^H - p_t^F X_t^F$ over the input demands X_t^H and X_t^F taking p_t^H and p_t^F as given.

Home Composite Goods. A representative home composite goods firm demands home goods of all varieties $j \in [0,1]$ in amounts $X_t^H(j)$ and combines them according to the technology

$$Y_t^H = \left[\int_0^1 X_t^H(j)^{\frac{\epsilon_H - 1}{\epsilon_H}} dj\right]^{\frac{\epsilon_H}{\epsilon_H - 1}}.$$

Let $p_t^H(j)$ denote the price of the good of variety j in terms of the home composite good. The profit maximization problem yields the following demand for the variety j:

$$X_t^H(j) = (p_t^H(j))^{-\epsilon_H} Y_t^H. \tag{4}$$

Home Goods of Variety j. Each home variety j is produced according to the technology

$$Y_t^H(j) = z_t K_{t-1}(j)^\alpha \left(A_t h_t(j)\right)^{1-\alpha}, \tag{5}$$

where z_t is an exogenous stationary technology shock, while A_t (with $a_t \equiv A_t/A_{t-1}$) is a non-stationary technology disturbance, both common to all varieties. The firm producing variety j has monopoly power but produces to satisfy the demand constraint given by (4). As the price setting decision is independent of the optimal choice of the factor inputs, the problem of firm j can also be represented in two stages. In the first stage, the firm hires labor and rents capital to minimize production costs subject to the technology constraint (5). Thus, the real marginal costs in units of the final domestic good is given by

$$mc_t^H(j) = \frac{1}{\alpha^\alpha (1-\alpha)^{1-\alpha}} \frac{(r_t^K)^\alpha W_t^{1-\alpha}}{p_t^H z_t (A_t)^{1-\alpha}}. \tag{6}$$

In the second stage of firm j's problem, given nominal marginal costs, the firm chooses its price $P_t^H(j)$ to maximize profits. In setting prices, the firm faces a Calvo-type problem, whereby each period the firm can change its price optimally with probability $1-\theta_H$, and if it cannot change its price, it indexes its previous price according to a weighted product of past and steady state inflation with weights $\vartheta_H \in [0,1]$ and $1-\vartheta_H$.[7]

Foreign Composite Goods. A representative foreign composite goods firm demands foreign goods of all varieties $j \in [0,1]$ in amounts $X_t^F(j)$ and combines them according to the technology

$$Y_t^F = \left[\int_0^1 X_t^F(j)^{\frac{\epsilon_F - 1}{\epsilon_F}} dj \right]^{\frac{\epsilon_F}{\epsilon_F - 1}}.$$

Let $p_t^F(j)$ denote the price of the good of variety j in terms of the foreign composite good. Thus, the input demand functions are

$$X_t^F(j) = (p_t^F(j))^{-\epsilon_F} Y_t^F. \tag{7}$$

Foreign Goods of Variety j. Importers buy an amount M_t of a homogenous foreign good at the price P_t^{F*} in the world market and convert this good into varieties $Y_t^F(j)$ that are sold domestically, where $M_t = \int_0^1 Y_t^F(j)dj$. The firm producing variety j has monopoly power but satisfies the demand constraint given by (7). As it takes one unit of the foreign good to produce one unit of variety j, nominal marginal costs in terms of composite goods prices are

$$P_t^F mc_t^F(j) = P_t^F mc_t^F = S_t P_t^{F*}. \tag{8}$$

Given marginal costs, the firm producing variety j chooses its price $P_t^F(j)$ to maximize profits. In setting prices, the firm faces a Calvo-type problem, whereby each period the firm can change its price optimally with probability $1-\theta_F$, and if it cannot change its price, it indexes its previous price according to a weighted product of past and steady state inflation with weights $\vartheta_F \in [0,1]$ and $1-\vartheta_F$. In this way, the model features delayed pass-trough from international to domestic prices.

Commodities. A representative commodity producing firm produces a quantity of a commodity good Y_t^{Co} in each period. Commodity production evolves according to an exogenous process, and it is co-integrated with the non-stationary TFP process. The entire production is sold abroad at a given international price P_t^{Co*}. The real foreign and domestic prices are denoted as p_t^{Co*} and p_t^{Co}, respectively, where p_t^{Co*} is assumed to evolve exogenously. The real domestic currency income generated in the commodity sector is therefore equal to $p_t^{Co} Y_t^{Co}$. The government receives a share $\chi \in [0,1]$ of this income and the remaining share goes to foreign agents.

2.1.3 Fiscal and Monetary Policy

The government consumes an exogenous stream of final goods (G_t), levies lump-sum taxes, issues one-period bonds and receives a share of the income generated in the commodity sector. We assume for simplicity that

[7] This indexation scheme eliminates the distortion generated by price dispersion up to a first-order expansion.

the public asset position is completely denominated in domestic currency. Hence, the government satisfies the following period-by-period constraint

$$G_t + r_t B_{t-1} = T_t + B_t + \chi p_t^{Co} Y_t^{Co}.$$

Monetary policy is carried out according to a Taylor rule of the form

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\bar{\pi}}\right)^{\alpha_\pi} \left(\frac{Y_t/Y_{t-1}}{a_{t-1}}\right)^{\alpha_y}\right]^{1-\rho_R} \exp(\varepsilon_t^R),$$

where $\bar{\pi}$ is target inflation and ε_t^R is an i.i.d. Gaussian shock that captures deviations from the rule.

2.1.4 The Rest of the World

Foreign agents demand home composite goods and buy the domestic commodity production. There are no transaction costs or other barriers to trade. The structure of the foreign economy is identical to the domestic economy, but the domestic economy is assumed to be small relative to the foreign economy. The latter implies that the foreign producer price level P_t^{F*} is identical to the foreign consumption-based price index P_t^*. Further, let P_t^{H*} denote the price of home composite goods expressed in foreign currency. Given full tradability and competitive export pricing, the law of one price holds separately for home composite goods and the commodity good, i.e. $P_t^H = S_t P_t^{H*}$ and $P_t^{Co} = S_t P_t^{Co*}$. That is, domestic and foreign prices of both goods are identical when expressed in the same currency. Due to local currency pricing, a weak form of the law of one price holds for foreign composite goods according to (8). Therefore, the real exchange rate rer_t satisfies

$$rer_t = \frac{S_t P_t^*}{P_t} = \frac{S_t P_t^{F*}}{P_t} = \frac{P_t^F mc_t^F}{P_t} = p_t^F mc_t^F,$$

and the commodity price in terms of domestic consumption goods is given by

$$p_t^{Co} = \frac{P_t^{Co}}{P_t} = \frac{S_t P_t^{Co*}}{P_t} = \frac{S_t P_t^*}{P_t} p_t^{Co*} = p_t^F p_t^{Co*}.$$

We also have the relation $rer_t/rer_{t-1} = \pi_t^S \pi_t^* / \pi_t$, where π_t^* denotes foreign inflation and $\pi_t^S = S_t/S_{t-1}$. Further, foreign demand for the home composite good X_t^{H*} is given by the schedule

$$X_t^{H*} = o^* \left(\frac{P_t^{H*}}{P_t^*}\right)^{-\eta^*} Y_t^*,$$

where Y_t^* denotes foreign aggregate demand. Both Y_t^* and π_t^* evolve exogenously.

2.1.5 Aggregation and Market Clearing

Taking into account the market clearing conditions for all the different markets, we can define the trade balance in units of final goods as

$$TB_t = p_t^H X_t^{H*} + rer_t p_t^{Co*} Y_t^{Co} - rer_t M_t, \tag{9}$$

Further, we define real GDP as follows:

$$Y_t \equiv C_t + I_t + G_t + X_t^{H*} + Y_t^{Co} - M_t.$$

Then, the GDP deflator (p_t^Y, expressed as a relative price in terms of the final consumption good) is implicitly defined as

$$p_t^Y Y_t = C_t + I_t + G_t + TB_t.$$

Finally, we can show that the net foreign asset position evolves according to

$$rer_t B_t^* = rer_t r_t^* B_{t-1}^* + TB_t - (1-\chi) rer_t p_t^{Co*} Y_t^{Co}.$$

2.1.6 Driving Forces

The exogenous processes in the model are $v_t, u_t, z_t, a_t, \zeta_t, R_t^*, \pi_t^*, p_t^{Co*}, y_t^{Co}, y_t^*$, and g_t. For each of them, we assume a process of the form

$$\log(x_t/\bar{x}) = \rho_x \log(x_{t-1}/\bar{x}) + \varepsilon_t^x, \qquad \rho_x \in [0,1), \qquad \bar{x} > 0,$$

for $x = \{v, u, z, a, \zeta, R^*, \pi^*, p^{Co*}, y^{Co}, y^*, g\}$, where the ε_t^x are i.i.d. Gaussian shocks.

2.2 Financial Frictions I: GK Banks

This version of the model differs from baseline model in the following aspects. In the baseline model, loans were not intermediated (households lent directly to entrepreneurs), but here we assume the presence of financial intermediaries (banks) that take deposits from households and combine them with their own net worth to produce state-contingent loans to entrepreneurs. The relationship between households and the bank is characterized by a moral hazard problem that gives rise to a premium between the lending and deposit rates. The latter is assumed to be equal to the monetary policy rate. The rest of the model remains as in the baseline case.

The balance sheet of a representative financial intermediary at the end of period t is given by

$$L_t = D_t + N_t,$$

where D_t denote deposits by domestic households at this intermediary, L_t denotes the intermediary's stock of interest-bearing claims on goods producing firms (with $L_t = \alpha_L^K q_t K_t$), and N_t denotes the intermediary's net worth (all in real terms of domestic units). The latter evolves over time as the difference between earnings on assets and interest payments on liabilities:

$$N_{t+1} = r_{t+1}^L L_t - r_{t+1} D_t = (r_{t+1}^L - r_{t+1}) L_t + r_{t+1} N_t \tag{10}$$

where r_t^L denotes the real gross return on loans and r_t is the real gross interest rates on domestic deposits.[8]

Financial intermediaries have finite lifetimes. At the beginning of period $t+1$, after financial payouts have been made, the intermediary continues operating with probability ω and exits the intermediary sector with probability

[8] In a different version of this model we added a shock to this equation, which some authors have included to represent shocks to bank capital (e.g. Villa, 2013). However, at least with the data we used, this shock does not seem to be properly identified.

$1-\omega$, in which case it transfers its retained capital to the household which owns that intermediary. Thus, the intermediary's objective in period t is to maximize expected terminal wealth, which is given by

$$V_t = E_t \sum_{s=0}^{\infty} (1-\omega)\omega^s \beta^{s+1} \Xi_{t,t+s+1} N_{t+s+1},$$

where $\Xi_{t,t+s}$ is the stochastic discount factor for real claims.

Further, following Gertler and Karadi (2011), a costly enforcement problem constrains the ability of intermediaries to obtain funds from depositors. In particular, at the beginning of period t, before financial payouts are made, the intermediary can divert an exogenous fraction μ_t of total assets (L_t). The depositors can then force the intermediary into bankruptcy and recover the remaining assets, but it is too costly for the depositors to recover the funds that the intermediary diverted. Accordingly, for the depositors to be willing to supply funds to the intermediary, the incentive constraint

$$V_t \geq \mu_t L_t \tag{11}$$

must be satisfied. That is, the opportunity cost to the intermediary of diverting assets cannot be smaller than the gain from diverting assets. As can be seen, shocks that increase μ_t will make this constraint tighter, making the financial problem more severe. We assume μ_t follows an AR(1) process.

Using the method of undetermined coefficients, V_t can be expressed as follows (see the Appendix):

$$V_t = \varrho_t^L L_t + \varrho_t^N N_t, \tag{12}$$

where

$$\begin{aligned}
\varrho_t^L &= \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\omega)(r_{t+1}^L - r_{t+1}) + \omega \frac{L_{t+1}}{L_t} \varrho_{t+1}^L \right] \right\}, \\
\varrho_t^N &= \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\omega) r_{t+1} + \omega \frac{N_{t+1}}{N_t} \varrho_{t+1}^N \right] \right\}
\end{aligned}$$

Holding the other variables constant, the variable ϱ_t^L is the expected discounted marginal gain of an additional unit of loans, while ϱ_t^N is the expected discounted marginal gain of and additional unit of net worth.

The intermediary maximizes (12) subject to (11) taking N_t as given. The first-order conditions to this problem are as follows:

$$\begin{aligned}
L_t &: (1+\varkappa_t)\varrho_t^L - \mu_t \varkappa_t = 0, \\
\varkappa_t &: \varrho_t^L L_t + \varrho_t^N N_t - \mu_t L_t \geq 0,
\end{aligned}$$

where $\varkappa_t \geq 0$ is the multiplier associated with the incentive constraint. The second condition holds with equality if $\varkappa_t > 0$, otherwise it holds with strict inequality. The condition for L_t implies that

$$\varkappa_t = \frac{\varrho_t^L}{\mu_t - \varrho_t^L},$$

such that the constraint is strictly positive if $\mu_t > \varrho_t^L$. That is, the incentive constraint holds with equality if the marginal gain to the financial intermediary from diverting assets and going bankrupt (μ_t) is larger than the marginal gain from expanding assets by one unit of deposits (i.e. holding net worth constant) and continuing to operate (ϱ_t^L). We assume that this is the case in a local neighborhood of the non-stochastic steady state. The condition for $\varkappa_t$ holding with equality implies that

$$L_t = lev_t N_t,$$

where

$$lev_t \equiv \frac{\varrho_t^N}{\mu_t - \varrho_t^L} \tag{13}$$

denotes the intermediary's leverage ratio. As indicated by (13), higher marginal gains from increasing assets ϱ_t^L support a higher leverage ratio in the optimum, the same is true for the higher marginal gains of net worth ϱ_t^N and for a larger fraction of divertable funds μ_t lower the leverage ratio.

The aggregate evolution of net worth follows from the assumption that a fraction $1-\omega$ of intermediaries exits intermediary sector in every period and an equal enters the sector. Each intermediary exiting the sector at the end of period $t-1$ transfer their remaining net worth ($\tilde{N}_{e,t} \equiv (r_t^L - r_t)L_{t-1} + r_t N_{t-1}$) to households. For each of them entering, households transfer them a starting capital equal to $\tilde{N}_{n,t} \equiv \frac{\iota}{1-\omega} n A_{t-1}$, with $\iota > 0$ (i.e. a fraction $\frac{\iota}{1-\omega}$ of balanced-growth-path net worth). Aggregate net worth then follows as

$$N_t = \omega \tilde{N}_{e,t} + (1-\omega)\tilde{N}_{n,t} = \omega\left[(r_t^L - r_t)L_{t-1} + r_t N_{t-1}\right] + \iota n A_{t-1}.$$

The rest of the model is exactly as in the baseline case, except for the first-order condition of the household that in the baseline model characterizes the choice of state-contingent loans that in this model is eliminated. In particular, the aggregation and the evolution of net foreign assets are the same as in the baseline model.

