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# **FINANCIAL FRICTIONS AND THE TRANSMISSION OF FOREIGN SHOCKS IN CHILE\***

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## **Abstract**

We set up and estimate a DSGE model of a small open economy to assess the role of domestic financial frictions in propagating foreign shocks. In particular, the model features two types of financial frictions: one in the relationship between depositors and banks (following Gertler and Karadi, 2011) and the other between banks and borrowers (along the lines of Bernanke et al, 1999). We use Chilean data to estimate the model, following a Bayesian approach. We find that the presence of financial frictions increases the importance of foreign shocks in explaining consumption, inflation, the policy rate, the real exchange rate and the trade balance. In contrast, under financial frictions the role of these foreign shocks in explaining output and investment is somehow reduced. The behavior of the real exchange rate and its interaction with the financial frictions is key to understand the results.

## **Resumen**

Se desarrolla y estima un modelo dinámico y estocástico de equilibrio general de una economía pequeña y abierta para estudiar el rol de fricciones financieras domésticas en propagar shocks externos. En particular, el modelo incluye dos tipos de fricciones: una en la relación entre depositantes y bancos (siguiendo a Gertler y Karadi, 2011) y otra entre los bancos y los deudores (siguiendo a Bernanke et al, 1999). Se utiliza datos de Chile para estimar el modelo, siguiendo un enfoque Bayesiano. Se encuentra que la presencia de fricciones financieras aumenta la importancia de shocks externos para explicar el comportamiento del consumo, la inflación, la tasa de política monetaria, el tipo de cambio real y la balanza comercial. Por otro lado, con la presencia de fricciones financieras los shocks externos parecen menos importantes en explicar la evolución del producto y la inversión. Finalmente, se enfatiza el comportamiento del tipo de cambio real y su interacción con las fricciones financieras para interpretar estos resultados.

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# 1 Introduction

In the early 90's a literature emerged emphasizing the role of external factors in explaining business cycles fluctuations in emerging countries. In particular, terms of trade and world interest rates are generally viewed as the main external factors affecting these economies.<sup>1</sup> Additionally, part of this literature has also highlighted the role of financial frictions in explaining the propagation of these external shocks, where these frictions arise in the relationship between foreign lenders and domestic borrowers. The role of country premia,<sup>2</sup> the possibility of sovereign default,<sup>3</sup> and dollarization<sup>4</sup> are some of the propagation mechanisms that have been highlighted by this literature. All these features generate a wedge between foreign and domestic interest rates. Given the number of financial and currency crisis, as well as episodes of sovereign default, that have affected the emerging world in the 80's and 90's, it is not hard to see the relevance of these arguments.

In the 20th century the situation has significantly changed for most emerging countries, particularly in Latin America: most countries seem to have controlled the fiscal situation, some governments are even net foreign lenders, dollarization has been reduced dramatically, and country premia have not displayed the high levels they used to show years ago. From that perspective, one can argue that financial frictions between foreign and domestic agents are not as relevant as they used to be. This, however, does not imply that financial frictions are irrelevant to understand fluctuations in emerging countries, particularly those generated by external factors. Financial frictions can still play an important role in the relationship between domestic borrowers and lenders. From this perspective, frictions may not generate a significant wedge between foreign and domestic interest rates, but they might be relevant for they induce a wedge between deposits and lending rates domestically.

The goal of this paper is to assess the importance of domestic financial frictions in propagating external shocks in Chile. The Chilean economy has most of the characteristics of the 20th-century emerging countries that we mentioned before. The fiscal situation is quite strong, particularly since the structural-balance rule was set in 2001. Indeed, the Chilean government has a positive net external investment position, which in particular implies that the country premium is generally quite small. For instance, as shown in Figure 1, the JP Morgan EMBI index for Chile has been significantly lower than both its world and its Latinamerican counterpart. Moreover, financial dollarization is almost nil in Chile. Still, the lending-deposits spread in domestic currency and the external finance premium are sizable, as can be seen in Figure 2. For instance, the average spread between 90-days lending and deposit rates between 2001 and 2012 was 380 basis points, and the average spread between A and AAA corporate bonds yields in that same period was 120 basis points. This might be an indication that domestic financial frictions are a relevant propagation channel.

To perform the analysis we develop a dynamic and stochastic DGSE New-Keynesian model of a small open economy featuring two types of domestic financial frictions. On one hand, there is a friction between depositors and banks that induce a spread between lending and deposit rates. We model this friction as a moral hazard problem following the work of Gertler and Karadi (2011).<sup>5</sup> On the other hand, there is a spread between the lending rate and the return to capital (the external finance premium) originated by a costly-state-verification problem, following Bernanke et al (1999). We estimate the model with quarterly Chilean data from 2001 to

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<sup>1</sup>Early contributions to this literature are Calvo *et al* (1993) and Hoffmaister and Roldos (1997), while Izquierdo *et al* (2008) and Osterholm and Zettelmeyer (2008) are some more recent examples focusing on Latin America.

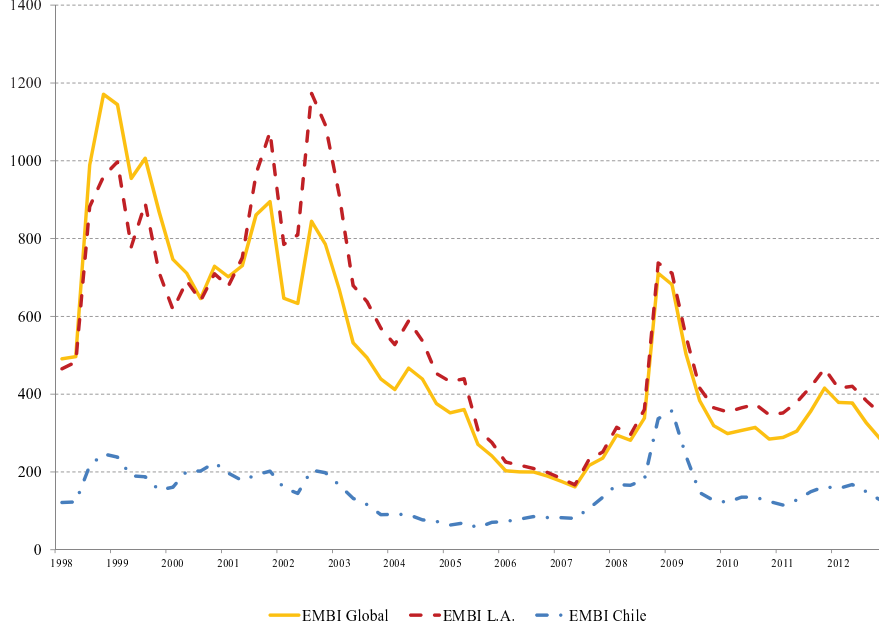
<sup>2</sup>See, for instance, Neumeyer and Perri (2005), Uribe and Yue (2008), and Mendoza (2011).

<sup>3</sup>For example, Arellano (2008), Yue (2010) and Mendoza and Yue (2012).

<sup>4</sup>For instance, Cespedes *et al* (2004), Deveraux *et al* (2006), and Gertler *et al* (2007).

<sup>5</sup>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).

Figure 1: External spreads (a.b.p)



Source: Bloomberg.

2012, using Bayesian techniques. The estimated model is used for two purposes: to assess if financial frictions help improving the goodness of fit of the model, and to understand the role that financial frictions play in the propagation of foreign shocks to commodity prices, foreign inflation, foreign demand, and world interest rates.

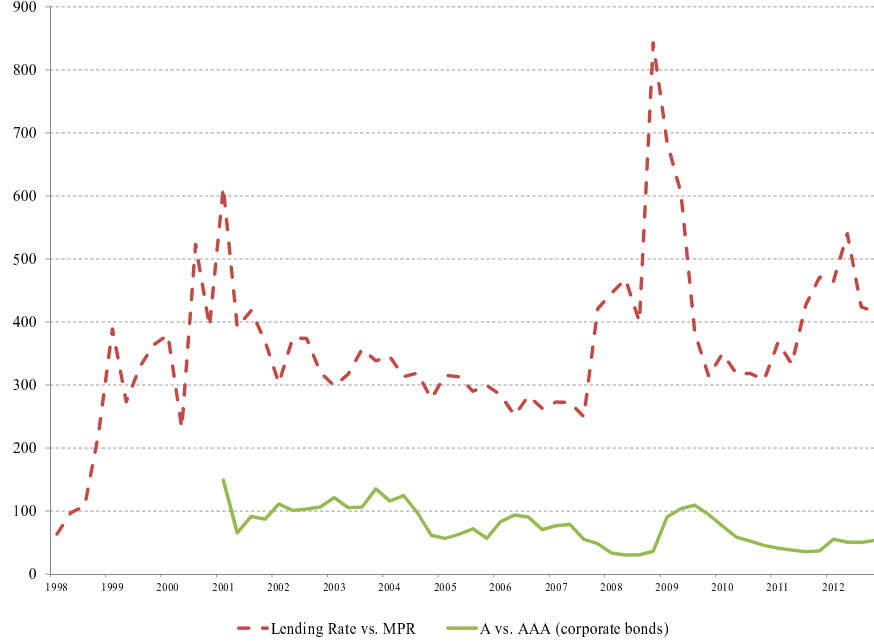
In terms of goodness of fit, the analysis shows that including financial frictions improves the fit of the model along some dimensions. For instance, the model without financial frictions cannot account for the higher volatility of consumption relative to output that is observed in the data, while the estimated models with financial frictions do feature this characteristic. Also, the volatility of inflation is similar to that in the data in models with financial frictions, and the persistence of most of the observables is better matched when financial frictions are in place.

