Domestic Financial Frictions and the Transmission of Foreign Shocks in Chile

Javier García-Cicco
Central Bank of Chile
Universidad Católica Argentina

Markus Kirchner
Central Bank of Chile

Santiago Justel
Central Bank of Chile

In the early 90's a literature emerged emphasizing the role of external factors in explaining business cycle fluctuations in emerging countries. In particular, changes in the terms of trade and world interest rates are generally viewed as the main external factors affecting these economies.[1] Additionally, part of this literature has also highlighted the role of financial frictions in explaining the propagation of external shocks where these frictions arise in the relationship between foreign lenders and domestic borrowers. The role of country premia,[2] the possibility of sovereign default,[3] and financial dollarization[4] are some of the propagation mechanisms

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1. 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.

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

3. For example, Arellano (2008), Yue (2010), and Mendoza and Yue (2012).

4. For instance, Cespedes et al. (2004), Devereux et al. (2006), and Gertler et al. (2007).

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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 crises, 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 contrast, the role of *domestic* financial frictions in propagating shocks emanating from the rest of the world has not been as deeply analyzed.[5] Such analysis might be of interest because for many emerging countries, including some in Latin America, the financial situation with the rest of the world seems to have changed in the last decade relative to the last quarter of the 20th century. For instance, most countries seem to have controlled the fiscal situation (some governments are even net foreign lenders), dollarization has been drastically reduced, country premia have not displayed the high levels they used to show years ago, and fixed exchange rate regimes (that greatly exacerbated the influence of foreign shocks) have been replaced by either managed floats or, in some cases, flexible inflation targeting frameworks. From that perspective, it might be argued that financial frictions between foreign and domestic agents are likely less relevant than they used to be. However, financial frictions between domestic agents—a factor that has been emphasized in the recent macroeconomic literature for developed countries—can still play an important role in explaining how foreign shocks affect emerging countries. In other words, while the spread between domestic and foreign interest rates could be small, it might still be the case that domestic spreads play a relevant role. And while we do not argue that frictions between domestic and foreign agents are irrelevant, the lack of studies tackling the role of domestic frictions in emerging countries motivates analysis of this issue.

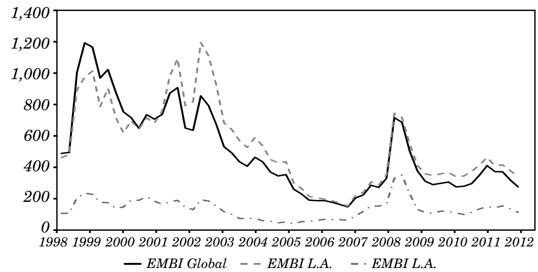
The goal of this paper is to assess the importance of domestic financial frictions in propagating external shocks in Chile. The Chilean economy has most of the characteristics of the 21th-century emerging countries that we mentioned above. Its fiscal situation is quite strong, particularly since the structural-balance rule that was introduced in 2001. Indeed, the Chilean government has a positive net external investment position, which in particular implies that

5. Some exceptions are Edwards and Vegh (1997) or Mandelman (2010) who consider how imperfections in the banking sector (e.g., monopolistic competition) propagate foreign shocks. More recently, Christiano et al. (2011) include a financial accelerator channel for the intermediation of domestic credit, but they do not focus on analyzing how this friction affects the propagation of external shocks.

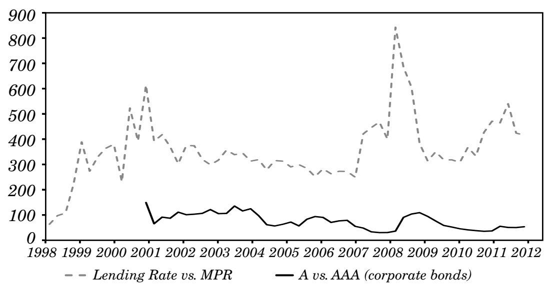
the country premium is generally quite small. For instance, as shown in figure 1 (panel A), the JP Morgan EMBI index for Chile has been significantly lower than both its world and its Latin American counterparts. Moreover, financial dollarization is almost nil in Chile. Still, the lending-deposit spread in domestic currency and the corporate bond premia are sizable, as can be seen in figure 1 (panel B). For instance, the average spread between 90-day bank 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. We take this evidence as an indication that domestic financial frictions might be a relevant propagation channel.

Figure 1. Selected Spreads (a.b.p)

A. External spreads



B. Domestic spreads



Sources: Bloomberg and the Central Bank of Chile.

To perform the analysis we develop a dynamic stochastic general equilibrium (DSGE) 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 induces a spread between lending and deposit rates. We model this friction as a moral hazard problem following the work of Gertler and Karadi (2011) (GK for short).[6] On the other hand, there is a spread between the lending rate and the return to capital (known as the external finance premium) that originates in a costly state verification problem, following Bernanke et al. (1999) (BGG for short). The model also features loans to finance working capital, although there are no informational asymmetries in this lending relationship. We estimate the model with quarterly Chilean data from 2001 to 2012, including both macro and financial variables, using Bayesian techniques. The estimated model is used to understand the role that domestic financial frictions play in the propagation of shocks to world commodity prices, foreign inflation, external demand, and world interest rates.

In the estimated model, foreign shocks have a non-trivial role as driving forces for some macro variables such as GDP, consumption, the trade balance and the country premium, particularly the shocks to commodity prices and to foreign inflation. In contrast, they have a more limited role in explaining fluctuations of other variables such as inflation, the monetary policy rate, and the real exchange rate.

When we assess the role of domestic financial frictions, we find that the latter are quite relevant in propagating foreign shocks. In particular, the analysis suggests that the behavior of the real exchange rate and its interaction with financial frictions is key to understanding how foreign shocks are propagated. For instance, when the economy is hit by a contractionary foreign shock, the real exchange rate tends to depreciate. In turn, because the home good is fully tradable in our model, the real depreciation improves (relative to a model with no financial frictions) the financial position of these firms, leading to a reduction in the premium they face. Thus, the negative effect on investment might be ameliorated in the presence of financial frictions.

However, another relevant channel in place, particularly for the propagation of commodity price shocks, is the presence of working

6. The Gertler and Karadi framework has become quite popular in 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).

capital loans, and its interaction with financial frictions. As we mentioned in our model, firms need to finance part of their operating costs (working capital) with loans, although there are no frictions in this lending activity. However, banks also have the possibility to lend to entrepreneurs that are subject to frictions. Thus, whenever the financial situation of these entrepreneurs worsens and the interest rate that banks charge them rises, it would also increase the rate that firms pay for working capital financing. Thus, while there are some loans that are not subject to frictions, in our model these loans are still affected by others that do face financial constraints. This channel is not present in models that just include a BGG-type financial friction, for instance, Christiano et al. (2011), and it arises in our framework from the interaction of both types of frictions (GK and BGG).

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.[7] In addition, we are the first to estimate a model featuring banks as in Gertler and Karadi (2011) for a small open economy.[8] Finally, while several studies use estimated DSGE models to assess the role of financial frictions between domestic and foreign agents in propagating external shocks,[9] we are among the few that assess the role of domestic financial frictions.

The rest of the paper is organized as follows. Section 1 presents the model. Section 2 describes the parametrization and estimation strategy, while section 3 addresses the role of financial frictions in propagating foreign shocks. Finally, section 4 concludes and discusses some possible relevant extensions.

1. The Model

Our model shares many features with those in the literature of small open economy DSGE models, particularly those used at

7. Rannenberg (2013) combines these two features but in a closed economy setup, using a calibrated model.

8. Some examples of estimations in closed-economy frameworks with these types of banks are Villa (2013), Villa and Yang (2013), and Areosa and Coelho (2013).

9. For instance, Tovar (2006) and Fernández and Gulan (2012)

central banks.[10] The non-financial part of our framework 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 and capital utilization. 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. We also assume that firms need to pay a fraction of their operating costs (working capital) in advance, which they finance with loans from banks. The economy also exports an exogenous endowment of a commodity good.

On top of that setup, we add two kinds of domestic financial frictions. On one hand, there are banks that intermediate credit from households to entrepreneurs (to finance capital accumulation) and to firms (for working capital), and that are subject to a moral hazard problem along the lines of Gertler and Karadi (2011). On the other hand, capital accumulation by entrepreneurs is risky and subject to a costly state verification problem as in Bernanke et al. (1999), making the return on the loans obtained by banks state-contingent, as every period, a fraction of the entrepreneurs will default on their loans.