2.3 Financial Frictions II: GK Banks with BGG Entrepreneurs

This model builds over the Gertler and Karadi (GK) setup previously introduced by modifying the entrepreneurs' problem along the lines of Bernanke *et al.* (1999) (BGG for short). Entrepreneurs have two distinctive features in this setup. On the one hand, they have a technology available to transform new capital produced by capital goods producers into productive capital that can be used by firms. In particular, if at t they buy K_t units of new capital, the amount of productive capital available to rent to firms in $t+1$ is $\omega_{t+1}^e K_t$. The variable $\omega_t^e > 0$ is the source of heterogeneity among entrepreneurs and it is distributed in the cross section with a c.d.f. $F(\omega_t^e; \sigma_{\omega,t})$, and p.d.f. $f(\omega_t^e; \sigma_{\omega,t})$, such that $E(\omega_t^e) = 1$. The variable $\sigma_{\omega,t}$ denotes the time-varying cross-sectional standard deviation of entrepreneurs' productivity, and it is assumed to follow an exogenous process, as in, for instance, Christiano, Motto and Rostagno (2010, 2013). On the other hand, they have finite lifetimes (we describe this in more detail below) and when they exit the market they transfer all their remaining wealth to households.

We assume that purchases of new capital ($q_t K_t$) have to be financed by loans from intermediaries. However, due to an informational asymmetry (see below) entrepreneurs will not be able to obtain loans to cover for the whole operation. This will create the incentives for entrepreneurs to accumulate net worth N_t^e so that they can use it to finance part of the capital purchases. Thus, we have

$$q_t K_t = N_t^e + L_t.$$

The fact that entrepreneurs have finite lifetimes prevents them to accumulate net worth until a point in which they can self-finance the operation. The gross interest rate on loans is denoted by r_t^{Le}, which is decided at the time the loan contract is signed.

The informational asymmetry takes the form of a costly-state-verification problem, as in BGG. In particular, we assume that ω_t^e is only revealed to the entrepreneur ex-post (i.e. after loans contracts have been signed) and can only be observed by a third party after paying a monitoring cost, equivalent to a fraction μ^e of the total revenues generated by the project. Thus, at the time the entrepreneurs have to repay the loans they can choose to either pay the loan plus interest or to default, in which case the intermediary will pay the monitoring cost and seize all entrepreneurial assets.

Following BGG, the optimal debt contract specifies a cut-off value $\bar{\omega}_{t+1}^e$ such that if $\omega_{t+1}^e \geq \bar{\omega}_{t+1}^e$ the borrower pays $\bar{\omega}_{t+1}^e[r_{t+1}^K + (1-\delta)q_{t+1}]K_t$ to the lender and keeps $(\omega_{t+1}^e - \bar{\omega}_{t+1}^e)[r_{t+1}^K + (1-\delta)q_{t+1}]K_t$, while if $\omega_{t+1}^e < \bar{\omega}_{t+1}^e$ the borrower receives nothing (defaults) and the lender obtains $(1-\mu^e)\omega_{t+1}^e[r_{t+1}^K + (1-\delta)q_{t+1}]K_t$. Therefore, the interest rate on the loan r_t^{Le} satisfies

$$r_t^{Le} = \bar{\omega}_{t+1}^e[r_{t+1}^K + (1-\delta)q_{t+1}]\frac{K_t}{L_t}, \tag{14}$$

i.e. the return obtained by the bank for each unit of money lent from an entrepreneur that pays back the loan.

While r^{Le} denotes the interest rate on the loan, the return for the intermediary for each unit lent (r^L) is not equal to r^{Le}: first, not all loans will be repaid and, second, from those entrepreneurs who default, the intermediary gets their assets net of monitoring costs. This in particular implies that, while the interest rate on the loan is not contingent on the aggregate state, the return obtained by the intermediary is instead state-contingent, for it depends on the aggregate conditions that determine whether entrepreneurs default or not. Therefore, for the intermediary to be willing to lend it must be the case that

$$L_t r_{t+1}^L \leq g(\bar{\omega}_{t+1}^e; \sigma_{\omega,t+1})[r_{t+1}^K + (1-\delta)q_{t+1}]K_t, \tag{15}$$

where $[r_{t+1}^K + (1-\delta)q_{t+1}]K_t$ is the average (across entrepreneurs) revenue obtained at $t+1$ if the amount of capital purchases at t was K_t, and with

$$g(\bar{\omega}_t^e; \sigma_{\omega,t}) \equiv \bar{\omega}_t^e[1 - F(\bar{\omega}_t^e; \sigma_{\omega,t})] + (1-\mu^e)\int_0^{\bar{\omega}_t^e} \omega^e f(\omega^e; \sigma_{\omega,t})\mathrm{d}\omega^e.$$

The first term on the right-hand side is the share of total revenues that the intermediary obtains from those who pay back the loan, while the second is the value of the assets seized from defaulting entrepreneurs, net of monitoring costs. Equation (15) represent the participation constraint for intermediaries.[9]

[9]A technical note: As we have stated the model, whether this constraint holds state-by-state or in expectations (as in, for instance, Rannenberg, 2013) is (up-to-first order) irrelevant for the characterization of the optimal contract (in equilibrium it will hold without expectations anyway, as in Rannenberg, 2013). What is key to allow to merge the BGG model within the Gertler and Karadi framework is the assumption that the loan rate r_t^{Le} is *not* contingent on the aggregate state, and if this is not the case the equilibrium is indeterminate. The intuition for this result is as follows. In the original BGG model, if the participation constraint for the lender holds state-by-state, the nature of r_t^{Le} is irrelevant. This is so because, as the required return r_{t+1}^L is determined elsewhere, the participation constraint pins down the current value of $\bar{\omega}_{t+1}^e$ and then the other optimality condition of the optimal contract (sew below) pins down the external-finance premium (in fact, given that such a setup is the usual way the BGG model is implemented, people do not even worry to have an equation like (14) as an equilibrium condition). However, if in the original BGG model the participation constraint for the lender holds in expectations, we do require r_t^{Le} to be non-contingent. In such a case, it is precisely equation (14) what pins down $\bar{\omega}_{t+1}^e$, while the participation constraint alone just determines (up-to-first order) $E_t\{\bar{\omega}_{t+1}^e\}$.
In our setup the reason why we need r_t^{Le} to be non-contingent is because r_{t+1}^L is not determined by any other equilibrium condition (the intermediary's problem just pins down $E_t\{r_{t+1}^L\}$). Thus, in our framework, equation (14) pins down $\bar{\omega}_{t+1}^e$ and, given that value, (15) determines r_{t+1}^L. If we don't assume this, as we mentioned, the equilibrium is indeterminate because only equation (15) display both r_{t+1}^L and $\bar{\omega}_{t+1}^e$, and there is no other equation that determines one of these.

From the entrepreneurs' viewpoint, the expected profits for the project of purchasing K_t units of capital equals

$$E_t\left\{[r^K_{t+1}+(1-\delta)q_{t+1}]K_t h(\bar{\omega}^e_{t+1};\sigma_{\omega,t+1})\right\}, \tag{16}$$

where

$$h(\bar{\omega}^e_t;\sigma_{\omega,t})\equiv\int_{\bar{\omega}^e_t}^{\infty}\omega^e f(\omega^e;\sigma_{\omega,t})\mathrm{d}\omega^e-\bar{\omega}^e_t[1-F(\bar{\omega}^e_t;\sigma_{\omega,t})].$$

The first term in the right-hand side is the expected share of average revenue they obtain given their productivity and the second term is the expected repayment, both conditional on not defaulting (i.e. if $\bar{\omega}^e_t\geq\omega^e_t$).

Defining $lev^e_t\equiv\frac{q_tK_t}{N^e_t}$, and given the revelation principle, the optimal debt contract specifies a value for lev^e_t and a state-contingent $\bar{\omega}^e_{t+1}$ such that (16) is maximized subject to (15) being satisfied with equality for every possible aggregate state at $t+1$. As shown in the Appendix, the optimality condition for this contract can be written as follows:

$$E_t\left\{\frac{[r^K_{t+1}+(1-\delta)q_{t+1}]}{q_t}\left[\frac{h'(\bar{\omega}^e_{t+1};\sigma_{\omega,t+1})g(\bar{\omega}^e_{t+1};\sigma_{\omega,t+1})}{g'(\bar{\omega}^e_{t+1};\sigma_{\omega,t+1})}-h(\bar{\omega}^e_{t+1};\sigma_{\omega,t+1})\right]\right\}=E_t\left\{r^L_{t+1}\frac{h'(\bar{\omega}^e_{t+1};\sigma_{\omega,t+1})}{g'(\bar{\omega}^e_{t+1};\sigma_{\omega,t+1})}\right\},$$

The ratio $E_t\left\{\frac{[r^K_{t+1}+(1-\delta)q_{t+1}]}{q_t}\right\}/E_t\left\{r^L_{t+1}\right\}$ is known as the external finance premium which, as shown by BGG, is (up-to-first order) an increasing function of entrepreneurs' leverage lev^e_t.

Finally, average entrepreneurs' net worth evolves over time as follows. The average return an entrepreneur gets after repaying its loan at t is given by $[r^K_t+(1-\delta)q_t]K_{t-1}h(\bar{\omega}^e_t;\sigma_{\omega,t})$. We assume that only a fraction υ of entrepreneurs survive every period, and an equal fraction enters the market with an initial capital injection from households equal to $\frac{\iota^e}{1-\upsilon}n^eA_{t-1}$, with $\iota^e>0$ (i.e. a fraction $\frac{\iota^e}{1-\upsilon}$ of balanced-growth-path net worth).[10] Thus, we have

$$N^e_t=\upsilon\left\{[r^K_t+(1-\delta)q_t]K_{t-1}h(\bar{\omega}^e_t;\sigma_{\omega,t})\right\}+\iota^e n^e A_{t-1}.$$

3 Parametrization

Our empirical strategy combines both calibrated and estimated parameters. The calibrated parameters and targeted steady state values are presented in Table 1. The parameters in the baseline model that are endogenously determined in steady state are: β, π^*, κ, o^*, $\bar{g}$, $\bar{b}^*$ and $\bar{y}^{Co}$. For most of the parameters, we draw from related studies using Chilean data. The parameters that deserve additional explanation are those related with the financial frictions: $\bar{\mu}$ (the steady state value of the fraction of divertible funds), ω (the fraction of surviving banks), ι (the capital injection for new banks), μ^e (bankruptcy costs), υ (the fraction of surviving entrepreneurs), ι^e (the capital injection for new entrepreneurs), and σ_ω (the steady state value of entrepreneurs' dispersion).

For the model that only includes GK banks (the GK model for short), and given that in the steady state there are only two equations characterizing the problem of the bank, we follow Gertler and Karadi (2011) and calibrate $\iota=0.002$ while the remaining two parameters of this version, $\bar{\mu}$ and ω, are determined to match two steady state values. On one hand, we pick a spread of 380 basis points, which corresponds to the average spread between 90-days loans and the monetary policy rate.[11] On the other hand, we set the bank leverage ratio equal to 9. This statistic is not easy to calibrate, for banks' balance sheets are more complicated in the data than in

[10] Entrepreneurs that leave that market transfer their remaining resources to households.

[11] All the rates and spread figures are presented here in annualized terms, although in the model they are included on a quarterly basis.

the model. Consolidated data from the banking system in Chile implies an average leverage ratio of around 13 between 2001 and 2012, but on the assets side of the balance sheet there are other types of assets that are not loans. To pick the value that we used, we compute an average ratio of the stock of loans to total consolidated assets of the banking system of 66% and adjusted the observed average leverage of the banking system by this percentage (i.e. $9 \approx 13 \times 0.66$). Finally, we choose a value for α_L^K (the ratio of loans to the value of the stock of capital) equal to 0.51. This number is consistent with the average leverage for entrepreneurs that we calibrate in the BGG model below.[12]

For the model with GK banks and BGG entrepreneurs (the GK-BGG model for short), we use the same targeted averages for the banking sector-related parameters as described above. However, we make the following distinction considering that r^{Le} (the loan rate) differs from r^L (the return for the bank from making loans). The loan rate that we observe in the data is in line with the definition of r^{Le}, thus the spread that we match is that of r^{Le} and r. For the entrepreneurs' problem, we set two parameters for which we don't have good estimates for Chile as in the related literature: $\upsilon = 0.97$ (the value used by BGG) and $\mu^e = 0.12$ (in the range used by Christiano *et al.*, 2010, for the US and the EU). The remaining two parameters, ι^e and σ_ω, are set to match a steady state risk premium (i.e. the difference between the return on capital $\frac{r^K+(1-\delta)q}{q}$ and r^L) of 120 basis points, and a leverage ratio for entrepreneurs of 2.05. For the premium figures, Christiano *et al.* (2010) use the spread on corporate bonds of different credit ratings as a proxy for the premium paid by riskier firms. Thus, the number we use is the average between the A vs. AAA corporate-bonds spread and the BBA vs. AAA spread, for the sample 2001 to 2012. For the leverage figure, the chosen value corresponds to the average between 2001 and 2012 for the largest Chilean firms.[13]

We have also calibrated the parameters characterizing those exogenous processes for which we have a data counterpart. In particular, for g we use linearly-detrended real government expenditures, for y^{Co} we use linearly-detrended real copper mining production, for R^* we use the LIBOR rate, for y^* we use linearly-detrended real GDP of commercial partners, for π^* we use CPI inflation (in dollars) for commercial partners, and for p^{Co*} we use international copper price deflated by the same price index we used to construct π^*.[14]

The other parameters of the model were estimated using Bayesian techniques, solving the model with a log-linear approximation around the non-stochastic steady state. The list of these parameters and the priors are described in columns one to four of Table 3.[15] The baseline model was estimated using the following variables (all from 2001.Q3 to 2012.Q4): the growth rates of real GDP, private consumption, investment, CPI inflation, the monetary policy rate, the multilateral real exchange rate, the growth rate of real wages, and the EMBI Chile. We also include in the set of observables the variables used to estimate the exogenous processes previously described.[16] Overall, the baseline model is estimated with 14 variables. For future references, we refer to this set of variables as the Macro dataset. Our estimation strategy also includes i.i.d. measurement errors for all the observables. For all the variables except for the real exchange rate, the variance of this measurement errors was set equal to 10% of the varaince of the corresponding observables. For the real exchange rate this variance was estimated. We do this since our model, as we describe below and in line with other estimation exercises with these types of models (e.g. Adolfson *et al.*, 2007), cannot adequatedly match the variance of the real exchange rate.

[12] In the baseline model, we set $\alpha^K = 1$.

[13] This average is computed by consolidating balance sheet data compiled by the SVS (the stock market authority in Chile). On average, this includes the largest 300 firms in the country.

[14] The data source for all Chilean-related data is the Central Bank of Chile, and for the other variables is Bloomberg.

[15] The prior means were set to represent the estimates of related papers for the Chilean economy (e.g. Medina and Soto, 2007).

[16] While the parameters of these exogenous processes were calibrated, including these variables in the data set is informative for the inference of the innovations associated with these exogenous processes.

Table 1: Calibrated Parameters.