In terms of the propagation of foreign shocks, we find that the presence of financial frictions increases the importance of foreign shocks in explaining consumption, inflation, the policy rate, the real exchange rate and the trade balance. In contrast, under financial frictions the role of these foreign shocks in explaining output and investment is somehow reduced. The behavior of the real exchange rate and its interaction with financial frictions is key to understand these results. For instance, when the economy is hit by a contractionary foreign shock, the real exchange rate depreciates. In turn, because in our model the home good is fully tradable, the real depreciation improves the financial position of these firms, leading to a reduction in the premium that these firms face. Thus, the negative effect on investment is ameliorated in the presence of financial frictions.

Our study makes several contributions to the related literature. First, to the best of our knowledge, we are the first to set up a model combining banks as in Gertler and Karadi (2011) with entrepreneurs as in Bernanke et al (1999) in a small open economy framework.<sup>6</sup> Also, we are the first to estimate a model featuring banks as in

<sup>6</sup>Ranneberg (2013) combines these two features but in a closed economy setup.

Figure 2: Domestic spreads (a.b.p)



Source: Central Bank of Chile.

Gertler and Karadi (2011) for a small open economy.<sup>7</sup> Finally, while several studies use estimated DSGE models to assess the role of financial frictions between domestic and foreign agents in propagating external shocks<sup>8</sup>, we are among the few that assess the role of domestic financial frictions.<sup>9</sup>

The rest of the paper is organized as follows. Section 2 describes the baseline model and the variants with financial frictions. Section 3 describes the parametrization and estimation strategy. Section 4 analyzes the goodness of fit of the different versions of the model, while Section 5 addresses the role of foreign shocks. Finally, Section 6 concludes.

## 2 Models

We first describe the baseline model (with no financial frictions) and then the extension that incorporates banks as in Gertler and Karadi (2011). Thereafter, we present 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.

<sup>7</sup>Some examples of estimations in closed-economy with these types of banks are Villa (2013), Villa and Yang (2013), and Areosa and Coelho (2013).

<sup>8</sup>For instance, Tovar (2006) and Fernandez and Gulán (2012)

<sup>9</sup>One exception is the work by Christiano *et al.* (2011).

## 2.1 Baseline Model

The baseline model is one of a small open economy 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 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.<sup>10</sup>

### 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 ( $t = 0, 1, 2, \dots$ ).<sup>11</sup> 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

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

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  $h_t(i) = [W_t^n(i)/W_t^n]^{-\epsilon_w} h_t^d$ , 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  $\Sigma_t$  collect real dividend income from the ownership of firms. The period-by-period budget constraint of the household is then given by

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

<sup>10</sup>In terms of the related literature, the baseline model is a simplified version of the model by Medina and Soto (2007), which is the DSGE models used for analysis and forecast at the Central Bank of Chile. Given the simplifications, the model is closer to that in Adolfson *et al* (2007).

<sup>11</sup>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.



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

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

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.<sup>12</sup> The variable  $\xi_t$  denotes a country premium given by<sup>13</sup>

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

where  $\zeta_t$  is an exogenous shock to the country premium. The foreign nominal interest rate  $R_t^*$  evolves exogenously, and the domestic central bank sets  $R_t$ .<sup>14</sup>

### 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  $\alpha_L^K$  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 earn zero profits in each period, and the state-contingent return  $r_t^L$  therefore satisfies

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

<sup>12</sup>Notice the difference with  $r_t^L$ , which is due to the state-contingent nature of these loans.

<sup>13</sup>See, for instance, Schmitt-Grohé and Uribe (2003) and Adolfson *et al.* (2007).

<sup>14</sup>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

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

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  $j$ :

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

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

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

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

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

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  $1-\vartheta_H$ .<sup>15</sup>

**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

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

**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

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

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-through 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

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<sup>15</sup>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  $\varepsilon_t^R$  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  $\pi_t^*$  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  $\pi_t^*$  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

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

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

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

for  $x = \{v, u, z, a, \zeta, R^*, \pi^*, p^{Co*}, y^{Co}, y^*, g\}$ , where the  $\varepsilon_t^x$  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:

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

where  $r_t^L$  denotes the real gross return on loans and  $r_t$  is the real gross interest rates on domestic deposits.<sup>16</sup>

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

<sup>16</sup>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 ( $V_t$ ), which is given by

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

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  $\mu_t$  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 (i.e. to continue operating and obtaining the value  $V_t$ ) cannot be smaller than the gain from diverting assets. As can be seen, shocks that increase  $\mu_t$  will make this constraint tighter, making the financial problem more severe. We assume  $\mu_t$  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  $\varrho_t^L$  is the expected discounted marginal gain of an additional unit of loans, while  $\varrho_t^N$  is the expected discounted marginal gain of an 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 ( $\mu_t$ ) is larger than the

marginal gain from expanding assets by one unit of deposits (i.e. holding net worth constant) and continuing to operate ( $\varrho_t^L$ ). 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

$$lev_t \equiv \frac{\varrho_t^N}{\mu_t - \varrho_t^L} \quad (13)$$

denotes the intermediary's leverage ratio. As indicated by (13), higher marginal gains from increasing assets  $\varrho_t^L$  support a higher leverage ratio in the optimum, the same is true for the higher marginal gains of net worth  $\varrho_t^N$  and for a larger fraction of divertable funds  $\mu_t$  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 number enters the sector. Each intermediary exiting the sector at the end of period  $t - 1$  transfers their remaining net worth ( $\tilde{N}_{e,t} \equiv (r_t^L - r_t)L_{t-1} + r_t N_{t-1}$ ) to households. To each new intermediary households transfer 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

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

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 from accumulating net worth beyond a point at

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  $\omega_t^e$  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  $\mu^e$  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

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

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

While  $r_t^{Le}$  denotes the interest rate on the loan, the return for the intermediary for each unit lent ( $r^L$ ) is not equal to  $r_t^{Le}$ : first, not all loans will be repaid and, second, from those entrepreneurs who default, the intermediary receives 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

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

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

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

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.<sup>17</sup>

<sup>17</sup>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 (see 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) that 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 the equilibrium is indeterminate because only equation (15) displays both  $r_{t+1}^L$  and



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

$$E_t \{ [r_{t+1}^K + (1 - \delta)q_{t+1}] K_t h(\bar{\omega}_{t+1}^e; \sigma_{\omega, t+1}) \}, \quad (16)$$

where

$$h(\bar{\omega}_t^e; \sigma_{\omega, t}) \equiv \int_{\bar{\omega}_t^e}^{\infty} \omega^e f(\omega^e; \sigma_{\omega, t}) d\omega^e - \bar{\omega}_t^e [1 - F(\bar{\omega}_t^e; \sigma_{\omega, t})]. \quad (17)$$

The first term in the right-hand side of equation (2.3) is the expected share of average revenue that entrepreneurs obtain given their productivity. The second term is the expected repayment. Both are conditional on not defaulting (i.e. if  $\bar{\omega}_t^e \geq \omega_t^e$ ).

Defining  $lev_t^e \equiv \frac{q_t K_t}{N_t^e}$ , and given the revelation principle, the optimal debt contract specifies a value for  $lev_t^e$  and a state-contingent  $\bar{\omega}_{t+1}^e$  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:

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

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

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  $[r_t^K + (1 - \delta)q_t] K_{t-1} h(\bar{\omega}_t^e; \sigma_{\omega, t})$ . We assume that only a fraction  $v$  of entrepreneurs survives every period, and an equal fraction enters the market with an initial capital injection from households equal to  $\frac{\iota^e}{1-v} n^e A_{t-1}$ , with  $\iota^e > 0$  (i.e. a fraction  $\frac{\iota^e}{1-v}$  of balanced-growth-path net worth).<sup>18</sup> Thus, we have

$$N_t^e = v \{ [r_t^K + (1 - \delta)q_t] K_{t-1} h(\bar{\omega}_t^e; \sigma_{\omega, t}) \} + \iota^e n^e A_{t-1}.$$

### 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:  $\beta$ ,  $\pi^*$ ,  $\kappa$ ,  $o^*$ ,  $\bar{g}$ ,  $\bar{b}^*$  and  $\bar{y}^{Co}$ . For most of the parameters, we draw from related studies using Chilean data, as indicated in the table. The parameters that deserve additional explanation are those related with financial frictions:  $\bar{\mu}$  (the steady state value of the fraction of divertible funds),  $\omega$  (the fraction of surviving banks),  $\iota$  (the capital injection for new banks),  $\mu^e$  (bankruptcy costs),  $v$  (the fraction of surviving entrepreneurs),  $\iota^e$  (the capital injection for new entrepreneurs), and  $\sigma_{\omega}$  (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  $\omega$ , 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

<sup>18</sup> $\bar{\omega}_{t+1}^e$ , and there is no other equation that determines one of these.