The model features 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, the international price of the commodity good, and two financial shocks. International driving forces will be the focus of our analysis.

In the main part of the paper, we describe and set up the problems faced by each agent, leaving the list of the relevant equilibrium conditions and the computation of the steady state for the appendix.

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

10. Our base model (without financial frictions) is a simplified version of the model by Medina and Soto (2007), which is the DSGE model used for policy analysis and forecasting at the Central Bank of Chile. Given the simplifications that we make, the model is closer to that in Adolfson et al. (2007).

(h_t) in each period (t= 0,1,2,...).[11] 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 can also deposit resources at banks (D_t). Expected discounted utility of a representative household is given by

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

where v_t is an exogenous preference shock.

Following Schmitt-Grohé and Uribe (2006a, 2006b), labor decisions are made by a central authority, a union, which monopolistically supplies labor to a continuum of labor markets indexed by [$i \in$ 0,1]. Households are indifferent between working in any of these markets. In each market, the union faces a demand for labor given by $h_t(i) = \left[W_t^n(i) / W_t^n \right]^{-\varepsilon_W} h_t^d$, 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 $\left(W_t^n\right)^{1-\varepsilon_W} = \int_0^1 W_t^n(i)^{1-\varepsilon_W} di$, 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 CPI inflation with weights $\vartheta_w \in 0,1]$ and $1-\vartheta_w$, respectively.

Let r_t and r_t^* denote the gross real returns on B_{t-1} and B_{t-1}^*, respectively. The real interest rate on deposits, by a non-arbitrage condition, will also equal r_t. Further, let W_t denote the real hourly wage rate, let rer_t be the real exchange rate (i.e., the price of foreign consumption goods in terms of domestic consumption goods), let T_t denote real lump-sum tax payments to the government and let Σ_t

11. Throughout, uppercase letters denote variables containing a unit root in equilibrium (either due to technology or due 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 subscripts denote non-stochastic steady state values in the stationary model.

collect real dividend income from the ownership of firms. The period-by-period budget constraint of the household is then given by

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

The household chooses C_t, h_t, $W_t^n(i)$, B_t, B_t^* and D_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

$$r_t = R_{t-1}\pi_t^{-1}, \quad r_t^* = R_{t-1}^* \xi_{t-1} \left(\pi_t^*\right)^{-1},$$

where π_t and π_t^* denote the gross inflation rates of the domestic and foreign consumption-based price indices P_t and P_t^*, respectively. The variable ξ_t denotes a country premium given by[12]

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

where ζ_t is an exogenous shock to the country premium.[13] The foreign nominal interest rate R_t^* evolves exogenously, and the domestic central bank sets R_t.

1.2 Production and Pricing

The supply side of the economy is composed of a set of monopolistically competitive firms producing different varieties of a home good with labor and capital services 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 a final group that bundles (with different combinations) the composite home and foreign goods to create a final good that will be purchased by household consumption (Y_t^C), capital goods producers (I_t) and the government (G_t). All of these firms are owned by domestic households. In addition, there is a set of competitive firms producing a homogeneous commodity good

12. See, for instance, Schmitt-Grohé and Uribe (2003) and Adolfson et al. (2007).

13. The variable A_t (with $a_t \equiv A_t / A_{t-1}$) is a non-stationary technology disturbance, see below.

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. We denote production/supply with the letter y and inputs/demand with x.

Final Goods

The final consumption good that generates utility for households, the final investment good that is used to increase the stock of capital, and expenditures by the government are produced with different technologies combining composite home and foreign goods. The three production functions are, respectively,

$$Y_t^C = \left[(1-o_C)^{\frac{1}{\eta_C}} (X_t^{C,H})^{\frac{\eta_C-1}{\eta_C}} + o_C^{\frac{1}{\eta_C}} (X_t^{C,F})^{\frac{\eta_C-1}{\eta_C}} \right]^{\frac{\eta_C}{\eta_C-1}}, \quad (3)$$

$$I_t = \left[(1-o_I)^{\frac{1}{\eta_I}} (X_t^{I,H})^{\frac{\eta_I-1}{\eta_I}} + o_I^{\frac{1}{\eta_I}} (X_t^{I,F})^{\frac{\eta_I-1}{\eta_I}} \right]^{\frac{\eta_I}{\eta_I-1}}, \quad (4)$$

$$G_t = \left[(1-o_G)^{\frac{1}{\eta_G}} (X_t^{G,H})^{\frac{\eta_G-1}{\eta_G}} + o_G^{\frac{1}{\eta_G}} (X_t^{G,F})^{\frac{\eta_G-1}{\eta_G}} \right]^{\frac{\eta_G}{\eta_G-1}}, \quad (5)$$

where $X_t^{C,H}$, $X_t^{I,H}$ and $X_t^{G,H}$ denote the demands of home composite goods by each representative firm, while $X_t^{C,F}$, $X_t^{I,F}$ and $X_t^{G,F}$ are the demands of foreign composite goods.[14] Each representative firm is competitive and takes input prices (p_t^H and p_t^F, measured in terms of the final consumption good) as well as selling prices (respectively, 1, p_t^I and p_t^G, in terms of the final consumption good) as given.

Home Composite Goods

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

14. Y_t^C will generally differ from C_t as we assume that utilization and monitoring costs are paid in final consumption units.

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

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:

$$X_t^H(j) = p_t^H(j)^{-\varepsilon_H} Y_t^H. \tag{6}$$

Home Goods of Variety *j*

Each home variety j is produced according to the technology

$$Y_t^H(j) = z_t K_t^d(j)^\alpha [A_t h_t^d(j)]^{1-\alpha}, \tag{7}$$

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. $K_t^d(j)$ denotes the demand for capital services by firm $p_t^H(j)$ while $h_t^d(j)$ denotes this firm's demand for labor. Additionally, we assume that a fraction α_L^{WC} of the operating costs need to be financed with an intra-temporal loan (i.e., $L_t^{WC} = \alpha_L^{WC}[W_t h_t(j) + r_t^K K_t^d(j)]$), with a non-state contingent nominal rate of $R_t^{L,WC}$ (with $r_t^{L,WC} \equiv R_{t-1}^{L,WC} / \pi_t$). The firm producing variety j has monopoly power but produces to satisfy the demand constraint given by (6). 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 (7). Thus, the firm's real marginal costs in units of the final domestic good is given by

$$mc_t^H(j) = \frac{1}{\alpha^\alpha (1-\alpha)^{1-\alpha}} \frac{(r_t^K)^\alpha W_t^{1-\alpha} [1 + \alpha_L^{WC}(R_t^{L,WC} - 1)]}{p_t^H z_t (A_t)^{1-\alpha}}, \tag{8}$$

which, given the assumptions, is the same for all varieties j.

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 inflation of home composite goods prices and steady state CPI inflation with weights $\vartheta_H \in 0,1]$ and $1-\vartheta_H$.[15]

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

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

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

$$X_t^F(j) = p_t^F(j)^{-\varepsilon_F} Y_t^F. \tag{9}$$

Foreign Goods of Variety

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 (9). As it takes one unit of the foreign good to produce one unit of variety j, nominal marginal costs in terms of composite goods prices are

$$P_t^F mc_t^F(j) = P_t^F mc_t^F = S_t P_t^{F*}. \tag{10}$$

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 inflation of foreign composite goods prices and steady state CPI 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.

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

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.

1.3 Capital Accumulation

Entrepreneurs

Entrepreneurs manage the economy's stock of capital (K_t). Following Bernanke et al. (1999), entrepreneurs have two distinctive features in this setup. On one hand, they have a technology available to transform new capital produced by capital-goods producers (described below) 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. $F(\omega_t^e;\sigma_{\omega,t-1})$, and p.d.f. $f(\omega_t^e;\sigma_{\omega,t-1})$, such that $E(\omega_t^e) = 1$. The variable $\sigma_{\omega,t}$ denotes the time-varying cross-sectional standard deviation of entrepreneurs' productivity, which is known in advance,[16] and is assumed to follow an exogenous process, as in, for instance, Christiano et al. (2010, 2014). On the other hand, entrepreneurs have finite lifetimes (we describe this in more detail below) and when they exit the market they transfer all their remaining wealth to households.