Param.	Description	Value	Source
σ	Risk aversion	1	Medina and Soto (2007)
ϕ	Frisch elasticity	1	Adolfson *et al.* (2008)
α	Capital share in production	0.33	Medina and Soto (2007)
δ	Capital depreciation	0.06/4	Medina and Soto (2007)
ϵ_H	E.o.S. domestic aggregate	11	Medina and Soto (2007)
ϵ_F	E.o.S. imported aggregate	11	Medina and Soto (2007)
o	Share of F in Y^C	0.32	Imports over absorption (avg. 1987-2012)
χ	Government share in commodity sector	0.61	Average (1987-2012)
s^{tb}	Trade balance to GDP in SS	4%	Average (1987-2012)
s^g	Gov. exp. to GDP in SS	11%	Average (1987-2012)
s^{Co}	Commodity prod. to GDP in SS	10%	Average (1987-2012)
$\bar{\pi}$	Inflation in SS	3%	Inflation Target in Chile
p^H	Relative price of H in SS	1	Normalization
h	Hours in SS	0.2	Normalization
$\bar{a}$	Long-run growth	2.50%	4.5% GDP - 2% labor force grth. (avg. 01-12)
R	MPR in SS.	5.80%	Fuentes and Gredig (2008)
R^*	Foreign rate in SS	4.50%	Fuentes and Gredig (2008)
ξ	Country premium in SS	140bp	EMBI Chile (avg. 01-12)
lev	Leverage financial sector	9	Own calculation (see text)
$spread$	90 days lending-borrowing spread	380bp	Loan rate vs. MP rate (avg. 01-12)
ι	Injection for new bankers	0.002	Gertler and Karadi (2011)
μ^e	Bankruptcy cost	0.12	Christiano *et al.* (2010)
υ	Survival rate of entrepreneurs	0.97	Bernanke *et al.* (1999)
rp	Entrepreneurs' external finance premium	120bp	Spread A vs. AAA, corp. bonds (avg. 01-12)
lev^e	Entrepreneurs' leverage	2.05	For the non-financial corp. sector (avg. 01-12)
$\rho_{y^{Co}}$	Auto corr. y^{Co}	0.4794	Own estimation
ρ_g	Auto corr. g	0.6973	Own estimation
ρ_{R^*}	Auto corr. R^*	0.9614	Own estimation
ρ_{y^*}	Auto corr. y^*	0.8665	Own estimation
ρ_{π^*}	Auto corr. π^*	0.3643	Own estimation
$\rho_{p^{Co*}}$	Auto corr. p^{Co*}	0.962	Own estimation
$\sigma_{y^{Co}}$	St. dev. shock to y^{Co}	0.0293	Own estimation
σ_g	St. dev. shock to g	0.0145	Own estimation
σ_{R^*}	St. dev. shock to R^*	0.0011	Own estimation
σ_{y^*}	St. dev. shock to y^*	0.0062	Own estimation
σ_{π^*}	St. dev. shock to π^*	0.0273	Own estimation
$\sigma_{p^{Co*}}$	St. dev. shock to p^{Co*}	0.1413	Own estimation

Note: All rates and spreads are annualized figures.

For the models with financial frictions, we estimate each of them with two alternative datasets: the Macro dataset and Macro dataset adding also the spread between the 90-days loans rate and the monetary policy rate,[17] and the growth rate of the real stock of loans.[18]

Finally, for the models with financial frictions we estimated several version that differ in the type of shocks that are being considered. In particular, we detected that for some versions of the model (particularly in the GK-BGG model) there is a strong correlation at the posterior between the parameters describing the evolution of u_t (the marginal efficiency of investment) and the financial shocks (either μ_t or $\sigma_{\omega,t}$, or both).[19] The fact that the shock to u_t generate similar dynamics as a financial shock was expected. For instance, Justiniano *et al.* (2011), after finding that the shock to the marginal efficiency of investment is the most important driver for US business cycles, document that this exogenous process is highly correlated with several financial variables. Therefore, the variable u_t is likely to capture financial shocks in a reduced-form way. Consequently, we estimate several versions of each model that include different combinations of the shocks u_t, μ_t and $\sigma_{\omega,t}$.

4 Goodness of Fit

We begin by computing the marginal likelihoods for each of the alternative models. Table 2 displays the log marginal likelihoods for the dataset used for estimation in each case, that differ between the type of model (Baseline, GK or GK-BGG),the shocks included $(u_t, \mu_t, \sigma_{\omega,t})$ and the dataset used for estimation (only Macro data or the Macro plus financial variables).[20] Focusing first on the results when only macro data is used, there are no significant difference in terms of this overall measure of goodness of fit, in particular in the GK model. In the GK-BGG model, including financial shocks seems to slightly worsen the fit of the model.

Turning to the results when financial variables are considered for estimation, in the GK framework we can see that the preferred version is the one that includes both the u_t and μ_t driving forces. For the GK-BGG model, considering financial shocks appears to be relevant as well, particularly the shock $\sigma_{\omega,t}$. Moreover, the variant that does not include the shock to the marginal efficiency of investment (u_t) seems to be dominated by the alternatives that include this shock and some financial shock. Finally, between the GK and the GK-BGG frameworks, the marginal likelihood criterion clearly favors the latter model.

To complement the previous analysis, we have also computed the marginal likelihood for each alternative but, instead of calculating it with the data used for the estimation we have done it with the macro data only, as reported in the last column of Table 2. This exercise is useful for it allows to see if the relative ranking of the different parameterizations is the same in terms of matching the macro data only. As we can see, the GK-BGG framework that includes both the shocks to u_t and some financial shock is preferred along this dimension.

We next turn to analyze the estimated parameters in those versions that were highlighted by the marginal-likelihood comparison. These results are presented in columns five to eight in Table 3. For most parameters the posterior mode is similar across different models. One of the main differences appears in the parameter governing investment adjustment costs (γ). In the baseline model, its posterior mode is close to 2, in the GK and in the GK-BGG models without a shock to u_t the estimated values is quite small, and in the GK-BGG model when the shock to u_t is included it is a large number of around 10. This pattern appears in other versions of the model

[17]For the model with GK banks, this spread is computed as $E_t\{r^L_{t+1}\} - r_t$, while in the model that adds BGG entrepreneurs this is $r^{Le}_t - r_t$.

[18]For financial variables we also included i.i.d. measurement errors, calibrating their variance to account for 10% of the variance of the observable.

[19]This identification analysis was carried using the approach proposed by Iskrev (2010).

[20]Of course, marginal likelihoods are not comparable with different datasets.

Table 2: Marginal Likelihood for Macroeconomic Data.

Model	Included Shocks	Estimation Dataset	$\log(MgL)$ Estim. Data	Macro Data
Baseline	u_t	Macro	-952.1	
GK	u_t	Macro	-952.0	
GK	μ_t	Macro	952.1	
GK	u, μ_t	Macro	-952.0	
GK-BGG	u_t	Macro	-952.5	
GK-BGG	$\mu_t, \sigma_{\omega,t}$	Macro	-956.7	
GK-BGG	$u_t, \mu_t, \sigma_{\omega,t}$	Macro	-953.2	
GK	u_t	Macro+Spread+Lending	-1330.6	-1022.3
GK	μ_t	Macro+Spread+Lending	-1302.9	-1043.9
GK	u, μ_t	Macro+Spread+Lending	-1160.2	-1004.5
GK-BGG	u_t	Macro+Spread+Lending	-1330.6	-1025.7
GK-BGG	$\mu_t, \sigma_{\omega,t}$	Macro+Spread+Lending	-1158.2	-1009.3
GK-BGG	$u_t, \mu_t, \sigma_{\omega,t}$	Macro+Spread+Lending	-1147.6	-998.2
GK-BGG	$u_t, \mu_t,$	Macro+Spread+Lending	-1156.1	-996.0
GK-BGG	$u_t, \sigma_{\omega,t}$	Macro+Spread+Lending	-1146.3	-997.8

Note: The marginal likelihood was computed using the Laplace approximation at the posterior mode.

that we have estimated (although not reported to save space): if the shock u_t is active in the GK-BGG models γ is inferred to be large (more than 7), and in the other alternatives (either GK or GK-BGG without the shock to u_t) this parameters is smaller than in the baseline case. We have also tried adding one financial series at a time to the macro dataset, finding that these differences arise due to the inclusion of the loans growth rate as an observable (when only the spread is added, parameter estimates are more similar to the baseline case). As we will see in the next section, this difference in the assigned value for γ accounts for most of the differences in the dynamics explained by the different models.

We can also observe that the differences in the estimated value for γ are compensated in the estimation process by changes in the values of the parameters describing the exogenous process u_t, μ_t and $\sigma_{\omega,t}$. In particular, in the GK-BGG model when u_t is excluded, the model requires large disturbances to both μ_t and $\sigma_{\omega,t}$ (despite the lower value of γ) to fit the data. In contrast, when u_t is also considered these two financial shocks are inferred to be much less volatile while the variance of the disturbance to u_t is larger than in other versions of the model, but with a smaller autocorrelation. In turn, the model requires a large value for γ to smooth these large disturbances.

As we already mentioned, it is reasonable to reconsider the role of u_t when financial frictions and shocks are included. A similar argument can be made with the parameter γ. In fact, in one of the earliest contributions to the financial accelerator literature, Carlstrom and Fuerst (1997) present a financial accelerator similar to BGG as an alternative to capital adjustment costs in order to account for the hump-shaped dynamics of investment. From that perspective, one might expect the presence of financial frictions to diminish the need for capital adjustment costs to fit the data (i.e. a lower value for γ, as in our cases GK and GK-BGG without u_t). However, it is also true that when both capital adjustment costs and financial frictions are considered, one can also expect a an interaction between both channels: as financial frictions should, keeping all other parameters constant, amplify the effect of most of the shocks hitting the economy the estimation of the parameters requires to change the value

Table 3: Estimated Parameters, Prior and Posterior Mode.

		Prior			Posterior Mode		
					GK	GK-BGG	GK-BGG
Param.	Description	Dist.	Mean	Base	u_t, μ_t	$\mu_t, \sigma_{\omega,t}$	$u_t, \mu_t, \sigma_{\omega,t}$
ς	Habits	beta	0.7	0.73	0.72	0.75	0.72
ψ	Country premium elast.	invg	0.01	0.010	0.008	0.008	0.009
η	E.o.S. H and F	invg	1.5	1.40	1.16	1.34	1.59
η^*	Demand elasticity for exports	invg	0.5	0.33	0.26	0.29	0.24
γ	Inv. adj. cost	norm	4	1.98	0.29	0.55	10.05
θ_W	Calvo prob. wages	beta	0.75	0.95	0.96	0.96	0.95
ϑ_W	Indexation past infl. wages	beta	0.5	0.37	0.33	0.36	0.40
θ_H	Calvo prob. H	beta	0.75	0.48	0.74	0.49	0.52
ϑ_H	Indexation past infl. H	beta	0.5	0.42	0.20	0.41	0.54
θ_F	Calvo prob. F	beta	0.75	0.79	0.82	0.81	0.82
ϑ_F	Indexation past infl. F	beta	0.5	0.40	0.33	0.41	0.45
ρ_R	MPR rule R_{t-1}	beta	0.75	0.83	0.76	0.84	0.82
α_π	MPR rule π_t	norm	1.5	1.54	1.54	1.64	1.59
α_y	MPR rule growth	norm	0.13	0.12	0.13	0.10	0.14
ρ_v	AC pref. shock	beta	0.75	0.76	0.75	0.80	0.80
ρ_u	AC inv. shock	beta	0.75	0.74	0.99		0.17
ρ_z	AC temporary TFP shock	beta	0.75	0.74	0.63	0.74	0.78
ρ_a	AC permanent TFP shock	beta	0.38	0.36	0.40	0.35	0.34
ρ_ζ	AC country premium shock	beta	0.75	0.91	0.94	0.94	0.92
ρ_μ	AC μ_t	beta	0.75		0.54	0.84	0.81
ρ_{σ_ω}	AC $\sigma_{\omega,t}$	beta	0.75			0.29	0.80
σ_v	Std. pref. shock	invg	0.01	0.024	0.023	0.026	0.024
σ_u	Std. inv. shock	invg	0.01	0.029	0.014		0.305
σ_z	Std. temporary TFP shock	invg	0.01	0.010	0.030	0.010	0.011
σ_a	Std. permanent TFP shock	invg	0.01	0.003	0.003	0.003	0.004
σ_ζ	Std. country premium shock	invg	0.003	0.001	0.001	0.001	0.001
σ_R	Std. MPR shock	invg	0.003	0.002	0.002	0.002	0.002
σ_μ	Std. μ_t	invg	0.01		0.026	0.087	0.004
σ_{σ_ω}	Std. $\sigma_{\omega,t}$	invg	0.01			1.237	0.073
$\sigma_{me_{RER}}$	Std. M.E. RER	norm	2.7	3.48	3.51	3.59	3.73

Note: The posterior for the models with financial frictions in this table were obtained with the dataset that includes both macro and financial variables.

Table 4: Selected Second Moments.

Variable	Data	Base	GK u_t, μ_t	GK-BGG $\mu_t, \sigma_{\omega,t}$	GK-BGG $u_t, \mu_t, \sigma_{\omega,t}$
			A. Std. Dev.		
GDP growth	1.02	0.91	1.59	1.35	0.82
Cons. growth	1.10	0.92	1.07	1.01	1.05
Inv. growth	3.75	3.91	9.17	9.70	3.26
Inflation	0.74	0.58	0.63	0.64	0.63
MPR	0.46	0.48	0.66	0.61	0.62
RER	5.41	9.13	12.20	10.11	9.99
TB/Y	5.32	3.64	3.80	3.72	3.65
Real wage growth	0.62	0.55	0.58	0.57	0.59
Spread	0.26		2.00	2.57	0.44
Lend. growth	1.41		3.85	2.48	1.45
			B. AC(1)		
GDP growth	0.25	0.31	0.24	0.29	0.19
Cons. growth	0.63	0.59	0.62	0.66	0.63
Inv. growth	0.40	0.65	0.24	0.37	0.21
Inflation	0.63	0.66	0.70	0.70	0.73
MPR	0.88	0.92	0.93	0.94	0.94
RER	0.73	0.91	0.94	0.93	0.92
TB/Y	0.73	0.91	0.90	0.91	0.91
Real wage growth	0.40	0.43	0.45	0.44	0.45
Spread	0.68		0.41	0.54	0.78
Lending growth	0.56		-0.25	0.00	0.29

Note: These are unconditional moments computed at the posterior mode. The posterior for the models with financial frictions in this table were obtained with the dataset that includes both macro and financial variables.

of some other parameter to match the same dataset. In that sense, it is reasonable that the model that best fits the data requires a large value for γ, particularly in the presence of shocks to u_t.

Finally, we asses the goodness of fit of the different models in accounting for the volatility and autocorrelation of the domestic variables included as observables. This comparison is displayed in Table 4. In terms of the baseline, the model implies a volatility of GDP growth similar to that of consumption growth, while in the data the latter is more volatile. The volatility of investment growth is somehow larger in the model and it also falls short in explaining the variance of inflation and of the trade-balance-to-output ratio, while implying a larger variance for the real exchange rate. And in terms of autocorrelations, the model seems to imply much more persistent processes for all the observables.