<sup>18</sup>Entrepreneurs that leave that market transfer their remaining resources to households.

between 90-days loans and the monetary policy rate.<sup>19</sup> 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 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  $\alpha_L^K$  (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.<sup>20</sup>

For the model with GK banks and BGG entrepreneurs (the GK-BGG model for short), we use the same targeted averages for the parameters related to the banking sector 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) in this version of the model. The loan rate that we observe in the data is in line with the definition of  $r^{Le}$ , thus the bank spread that we match is that between  $r^{Le}$  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:  $v = 0.97$  (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,  $\iota^e$  and  $\sigma_\omega$ , 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. In terms of the leverage figure, this chosen value corresponds to the average leverage between 2001 and 2012 for the largest Chilean firms.<sup>21</sup>

Finally, for the model that includes BGG entrepreneurs but with frictionless banks (the BGG model), the external finance premium is now the spread between the deposit rates and the expected return on capital. We calibrate that premium in steady state to be the sum of the bank's spread and the firm's spread used in the GK-BGG model (i.e. we assume a premium of  $380 + 120 = 500$  basis points), while keeping the leverage for entrepreneurs equal to 2.05.<sup>22</sup>

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 mining production, for  $R^*$  we use the LIBOR rate, for  $y^*$  we use linearly-detrended real GDP of commercial partners, for  $\pi^*$  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  $\pi^*$ .<sup>23</sup>

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 2.<sup>24</sup> The baseline model was estimated using the following variables (all from 2001.Q3 to 2012.Q4): the growth rates of real GDP, private consumption and investment, the CPI inflation, the monetary policy rate, the multilateral real exchange rate, the growth rate of real wages, and the

<sup>19</sup>All the rates and spread figures are presented here in annualized terms, although in the model they are included on a quarterly basis.

<sup>20</sup>In the baseline model, we set  $\alpha_L^K = 1$ .

<sup>21</sup>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.

<sup>22</sup>In this way, real allocations in steady state are the same in both the GK-BGG and the BGG models.

<sup>23</sup>The data source for all Chilean-related data is the Central Bank of Chile, and for the other variables is Bloomberg.

<sup>24</sup>The prior means were set to represent the estimates of related papers for the Chilean economy (e.g. Medina and Soto, 2007).

Table 1: Calibrated Parameters.

Param.	Description	Value	Source
$\sigma$	Risk aversion	1	Medina and Soto (2007)
$\phi$	Frisch elasticity	1	Adolfson <i>et al.</i> (2008)
$\alpha$	Capital share in production	0.33	Medina and Soto (2007)
$\delta$	Capital depreciation	0.06/4	Medina and Soto (2007)
$\epsilon_H$	E.o.S. domestic aggregate	11	Medina and Soto (2007)
$\epsilon_F$	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)
$\chi$	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)
$\xi$	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)
$\iota$	Injection for new bankers	0.002	Gertler and Karadi (2011)
$\mu^e$	Bankruptcy cost	0.12	Christiano <i>et al.</i> (2010)
$v$	Survival rate of entrepreneurs	0.97	Bernanke <i>et al.</i> (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
$\rho_g$	Auto corr. $g$	0.6973	Own estimation
$\rho_{R^*}$	Auto corr. $R^*$	0.9614	Own estimation
$\rho_{y^*}$	Auto corr. $y^*$	0.8665	Own estimation
$\rho_{\pi^*}$	Auto corr. $\pi^*$	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
$\sigma_g$	St. dev. shock to $g$	0.0145	Own estimation
$\sigma_{R^*}$	St. dev. shock to $R^*$	0.0011	Own estimation
$\sigma_{y^*}$	St. dev. shock to $y^*$	0.0062	Own estimation
$\sigma_{\pi^*}$	St. dev. shock to $\pi^*$	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.

EMBI Chile. We also include in the set of observables the variables used to estimate the exogenous processes previously described.<sup>25</sup> Overall, the baseline model is estimated with 14 variables. For future reference, 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 variance 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 adequately match the variance of the real exchange rate.

For the models with financial frictions, we estimate each of them with two alternative datasets: the Macro dataset (in which case we do not include financial shocks) and the Macro dataset adding also the spread between the 90-days loans rate and the monetary policy rate (in the tables and figures we refer to this as the bank spread),<sup>26</sup> and the entrepreneurs risk premium, measured as the spread between the A vs. AAA corporate-bonds rates (we refer to this as the firms' spread).<sup>27</sup> For the model with both types of frictions (GK-BGG) both spreads are used as observables, for the GK model only the bank spread is the observable, and in the BGG alternative the observable is the sum of both spreads.

In columns 5 to 11 of Table 2 the posterior mode of the estimated parameters is shown. Many parameters are estimated to have similar values across models, so we just comment here some relevant highlights. First, we can see that estimated value for  $\psi$  (the elasticity of the country premium with respect to external debt to GDP) is quite small for all models. While the model does not include any detailed financial friction between domestic and foreign agents, the fact that this parameter is a small can be seen as evidence on the conjecture we described in the introduction that, at least for the case of Chile, financial frictions with foreign agents do not seem to be a relevant transmission mechanism.

A parameter that seems to be affected by the inclusion of the financial frictions is that governing investment adjustment costs ( $\gamma$ ). When only macro data is used for the estimation, this parameter is smaller in the GK model than in the baseline, it is larger in GK-BGG model, and it is similar in the BGG model. When spread data is included in the estimation, the value of ( $\gamma$ ) in the GK model is much smaller than in the baseline, in the GK-BGG is a bit smaller than in the baseline, and it is somehow similar in the BGG framework.

That the presence of financial frictions changes the assessment of capital adjustment cost was expected. 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  $\gamma$ ). However, it is also true that when both capital adjustment costs and financial frictions are considered, one can also expect 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 of some other parameter to match the same dataset.

Finally, it is also worth mentioning that in the models with financial frictions that also include financial shocks the inference regarding the volatility of the investment shock  $u_t$  is different, which was also expected. For

<sup>25</sup>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.

<sup>26</sup>For the model with GK banks, this spread is computed as  $E_t\{r_{t+1}^L\} - r_t$ , while in the model that adds BGG entrepreneurs this is  $r_t^{Le} - r_t$ .

<sup>27</sup>For financial variables we also included i.i.d. measurement errors, calibrating their variance to account for 10% of the variance of the observable.

Table 2: Estimated Parameters, Prior and Posterior Mode.

Para.	Description	Posterior Mode								
		Prior	Macro data			Financial data				
		Dist.	Mean	Base	GK	BGG	GK-BGG	GK	BGG	GK-BGG
$\varsigma$	Habits	beta	0.7	0.73	0.73	0.73	0.73	0.70	0.74	0.71
$\psi$	Country Premium. Elast.	invg	0.01	0.010	0.009	0.009	0.009	0.008	0.009	0.010
$\eta$	E.o.S. $H$ and $F$	invg	1.5	1.40	1.36	1.36	1.38	1.30	1.35	1.37
$\eta^*$	Demand elasticity for exports	invg	0.5	0.33	0.32	0.38	0.40	0.32	0.38	0.43
$\gamma$	Inv. Adj. Cost	norm	4	1.98	1.25	1.96	2.13	0.43	1.91	1.22
$\theta_W$	Calvo prob. Wages	beta	0.75	0.95	0.94	0.95	0.95	0.94	0.95	0.95
$\vartheta_W$	Indexation past infl. Wages	beta	0.5	0.37	0.35	0.35	0.36	0.37	0.35	0.32
$\theta_H$	Calvo prob. $H$	beta	0.75	0.49	0.51	0.51	0.50	0.46	0.50	0.47
$\vartheta_H$	Indexation past infl. $H$	beta	0.5	0.42	0.41	0.44	0.44	0.39	0.45	0.43
$\theta_F$	Calvo prob. $F$	beta	0.75	0.79	0.80	0.83	0.84	0.81	0.83	0.85
$\vartheta_F$	Indexation past infl. $F$	beta	0.5	0.40	0.41	0.40	0.40	0.39	0.41	0.38
$\rho_R$	MPR Rule $R_{t-1}$	beta	0.75	0.83	0.82	0.82	0.83	0.75	0.82	0.79
$\alpha_\pi$	MPR Rule $\pi_t$	norm	1.5	1.54	1.57	1.56	1.57	1.50	1.57	1.49
$\alpha_y$	MPR Rule growth	norm	0.13	0.12	0.13	0.13	0.13	0.11	0.12	0.14
$\rho_v$	AC. Pref. Shock	beta	0.75	0.76	0.79	0.79	0.77	0.74	0.80	0.76
$\rho_u$	AC. Inv. Shock	beta	0.75	0.74	0.75	0.78	0.79	0.60	0.75	0.74
$\rho_z$	AC. Temporary TFP Shock	beta	0.75	0.74	0.74	0.75	0.75	0.73	0.75	0.74
$\rho_a$	AC. Permanent TFP Shock	beta	0.38	0.36	0.36	0.35	0.35	0.36	0.35	0.35
$\rho_\zeta$	AC. Country premium Shock	beta	0.75	0.91	0.90	0.93	0.93	0.92	0.93	0.92
$\rho_\mu$	AC. $\mu_t$	beta	0.75					0.85		0.86
$\rho_{\sigma_\omega}$	AC. $\sigma_{\omega,t}$	beta	0.75						0.84	0.89
$\sigma_v$	Std. Pref. Shock	invg	0.01	0.024	0.025	0.024	0.024	0.023	0.025	0.022
$\sigma_u$	Std. Inv. Shock	invg	0.01	0.029	0.040	0.034	0.033	0.016	0.030	0.021
$\sigma_z$	Std. Temporary TFP Shock	invg	0.01	0.010	0.011	0.011	0.011	0.009	0.011	0.010
$\sigma_a$	Std. Permanent TFP Shock	invg	0.01	0.003	0.003	0.003	0.003	0.003	0.003	0.003
$\sigma_\zeta$	Std. Country premium Shock	invg	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001
$\sigma_R$	Std. MPR Shock	invg	0.003	0.002	0.002	0.002	0.002	0.001	0.002	0.002
$\sigma_\mu$	Std. $\mu_t$	invg	0.01					0.004		0.013
$\sigma_{\sigma_\omega}$	Std. $\sigma_{\omega,t}$	invg	0.01						0.032	0.019
$\sigma_{meRER}$	Std. M.E. RER	norm	2.7	3.48	3.50	3.55	3.55	3.69	3.55	3.60

instance, Justiniano *et al.* (2011), after finding that the shock to the marginal efficiency of investment is the most important driver for U.S. 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.