In each period, after the idiosyncratic productivity shock is realized, entrepreneurs rent capital services (which for each individual

16. That is, at the time the financial contract is signed, everybody knows the distribution from which individual productivity will be drawn next period.

entrepreneur $u_t \omega_t^e K_{t-1}$, where u_t denotes capital utilization)[17] to home goods producing firms, at a rental rate (in real terms) r_t^K. They face a utilization cost per unit of capital, which in real terms is given by

$$\phi(u_t) = \frac{r^K}{\phi_u}\{\exp[\phi_u(u_t - 1)] - 1\},$$

where r^K is the steady state value of the rental rate of capital services, and ϕ_u governs the importance of these utilization costs.[18] After non-depreciated capital is returned, they sell it to capital goods producers at a real price q_t. Afterwards, they buy new capital ($q_t K_t$).

We assume that purchases of new capital 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 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

$$q_t K_t = N_t^e + L_t^K,$$

where L_t^K is the loan obtained from banks in real terms. We assume that the loan contract signed at t is nominal and it specifies a non-contingent interest rate $R_t^{L,e}$ (with $r_t^{L,e} \equiv R_{t-1}^{L,e} / \pi_t$). 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 informational asymmetry takes the form of a costly-state-verification problem, as in BGG. In particular, we assume that ω_t^e is only revealed to the entrepreneur ex-post (i.e., after loan contracts have been signed) and can only be observed by a third party after paying a monitoring cost, equivalent to a fraction μ^e of the total revenues generated by the project. Thus, at the time entrepreneurs have to repay the loan they can choose to either pay it (plus the specified interest) or to default, in which case the intermediary will pay the monitoring cost and seize all entrepreneurial assets.

17. We are abusing the notation here, as u_t, ω_t^e and K_{t-1} should have an index identifying the individual entrepreneur. However, as we assume that entrepreneurs are identical ex-ante, and that $E(\omega_t^e)=1$, in equilibrium the aggregate capital service unit will be given by $u_t K_{t-1}$.

18. Note that the choice of u_t is intra-periodic, so it does not depend on financing conditions.

Following BGG, the optimal debt contract specifies a cut-off value $\bar{\omega}^e_{t+1}$ such that if $\omega^e_{t+1} \geq \bar{\omega}^e_{t+1}$ the borrower pays $\bar{\omega}^e_{t+1}[r^K_{t+1}u_{t+1} - \phi(u_{t+1}) + (1-\delta)q_{t+1}]K_t$ units of final consumption goods to the lender and keeps $(\omega^e_{t+1} - \bar{\omega}^e_{t+1})[r^K_{t+1}u_{t+1} - \phi(u_{t+1}) + (1-\delta)q_{t+1}]K_t$, while if $\omega^e_{t+1} < \bar{\omega}^e_{t+1}$ the borrower receives nothing (defaults) and the lender obtains $(1-\mu^e)\omega^e_{t+1}[r^K_{t+1}u_{t+1} - \phi(u_{t+1}) + (1-\delta)q_{t+1}]K_t$. Therefore, under the assumption of a competitive the lending market, the mapping between the cut-off value and the interest rate on the loan R^{Le}_t satisfies

$$R^{L,e}_t = \bar{\omega}^e_{t+1}[r^K_{t+1}u_{t+1} - \phi(u_{t+1}) + (1-\delta)q_{t+1}]\frac{K_t}{L^K_t}\pi_{t+1}, \tag{11}$$

where the right-hand side is the return obtained by the bank for each unit of money lent from an entrepreneur that pays back the loan. As we assume that entrepreneurs bear all the risk (as in BGG), this condition is assumed to hold state by state.

While R^{Le}_t denotes the interest rate of a loan signed at , the ex-post return for the intermediary for each unit lent at t (which we denote by $R^{L,K}_{t+1}$, with $r^{(L,K)}_t \equiv R^{(L,K)}_t / \pi_t$) is not equal to R^{Le}_t for two reasons: not all loans will be repaid and, 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 known at the time the contract is signed, 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

$$L^K_t r^{L,K}_{t+1} \leq g(\bar{\omega}^e_{t+1};\sigma_{\omega,t})[r^K_{t+1}u_{t+1} - \phi(u_{t+1}) + (1-\delta)q_{t+1}]K_t, \tag{12}$$

where the terms in brackets on the right-hand side of (12) are the average (across entrepreneurs) revenue obtained at t+1 if the amount of capital purchases at t was K_t, and with

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

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. As we will see below, the banks' problem defines a non-arbitrage condition that relates the *expected value* of $R_{t+1}^{L,K}$ with other interest rates relevant for banks. Thus, (12) is the participation constraint for the banks to be willing to lend.[19] As before, this condition holds state-by-state under the assumption that entrepreneurs bear all the risk.

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

$$E_t \left\{[r_{t+1}^K u_{t+1} - \phi(u_{t+1}) + (1-\delta)q_{t+1}]K_t h(\bar{\omega}_{t+1}^e; \sigma_{\omega,t})\right\}, \tag{13}$$

where

$$h(\bar{\omega}_t^e; \sigma_{\omega,t-1}) \equiv \int_{\bar{\omega}_t^e}^{\infty} \omega^e f(\omega^e; \sigma_{\omega,t-1}) d\omega^e - \bar{\omega}_t^e [1 - F(\bar{\omega}_t^e; \sigma_{\omega,t-1})]. \tag{14}$$

The first term on the right-hand side of (14) 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., $\bar{\omega}_t^e \geq \omega_t^e$). 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 (13) is maximized subject

19. A technical note: As we have stated the model, it turns out that 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 the BGG model to merge within the Gertler and Karadi framework is the assumption that the loan rate $r_t^{L,e}$ 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 $r_t^{L,e}$ is irrelevant. This is so because, as the required return $r_{t+1}^{L,K}$ 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 such a setup is the usual way the BGG model is implemented an equation like (11) is generally omitted as an equilibrium condition). However, if in the original BGG model the participation constraint for the lender holds in expectations, we do require $r_t^{L,e}$ to be non-contingent. In such a case, it is precisely equation (11) 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 $r_t^{L,e}$ to be non-contingent is because $r_{t+1}^{L,K}$ is not determined by any other equilibrium condition (the intermediary's problem just pins down $E_t\{r_{t+1}^{L,K}\}$). Thus, in our framework, equation (11) pins down $\bar{\omega}_{t+1}^e$ and, given that value, (12) determines $r_{t+1}^{L,K}$. Under the other alternative, the equilibrium is indeterminate because only equation (12) displays both $r_{t+1}^{L,K}$ and $\bar{\omega}_{t+1}^e$, and there is no other equation that determines one of these.

to (12) being satisfied with equality for every possible aggregate state at $t+1$. As shown in the appendix, the optimality condition for this contract can be written as follows:

$$E_t\left\{\frac{[r^K_{t+1}u_{t+1}-\phi(u_{t+1})+(1-\delta)q_{t+1}]}{q_t}\left[\frac{h'(\bar{\omega}^e_{t+1};\sigma_{\omega,t})g(\bar{\omega}^e_{t+1};\sigma_{\omega,t})}{g'(\bar{\omega}^e_{t+1};\sigma_{\omega,t})}-h(\bar{\omega}^e_{t+1};\sigma_{\omega,t})\right]\right\}=E_t\left\{r^{L,K}_{t+1}\frac{h'(\bar{\omega}^e_{t+1};\sigma_{\omega,t})}{g'(\bar{\omega}^e_{t+1};\sigma_{\omega,t})}\right\}, \quad (15)$$

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

Finally, average entrepreneurs' net worth evolves over time as follows. The average return an entrepreneur gets after repaying its loan at t is given by $[r^K_t u_t-\phi(u_t)+(1-\delta)q_t]K_{t-1}h(\bar{\omega}^e_t;\sigma_{\omega,t-1})$. We assume that only a fraction of entrepreneurs survives every period, and an equivalent fraction enters the market with an initial capital injection from households equal to $\frac{\iota^e}{1-\upsilon}n^e A_{t-1}$, with $\iota^e>0$ (i.e., a fraction $\frac{\iota^e}{1-\upsilon}$ of balanced-growth-path net worth).[20] Thus, we have

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

Capital Goods

Capital goods producers operate the technology that allows 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 (which they buy at a price P^I_t) 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

$$K_t=(1-\delta)K_{t-1}+[1-\text{“}\left(I_t/I_{t-1}\right)]\varpi_t I_t,$$

20. Entrepreneurs that leave that market transfer their remaining resources to households.

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 ϖ_t is an investment shock that captures changes in the efficiency of the investment process (see, for instance, Justiniano et al., 2011).