When we add banks *à la* Gertler and Karadi (2011), the results in terms of matching these moments seem to worsen. For instance, the GK model generates a variance of GDP growth that is more than 15% percent larger than that of consumption growth, and the volatility of most of the other variables is overstated as well, particularly for financial variables. The fit is not better either in terms of persistence. For instance, the model predicts that lending growth has a negative autocorrelation, which is not in line with the data. A similar pattern arises in the GK-BGG model when the shock to u_t is not considered.

The GK-BGG model that includes u_t seems to match these statistics much more satisfactorily than the GK model, even improving in some dimension relative to the baseline. In particular, the model does feature consumption growth being more volatile than output growth, although the level is somehow underestimated. The ability to match moments related with financial variables is better than with the other models, although it implies a more volatile and persistent spread than in the data.

5 Variance Decomposition and Impulse Responses

We now discuss variance decompositions and impulse response dynamics obtained with the different variants of the model. As in the previous section, we compare the baseline model with the GK model and two versions of the GK-BGG model (one with shocks to μ_t and $\sigma_{\omega,t}$, and the other one with shocks to μ_t, $\sigma_{\omega,t}$ and the marginal efficiency of investment, u_t). Table 5 summarizes the variance decomposition of selected variables, reporting the contributions to the unconditional variances of the data (computed using the posterior mode of the estimated parameters) due to preference shocks (Pref.), marginal efficiency of investment shocks (Inv.), temporary and permanent TFP shocks (TFP x2), monetary policy rate shocks (MPR), foreign interest rate shocks (Fore. Rate), commodity price shocks (P. Co.), and shocks to μ_t and $\sigma_{\omega,t}$. The sum of those shocks explains at least 70% of the unconditional variances of each variable.

In the baseline model, the majority of the variances of the growth rates of GDP and investment, as well as inflation, real wage growth and the monetary policy rate, is due to TFP shocks and/or marginal efficiency of investment shocks (see Panel A of Table 5). The importance of those shocks is somewhat lower in the GK model, where shocks to μ_t explain between 20 and 30 percent of the variances of GDP growth and investment growth and also a significant fraction of the variances of lending growth and the lending spread (see Panel B). The importance of monetary policy rate shocks for GDP growth and investment growth also increases in the GK model relative to the baseline. This result seems to be a consequence of the amplification of those shocks through the financial accelerator mechanism in the GK model (see the impulse responses below).

In the GK-BGG model, the results differ according to whether the marginal efficiency of investment shock (u_t) is included in the estimation or not. When this shock is not included in the estimation, then the majority of the variances of GDP growth and investment growth is explained by the two shocks originating in the financial sector, μ_t and $\sigma_{\omega,t}$ (see panel C). However, when we do include the shock u_t, then the contribution of the shocks to μ_t and $\sigma_{\omega,t}$ is almost nil for GDP, investment and lending. The only significant role for those shocks is to explain variations in the spread in this variant, whereas shocks to u_t explain the majority of the variations in lending growth while their role for GDP and investment growth even increases relative to the baseline case. In addition, TFP shocks explain a larger fraction of inflation, monetary policy rate and real wage growth in the variant of the GK-BGG model with the shock u_t.

Overall, the variance decompositions seem to confirm our intuition that the shock to the marginal efficiency of investment plays a similar role as financial shocks (to μ_t and $\sigma_{\omega,t}$), as the former is likely to capture financial shocks in a reduced-form way. When we abstract from the marginal efficiency of investment shock, then financial shocks take a significant role in explaining the fluctuations of both macroeconomic and financial variables especially in the GK-BGG model, while the real effects of some other shocks also seem to be amplified by the different financial accelerator mechanisms of Bernanke *et al.* (1999) and Gertler and Karadi (2011). This amplification is discussed next in terms of the impulse response dynamics generated by selected shocks.

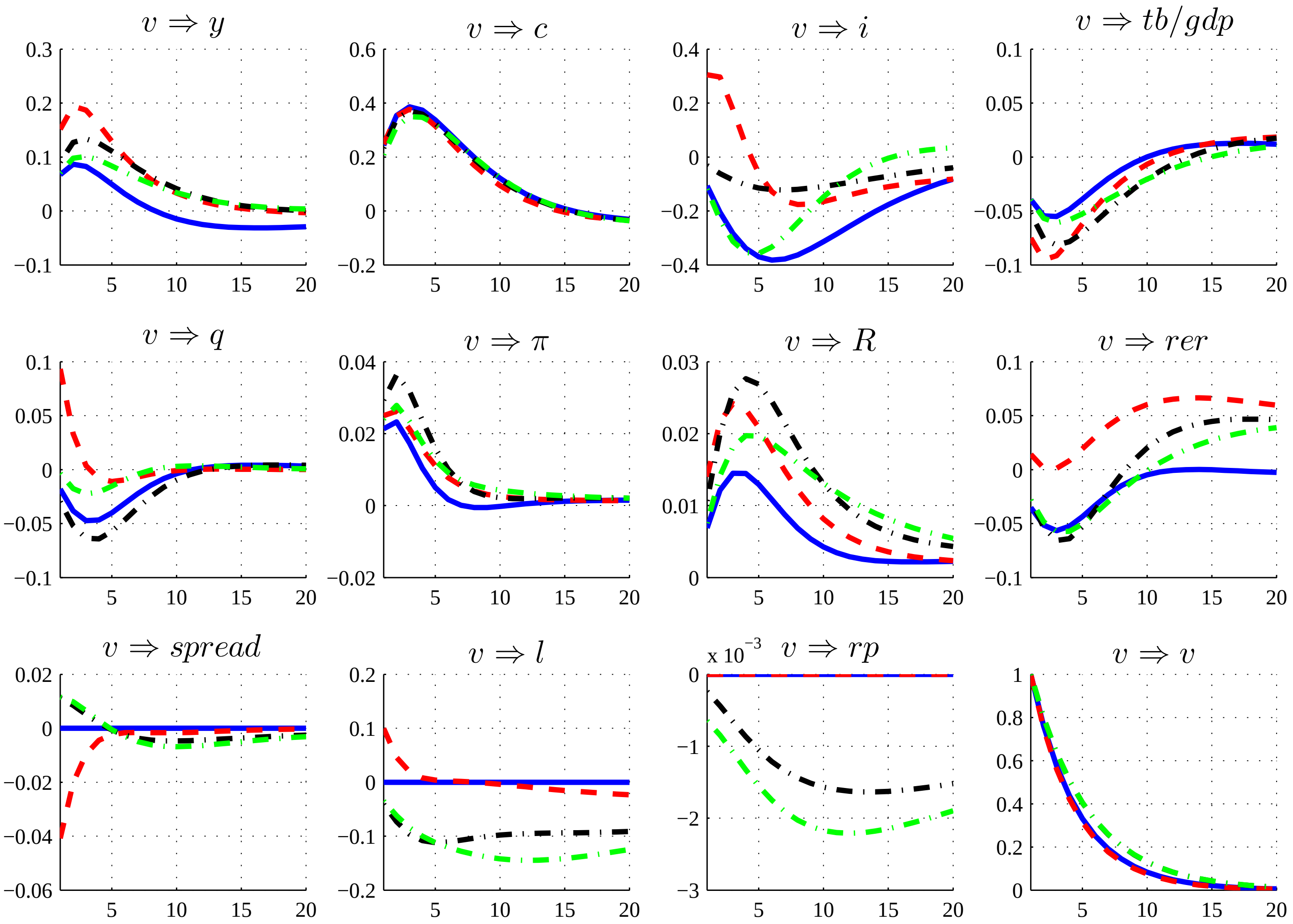
We first summarize the impulse responses to the standard macro shocks. Figures 1-6 show the responses of

Table 5: Variance Decomposition of Selected Variables.

Variable	Shock								
	Pref.	Inv.	TFP (x2)	MPR	Fore. Rate	P. Co.	μ_t	$\sigma_{\omega,t}$	Sum
A. Baseline									
GDP Growth	4	28	28	6	3	3			73
Cons. Growth	58	2	5	1	5	21			92
Inv. Growth	1	60	8	3	11	10			92
Inflation	3	19	46	11	6	8			93
MPR	3	24	14	11	12	25			89
RER	0	7	3	3	17	46			75
TB/Y	1	6	1	1	17	49			75
Real Wage Growth	0	7	67	3	5	11			93
B. GK, u_t, μ_t									
GDP Growth	6	24	10	26	1	2	21		91
Cons. Growth	40	2	6	0	10	31	0		88
Inv. Growth	1	33	5	28	2	2	29		99
Inflation	3	4	53	7	11	12	1		92
MPR	4	9	23	5	19	26	1		86
RER	0	11	3	5	14	47	0		79
TB/Y	2	3	1	5	12	54	1		78
Real Wage Growth	1	1	73	3	5	11	0		94
Lend. Growth	0	54	3	12	0	0	30		100
Spread	0	33	3	8	0	0	56		100
C. GK-BGG, μ_t, $\sigma_{\omega,t}$									
GDP Growth	2		17	10	2	3	17	37	88
Cons. Growth	45		4	1	10	27	0	1	89
Inv. Growth	0		6	7	3	3	25	54	97
Inflation	4		34	15	9	9	5	17	93
MPR	7		10	8	21	27	4	9	85
RER	1		2	6	14	49	0	5	77
TB/Y	1		1	3	14	51	2	7	78
Real Wage Growth	1		60	7	4	8	4	12	95
Lend. Growth	0		4	2	1	2	33	58	99
Spread	0		0	0	0	0	45	54	100
D. GK-BGG, u_t, μ_t, $\sigma_{\omega,t}$									
GDP Growth	10	29	28	3	1	1	0	0	71
Cons. Growth	43	2	7	1	11	25	0	0	89
Inv. Growth	0	86	2	1	3	4	0	1	98
Inflation	6	3	55	6	12	10	0	0	92
MPR	8	5	20	9	21	23	0	0	87
RER	1	3	4	2	18	49	0	0	76
TB/Y	2	2	1	0	13	60	0	0	78
Real Wage Growth	1	1	78	1	5	8	0	0	95
Lend. Growth	1	73	15	4	2	2	0	1	98
Spread	2	36	2	5	3	5	4	41	98

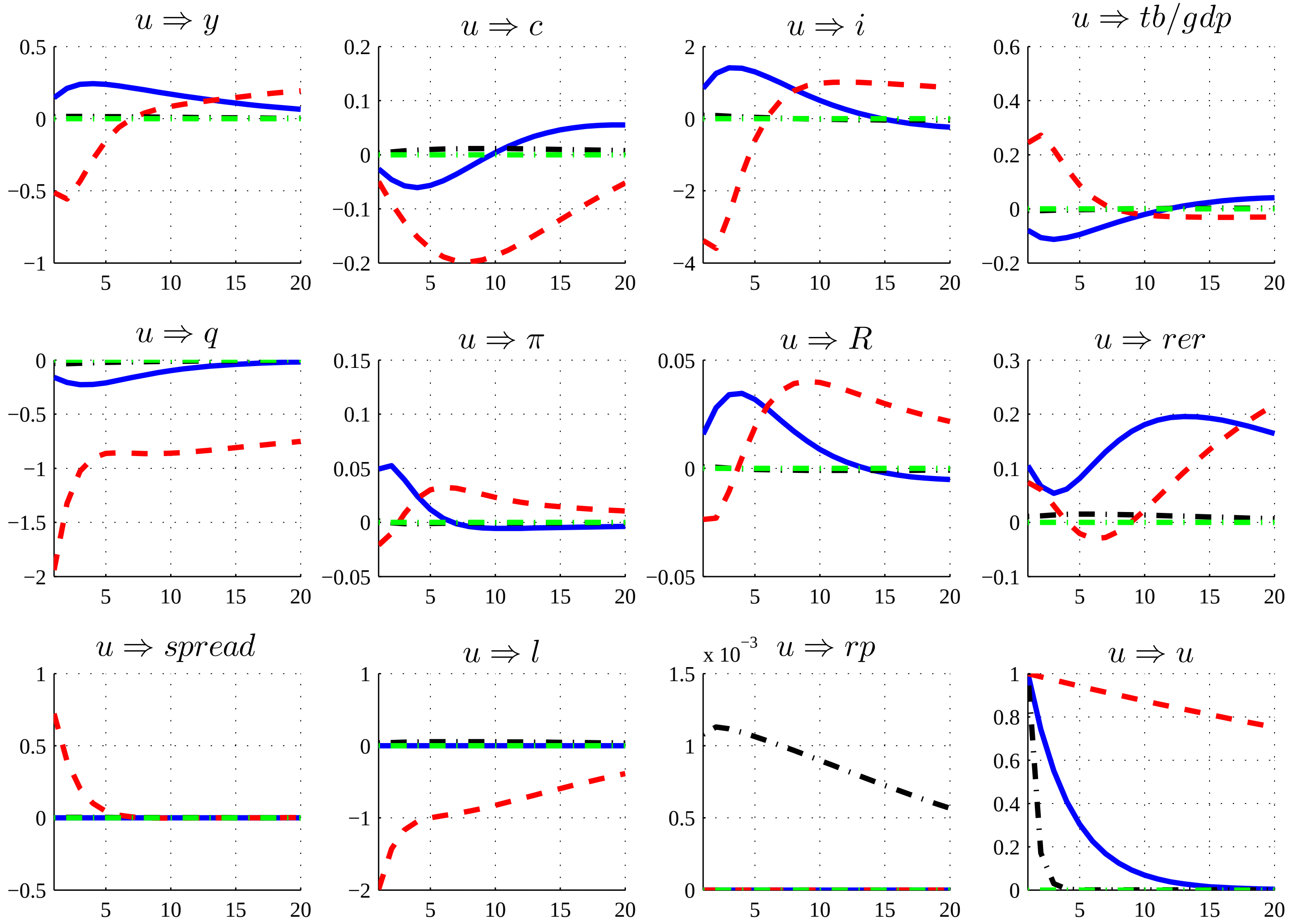
Note: These are the contributions to the unconditional variances of the observed endogenous variables computed at the posterior mode. The posterior for the models with financial frictions in this table were obtained with the dataset that includes both macro and financial variables.

Figure 1: Impulse Responses to a Preference Shock.