## 4 Goodness of Fit

To assess the goodness of fit of the different models, we begin by computing the marginal likelihood for each of the alternative models. Table 3 displays, for each model, the log marginal likelihoods for the dataset used for estimation<sup>28</sup> and for the Macro dataset as well. Focusing first on the results when only macro data is used and no financial shocks are included, we can see that there are no significant difference in terms of this overall measure of goodness of fit. The last three rows in Table 3 show the marginal likelihoods for the models with financial frictions. We can see that when data on spreads is included, the fit of the macro dataset deteriorates. This is particularly so for the GK model, and to a less extent for the GK-BGG model. The BGG model is the one that performs the best in terms of fitting macro data. Still, it is desirable to estimate the models with financial frictions with spread data, for it gives more discipline to the financial part of the model.

Table 3: Marginal Likelihood for Macroeconomic Data.

Model	Financial Shocks	Estimation Dataset	$\log(MgL)$	
			Estim. Data	Macro Data
Baseline	No	Macro	-952.0	
GK	No	Macro	-952.0	
BGG	No	Macro	-952.7	
GK-BGG	No	Macro	-952.5	
GK	$\mu_t$	Macro, Spr. Bank	-986.7	-974.4
BGG	$\sigma_{\omega,t}$	Macro, Spr. Bank+Firm	-945.1	-957.8
GK-BGG	$\mu_t, \sigma_{\omega,t}$	Macro, Spr. Bank, Spr. Firm	-880.2	-964.2

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

While the marginal likelihood provides an overall measure of goodness of fit, it is also of interest to analyze which dimensions of the data are better matched once financial frictions are included. To that end, Table 4 shows standard deviations (panel A) and first order auto-correlation (Panel B) of the domestic variables that were used as observables, both in the data and in the different models. 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.

All models of financial frictions can reproduce a volatility of consumption larger than that of output, although the level of the volatility of output is smaller than in the data and than in the baseline. The models with BGG entrepreneurs produce a volatility of inflation similar to that in the data. However, all models with financial frictions exacerbate the volatility of the monetary policy rate and the RER. In terms of matching the volatility of spreads, we can see that both the BGG and the GK-BGG model produce variances for these variables closer to

<sup>28</sup>Of course, marginal likelihoods are not comparable when computed with different datasets.

Table 4: Selected Second Moments.

Variable	Data	Base	Macro data			Financial data		
			GK	BGG	GK-BGG	GK	BGG	GK-BGG
A. St. Dev.								
GDP Growth	1.02	0.91	0.87	0.86	0.87	0.89	0.87	0.87
Cons. Growth	1.10	0.92	1.00	1.00	0.99	1.00	1.00	0.98
Inv. Growth	3.75	3.91	3.50	3.90	3.94	3.67	4.03	3.90
Inflation	0.74	0.58	0.55	0.64	0.61	0.62	0.64	0.62
MPR	0.46	0.48	0.55	0.63	0.63	0.56	0.63	0.60
RER	5.41	9.14	10.19	10.28	9.95	10.49	10.32	10.06
TB/Y	5.32	3.64	3.60	3.64	3.55	3.67	3.64	3.61
Real Wage Growth	0.62	0.55	0.53	0.54	0.52	0.57	0.55	0.54
Spr. Bank	0.26		0.52		0.36	1.38		0.28
Spr. Firm	0.07				0.13			0.13
Spr. Bank + Firm	0.25			0.36			0.28	
B. AC(1)								
GDP Growth	0.25	0.31	0.26	0.27	0.26	0.21	0.27	0.24
Cons. Growth	0.63	0.59	0.62	0.65	0.63	0.58	0.64	0.61
Inv. Growth	0.40	0.65	0.58	0.65	0.63	0.44	0.65	0.59
Inflation	0.63	0.66	0.69	0.72	0.70	0.67	0.72	0.70
MPR	0.88	0.92	0.94	0.95	0.94	0.95	0.95	0.95
RER	0.73	0.91	0.93	0.93	0.92	0.93	0.93	0.92
TB/Y	0.73	0.91	0.91	0.92	0.92	0.91	0.92	0.92
Real Wage Growth	0.40	0.43	0.46	0.45	0.44	0.42	0.45	0.43
Spr. Bank	0.68		0.57		0.83	0.57		0.70
Spr. Firm	0.84				0.98			0.96
Spr. Bank + Firm	0.67			0.90			0.97	

Note: These are unconditional moments computed at the posterior mode.

the data than the GK model. Finally, in terms of auto-correlations, the models with financial frictions seem to improve over the baseline.

Overall, the presence of financial frictions seems to marginally improve the fit of the baseline model along some dimensions, although there is still room for improvement in terms of matching these moments, both in the baseline and in the other versions of the model.

## 5 The Role of External Shocks

In this section we assess how the presence of financial frictions affects the propagation of foreign shocks. In the model, there are four exogenous foreign variables: the world interest rate ( $R_t^*$ ), the international relative price of commodities ( $p_t^{Co*}$ ), the world inflation ( $\pi_t^*$ ), and the world output ( $y_t^*$ ). We begin by analyzing the contribution of each of these external variables to explain the variance of the domestic observables both in the baseline model and in the models with financial frictions, as displayed in Table 5.

Table 5: Variance decomposition.

Variable	$R_t^*$	$y_t^*$	$\pi_t^*$	$p_t^{Co*}$	Sum	$R_t^*$	$y_t^*$	$\pi_t^*$	$p_t^{Co*}$	Sum
A. Baseline						B. GK				
GDP Growth	3	2	6	3	14	3	2	5	2	13
Cons. Growth	5	0	7	21	34	10	0	9	28	47
Inv. Growth	10	0	7	10	27	7	0	3	6	16
MPR	12	0	10	25	47	27	0	13	31	71
Country Premium	6	0	31	34	72	3	0	28	41	72
Inflation	6	0	6	8	20	16	0	8	15	39
RER	17	0	22	46	85	18	0	21	55	94
TB/Y	17	0	23	49	89	14	0	19	61	94
Spr. Bank						2	0	0	0	3
Spr. Firm										
C. BGG						D. GK-BGG				
GDP Growth	3	2	7	3	15	3	2	8	4	17
Cons. Growth	11	0	10	28	48	10	0	11	29	50
Inv. Growth	7	0	4	7	17	9	0	5	9	23
MPR	22	0	12	27	61	22	0	13	32	67
Country Premium	2	0	28	37	67	3	0	31	38	72
Inflation	11	0	6	11	29	12	0	8	15	35
RER	17	0	21	49	87	17	0	23	49	90
TB/Y	14	0	19	57	90	15	0	22	55	92
Spr. Bank						7	0	4	9	21
Spr. Firm	5	0	3	7	14	10	0	8	24	42

Note: For the models with financial frictions, the decomposition was computed with the posterior mode estimated using spread variables. Results are similar if the estimates obtained using Macro data only are used.

Starting from the Baseline model, we can see that external shocks explain an important fraction of macro variables, particularly for the country premium, the real exchange rate and the trade balance. Of the four foreign shocks, the price of commodities seems to be the most relevant, followed by foreign inflation and the world interest rate, while foreign output plays a negligible role.



Once financial frictions are considered the role of external variables as business cycles drivers increases for consumption, the monetary policy rate, inflation, the real exchange rate and the trade balance. In particular, financial frictions increase the role played by foreign interest rate and the price of commodities in explaining these variables. For GDP and investment, the role of external shocks is somehow reduced once financial frictions are included, while for the country premium the percentage explained by foreign shocks is overall the same, although the price of commodities seems to have a more important role while foreign inflation loses some relevance in explaining this variance.

To understand how financial frictions alter the propagation of these foreign shocks, we analyze the impulse responses generated by these disturbances. Figure 3 displays the responses to an increase in the world interest rate. Regardless of the presence of financial frictions, this shock is contractionary. This happens because it reduces consumption through both a negative wealth effect and through an intertemporal effect, and also contracts investment for it increases the real interest rate. This drop in aggregate absorption generates a real depreciation, which in turn rises aggregate inflation due to the increase in the domestic price of foreign goods. As a consequence, the policy rate rises. Moreover, the trade balance improves and the country premium increases.