1.4 Banks

We assume the presence of competitive financial intermediaries (banks) that take deposits from households and combine them with their own net worth to produce loans to both firms and to entrepreneurs. Following Gertler and Karadi (2011), the relationship between households and banks is characterized by a moral hazard problem that gives rise to a premium between lending and deposit rates.

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

$$L_t^{WC}+L_t^K=D_t+N_t,$$

where D_t denote deposits by domestic households at this intermediary, L_t^{WC} and L_t^K denote the intermediary's stock of loans to, respectively, home goods producing firms and entrepreneurs, 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:

$$\begin{aligned}N_{t+1}&=r_{t+1}^{L,WC}L_t^{WC}+r_{t+1}^{L,K}L_t^K-r_{t+1}D_t=(r_{t+1}^{L,WC}-r_{t+1})L_t^{WC}\\&\quad+(r_{t+1}^{L,K}-r_{t+1})L_t^K+r_{t+1}N_t\end{aligned}\tag{16}$$

where $r_t^{L,WC}$ and $r_t^{L,K}$ denote the real gross returns on both types of loans.[21/22]

21. These real rates relate to their nominal counterparts in a similar way as the real domestic deposit rate r_t defined above.

22. We assume that, while loans to working capital are intra-periodic, firms repay loans after banks' choices in period t have been made, which is the same as assuming that the return from this loan is received in the next period as in (16). This is in line with the assumption of working capital loans in the related literature without banks (e.g., Christiano et al. 2014).

Financial intermediaries have finite lifetimes. At the beginning of period $t+1$, after financial payouts have been made, the intermediary continues operating with probability ω and exits the intermediary sector with probability $1-\omega$, 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 households' stochastic discount factor for real payoffs.

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

$$V_t \geq \mu_t (L_t^{WC} + L_t^K) \tag{17}$$

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 μ_t will make this constraint tighter, making the financial problem more severe.

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

$$V_t = \rho_t^{L,WC} L_t^{WC} + \rho_t^{L,K} L_t^K + \rho_t^N N_t, \tag{18}$$

where

$$\rho_t^{L,WC} = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\omega)(r_{t+1}^{L,WC} - r_{t+1}) + \omega \frac{L_{t+1}^{WC}}{L_t^{WC}} \rho_{t+1}^{L,WC} \right] \right\},$$

$$\rho_t^{L,K} = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\omega)(r_{t+1}^{L,K} - r_{t+1}) + \omega \frac{L_{t+1}^K}{L_t^K} \rho_{t+1}^{L,K} \right] \right\},$$

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

Holding the other variables constant, $P_t^{L,WC}$ and $P_t^{L,K}$ are the expected discounted marginal gain of an additional unit of each type of loan, while P_t^N is the expected discounted marginal gain, and additional unit, of net worth.

The intermediary maximizes (18) subject to (17) taking N_t as given. The first-order conditions to this problem are as follows:

$$L_t^{WC} : (1 + \varrho_t)\,\rho_t^{L,WC} - \mu_t\,\varrho_t = 0,$$
$$L_t^{K} : (1 + \varrho_t)\,\rho_t^{L,K} - \mu_t \grave{u}_t = 0,$$
$$\varrho_t : \rho_t^{L,WC} L_t^{WC} + \rho_t^{L,K} L_t^{K} + \rho_t^{N} N_t - \mu_t (L_t^{WC} + L_t^{K}) \geq 0,$$

where $\varrho_t \geq 0$ is the multiplier associated with the incentive constraint. The second condition holds with equality if $\varrho_t > 0$, otherwise it holds with strict inequality. Notice that the optimality conditions for each type of loan implies that $\rho_t^{L,WC} = \rho_t^{L,K} \equiv \rho_t^{L}$. In other words, as the incentive constraint is symmetric for both types of loans, banks need to be indifferent ex-ante between lending one unit to firms or to entrepreneurs. However, the arbitrage condition is simply not that the expected return of both loans are ex-ante identical (not even up to first order), because the marginal value for each type of loan depends on the growth rate of each of these loans. In addition, either of the conditions for the choice of loans imply that

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

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

$$L_t \equiv L_t^{WC} + L_t^{K} = lev_t N_t,$$

where

$$lev_t \equiv \frac{\rho_t^N}{\mu_t - \rho_t^L} \tag{19}$$

denotes the intermediary's leverage ratio. As indicated by (19), higher marginal gains from increasing assets P_t^L support a higher leverage ratio in the optimum, the same is true for the higher marginal gains of net worth P_t^N, while a larger fraction of divertable funds μ_t lowers the leverage ratio.

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

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

Finally, we define the average lending-deposit spread as

$$spr_t = \frac{(R_t^{L,WC} L_t^{WC} + R_t^{L,e} L_t^{K})}{L_t} \frac{1}{R_t}. \quad (20)$$

i.e., the average of both contractual loan rates, weighted by the size of each loan on total loans, relative to the deposit rate. This measure would be the data counterpart of the spread we will use for the estimation.

1.5 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 χ of the income generated in the commodity sector. We assume for simplicity that the public asset position is completely denominated in domestic currency. Hence, the government satisfies the following period-by-period constraint:

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

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

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

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

1.6 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 (10). 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

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

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

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

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

1.7 Aggregation and Market Clearing

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

$$TB_t = p_t^H X_t^{H*} + rer_t p_t^{Co*} Y_t^{Co} - rer_t M_t. \tag{21}$$

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

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

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

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

1.8 Driving Forces

The exogenous processes in the model are ν_t, ϖ_t, z_t, a_t, ζ_t, R_t^*, π_t^*, P_t^{Co*}, y_t^{Co}, y_t^*, g_t, μ_t and $\sigma_{\omega,t}$. For each of them, we assume a process of the form

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

for $x = \left\{ \upsilon, \varpi, z, a, \zeta, R^*, \pi^*, p^{Co*}, y^{Co}, y^*, g, \mu, \sigma_\omega \right\}$, where the ε_t^x are i.i.d. Gaussian shocks.

1.9 Alternative Versions of the Model

In addition to this complete model, for comparison purposes we will also consider three alternative versions. The Base model is one in which there are no financial frictions (i.e., with no banks and where entrepreneurs do not face idiosyncratic shocks), and households lend directly to both firms and entrepreneurs. The GK model features banks following Gertler and Karadi (2011) as we have described, but entrepreneurs face no financial frictions.[23] The BGG model is one with entrepreneurs facing the costly-state-verification problem we have detailed above, but where they obtain funds directly from households. Finally, the full model we have described will be labeled as GK+BGG.

2. 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 not related with financial frictions that are endogenously determined in steady state are: β, π^*, k, o^*, $\bar{g}$, $\bar{b}^*$ and $\bar{y}^{Co}$. For most of the calibrated 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), ω (the fraction of surviving banks), ι (the capital injection for new banks), μ^e (bankruptcy costs), υ (the fraction of surviving entrepreneurs), ι^e (the capital injection for new entrepreneurs), and σ_ω (the steady state value of entrepreneurs' dispersion).

23. In this version of the model, we force the share of total capital purchases financed by loans to be the same as in the model with BGG entrepreneurs. Moreover, following Gertler and Karadi (2011), we assume in this version of the model that loans to entrepreneurs are state-contingent.