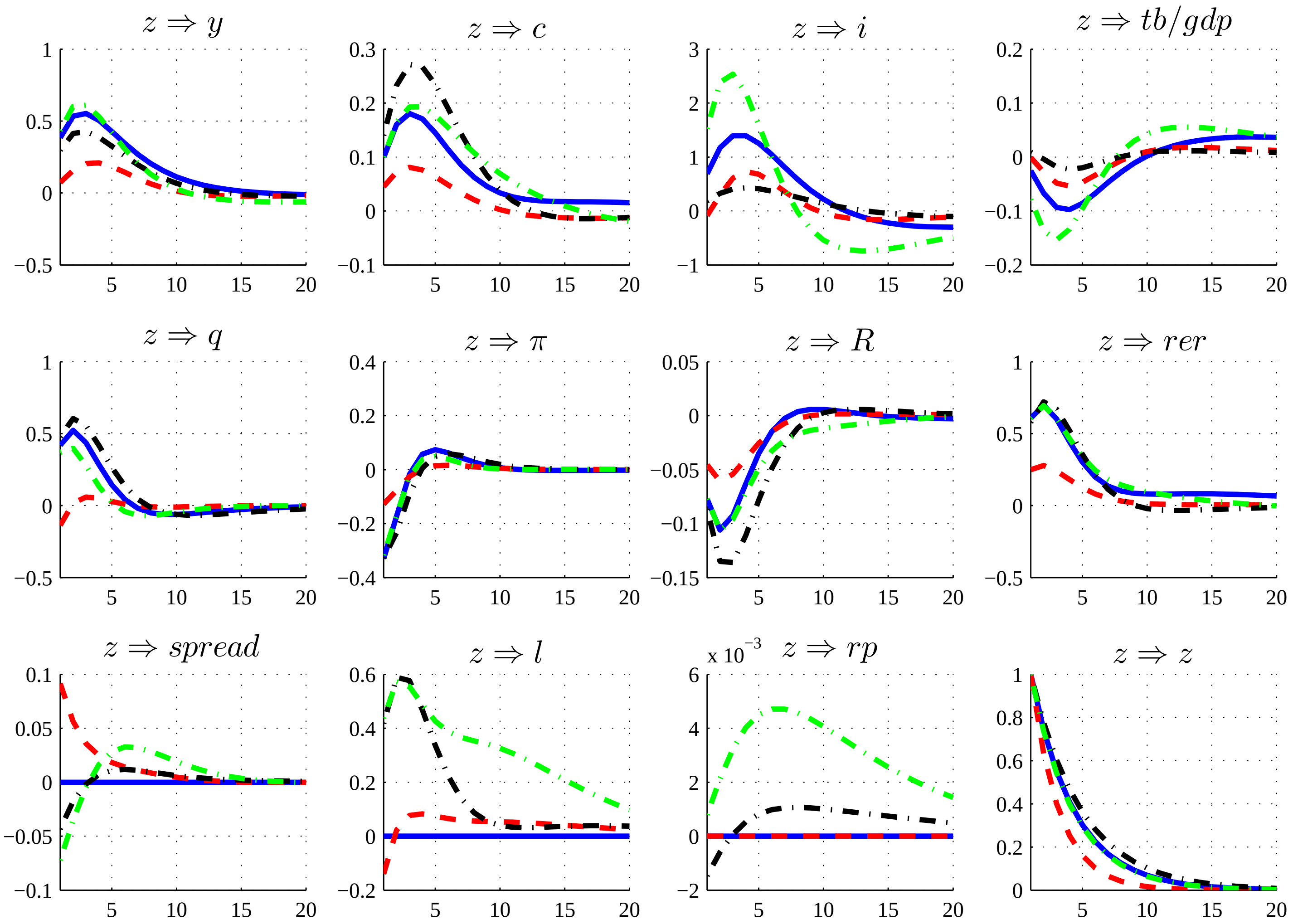
Note: The blue solid line is the baseline model, the dashed red line corresponds to the GK model, the dash-dotted green line is from the GK-BGG model with shocks to μ_t and $\sigma_{\omega,t}$, and the dash-dotted black line is the GK-BGG model with shocks to u_t, μ_t and $\sigma_{\omega,t}$.

Figure 2: Impulse Responses to a Marginal Efficiency of Investment Shock.



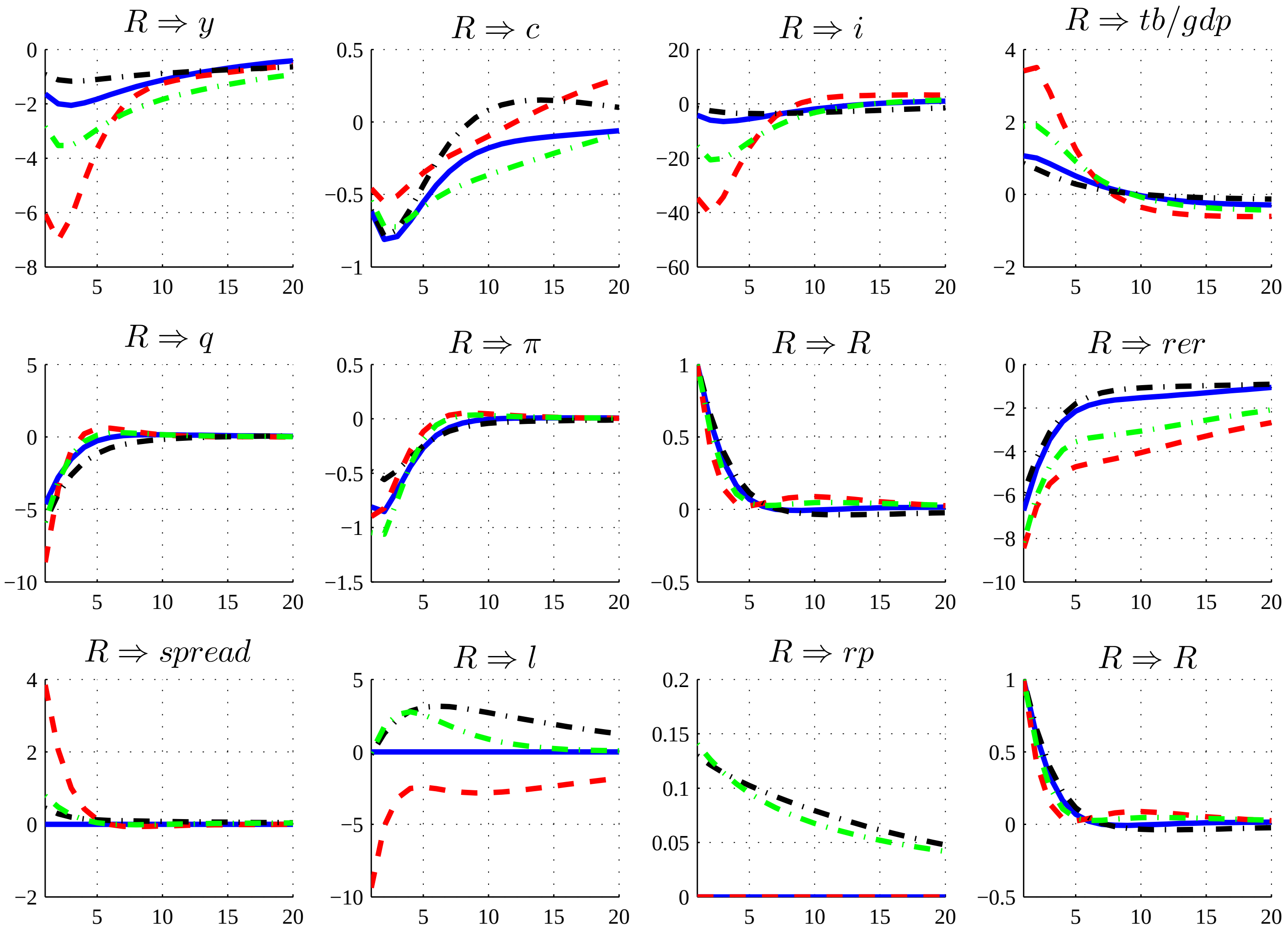
Note: The blue solid line is the baseline model, the dashed red line corresponds to the GK model, the dash-dotted green line is from the GK-BGG model with shocks to μ_t and $\sigma_{\omega,t}$, and the dash-dotted black line is the GK-BGG model with shocks to u_t, μ_t and $\sigma_{\omega,t}$.

Figure 3: Impulse Responses to a Temporary TFP Shock.



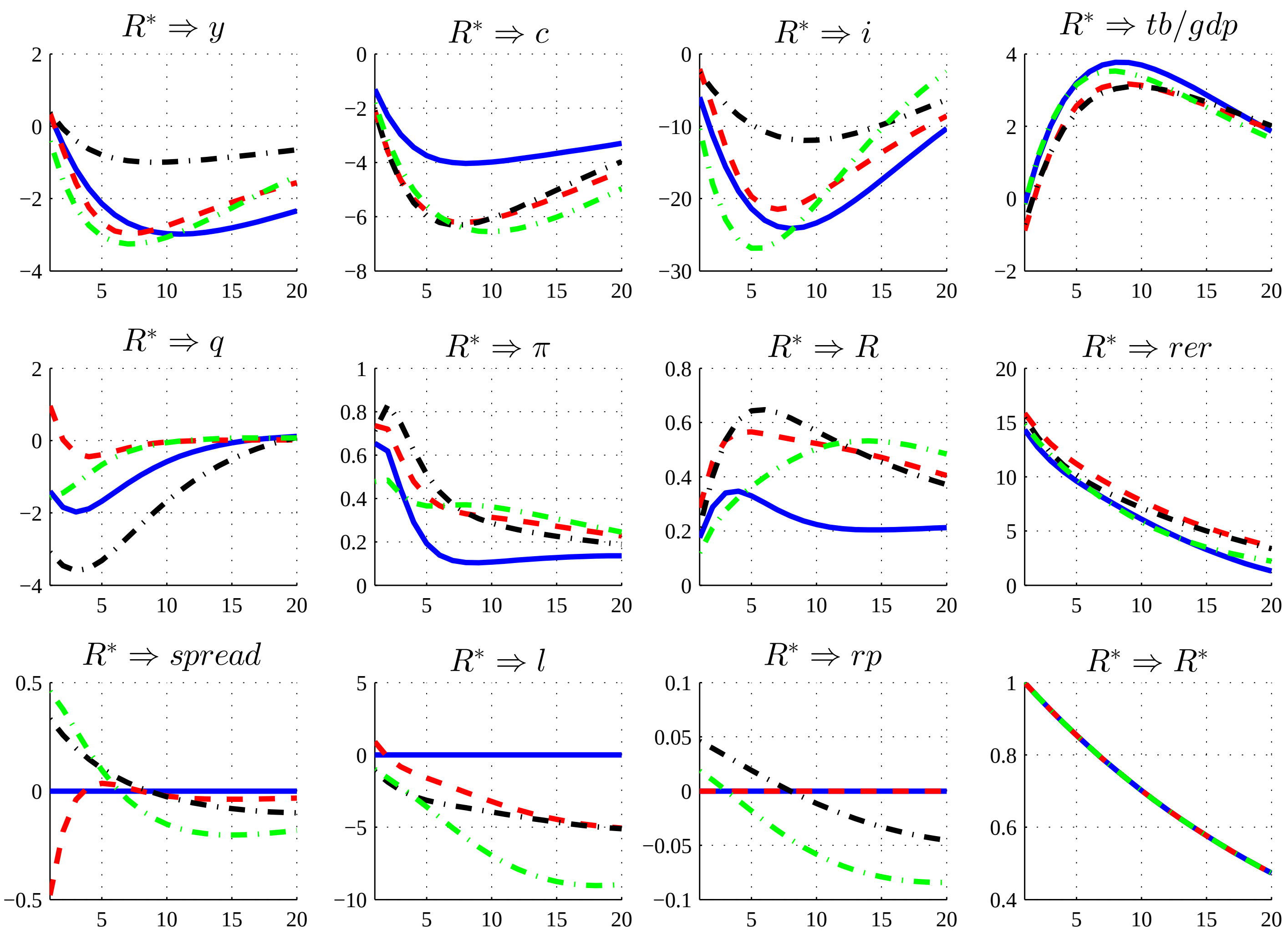
Note: The blue solid line is the baseline model, the dashed red line corresponds to the GK model, the dash-dotted green line is from the GK-BGG model with shocks to μ_t and $\sigma_{\omega,t}$, and the dash-dotted black line is the GK-BGG model with shocks to u_t, μ_t and $\sigma_{\omega,t}$.

Figure 4: Impulse Responses to a Monetary Policy Rate Shock.



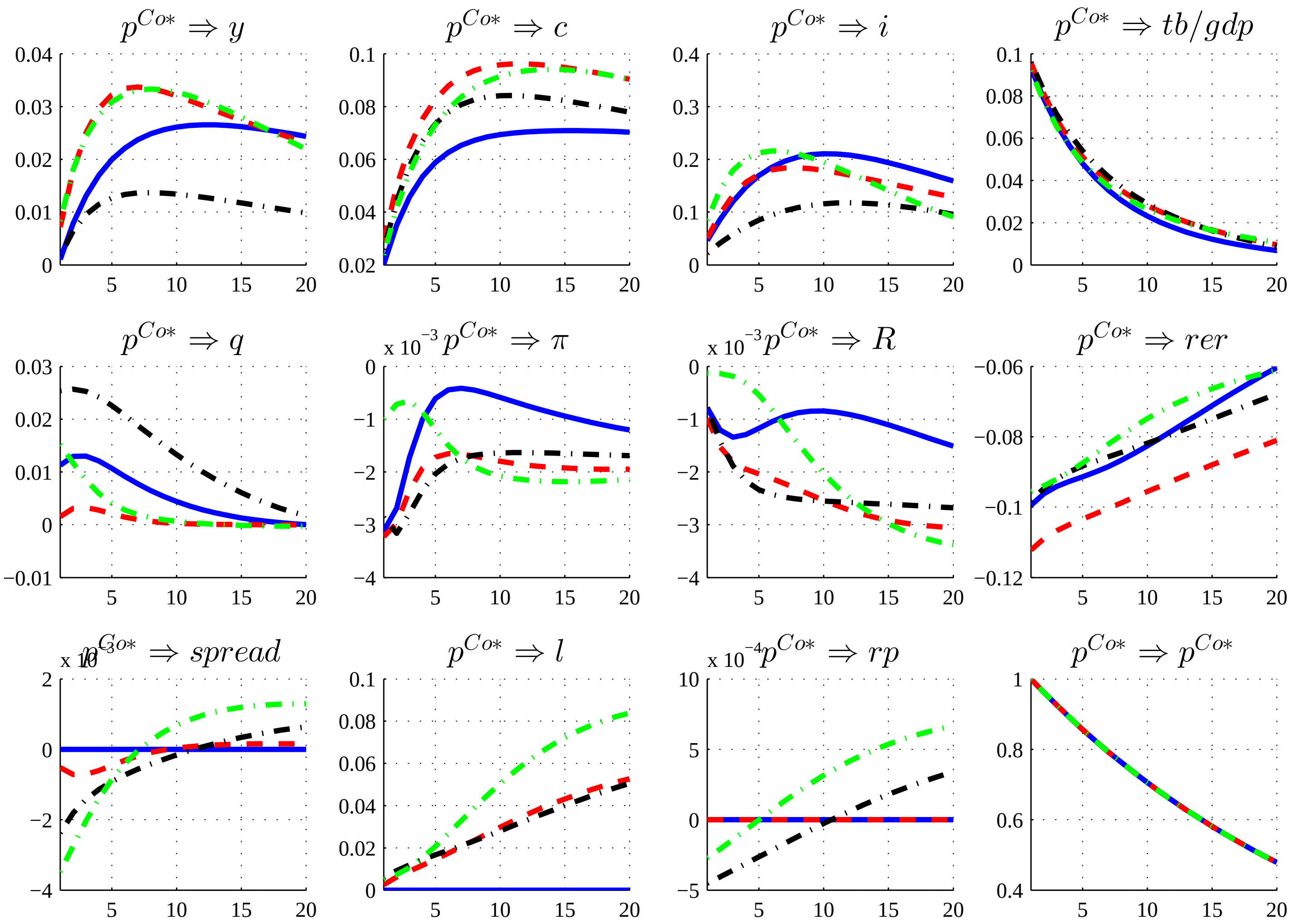
Note: The blue solid line is the baseline model, the dashed red line corresponds to the GK model, the dash-dotted green line is from the GK-BGG model with shocks to μ_t and $\sigma_{\omega,t}$, and the dash-dotted black line is the GK-BGG model with shocks to u_t, μ_t and $\sigma_{\omega,t}$.