The presence of financial frictions dampens the response of investment given this shock. While the price of capital tends to fall after the shock (except in the GK model) the persistent real depreciation induces an increase in the marginal product of capital (equal to the rental rate), because home firms produce tradable goods. In equilibrium, and given the estimated parameters, the second effect dominates and thus the return on capital for entrepreneurs increases, which improves the value of assets for both entrepreneurs and financial intermediaries. Therefore, financial constraints get relaxed after this shock (spreads are reduced) and therefore the negative effect on investment is ameliorated in the presence of financial frictions. Consumption, on the other hand, drops by more in the presence of financial frictions. This is the result of the larger increase in the policy rate that is produced in the presence of financial frictions.

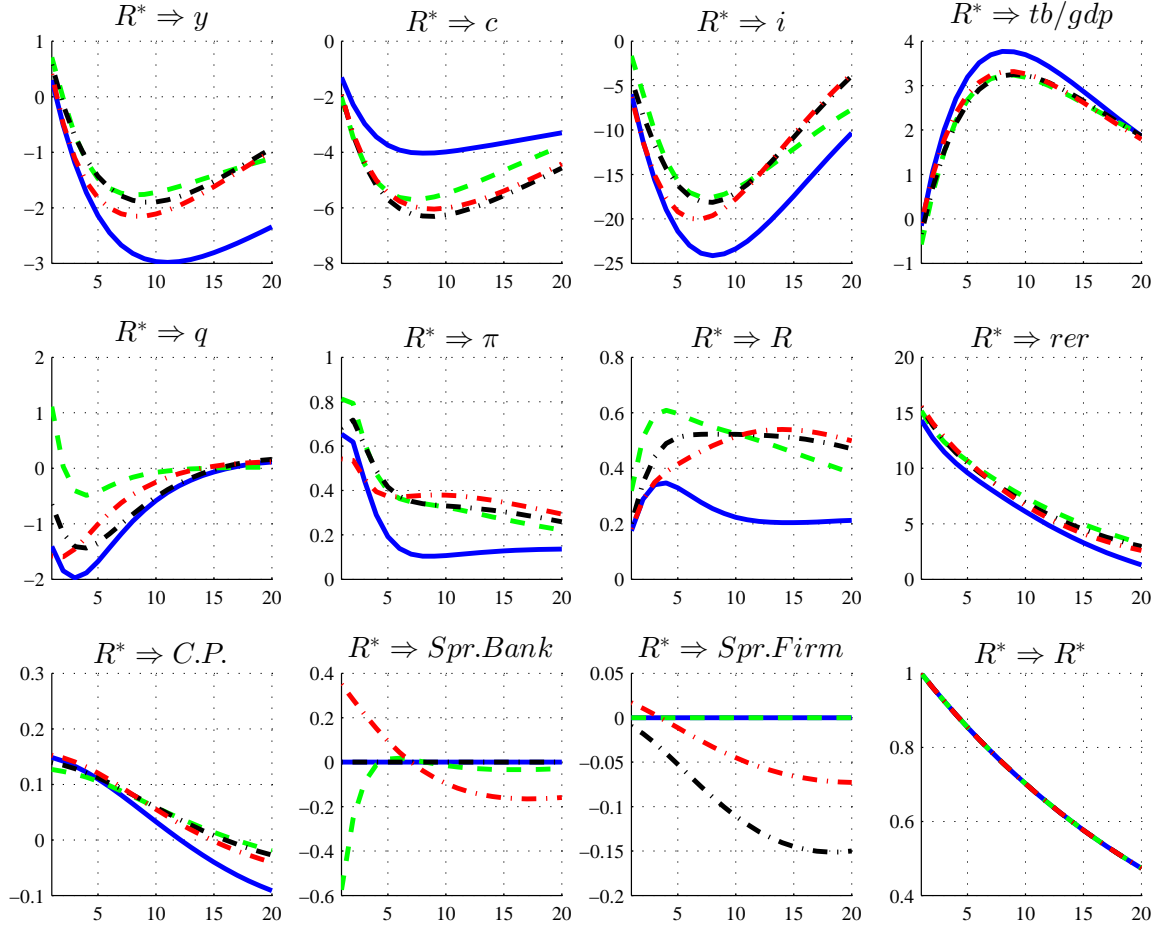
It is relevant to highlight at this point that the effect on investment will be likely amplified if financial frictions were instead placed in the relationship between domestic borrowers and foreign lenders. This would be the case because for two different reasons: first, the real exchange rate depreciation would negatively affect the liability position of borrowers and, second, because the cost of borrowing changes one-by-one with the world interest rate in such a setup, further deteriorating their net worth. Thus, in such a setup spreads will likely increase, making the recession even worse. But in the context of this model, because financial frictions are between domestic agents, this effect is absent and the presence of domestic financial frictions reduce the negative impact of investment as we already discussed.

Figure 4 displays the responses obtained after an increase in the world price of commodities. Qualitatively, this shock generates a positive wealth effect that rises consumption which in turn, by increasing the demand for domestic goods, rises the marginal product of capital expanding also investment. The increase in absorption leads to a real appreciation. Inflation experiences a minor drop, again led by a reduction in the domestic price of imported goods due to the real appreciation. Consequently, the policy rate mildly drops.

In line with the arguments used to analyze the world interest rate shock, the presence of financial frictions reduces the effect that the shock has on investment. In this case, as the currency is appreciating in real terms, the return on capital is reduced and, in the presence of financial frictions, the spread rises. This counteracts in part the expansionary effect on investment in the Baseline model. Consumption, on the other hand, increases by more because the drop in the policy rate is more persistent in the presence of financial frictions.

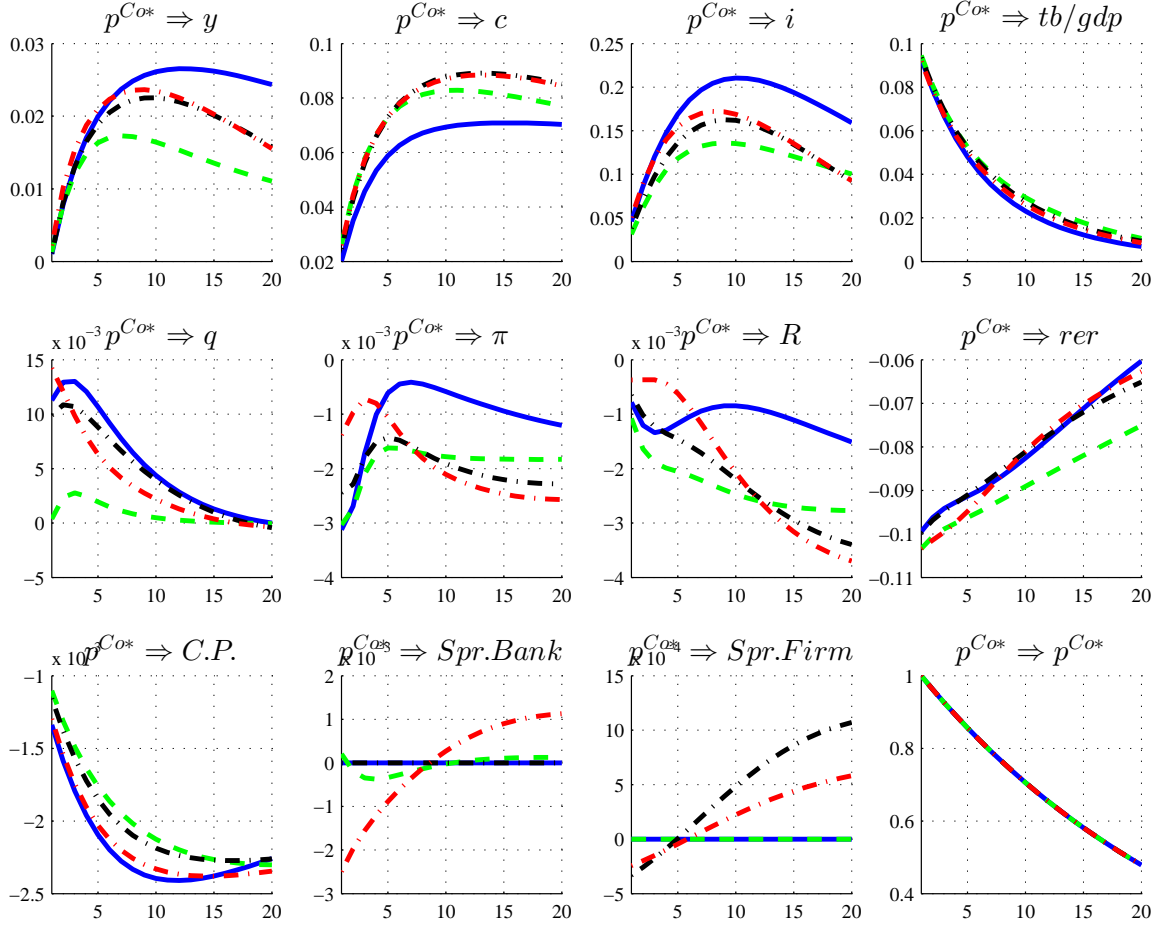
Figure 5 shows the effects generated by an increase in foreign inflation. This shock affects the economy through

Figure 3: Impulse Responses to a World Interest Rate Shock.