Table 1. Calibrated Parameters

Param.	*Description*	*Value*	*Source*
σ	Risk aversion	1	Medina and Soto (2007)
ϕ	Frisch elasticity	1	Adolfson et al. (2008)
a	Capital share in production	0.33	Medina and Soto (2007)
δ	Capital depreciation	0.06/4	Medina and Soto (2007)
ε_H	E.o.S. domestic aggregate	11	Medina and Soto (2007)
ε_F	E.o.S. imported aggregate	11	Medina and Soto (2007)
o_C	Share F of in Y^C	0.26	Input-ouput matrix (2008-2012)
o_I	Share of F in I	0.36	Input-ouput matrix (2008-2012)
o_G	Share of F in G	0	Normalization
χ	Government share in commodity sector	0.61	Average (1987-2012)
s^{tb}	Trade balance to GDP in SS	4%	Average (1987-2012)
s^{g}	Gov. exp. to GDP in SS	11%	Average (1987-2012)
s^{Co}	Commodity prod. to GDP in SS	10%	Average (1987-2012)
$\bar{\pi}$	Inflation in SS	3%	Inflation Target in Chile
p^H	Relative price of H in SS	1	Normalization
h	Hours in SS	0.3	Normalization
$\bar{a}$	Long-run growth	2.50%	4.5% GDP - 2% labor force grth. (avg. 01-12)
R	MPR in SS.	5.80%	Fuentes and Gredig (2008)
R^*	Foreign rate in SS	4.50%	Fuentes and Gredig (2008)
ξ	Country premium in SS	140bp	EMBI Chile (avg. 01-12)
lev	Leverage financial sector	9	Own calculation (see text)
$spread$	90 days lending-borrowing spread	380bp	Loan rate vs. MP rate (avg. 01-12)
ι	Injection for new bankers	0.002	Gertler and Karadi (2011)
μ_e	Bankruptcy cost	0.12	Christiano et al. (2010)
υ	Survival rate of entrepreneurs	0.97	Bernanke et al. (1999)
rp	Entrepreneurs' external finance premium	120bp	Spread A vs. AAA, corp. bonds (avg. 01-12)
lev^e	Entrepreneurs' leverage	2.05	For the non-financial corp. sector (avg. 01-12)

Table 1. (continued)

Param.	*Description*	*Value*	*Source*
$\rho_{y^{Co}}$	Auto corr. y^{Co}	0.4794	Own estimation
ρ_g	Auto corr. g	0.6973	Own estimation
ρ_{R^*}	Auto corr. R^*	0.9614	Own estimation
ρ_{y^*}	Auto corr. y^*	0.8665	Own estimation
ρ_{π^*}	Auto corr. π^*	0.3643	Own estimation
$\rho_{p^{Co*}}$	Auto corr. p^{Co*}	0.962	Own estimation
$\sigma_{y^{Co}}$	St. dev. shock to y^{Co}	0.0293	Own estimation
σ_g	St. dev. shock to g	0.0145	Own estimation
σ_{R^*}	St. dev. shock to R^*	0.0011	Own estimation
σ_{y^*}	St. dev. shock to y^*	0.0062	Own estimation
σ_{π^*}	St. dev. shock to π^*	0.0273	Own estimation
$\sigma_{p^{Co*}}$	St. dev. shock to p^{Co*}	0.1413	Own estimation

Note: All rates and spreads are annualized figures.

We target the following averages for financial variables. We set the spread between the interest rate on entrepreneurs ($R^{L,e}$) and the deposit rate (R) to 380 basis points, which corresponds to the average spread between 90-day loans and the monetary policy rate.[24, 25] We further set the bank leverage ratio 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 ≈ 13 x 0.66). For the entrepreneurs' problem, we choose a steady state leverage of 2.05, which corresponds to the average leverage between

24. All the rates and spread figures are presented here in annualized terms, although in the mod el they are included on a quarterly basis.

25. We match this spread instead of the one defined in (20) because the computation of the steady state simplifies significantly with this choice. At the posterior mode, the difference between these two spreads is less than 3 annualized basis points.

2001 and 2012 for the largest Chilean firms.[26] In addition, we also calibrate the external finance premium in steady state (rp), for which we choose a value of 120 basis points, which corresponds to the average between the A vs. AAA corporate-bond spread and the BBA vs. AAA spread, for the sample from 2001 to 2012.[27] Finally, as the steady state for both financial problems imposes less restriction than parameters, we normalize $\iota = 0.002$ (as in Gertler and Karadi, 2011), $\upsilon = 0.97$ (the value used by BGG) and $\mu^e = 0.12$ (in the range used by Christiano et al., 2010, for the U.S. and the EU). Thus, the parameters $\bar{\mu}$, ω, ι^e and σ_ω are endogenously set in steady state to match these targets.

We also calibrate 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 π^* we use CPI inflation (in dollars) for commercial partners, and for p^{Co*} we use international copper price deflated by the same price index we used to construct π^*.[28]

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.[29] We use the following variables (all from 2001Q3 to 2012Q4): the growth rates of real GDP, private consumption and investment, the CPI inflation rate, the monetary policy rate, the multilateral real exchange rate, the growth rate of real wages, the EMBI Chile (a proxy for ξ_t), the spread between the 90-day loan rate and the monetary policy rate (as a counterpart of spr_t), and the growth rate of total loans in the banking system.[30] We also include the variables used to estimate the exogenous processes previously described in the set of

26. 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.

27. Here we follow Christiano et al. (2010) who use the spread on corporate bonds of different credit ratings as a proxy for the premium paid by riskier firms.

28. The data source for all Chilean-related data is the Central Bank of Chile, while the other variables are obtained from Bloomberg.

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

30. Results do not significantly change if the growth rate of commercial loans is only used instead.

observables.[31] Overall, the model is estimated with 16 variables. 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 error was set to 10% of the variance of the corresponding observables. For the real exchange rate this variance was estimated.[32]

Table 2 displays the posterior mode and standard deviation of the estimated parameters in the last two columns. For many parameters the posterior mode is similar to related studies for Chile, so we only comment here on some relevant highlights. First, we can see that the estimated value for ψ (the elasticity of the country premium with respect to external debt to GDP) is quite small. While the model does not include any detailed financial friction between domestic and foreign agents, the fact that this parameter is so small can be seen as evidence on the conjecture that we described in the introduction that, at least for the case of Chile, financial frictions with foreign agents may not be a relevant transmission mechanism.

We can also see that the utilization cost parameter (ϕ_u) is significantly different from zero, which highlights the relevance of this channel to account for the data. In addition, the posterior mode indicates that the share of working capital that needs to be financed is close to 55%. As a consequence, we expect that this channel will play a relevant role in the propagation of shocks.

Finally, while the focus of this paper would be on the role of foreign driving forces, it is worth highlighting other exogenous processes that play a relevant role according to the estimation. In particular, the shocks to the marginal efficiency of investment (ω_t) and to entrepreneurs' risk ($\sigma_{\omega,t}$) are estimated to have large variances and to be quite persistent. Together, they explain more than 50% of the variance of GDP, and are also the main driving forces behind other variables such as consumption, inflation and, particularly, investment.

31. 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.

32. Similar to other papers estimating this type of model (e.g., Adolfson et al., 2007), the model cannot adequately match the variance of the real exchange rate, which motivates estimating its measurement error variance.

Table 2. Estimated Parameters, Prior and Posterior Mode

			Prior		Posterior mode	
Param.	*Description*	*Dist.*	*Mean*	*St. Dev.*	*Mode*	*St. Dev.*
ς	Habits	beta	0.7	0.1	0.69	0.09
ψ	Country premium elasticity	invg	0.01		0.007	0.002
η^C	E.o.S. $X^{C,H}$ and $X^{C,F}$	invg	1.5	0.25	1.24	0.15
η^I	E.o.S. $X^{I,H}$ and $X^{I,F}$	invg	1.5	0.25	1.35	0.19
η^*	Demand elasticity for exports	invg	0.4	0.3	0.95	0.19
γ	Inv. Adj. Cost	norm	4	1.5	4.68	1.14
θ_W	Calvo prob. Wages	beta	0.75	0.1	0.96	0.02
ϑ_W	Indexation past infl. Wages	beta	0.5	0.15	0.46	0.11
θ_H	Calvo prob. H	beta	0.75	0.1	0.82	0.02
ϑ_H	Indexation past infl. H	beta	0.5	0.15	0.10	0.04
θ_F	Calvo prob. F	beta	0.75	0.1	0.95	0.02
ϑ_F	Indexation past infl. F	beta	0.5	0.15	0.48	0.20
ρ_R	MPR Rule R_{t-1}	beta	0.75	0.1	0.77	0.03
α_π	MPR Rule π_t	norm	1.5	0.1	1.49	0.09
α_y	MPR Rule growth	norm	0.13	0.05	0.14	0.05
ϕ_u	Utilization Cost	norm	1	0.5	1.51	0.42
α_L^{WC}	Share of working capital	norm	0.7	0.25	0.55	0.09
ρ_v	AC. Pref. shock	beta	0.75	0.1	0.76	0.09
ρ_u	AC. Inv. shock	beta	0.75	0.1	1.00	0.00
ρ_z	AC. Temporary TFP shock	beta	0.75	0.1	0.86	0.04
ρ_a	AC. Permanent TFP shock	beta	0.38	0.1	0.44	0.10
ρ_ζ	AC. Country premium shock	beta	0.75	0.1	0.90	0.05
ρ_μ	AC. μ_t	beta	0.75	0.1	0.71	0.09
ρ_{σ_ω}	AC. $\sigma_{\omega,t}$	beta	0.75	0.1	0.93	0.02
σ_v	St. Dev. Pref. shock	invg	0.01		0.019	0.008
σ_u	St. Dev. Inv. shock	invg	0.01		0.138	0.019
σ_z	St. Dev. Temporary TFP shock	invg	0.01		0.017	0.003
σ_a	St. Dev. Permanent TFP shock	invg	0.01		0.003	0.0004
σ_ζ	St. Dev. Country premium shock	invg	0.003		0.001	0.0001
σ_R	St. Dev. MPR shock	invg	0.003		0.002	0.0003
σ_μ	St. Dev. μ_t	invg	0.01		0.010	0.004
σ_{σ_ω}	St. Dev. $\sigma_{\omega,t}$	invg	0.01		0.164	0.054
$\sigma_{me_{RER}}$	St. Dev. M.E. RER	norm	2.7	0.5	3.50	0.36

Source: Authors' elaboration.