Figure 5: Impulse Responses to a Foreign Interest Rate Shock.



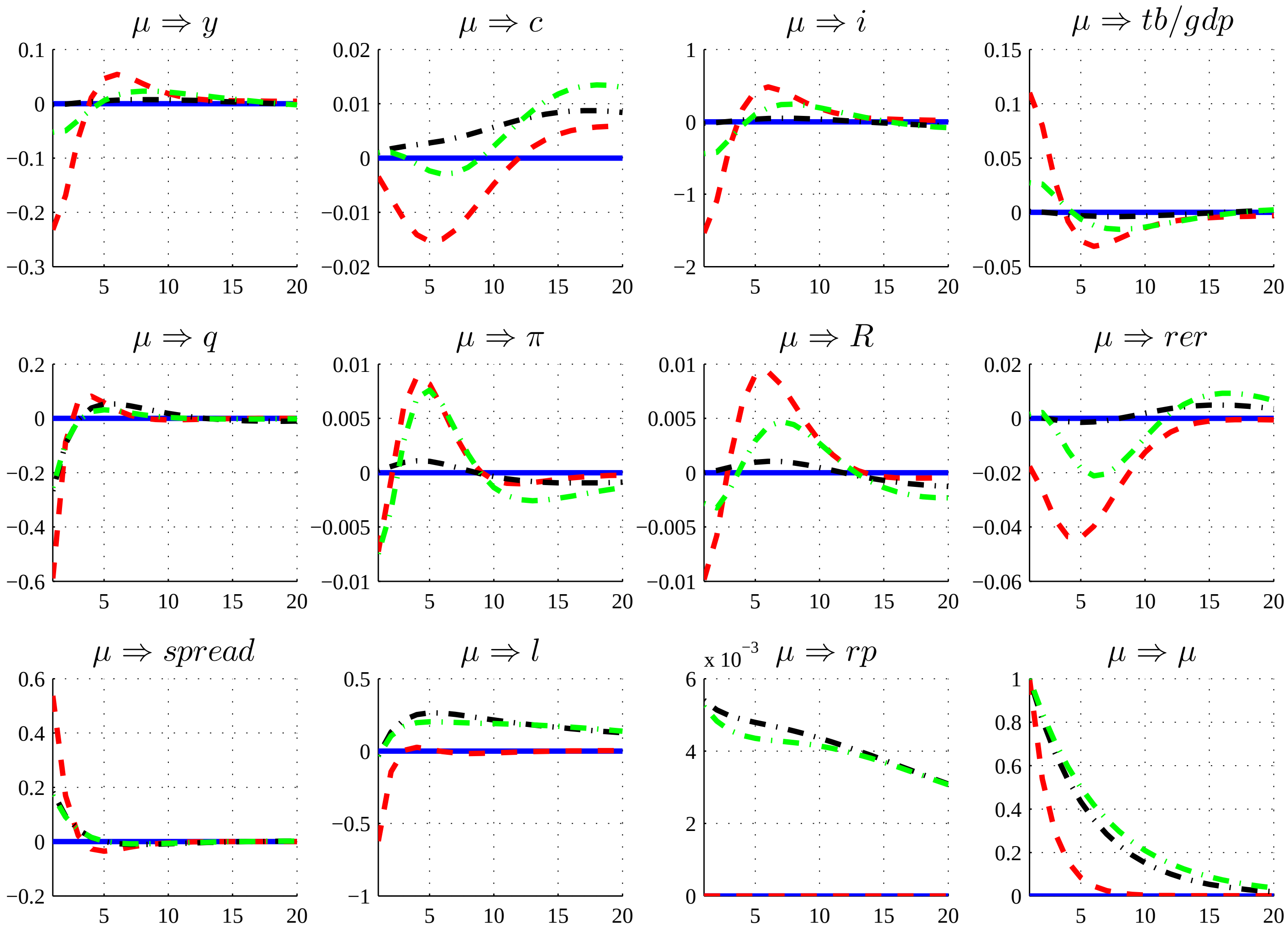
Note: The blue solid line is the baseline model, the dashed red line corresponds to the GK model, the dash-dotted green line is from the GK-BGG model with shocks to μ_t and $\sigma_{\omega,t}$, and the dash-dotted black line is the GK-BGG model with shocks to u_t, μ_t and $\sigma_{\omega,t}$.

Figure 6: Impulse Responses to a Commodity Price Shock.



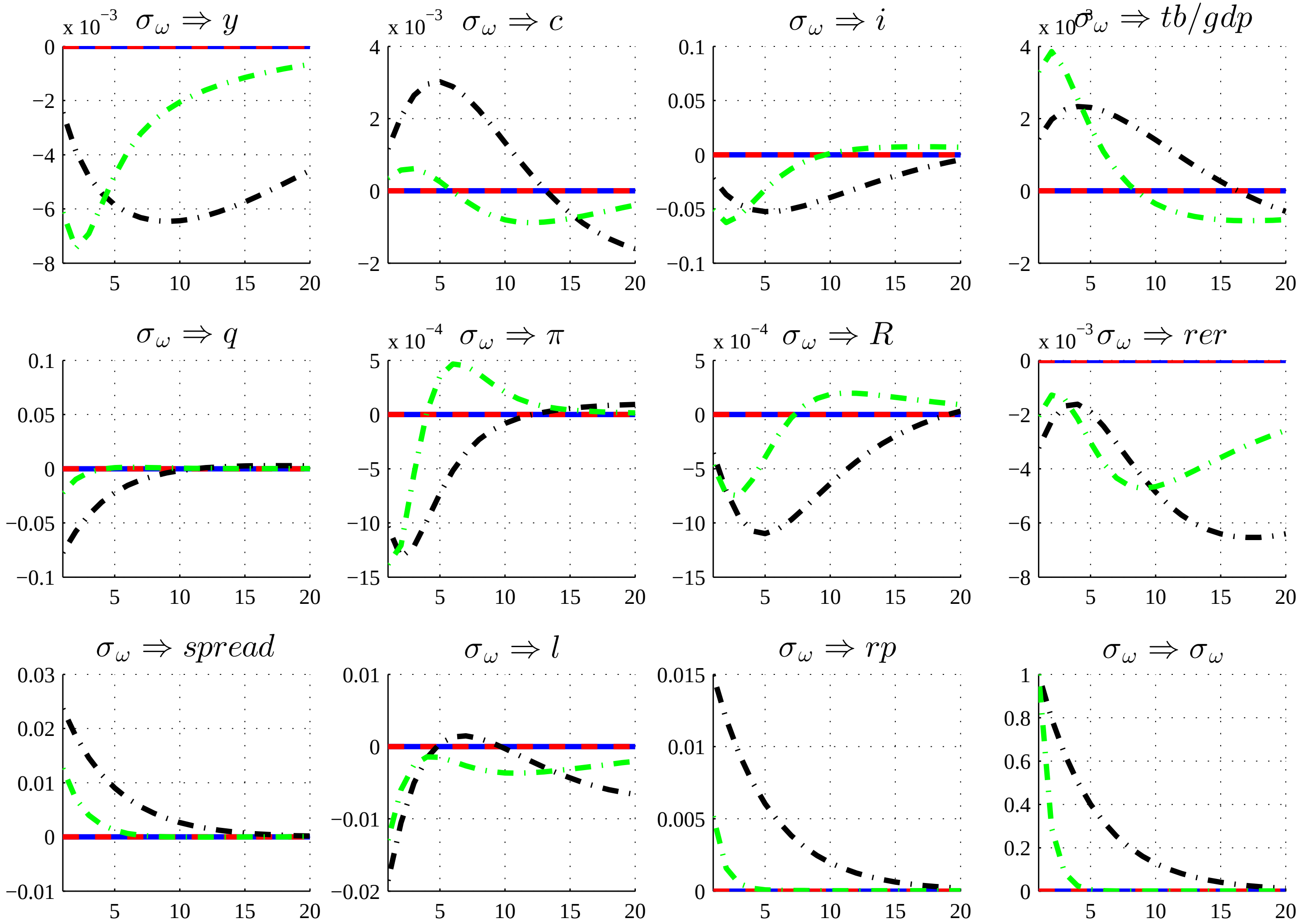
Note: The blue solid line is the baseline model, the dashed red line corresponds to the GK model, the dash-dotted green line is from the GK-BGG model with shocks to μ_t and $\sigma_{\omega,t}$, and the dash-dotted black line is the GK-BGG model with shocks to u_t, μ_t and $\sigma_{\omega,t}$.

Figure 7: Impulse Responses to a Shock to μ_t.



Note: The blue solid line is the baseline model, the dashed red line corresponds to the GK model, the dash-dotted green line is from the GK-BGG model with shocks to μ_t and $\sigma_{\omega,t}$, and the dash-dotted black line is the GK-BGG model with shocks to u_t, μ_t and $\sigma_{\omega,t}$.

Figure 8: Impulse Responses to a Shock to $\sigma_{\omega,t}$.



Note: The blue solid line is the baseline model, the dashed red line corresponds to the GK model, the dash-dotted green line is from the GK-BGG model with shocks to μ_t and $\sigma_{\omega,t}$, and the dash-dotted black line is the GK-BGG model with shocks to u_t, μ_t and $\sigma_{\omega,t}$.

selected variables (i.e. real GDP, private consumption, investment, the trade-balance-to-output ratio, the relative price of capital, inflation, the domestic monetary policy rate, the real exchange rate, the lending spread, loans, and the external finance premium) to shocks to preferences, the marginal efficiency of investments, temporary TFP, the monetary policy rate, the foreign interest rate, and the commodity price, respectively.

Figure 4, corresponding to domestic monetary policy rate shocks, shows the amplification role of financial frictions following Bernanke *et al.* (1999) and Gertler and Karadi (2011) most clearly. In the baseline model, the interest rate shock leads to a fall in investment, consumption and GDP, while inflation decreases and the real exchange appreciates. In the GK model, the shock increases the costs of borrowed funds for the banks, decreases net worth, tightens leverage, and therefore raises the lending spread. In addition, the initial fall of investment leads to a fall in the price of capital, which further tightens the banks' balance sheet constraints. This effect amplifies the fall of investment, such that the price of capital falls even more, and so on. Those effects are similar (although somewhat smaller) in the GK-BGG model when the marginal efficiency of investment shock is not included in the estimation, while the effects are smaller when this shock is included due to the associated differences in critical parameters such as the larger parameter governing investment adjustment costs generating a more sluggish investment response. In that model, changes in investment and the price of capital affect entrepreneurial net worth and the external finance premium (rp_t).

The amplification effects that are present in the case of domestic monetary policy rate shocks and some other shocks (typically for the GK model and the version of the GK-BGG model without the shock u_t) do not seem to play an important role in the cases of different shocks such as the temporary TFP shock and the marginal efficiency of investment shock (see Figures 2 and 3). In those cases, the expansionary effects of the shocks tend to be dampened by an offsetting response of the price of capital; for instance, as we can see from the baseline model a positive shock to the marginal efficiency of investment lowers the price of capital given higher supply of capital/investment goods. However, this fall in the price of capital raises the spreads and puts a drain on investment in the GK and GK-BGG models. Hence, not all shocks are necessarily amplified relative to the baseline case through the introduction of GK-type and BGG-type financial frictions.

Turning to the effects of the financial-sector-specific shocks (to μ_t and $\sigma_{\omega,t}$), the corresponding impulse responses are shown in Figures 7 and 8. A shock to μ_t directly affects the financial friction on the banks' side in the GK and GK-BGG models. It tightens bank leverage constraints, which leads to a rise in the bank lending spread and a fall in investment and GDP. A shock to σ_{ω_t} raises the external finance premium for entrepreneurs, with negative effects on investment and output. Note that the estimated effects differ across the three models with financial frictions not only due to differences in key parameters (in particular, the parameter governing investment adjustment costs), but also the estimated persistence of the shocks.

6 Conclusions and Next Steps

To be written...

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A Baseline Model

A.1 Equilibrium Conditions

The variables in uppercase that are not prices contain a unit root in equilibrium due to the presence of the non-stationary productivity shock A_t. We need to to transform these variables to have a stationary version of the model. To do this, with the exceptions we enumerate below, lowercase variables denote the uppercase variable divided by A_{t-1} (e.g. $c_t \equiv \frac{C_t}{A_{t-1}}$). The only exception is the Lagrange multiplier Λ_t that is multiplied by A_{t-1} (i.e. $\lambda_t \equiv \Lambda_t A_{t-1}$), for it decreases along the balanced growth path.