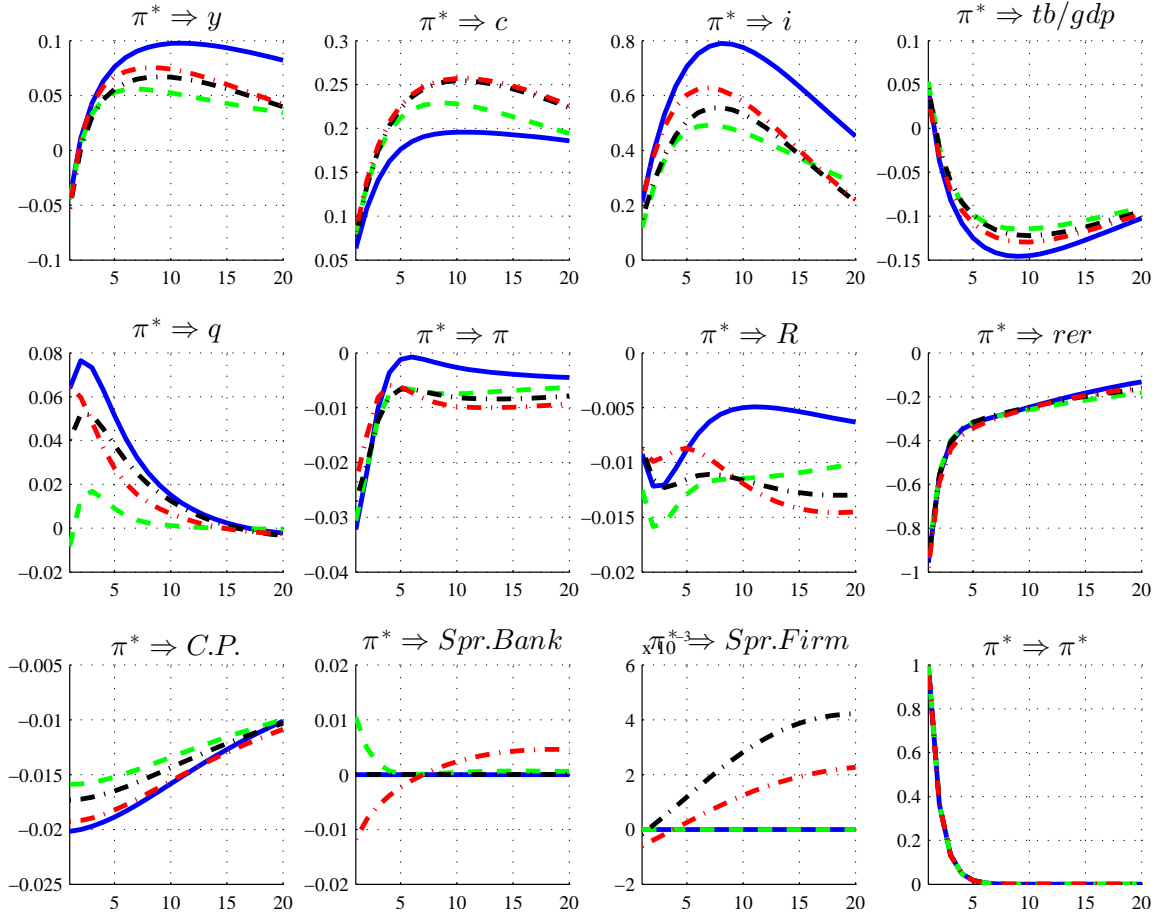
Note: The blue solid line is the baseline model, the dashed green line corresponds to the GK model, the dash-dotted black line is from the BGG model, and the dashed-dotted red line is the GK-BGG model. For the models with financial frictions, these were computed with the posterior mode estimated using spread variables. Results are similar if the estimates obtained using Macro data only are used. The shock has been normalized to take a value of 1% in each model. The variables included in the graph are GDP, consumption, investment, the trade-balance-to-GDP ratio, the price of capital goods, the CPI inflation, the monetary policy rate, the real exchange rate, the country premium, the banks' spread, the firms' spread, and the variable being shocked. Responses of all variables are expressed as percentage deviations from their respective steady state values.

Figure 4: Impulse Responses to a Commodity Price Shock.



Note: See Figure 3.

Figure 5: Impulse Responses to a Foreign Inflation Shock.



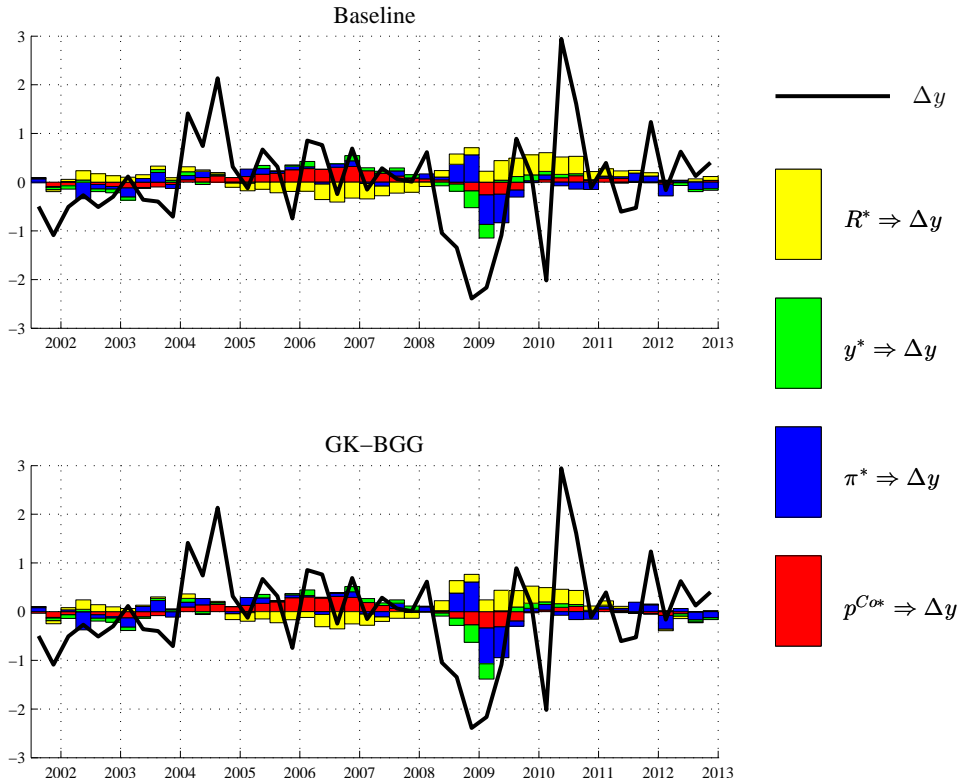
Note: See Figure 3.

two channels. First, it generates a positive wealth effect because exports will, *ceteris paribus*, rise as the demand for exports of home goods negatively depends on foreign inflation. Second, the shock rises, *ceteris paribus*, the marginal cost of imports, generating an upward pressure for imported inflation. As can be seen from the figure, the positive wealth effect generates an expansion in consumption and investment, and a deterioration in the trade balance. In turn, the economy experiences a real appreciation which, in equilibrium counteracts the direct effect on inflation of the rise in foreign prices and inflation is reduced. Once more, the presence of financial frictions dampens the response of investment and increases that of consumption.

Overall, after this analysis, it is clear why models with financial frictions assign a more prominent role for foreign shock in explaining consumption, inflation and the monetary policy rate, while reducing the influence of these shocks in explaining output and investment. Moreover, we have argued that this happens in the context of this model because financial friction are between domestic agents instead of in the borrowing relationship with the rest of the world.

We finish the analysis by computing the historical decomposition to some macro variables to asses the role of these four external shocks in explaining the observed macroeconomic fluctuations over the sample period. This exercise complements the previous analysis for it allows to study the importance of these shocks at different points in time, while the previous analysis was only unconditional. In particular, we want to explore if the inclusion of financial frictions changes the role that external shocks had during the 2008-2009 recession.