3. The Role of External Shocks

Using the estimated model, we now assess how the presence of financial frictions affects the propagation of foreign shocks. In the model, there are four exogenous external variables: the world interest rate (R_t^*), the international relative price of commodities (p_t^{Co*}), world inflation (π_t^*), and world output (y_t^*). We begin by analyzing the contribution of each of these external variables to explain the unconditional variance of the domestic observables both in the full model (GK+BGG) as well as in the other alternative versions that shut down one financial friction at a time, as displayed in table 3.

Table 3. Variance Decomposition

Variable	R^*	p^{Co*}	π^*	y^*	*Sum*	R^*	p^{Co*}	π^*	y^*	*Sum*
	A. GK+BGG					*B. GK*				
ΔGDP	4	2	11	1	18	2	1	5	0	9
ΔC	5	11	4	0	19	1	3	1	0	5
ΔI	1	2	0	0	3	1	1	0	0	2
TB/GDP	7	34	9	0	50	8	47	11	0	67
π	2	3	1	0	6	1	1	0	0	2
R	3	4	1	0	7	1	1	0	0	2
rer	2	3	1	0	5	1	2	1	0	5
ξ	1	15	11	0	26	1	16	11	0	28
$spread$	1	2	4	0	8	0	0	0	0	0
ΔL	2	3	1	0	6	0	0	0	0	0
	C. BGG					*D. Base*				
ΔGDP	2	1	6	0	9	4	2	9	1	16
ΔC	6	16	4	0	26	1	3	1	0	4
ΔI	0	1	0	0	1	1	1	0	0	3
TB/GDP	8	45	11	0	64	7	26	7	0	40
π	4	5	2	0	11	1	1	0	0	2
R	4	5	2	0	11	1	1	0	0	2
rer	2	3	1	0	6	1	1	0	0	2
ξ	1	22	14	0	38	1	6	5	0	12
$spread$	0	0	0	0	0					
ΔL	0	1	0	0	1					

Source: Authors' elaboration.

We can see that in the estimated model (panel A) external shocks explain an important fraction of the variance of some macro variables, in particular the trade balance, GDP, consumption and the country premium, while these shocks are less important for other variables such as inflation, the policy rate, and the real exchange rate. Of the four foreign shocks, the price of commodities seems to be the most relevant on average, followed by foreign inflation and the world interest rate, while foreign output plays a negligible role.

When this decomposition is applied to the model featuring no financial frictions (panel D) we can see that the relative importance of external shocks in explaining these domestic variables decreases significantly. The largest decrease can be noted in the case of commodity price shocks, which play a much smaller role in the Base model for consumption, the trade balance, and the country premium. Foreign inflation also plays a relatively smaller role in the Base model.

The comparison with the other two alternative models that feature only one financial friction (panels B and C) sheds light on which of the two frictions might be behind the differences found between the GK+BGG and the Base model. In particular, it seems that the BGG frictions are relatively more relevant to explain how foreign shocks propagate to consumption, inflation, and the policy rate. On the other hand, both frictions appear to be relevant to explain the role of foreign shocks in the GK+BGG model for the trade balance and the country premium.

To better understand how financial frictions alter the propagation of the foreign shocks, we analyze the impulse responses generated by these disturbances under the four different versions of the model. Figure 2 displays the responses obtained after an increase in the world price of commodities. Qualitatively, this shock generates a positive wealth effect (which is quite large given the estimated persistence for this shock) that raises consumption. In turn, by increasing the demand for domestic goods, the rise in desired consumption raises the marginal product of capital, also expanding investment. The increase in absorption leads to a real appreciation. In the Base model with no financial frictions, inflation experiences a minor drop, led by a reduction in the domestic price of imported goods due to the real appreciation. Consequently, the policy rate drops mildly.

Figure 2. Impulse Responses to a Commodity Price Shock

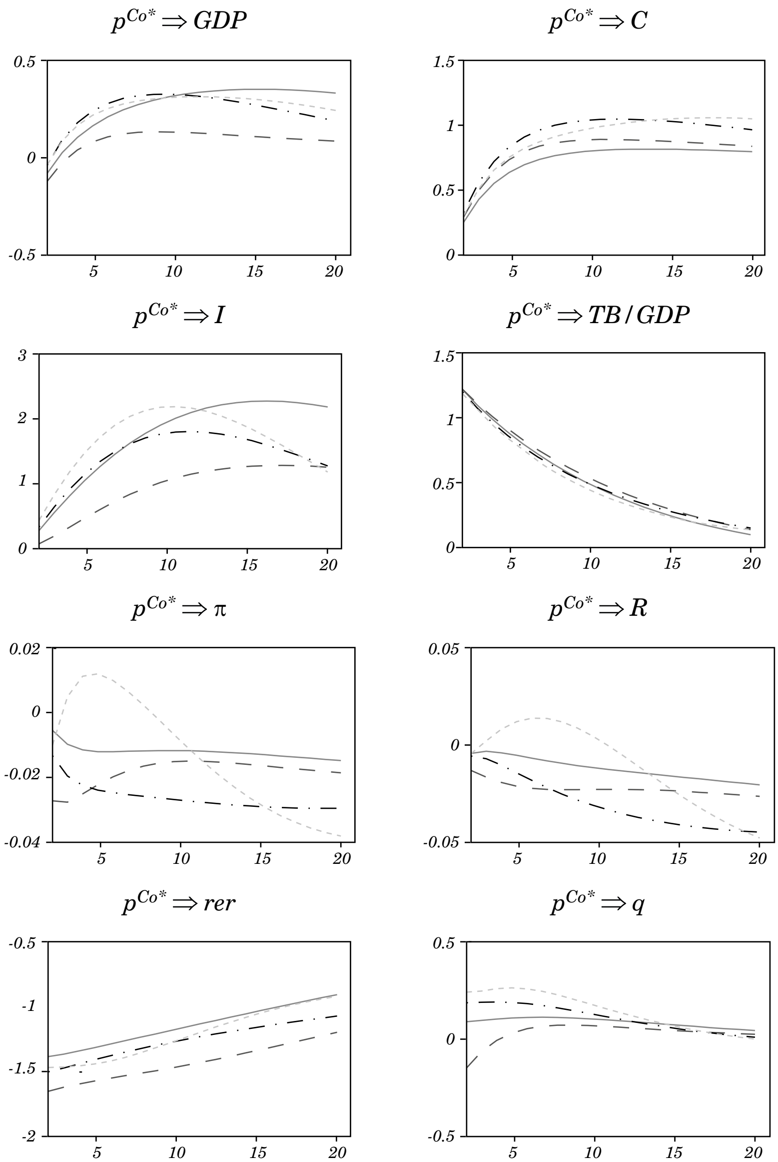
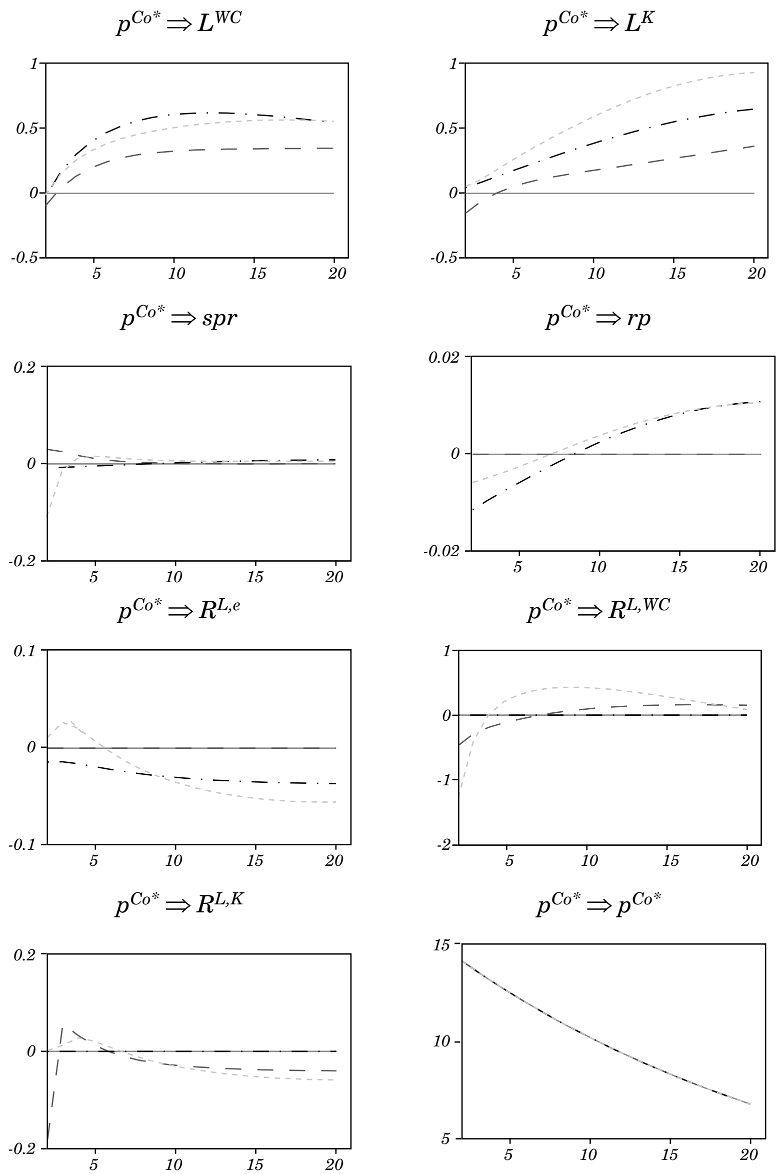