The rational expectations equilibrium of the stationary version of the model model is the set of sequences

$$\{\lambda_t, c_t, h_t, h_t^d, w_t, \tilde{w}_t, mc_t^W, f_t^W, \Delta_t^W, i_t, k_t, r_t^K, q_t, y_t, y_t^C, y_t^F, y_t^H, x_t^F, x_t^H, x_t^{H*}, R_t,$$
$$\xi_t, R_t^L, \pi_t, rer_t, p_t^H, \tilde{p}_t^H, p_t^F, \tilde{p}_t^F, p_t^Y, d_t, mc_t^H, f_t^H, \Delta_t^H, mc_t^F, f_t^F, \Delta_t^F, b_t^*, m_t, tb_t\}_{t=0}^{\infty},$$

(40 variables) such that for given initial values and exogenous sequences

$$\{v_t, u_t, z_t, a_t, \zeta_t, R_t^*, \pi_t^*, p_t^{Co*}, y_t^{Co}, y_t^*, g_t\}_{t=0}^{\infty},$$

the following conditions are satisfied:

$$\lambda_t = \left(c_t - \varsigma\frac{c_{t-1}}{a_{t-1}}\right)^{-1} - \beta\varsigma E_t\left\{\frac{v_{t+1}}{v_t}\left(c_{t+1}a_t - \varsigma c_t\right)^{-1}\right\}, \tag{E.1}$$

$$w_t mc_t^W = \kappa\frac{h_t^{\phi}}{\lambda_t}, \tag{E.2}$$

$$\lambda_t = \frac{\beta}{a_t}R_t E_t\left\{\frac{v_{t+1}}{v_t}\frac{\lambda_{t+1}}{\pi_{t+1}}\right\}, \tag{E.3}$$

$$\lambda_t = \frac{\beta}{a_t}R_t^*\xi_t E_t\left\{\frac{v_{t+1}}{v_t}\frac{\pi_{t+1}^S\lambda_{t+1}}{\pi_{t+1}}\right\}, \tag{E.4}$$

$$y_t^C = \left[(1-o)^{\frac{1}{\eta}}\left(x_t^H\right)^{\frac{\eta-1}{\eta}} + o^{\frac{1}{\eta}}\left(x_t^F\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{E.5}$$

$$x_t^F = o\left(p_t^F\right)^{-\eta}y_t^C, \tag{E.6}$$

$$x_t^H = (1-o)\left(p_t^H\right)^{-\eta}y_t^C, \tag{E.7}$$

$$mc_t^H = \frac{1}{\alpha^\alpha (1-\alpha)^{1-\alpha}} \frac{(r_t^K)^\alpha w_t^{1-\alpha}}{p_t^H z_t a_t^{1-\alpha}}, \tag{E.8}$$

$$f_t^H = \left(\tilde{p}_t^H\right)^{-\epsilon_H} y_t^H mc_t^H + \beta\theta_H E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_H} \pi^{1-\vartheta_H}}{\pi_{t+1}} \right)^{-\epsilon_H} \left(\frac{\tilde{p}_t^H}{\tilde{p}_{t+1}^H} \right)^{-\epsilon_H} \left(\frac{p_t^H}{p_{t+1}^H} \right)^{-1-\epsilon_H} f_{t+1}^H \right\}, \tag{E.9}$$

$$f_t^H = \left(\tilde{p}_t^H\right)^{1-\epsilon_H} y_t^H \left(\frac{\epsilon_H - 1}{\epsilon_H} \right) + \beta\theta_H E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_H} \pi^{1-\vartheta_H}}{\pi_{t+1}} \right)^{1-\epsilon_H} \left(\frac{\tilde{p}_t^H}{\tilde{p}_{t+1}^H} \right)^{1-\epsilon_H} \left(\frac{p_t^H}{p_{t+1}^H} \right)^{-\epsilon_H} f_{t+1}^H \right\}, \tag{E.10}$$

$$x_t^{H*} = o^* \left(\frac{p_t^H}{rer_t} \right)^{-\eta^*} y_t^*, \tag{E.11}$$

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R} \right)^{\rho_R} \left[\left(\frac{\pi_t}{\bar{\pi}} \right)^{\alpha_\pi} \left(\frac{y_t}{y_{t-1}} \right)^{\alpha_y} \right]^{1-\rho_R} \exp(\varepsilon_t^R), \tag{E.12}$$

$$y_t^H \Delta_t^H = z_t \left(\frac{k_{t-1}}{a_{t-1}} \right)^\alpha (a_t h_t^d)^{1-\alpha}, \tag{E.13}$$

$$1 = \theta_H \left(\frac{p_{t-1}^H}{p_t^H} \frac{\pi_{t-1}^{\vartheta_H} \pi^{1-\vartheta_H}}{\pi_t} \right)^{1-\epsilon_H} + (1-\theta_H) \left(\tilde{p}_t^H\right)^{1-\epsilon_H}, \tag{E.14}$$

$$y_t^H = x_t^H + x_t^{H*}, \tag{E.15}$$

$$y_t^C = c_t + i_t + g_t, \tag{E.16}$$

$$\frac{rer_t}{rer_{t-1}} = \frac{\pi_t^S \pi_t^*}{\pi_t}. \tag{E.17}$$

$$y_t = c_t + i_t + g_t + x_t^{H*} + y_t^{Co} - m_t, \tag{E.18}$$

$$tb_t = p_t^H x_t^{H*} + rer_t p_t^{Co*} y_t^{Co} - rer_t m_t, \tag{E.19}$$

$$rer_t b_t^* = rer_t \frac{b_{t-1}^*}{a_{t-1} \pi_t^*} R_{t-1}^* \xi_{t-1} + tb_t - (1-\chi) rer_t p_t^{Co*} y_t^{Co}, \tag{E.20}$$

$$\xi_t = \bar{\xi} \exp \left[-\psi_1 \frac{rer_t b_t^* - rer \times b^*}{rer \times b^*} - \psi_2 \frac{E_t \pi_{t+1}^S \pi_t^S - (\pi^S)^2}{(\pi^S)^2} + \frac{\zeta_t - \zeta}{\zeta} \right], \tag{E.21}$$

$$\Delta_t^H = (1-\theta_H) \left(\tilde{p}_t^H\right)^{-\epsilon_H} + \theta_H \left(\frac{p_{t-1}^H}{p_t^H} \frac{\pi_{t-1}^{\vartheta_H} \pi^{1-\vartheta_H}}{\pi_t} \right)^{-\epsilon_H} \Delta_{t-1}^H, \tag{E.22}$$

$$k_t = (1-\delta) \frac{k_{t-1}}{a_{t-1}} + \left[1 - \frac{\gamma}{2} \left(\frac{i_t}{i_{t-1}} a_{t-1} - \bar{a} \right)^2 \right] u_t i_t, \tag{E.23}$$

$$\lambda_t = \frac{\beta}{a_t} E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1} R_{t+1}^L}{\pi_{t+1}} \right\}, \tag{E.24}$$

$$\frac{k_{t-1}}{h_t^d} = a_{t-1} \frac{\alpha}{1-\alpha} \frac{w_t}{r_t^K}, \tag{E.25}$$

$$\frac{1}{q_t} = \left[1-\frac{\gamma}{2}\left(\frac{i_t}{i_{t-1}}a_{t-1}-\bar{a}\right)^2-\gamma\left(\frac{i_t}{i_{t-1}}a_{t-1}-\bar{a}\right)\frac{i_t}{i_{t-1}}a_{t-1}\right]u_t$$
$$+\frac{\beta}{a_t}\gamma E_t\left\{\frac{v_{t+1}}{v_t}\frac{\lambda_{t+1}}{\lambda_t}\frac{q_{t+1}}{q_t}\left(\frac{i_{t+1}}{i_t}a_t-\bar{a}\right)\left(\frac{i_{t+1}}{i_t}a_t\right)^2 u_{t+1}\right\}. \tag{E.26}$$

$$p_t^Y y_t = c_t + i_t + g_t + tb_t. \tag{E.27}$$

$$1 = \theta_F\left(\frac{p_{t-1}^F}{p_t^F}\frac{\pi_{t-1}^{\vartheta_F}\pi^{1-\vartheta_F}}{\pi_t}\right)^{1-\epsilon_F} + (1-\theta_F)\left(\tilde{p}_t^F\right)^{1-\epsilon_F}. \tag{E.28}$$

$$y_t^F = x_t^F. \tag{E.29}$$

$$m_t = y_t^F\Delta_t^F. \tag{E.30}$$

$$\Delta_t^F = (1-\theta_F)\left(\tilde{p}_t^F\right)^{-\epsilon_F} + \theta_F\left(\frac{p_{t-1}^F}{p_t^F}\frac{\pi_{t-1}^{\vartheta_F}\pi^{1-\vartheta_F}}{\pi_t}\right)^{-\epsilon_F}\Delta_{t-1}^F. \tag{E.31}$$

$$mc_t^F = rer_t/p_t^F. \tag{E.32}$$

$$f_t^F = \left(\tilde{p}_t^F\right)^{-\epsilon_F} y_t^F mc_t^F + \beta\theta_F E_t\left\{\frac{v_{t+1}}{v_t}\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\pi_t^{\vartheta_F}\pi^{1-\vartheta_F}}{\pi_{t+1}}\right)^{-\epsilon_F}\left(\frac{\tilde{p}_t^F}{\tilde{p}_{t+1}^F}\right)^{-\epsilon_F}\left(\frac{p_t^F}{p_{t+1}^F}\right)^{-1-\epsilon_F} f_{t+1}^F\right\}. \tag{E.33}$$

$$f_t^F = \left(\tilde{p}_t^F\right)^{1-\epsilon_F} y_t^F\left(\frac{\epsilon_F-1}{\epsilon_F}\right) + \beta\theta_F E_t\left\{\frac{v_{t+1}}{v_t}\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\pi_t^{\vartheta_F}\pi^{1-\vartheta_F}}{\pi_{t+1}}\right)^{1-\epsilon_F}\left(\frac{\tilde{p}_t^F}{\tilde{p}_{t+1}^F}\right)^{1-\epsilon_F}\left(\frac{p_t^F}{p_{t+1}^F}\right)^{-\epsilon_F} f_{t+1}^F\right\}. \tag{E.34}$$

$$\frac{R_t^L}{\pi_t} = \frac{r_t^K + q_t(1-\delta)}{\alpha_L^K q_{t-1}} + \frac{\left(\alpha_L^K-1\right)q_t k_t a_{t-1}}{\alpha_L^K q_{t-1}k_{t-1}}. \tag{E.35}$$

$$f_t^W = mc_t^W\tilde{w}_t^{-\epsilon_W}h_t^d + \beta\theta_W E_t\left\{\frac{v_{t+1}}{v_t}\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\pi_t^{\vartheta_W}\pi^{1-\vartheta_W}}{\pi_{t+1}}\right)^{-\epsilon_W}\left(\frac{\tilde{w}_t}{\tilde{w}_{t+1}}\right)^{-\epsilon_W}\left(\frac{w_t}{w_{t+1}}\right)^{-1-\epsilon_W} f_{t+1}^W\right\}. \tag{E.36}$$

$$f_t^W = \tilde{w}_t^{1-\epsilon_W}h_t^d\left(\frac{\epsilon_W-1}{\epsilon_W}\right) + \beta\theta_W E_t\left\{\frac{v_{t+1}}{v_t}\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\pi_t^{\vartheta_W}\pi^{1-\vartheta_W}}{\pi_{t+1}}\right)^{1-\epsilon_W}\left(\frac{\tilde{w}_t}{\tilde{w}_{t+1}}\right)^{1-\epsilon_W}\left(\frac{w_t}{w_{t+1}}\right)^{-\epsilon_W} f_t^W\right\}. \tag{E.37}$$

$$1 = (1-\theta_W)\tilde{w}_t^{1-\epsilon_W} + \theta_W\left(\frac{w_{t-1}}{w_t}\frac{\pi_{t-1}^{\vartheta_W}\pi^{1-\vartheta_W}}{\pi_t}\right)^{1-\epsilon_W}. \tag{E.38}$$

$$\Delta_t^W = (1-\theta_W)\tilde{w}_t^{-\epsilon_W} + \theta_w\left(\frac{w_{t-1}}{w_t}\frac{\pi_{t-1}^{\vartheta_W}\pi^{1-\vartheta_W}}{\pi_t}\right)^{-\epsilon_W}\Delta_{t-1}^W. \tag{E.39}$$

$$h_t = h_t^d\Delta_t^W. \tag{E.40}$$

The exogenous processes are

$$\log\left(x_t/\bar{x}\right) = \rho_x\log\left(x_{t-1}/\bar{x}\right) + \varepsilon_t^x, \qquad \rho_x\in[0,1), \qquad \bar{x}>0,$$

for $\zeta = \{v, u, z, a, \zeta, R^*, \pi^*, p^{Co*}, y^{Co}, y^*, g\}$, where the ε_t^x are n.i.d. shocks.

A.2 Steady State

We show how to compute the steady state for given values of R, h, p^H, $s^{tb} = tb/\left(p^Y y\right)$, $s^g = g/\left(p^Y y\right)$ and $s^{Co} = rer \times p^{Co*} y^{Co}/\left(p^Y y\right)$. The parameters β, $\bar{\pi}^*$, κ, α^*, $\bar{g}$ and $\bar{y}^{Co}$ are determined endogenously while the values of the remaining parameters are taken as given.

From the exogenous processes for v_t, u_t, z_t, a_t, y_t^{Co}, R_t^*, y_t^* and p_t^{Co*},

$$v = \bar{v},\ u = \bar{u},\ z = \bar{z},\ a = \bar{a},\ y^{Co} = \bar{y}^{Co},\ \zeta = \bar{\zeta},\ R^* = \bar{R}^*,\ y^* = \bar{y}^*,\ p^{Co*} = \bar{p}^{Co*},$$

From (E.21),

$$\xi = \bar{\xi}.$$

From (E.12),

$$\pi = \bar{\pi}.$$

From (E.3),

$$\beta = a\pi/R.$$

From (E.24),

$$r^L = \frac{a}{\beta}.$$

From (E.4),

$$\pi^S = a\pi/(\beta R^* \xi).$$

From (E.17) and the exogenous process for π_t^*,

$$\pi^* = \bar{\pi}^* = \pi/\pi^S.$$

From (E.14), (E.28) and (E.38),

$$\tilde{p}^H = 1,\ \tilde{p}^F = 1,\ \tilde{w} = 1.$$

From (E.22), (E.31) and (E.39),

$$\Delta^H = (\tilde{p}^H)^{-\epsilon_H},\ \Delta^F = (\tilde{p}^H)^{-\epsilon_F},\ \Delta^W = \tilde{w}^{-\epsilon_W}.$$

From (E.9)-(E.10), (E.33)-(E.34) and (E.36)-(E.37),

$$mc^H = \frac{\epsilon_H - 1}{\epsilon_H}\tilde{p}^H,\ mc^F = \frac{\epsilon_F - 1}{\epsilon_F}\tilde{p}^F,\ mc^W = \left(\frac{\epsilon_W - 1}{\epsilon_W}\right)\tilde{w}.$$

From (E.40),

$$h^d = h/\Delta^W.$$

From (E.26),

$$q = u^{-1}.$$

From (E.35),

$$r^K = q\left[\alpha_L^K r^L - 1 + \delta - \left(\alpha_L^K - 1\right)a\right].$$

From (E.8),

$$w = \left[\frac{\alpha^{\alpha}\left(1-\alpha\right)^{1-\alpha} p^{H} mc^{H} z a^{1-\alpha}}{\left(r^{K}\right)^{\alpha}}\right]^{\frac{1}{1-\alpha}}.$$

From (E.36),

$$f^{W} = \tilde{w}^{-\epsilon_W} h^{d} mc^{W} / (1-\beta\theta_W).$$

From (E.25),

$$k = \frac{\alpha a w h^{d}}{\left(1-\alpha\right) r^{K}}.$$

From (E.13),

$$y^{H} = z\left(k/a\right)^{\alpha}\left(ah^{d}\right)^{1-\alpha}/\Delta^{H}.$$

From (E.9),

$$f^{H} = mc^{H}\left(\tilde{p}^{H}\right)^{-\epsilon_H} y^{H}/(1-\beta\theta_H).$$

From (E.23),

$$i = k\left(\frac{1-(1-\delta)/a}{u}\right).$$

From (E.5)-(E.7),

$$p^{F} = \left[\frac{1}{o} - \frac{1-o}{o}\left(p^{H}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}.$$

From (E.32),

$$rer = mc^{F} p^{F}.$$

From GDP equal to value added, equivalent to (E.27), (E.27) itself and (E.30),

$$p^{Y} y = p^{H} y^{H} + p^{Y} y s^{Co} + p^{F}\left(1 - mc^{F}\Delta^{F}\right) o \left(p^{F}\right)^{-\eta}\left(1-s^{tb}\right) p^{Y} y.$$