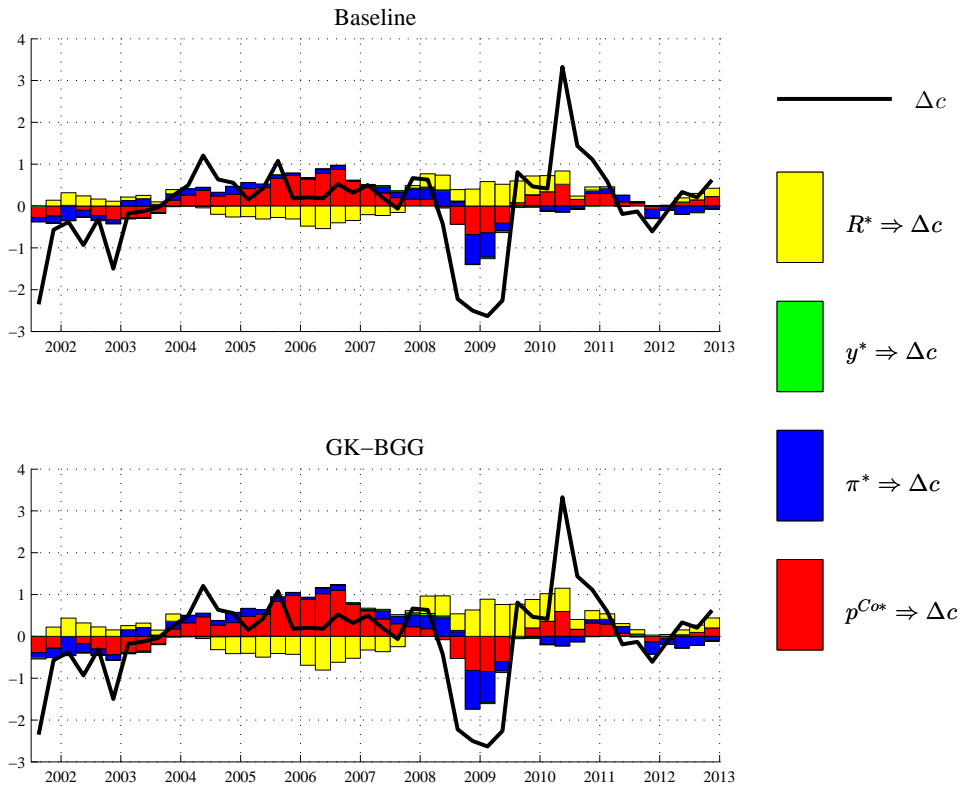
Figure 6: Historical decomposition of output growth due to foreign shocks.



Note: Historical decomposition computed at the posterior mode. For the GK-BGG model, we used the mode obtained from the estimation that includes spreads as observables.

Figure 6 shows the decomposition of output growth. In “normal” times, we can see that in both the baseline and in the GK-BGG model the contribution of foreign shocks appear to be similar. However, some difference arise during the 2008-2009 recession. While GDP growth began to drop relative to its average in early 2008, during 2008 the foreign variables that contributed to this decrease were the world output and the price of copper. But during 2009 also the evolution of foreign inflation negatively contributed to decrease GDP. This description is valid for both models. But the size of the contribution of these shocks is larger in the GK-BGG model. For instance, in 2009.Q1 the fall in world inflation generated a drop of 0.6 percentage point in GDP growth in the Baseline model, while in the GK-BGG model this shock decreased GDP growth by 0.74. Given that these are quarterly figures, the difference is sizable (more than half of a percentage point of annualized growth).

Figure 7: Historical decomposition of consumption growth due to foreign shocks.

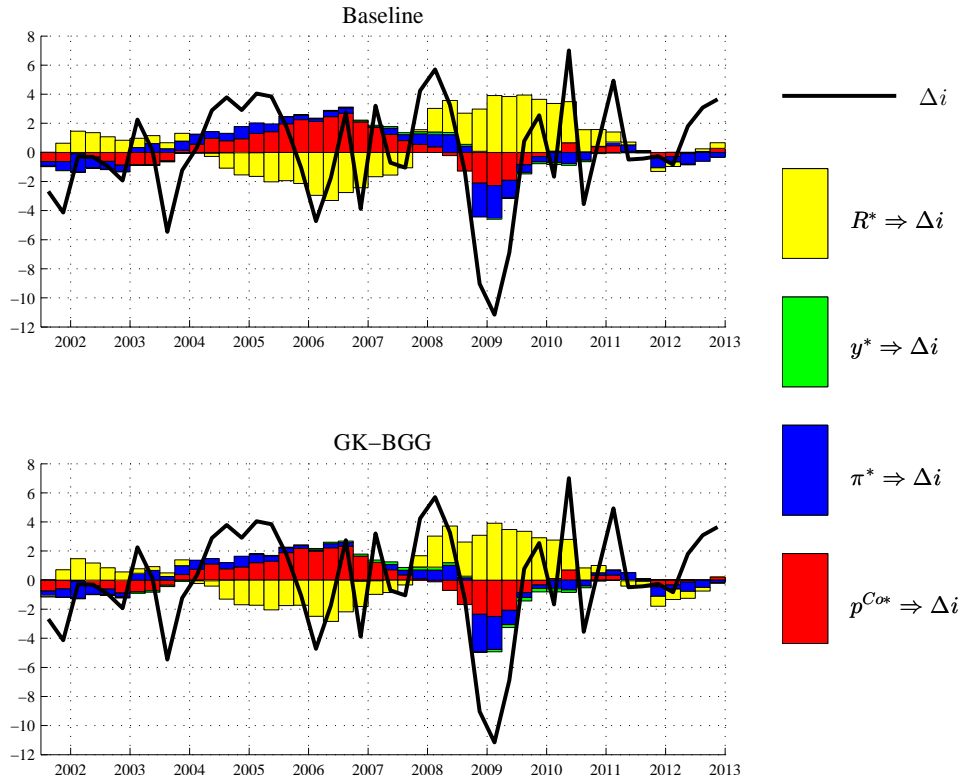


Note: See figure 6.

In Figure 7 we display the decomposition for consumption growth. As expected, given the results previously analyzed, the role of external variables in explaining the evolution of consumption is amplified in the GK-BGG model, both in normal times and during the crisis. Given the size of the contraction during the crisis, the difference between models in the contribution of external variables during that episode is quite large. As an example, in the GK-BGG model the contribution to the drop in consumption growth at the trough explained by the fall in world inflation and in copper price is 0.35 percentage points more than in the baseline model. At the other end, we should also mention that the presence of financial frictions also emphasize the stabilizing role that the drop in the world interest rate had on consumption. For instance, in 2009.Q1, the world interest rate generated an increase of 0.9 percentage points in the GK-BGG model, while in the baseline that contribution was close to 0.6

percentage points.

Figure 8: Historical decomposition of investment growth due to foreign shocks.



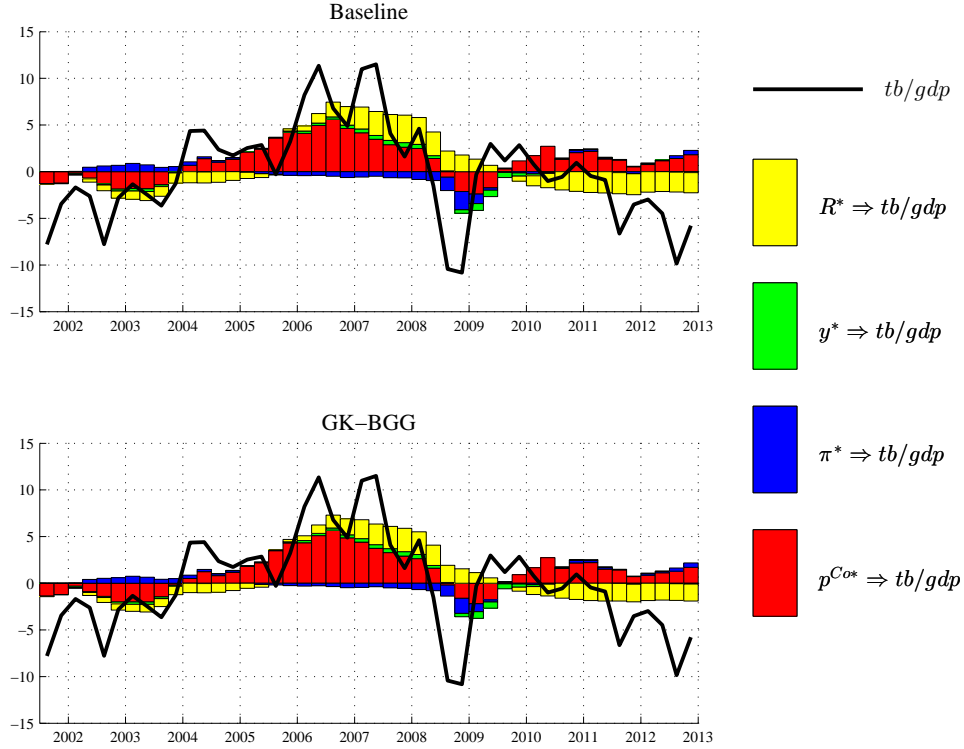
Note: See figure 6.

The decomposition for investment is displayed in figure 8. The pattern for this variable is less clear. In normal times, foreign shocks explain a larger fraction of the evolution of this variable in the baseline model, in line with the unconditional analysis previously presented. But during the recession, the role of world inflation and the price of copper is somehow larger in the GK-BGG model, while the expansionary contribution of world interest rates is milder in the model with financial frictions.

Figure 9 shows the contribution of foreign shocks to the evolution of the trade-balance-to-output ratio. For this variable there is no significant difference between the contribution of the two models. If anything, it seems that during the recession external shocks played a milder role in the GK-BGG model, although the differences are not large. Finally, figure 10 contains the decomposition for inflation. It can be seen that the role of the copper price and the world interest rate is exacerbated in the GK-BGG model, both in normal times and during the crisis.

In general, the historical decomposition allows to draw three main conclusions. First, according to both models that we have analyzed external shocks play a significant fraction of the 2008-2009 crisis in Chile, as well as part of the recovery of the economy (mainly due to recovering copper prices and low foreign interest rates). In addition, for those variables for which we have detected from the unconditional analysis that financial frictions increase the role of external shocks (in particular consumption), the historical decomposition illustrates that this is generally true both in normal times and during the 2008-2009 recession. In contrast, while the contribution of

Figure 9: Historical decomposition of trade-balance-to-output ratio due to foreign shocks.