Figure 2. (continued)



Note: The solid lines are from the Base model, the dashed-grey lines correspond to the GK model, the dash-dotted black lines are from the BGG model, and the dash-short light grey lines represent the GK-BGG model. Responses where computed at the posterior mode estimated with the GK+BGG model, and correspond to one-standard-deviation innovations. The variables included in the graph are GDP, consumption, investment, the trade-balance-to-GDP ratio, CPI inflation, the monetary policy rate, the real exchange rate, the price of capital, loans to working capital and to entrepreneurs, the bank spread, the external finance premium, the nominal interest rates on entrepreneurs loans and on working capital loans, the (ex-post) nonimal return on loans to entrepreneurs, and the variable being shocked. Responses of all variables are expressed as percentage deviations from their respective steady state values.

In models with only one financial friction, the rise in investment is relatively milder than in the Base model, particularly for the GK model. While the price of capital tends to rise after the shock (except in the GK model) the persistent real appreciation induces a drop 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 falls, reducing the value of assets for either entrepreneurs (in the BGG model) and financial intermediaries (in the GK model). Moreover, this effect seems to be reinforced in general equilibrium, as the *rer* appreciates by more in both models. Overall, financial conditions become more restrictive. In the GK model, this can be seen by a rise in the spread, while in the BGG model we can see that the external finance premium, while dropping in the first periods, it is expected to rise in the medium term. Quantitatively, this seems to be more important for the GK model than for the BGG framework.

Consumption, on the other hand, increases by more in both the GK and the BGG models. This can be attributed in part to the larger reduction in the policy rate that is produced in the presence of financial frictions.

When we consider the GK+BGG model that features both frictions, there is an additional channel in place that makes investment more responsive to the increase in commodity prices. In this model, the bank's problem implies that the interest rate charged on working-capital loans is affected by the expected return on loans to entrepreneurs,[33] which in turn is affected by financial frictions as well.[34] Thus, as financial conditions are expected to be tighter in the future for the reasons we already described, the interest rate on working capital loans is also expected to rise by more than in the other models. Moreover, there is also a rise in the demand for working capital loans as domestic production is increasing. This expected rise in the cost to finance working capital increases the expected real marginal cost faced by firms and, as inflation in Home goods is forward looking, this tends to increase inflation *ceteris paribus*. In the figure, we can see that inflation is actually expected to rise in

33. Recall that from the Banks optimization problem, $\rho_t^{L,WC} = \rho_t^{L,K}$, which is the appropriate indifference conditions between the expected return on both types of loans.

34. In the other two models this interaction is not present. In the BGG model, where there are no banks, the interest rate on working capital loans equals the monetary policy rate. In the GK model, the rate on working capital loans is related to the expected return on capital, but in such a model this return on capital is not subject to frictions.

the first periods after the shock. In turn, given the presence of price rigidities, this provides an additional increase in investment, as the marginal product of capital is expected to increase (which can also be observed in the rise of the real price of capital q).

In terms of the role of foreign inflation shocks, figure 3 shows the effects generated by an increase in this variable. This shock affects the economy through two channels. First, it generates a positive wealth effect because exports will rise *ceteris paribus,* as the demand for exports of home goods depends negatively on foreign inflation. Second, the shock raises, *ceteris paribus*, the marginal cost of imports, generating upward pressure on imported inflation. As can be seen from the figure, the positive wealth effect generates an expansion in consumption and investment. In turn, the economy experiences a real appreciation that, in equilibrium, counteracts the direct effect on inflation from the rise in foreign prices, and inflation is reduced. Moreover, the trade balance deteriorates due to the real appreciation. The latter seems to dominate over the increase in domestic absorption in the first periods, leading to a fall in GDP; although, this effect is reversed after a few quarters and GDP rises afterwards.

The presence of financial frictions reduces the impact of this shock on investment while increasing the response of consumption. This can be attributed to the same exchange rate channel that we mentioned before: the real appreciation worsens the return on assets for entrepreneurs, leading to more restrictive financial conditions. The working capital channel that we highlighted in the case of commodity price shocks is not present because, as production of home goods falls as we already mentioned, the demand for working capital loans is reduced. Thus, while from the banks perspective they would like to raise the interest rate on working capital loans due to the increase in the required interest rate for entrepreneurs (i.e., the supply for working capital loans is reduced), in equilibrium, the contraction in the demand for working capital loans dominates and the interest rate on these loans falls.