From $s^{tb} = tb/\left(p^{Y} y\right)$, $s^{g} = g/\left(p^{Y} y\right)$, $s^{Co} = rer \times p^{Co*} y^{Co}/\left(p^{Y} y\right)$ and the exogenous process for g_t,

$$tb = s^{tb} p^{Y} y,\ \ g = \bar{g} = s^{g} p^{Y} y,\ \ y^{Co} = \bar{y}^{Co} = s^{Co} p^{Y} y/\left(rer \times p^{Co*}\right).$$

From (E.7), (E.15), (E.16) and (E.27),

$$x^{H*} = y^{H} - (1-o)\left(p^{H}\right)^{-\eta}\left(p^{Y} y - tb\right).$$

From (E.15),

$$x^{H} = y^{H} - x^{H*}.$$

From (E.19),

$$x^{F} = \left(p^{H} x^{H*} + rer \times p^{Co*} y^{Co} - tb\right)/rer.$$

From (E.29),

$$y^{F} = x^{F}.$$

From (E.33),

$$f^F = mc^F \left(\tilde{p}^F\right)^{-\epsilon_F} y^F/(1-\beta\theta_F).$$

From (E.30),

$$m = y^F \Delta^F.$$

From (E.6),

$$y^C = \left(x^F/o\right)\left(p^F\right)^{\eta}.$$

From (E.16),

$$c = y^C - g - i.$$

From (E.18),

$$y = c + i + g + x^{H*} + y^{Co} - m.$$

From (E.27),

$$p^Y = \left(c + i + g + tb\right)/y.$$

From (E.1),

$$\lambda = (c - \varsigma\frac{c}{a})^{-1} - \beta\varsigma\left\{(ca - \varsigma c)^{-1}\right\}.$$

From (E.2),

$$\kappa = mc^W \lambda w/h^{\phi}.$$

From (E.11),

$$o^* = \left(x^{H*}/y^*\right)\left(p^H/rer\right)^{\eta^*}.$$

From (E.20),

$$b^* = \frac{tb - (1-\chi)rer \times p^{Co*}y^{Co}}{rer\left[1 - (R^* + \xi)/(\pi^* a)\right]}.$$

B Models with Financial Frictions

B.1 Intermediary Objective

This section shows that the objective of financial intermediaries, given by

$$V_t = E_t\sum_{s=0}^{\infty}(1-\omega)\omega^s\beta^{s+1}\Xi_{t,t+s+1}\left[(r^L_{t+1+s} - r_{t+1+s})L_{t+s} + r_{t+1+s}N_{t+s}\right],$$

can be expressed as

$$V_t = \varrho^L_t L_t + \varrho^N_t N_t.$$

First, notice that

$$V_t = E_t\sum_{s=0}^{\infty}(1-\omega)\omega^s\beta^{s+1}\Xi_{t,t+s+1}\left[(r^L_{t+1+s} - r_{t+1+s})\frac{L_{t+s}}{L_t}L_t + r_{t+1+s}\frac{N_{t+s}}{N_t}N_t\right],$$

Thus,

$$\varrho_t^L \equiv E_t \sum_{s=0}^{\infty} (1-\omega)\omega^s \beta^{s+1} \Xi_{t,t+s+1} (r_{t+1+s}^L - r_{t+1+s}) \frac{L_{t+s}}{L_t},$$

and

$$\varrho_t^N \equiv E_t \sum_{s=0}^{\infty} (1-\omega)\omega^s \beta^{s+1} \Xi_{t,t+s+1} r_{t+1+s} \frac{N_{t+s}}{N_t}.$$

In terms of ϱ_t^N,

$$\varrho_t^N = E_t \left\{ (1-\omega)\beta \Xi_{t,t+1} r_{t+1} + \sum_{s=1}^{\infty} (1-\omega)\omega^s \beta^{s+1} \Xi_{t,t+s+1} r_{t+1+s} \frac{N_{t+s}}{N_t} \right\},$$

or,

$$\varrho_t^N = E_t \left\{ (1-\omega)\beta \Xi_{t,t+1} r_{t+1} + \beta\omega \Xi_{t,t+1} \frac{N_{t+1}}{N_t} \sum_{s=1}^{\infty} (1-\omega)\omega^{s-1} \beta^{s} \Xi_{t+1,t+s+1} r_{t+1+s} \frac{N_{t+s}}{N_{t+1}} \right\}.$$

Finally, changing the index in the sum by $j = s-1$, we get

$$\varrho_t^N = E_t \left\{ (1-\omega)\beta \Xi_{t,t+1} r_{t+1} + \beta\omega \Xi_{t,t+1} \frac{N_{t+1}}{N_t} \sum_{j=0}^{\infty} (1-\omega)\omega^{j} \beta^{j+1} \Xi_{t+1,t+1+j+1} r_{t+1+j+1} \frac{N_{t+j+1}}{N_{t+1}} \right\}.$$

or, using the definition of ϱ_t^N evaluated at $t+1$,

$$\varrho_t^N = E_t \left\{ (1-\omega)\beta \Xi_{t,t+1} r_{t+1} + \beta\omega \Xi_{t,t+1} \frac{N_{t+1}}{N_t} \varrho_{t+1}^N \right\} = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\omega) r_{t+1} + \omega \frac{N_{t+1}}{N_t} \varrho_{t+1}^N \right] \right\},$$

With an analogous procedure we can obtain the expression for ϱ_t^L.

B.2 Entrepreneurs' Optimization Problem

Using the definition for lev_t^e and (16), the Lagrangian for the optimal-contract problem can be written as,

$$E_t \left\{ lev_t^e \frac{[r_{t+1}^K + (1-\delta)q_{t+1}]}{q_t} h(\bar{\omega}_{t+1}^e; \sigma_{\omega,t+1}) + \eta_{t+1} \left[g(\bar{\omega}_{t+1}^e; \sigma_{\omega,t+1}) \frac{[r_{t+1}^K + (1-\delta)q_{t+1}]}{q_t} lev_t^e - (lev_t^e - 1) r_{t+1}^L \right] \right\},$$

where η_{t+1} is the Lagrange multiplier. The choice variables are lev_t^e and a state-contingent $\bar{\omega}_{t+1}^e$. The first order conditions are the constraint holding with equality and

$$E_t \left\{ \frac{[r_{t+1}^K + (1-\delta)q_{t+1}]}{q_t} h(\bar{\omega}_{t+1}^e; \sigma_{\omega,t+1}) + \eta_{t+1} \left[g(\bar{\omega}_{t+1}^e; \sigma_{\omega,t+1}) \frac{[r_{t+1}^K + (1-\delta)q_{t+1}]}{q_t} - (lev_t^e - 1) r_{t+1}^L \right] \right\} = 0,$$

$$h'(\bar{\omega}_{t+1}) + \eta_{t+1} g'(\bar{\omega}_{t+1}) = 0.$$

Combining these to eliminate η_{t+1} and rearranging we obtain (2.3) in the text.

Finally, we need a functional form for $F(\omega_t^e; \sigma_{\omega,t})$. We follow BGG and assume that $\ln(\omega_t^e) \sim N(-.5\sigma_{\omega,t}^2, \sigma_{\omega,t}^2)$ (so that $E(\omega_t^e) = 1$). Under this assumption, we can define

$$aux_t^1 \equiv \frac{ln(\bar{\omega}_t^e) + .5\sigma_{\omega,t}^2}{\sigma_{\omega,t}},$$

and, letting $\Phi(\cdot)$ be the standard normal c.d.f. and $\phi(\cdot)$ its p.d.f., we can write,[21]

$$\begin{aligned}
g(\bar{\omega}_t;\sigma_{\omega,t}) &= \bar{\omega}_t[1-\Phi(aux_t^1)] + (1-\mu^e)\Phi(aux_t^1-\sigma_{\omega,t}),\\
g'(\bar{\omega}_t;\sigma_{\omega,t}) &= [1-\Phi(aux_t^1)] - \bar{\omega}_t\phi(aux_t^1)\frac{1}{\sigma_{\omega,t}}\frac{1}{\bar{\omega}_t} + (1-\mu^e)\phi(aux_t^1-\sigma_{\omega,t})\frac{1}{\sigma_{\omega,t}}\frac{1}{\bar{\omega}_t}\\
&= [1-\Phi(aux_t^1)] - \mu^e\phi(aux_t^1),\\
h(\bar{\omega}_t;\sigma_{\omega,t}) &= 1-\Phi(aux_t^1-\sigma_{\omega,t}) - \bar{\omega}_t[1-\Phi(aux_t^1)],\\
h'(\bar{\omega}_t;\sigma_{\omega,t}) &= -\phi(aux_t^1-\sigma_{\omega,t})\frac{1}{\sigma_{\omega,t}}\frac{1}{\bar{\omega}_t} - [1-\Phi(aux_t^1)] + \bar{\omega}_t\phi(aux_t^1)\frac{1}{\sigma_{\omega,t}}\frac{1}{\bar{\omega}_t}\\
&= -[1-\Phi(aux_t^1)],
\end{aligned}$$

B.3 Equilibrium

The rational expectations equilibrium of the stationary version of the GK-BGG model includes the additional set of sequences

$$\{l_t, d_t, n_t, \varrho_t^L, \varrho_t^N, lev_t, r_t^L, r_t^{Le}, \bar{\omega}_t, n_t^e, rp_t, lev_t^e\}_{t=0}^{\infty},$$

(12 variables) such that for given initial values and exogenous sequences the following conditions are satisfied,

$$\varrho_t^L = \frac{\beta}{a_t}E_t\left\{\frac{\upsilon_{t+1}}{\upsilon_t}\frac{\lambda_{t+1}}{\lambda_t}\left[(1-\omega)(r_{t+1}^L - r_{t+1}) + \omega\frac{l_{t+1}}{l_t}a_t\varrho_{t+1}^L\right]\right\} \tag{E.1}$$

$$\varrho_t^N = \frac{\beta}{a_t}E_t\left\{\frac{\upsilon_{t+1}}{\upsilon_t}\frac{\lambda_{t+1}}{\lambda_t}\left[(1-\omega)r_{t+1} + \omega\frac{n_{t+1}}{n_t}a_t\varrho_{t+1}^N\right]\right\} \tag{E.2}$$

$$lev_t = \frac{\varrho_t^N}{\mu_t - \varrho_t^L}, \tag{E.3}$$

$$l_t = lev_t n_t, \tag{E.4}$$

$$d_t = l_t - n_t, \tag{E.5}$$

$$n_t = \frac{\omega}{a_{t-1}}\left[(r_t^L - r_t)l_{t-1} + r_t n_{t-1}\right] + \iota n, \tag{E.6}$$

$$l_{t-1}r_t^L = g(\bar{\omega}_t;\sigma_{\omega,t})[r_t^K + (1-\delta)q_t]k_{t-1}, \tag{E.7}$$

$$E_t\left\{\frac{[r_{t+1}^K + (1-\delta)q_{t+1}]}{q_t}\left[\frac{h'(\bar{\omega}_{t+1}^e;\sigma_{\omega,t+1})g(\bar{\omega}_{t+1}^e;\sigma_{\omega,t+1})}{g'(\bar{\omega}_{t+1}^e;\sigma_{\omega,t+1})} - h(\bar{\omega}_{t+1}^e;\sigma_{\omega,t+1})\right]\right\} = E_t\left\{r_{t+1}^L\frac{h'(\bar{\omega}_{t+1}^e;\sigma_{\omega,t+1})}{g'(\bar{\omega}_{t+1}^e;\sigma_{\omega,t+1})}\right\}, \tag{E.8}$$

$$r_{t-1}^{Le} = \bar{\omega}_t[r_t^K + (1-\delta)q_t]\frac{k_{t-1}}{l_{t-1}}, \tag{E.9}$$

$$n_t^e = \frac{\upsilon}{a_{t-1}}\left\{[r_t^K + (1-\delta)q_t]k_{t-1}h(\bar{\omega}_t^e;\sigma_{\omega,t})\right\} + \iota^e n^e, \tag{E.10}$$

$$l_t = q_t k_t - n_t^e, \tag{E.11}$$

$$rp_t = \frac{E_t\left\{[r_t^K + (1-\delta)q_t]/q_{t-1}\right\}}{E_t\left\{r_t^L\right\}}, \tag{E.12}$$

[21] See, for instance, the Appendix of Devereux, Lane and Xu (2006).

$$lev_t^e = \frac{q_t k_t}{n_t^e}, \tag{E.13}$$

In addition, equations (E.24) and (E.35) in the baseline have to be eliminated. The new exogenous processes are μ_t and $\sigma_{\omega,t}$.

For the GK model, the entrepreneurs' related equations are eliminated and equation (E.35) in the baseline is used.

B.4 Steady State

We solve for the steady state for a given value of R, q and k (these are determined from the non-financial part of the economy for a given value of r^L), $\Gamma = r^L - r$, lev, ι, rp, υ, σ_ω and μ^e. The free parameters are μ, ω, ι^e.

From the definition of Γ (replacing the solution for r^L in the version of the model without financial intermediaries),

$$r^L = \Gamma + r.$$

Also, from (E.8), and (E.12),

$$rp\,[h'(\bar{\omega};\sigma_\omega)g(\bar{\omega};\sigma_\omega) - h(\bar{\omega};\sigma_\omega)g'(\bar{\omega};\sigma_\omega)] = h'(\bar{\omega};\sigma_\omega). \tag{E.14}$$

This equation can be solved numerically to obtain $\bar{\omega}$. The rest of the equations for the entrepreneurs are,

$$r^K = r^L rp - 1 + \delta,$$

$$aux^1 \equiv \frac{ln(\bar{\omega}) + .5\sigma_\omega^2}{\sigma_\omega},$$

$$lev^e = \frac{1}{1 - g(\bar{\omega},\sigma)rp},$$

$$r^{Le} = \bar{\omega}\frac{[r^K + (1-\delta)q]k}{l},$$

$$n^e = \frac{qk}{lev^e},$$

$$l = qk - n^e,$$

$$\iota^e = \left\{n^e - \omega^e\left([r^K + (1-\delta)q]kh(\bar{\omega},\sigma_\omega)\right)\right\}/n^e,$$

The other variables associated with the intermediaries are, from (E.6),

$$\omega = a\,(1-\iota)\,/\,\left[(r^L - r)lev + r\right].$$

From (E.2),

$$\varrho^N = \frac{\beta}{a}\frac{1-\omega}{1-\beta\omega}r.$$

From (E.1),

$$\varrho^L = \frac{\beta}{a}\frac{1-\omega}{1-\beta\omega}(r^L - r).$$

From (E.3),

$$\mu = \varrho^L + \frac{\varrho^N}{lev}.$$

From (E.4),

$$n = \frac{l}{lev}.$$

From (E.5),

$$d = l - n.$$

Note that

$$\mu - \varrho^L = \frac{\varrho^N}{lev} = \frac{\beta}{a} \frac{1-\omega}{1-\beta\omega} \frac{r}{lev} > 0,$$

such that the intermediaries' incentive constraint is binding in the steady state.