Note: See figure 6.

foreign shocks in explaining both GDP and investment growth was found, unconditionally, to be similar or even less important with financial frictions, during the recession these external shocks seem to explain a larger fraction of the downturn if financial frictions are considered.

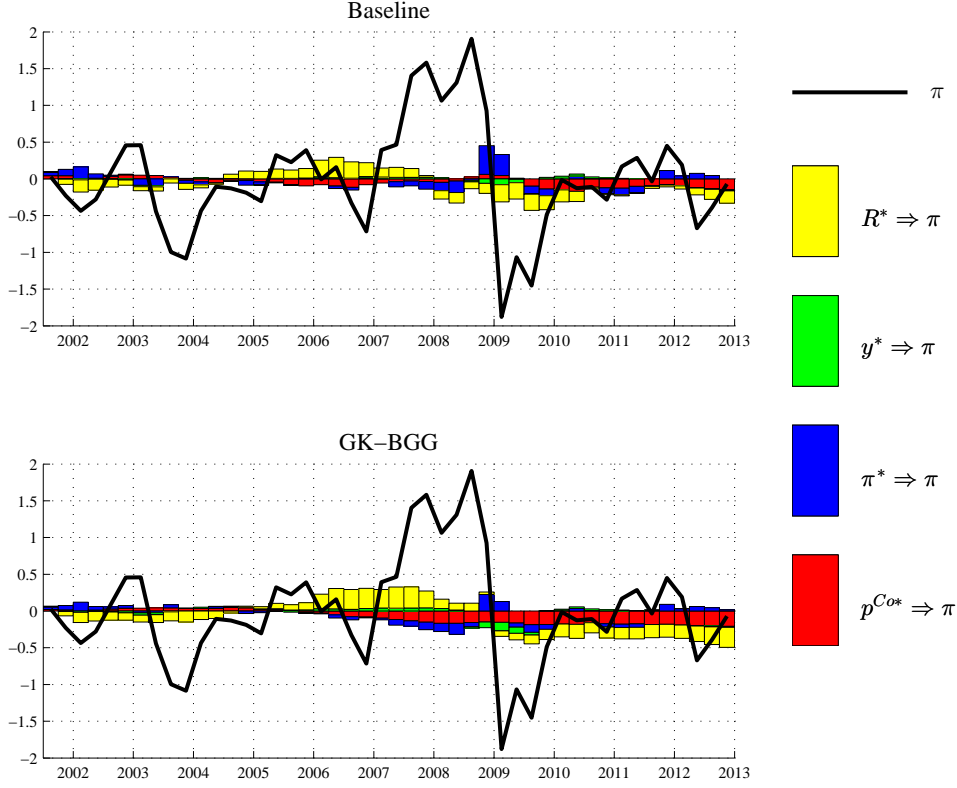
## 6 Conclusions

In this paper we have set up and estimated a DSGE model of a small open economy that includes two types of financial frictions: between depositors and banks, and between banks and borrowers. The model was estimated with Chilean data from 2001 to 2012. We have used the model to asses whether the inclusion of financial frictions improves the goodness of fit of the model to macroeconomic data, and to determine how the propagation of foreign shocks is altered by the presence of these frictions.

In terms of goodness of fit, we have found that the inclusion of financial frictions improves the ability of the mode to match some dimension of the data. And in terms of the propagation of foreign shocks, our results showed that, because the friction is between domestic agents, the effect of the shock on the real exchange rate is crucial for the results. In particular, this implies that, unconditionally, the responses of investment and output are milder in the presence of financial friction, while the responses of consumption and inflation are exacerbated. Nonetheless, we have also showed that in the presence of financial frictions the contribution of external factors in explaining the evolution of most macro variables (including output and investment) during the 2008-2009 recession is larger than in the baseline model.



Figure 10: Historical decomposition of inflation due to foreign shocks.



Note: See figure 6.

Looking ahead, given the relevance highlighted for the real exchange rate, it would be of interest to consider a multi-sector model, with tradables and non-tradables. Arguably, the effects that we have described arise because all goods are tradables and in that way, for instance, a real depreciation improves the financial position of these firms. But if firms in the non-traded sector are also subject to financial constraints, a real depreciation will deteriorate their financial conditions, making less clear what the final effect would be.

Another relevant extension would be the addition of frictions also between domestic and foreign agents, to have a more formal test of the relative relevance of both types of frictions. For instance, we could consider banks obtaining funds also from abroad, subject to the same type of frictions that we assume between banks and domestic depositors. In such a setup, movements in the real exchange rate will also alter the banks' balance sheet, leading to an additional amplification of shocks. Alternatively, one can also consider firms obtaining funds not only through the domestic banking system but also using the international market (for instance, by issuing corporate bonds), along the lines of the argument presented by Caballero (2002) to explain how the Asian crisis propagated to the Chilean economy. We left these extensions for future research.

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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 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  $\Lambda_t$  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 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:

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

$$w_t mc_t^W = \kappa \frac{h_t^\phi}{\lambda_t}, \quad (\text{E.2})$$

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

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

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

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

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

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

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

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

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

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

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

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

$$y_t^H = x_t^H + x_t^{H*}, \quad (\text{E.15})$$

$$y_t^C = c_t + i_t + g_t, \quad (\text{E.16})$$

$$\frac{rer_t}{rer_{t-1}} = \frac{\pi_t^S \pi_t^*}{\pi_t}. \quad (\text{E.17})$$

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

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

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

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

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

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

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

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

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

$$p_t^Y y_t = c_t + i_t + g_t + tb_t. \quad (\text{E.27})$$

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

$$y_t^F = x_t^F. \quad (\text{E.29})$$

$$m_t = y_t^F \Delta_t^F. \quad (\text{E.30})$$

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

$$mc_t^F = rer_t / p_t^F. \quad (\text{E.32})$$

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

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

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

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

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

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

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

$$h_t = h_t^d \Delta_t^W. \quad (\text{E.40})$$

The exogenous processes are

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

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

## A.2 Steady State

We show how to compute the steady state for given values of  $R$ ,  $h$ ,  $p^H$ ,  $s^{tb} = tb/(p^Y y)$ ,  $s^g = g/(p^Y y)$  and  $s^{Co} = rer \times p^{Co*} y^{Co}/(p^Y y)$ . The parameters  $\beta$ ,  $\bar{\pi}^*$ ,  $\kappa$ ,  $\alpha^*$ ,  $\bar{g}$  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  $p_t^{Co*}$ ,

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

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  $\pi_t^*$ ,

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

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),

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

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),

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

From (E.8),

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

From (E.36),

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

From (E.25),

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

From (E.13),

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

From (E.9),

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

From (E.23),

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

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

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

From (E.32),

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

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

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

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

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

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

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

From (E.15),

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

From (E.19),

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

From (E.29),

$$y^F = x^F.$$

From (E.33),

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

From (E.30),

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

From (E.6),

$$y^C = (x^F / o) (p^F)^\eta.$$

From (E.16),

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

From (E.18),

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



From (E.27),

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

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),

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

From (E.20),

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

## B Models with Financial Frictions

### B.1 Intermediary Objective

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

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

can be expressed as

$$V_t = \varrho_t^L L_t + \varrho_t^N N_t.$$

First, notice that

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

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  $\varrho_t^N$ ,

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

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  $\varrho_t^N$  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  $\varrho_t^L$ .

## 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  $\eta_{t+1}$  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  $\eta_{t+1}$  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,<sup>29</sup>

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

<sup>29</sup>See, for instance, the Appendix of Devereux, Lane and Xu (2006).

### 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,

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

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

$$lev_t = \frac{\varrho_t^N}{\mu_t - \varrho_t^L}, \quad (\text{E.3})$$

$$l_t = lev_t n_t, \quad (\text{E.4})$$

$$d_t = l_t - n_t, \quad (\text{E.5})$$

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

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

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

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

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

$$l_t = q_t k_t - n_t^e, \quad (\text{E.11})$$

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

$$lev_t^e = \frac{q_t k_t}{n_t^e}, \quad (\text{E.13})$$

In addition, equations (E.24) and (E.35) in the baseline have to be eliminated. The new exogenous processes are  $\mu_t$  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  $r^L$ ),  $\Gamma = r^L - r$ ,  $lev$ ,  $\iota$ ,  $rp$ ,  $v$ ,  $\sigma_\omega$  and  $\mu^e$ . The free parameters are  $\mu$ ,  $\omega$ ,  $\iota^e$ .

From the definition of  $\Gamma$  (replacing the solution for  $r^L$  in the version of the model without financial interme-

diaries),

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

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

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

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

$$\begin{aligned} r^K &= r^L rp - 1 + \delta, \\ aux^1 &\equiv \frac{\ln(\bar{\omega}) + .5\sigma_\omega^2}{\sigma_\omega}, \\ lev^e &= \frac{1}{1 - g(\bar{\omega}, \sigma)rp}, \\ r^{Le} &= \bar{\omega} \frac{[r^K + (1 - \delta)q]k}{l}, \\ n^e &= \frac{qk}{lev^e}, \\ l &= qk - n^e, \\ \iota^e &= \{n^e - \omega^e ([r^K + (1 - \delta)q]kh(\bar{\omega}, \sigma_\omega))\} / n^e, \end{aligned}$$

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

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

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.

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