Figure 3. Impulse Responses to a Foreign Inflation Shock

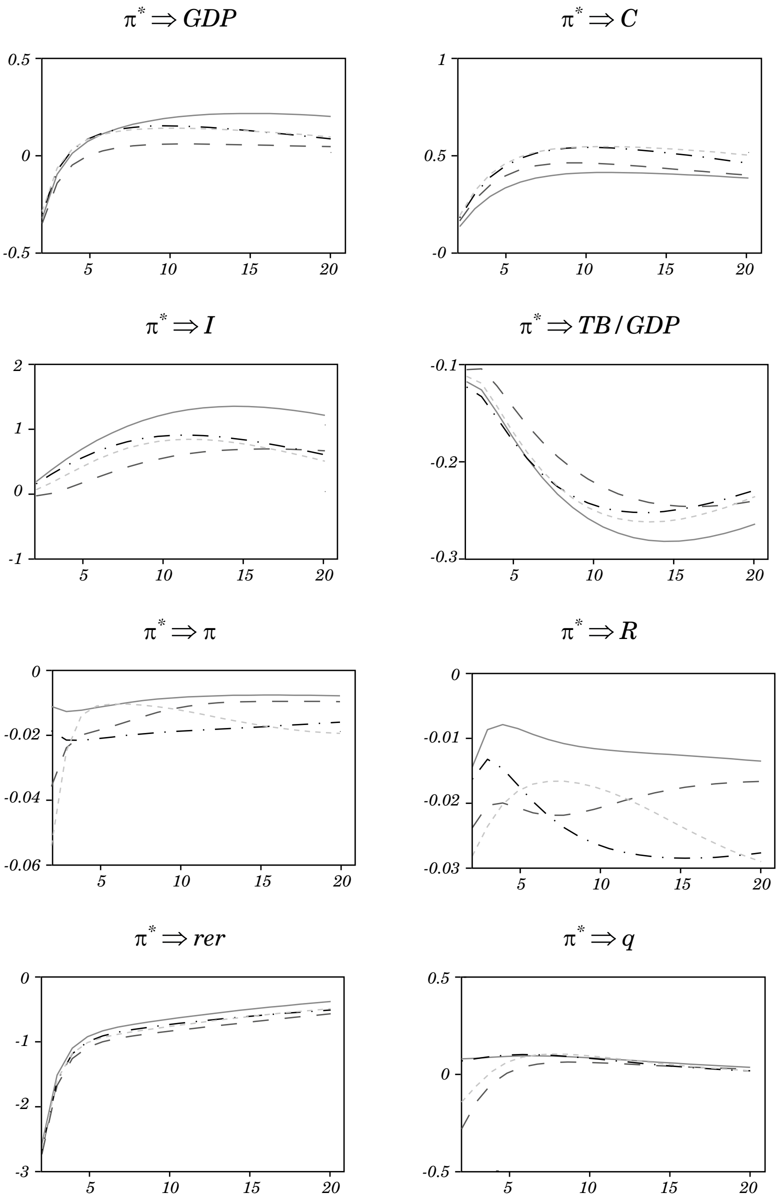
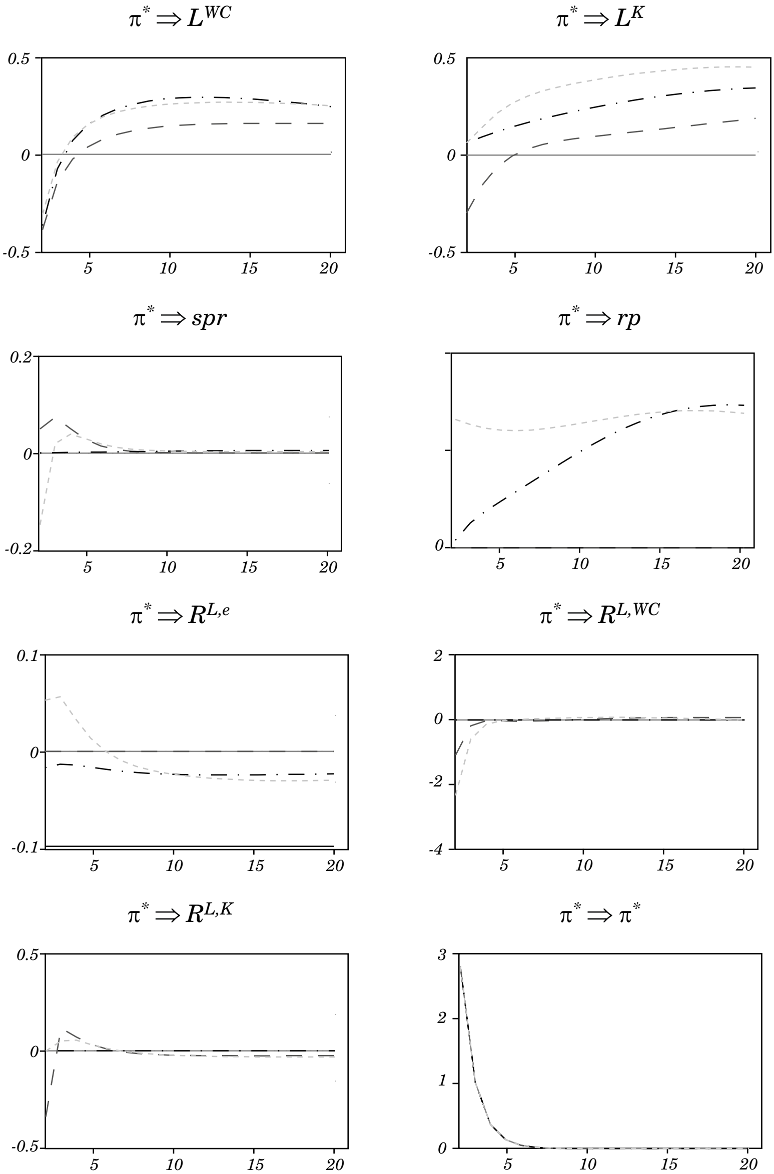


Figure 3. (continued)



Note: See figure 2.

Figure 4 displays the responses to an increase in the world interest rate. Regardless of the presence of financial frictions, this shock is contractionary for both consumption and investment. This happens because it reduces consumption through both a negative wealth effect and through an intertemporal substitution effect. It also contracts investment because it increases the real interest rate. This drop in aggregate absorption generates a real depreciation, which in turn raises 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. In the first periods, output increases as the trade balance effect dominates, but after 3 quarters, the output effect turns negative.

The presence of financial frictions dampens the response of investment to this shock. While the price of capital tends to fall after the shock, the persistent real depreciation induces an increase in the marginal product of capital (equal to the rental rate) because home firms produce tradable goods (i.e., the same exchange rate channel mentioned above). 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 are relaxed after this shock (the external finance premium is 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.

We finish the analysis by computing the historical decomposition of consumption and investment growth to assess the role of the four external shocks in explaining the observed macroeconomic fluctuations over the sample period. This exercise complements the previous analysis as 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 domestic financial frictions changes the role that external shocks had during the 2008-2009 recession triggered by the financial crisis in the U.S.

Figure 4. Impulse Responses to a World Interest Rate Shock

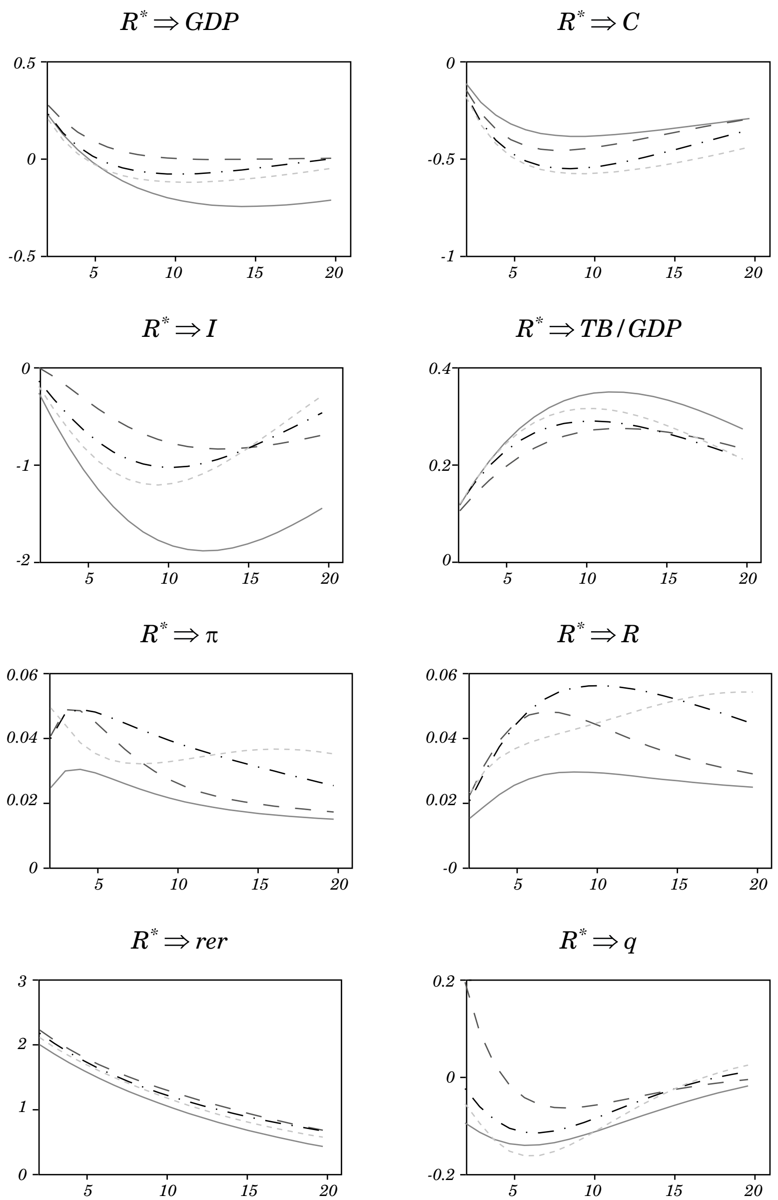
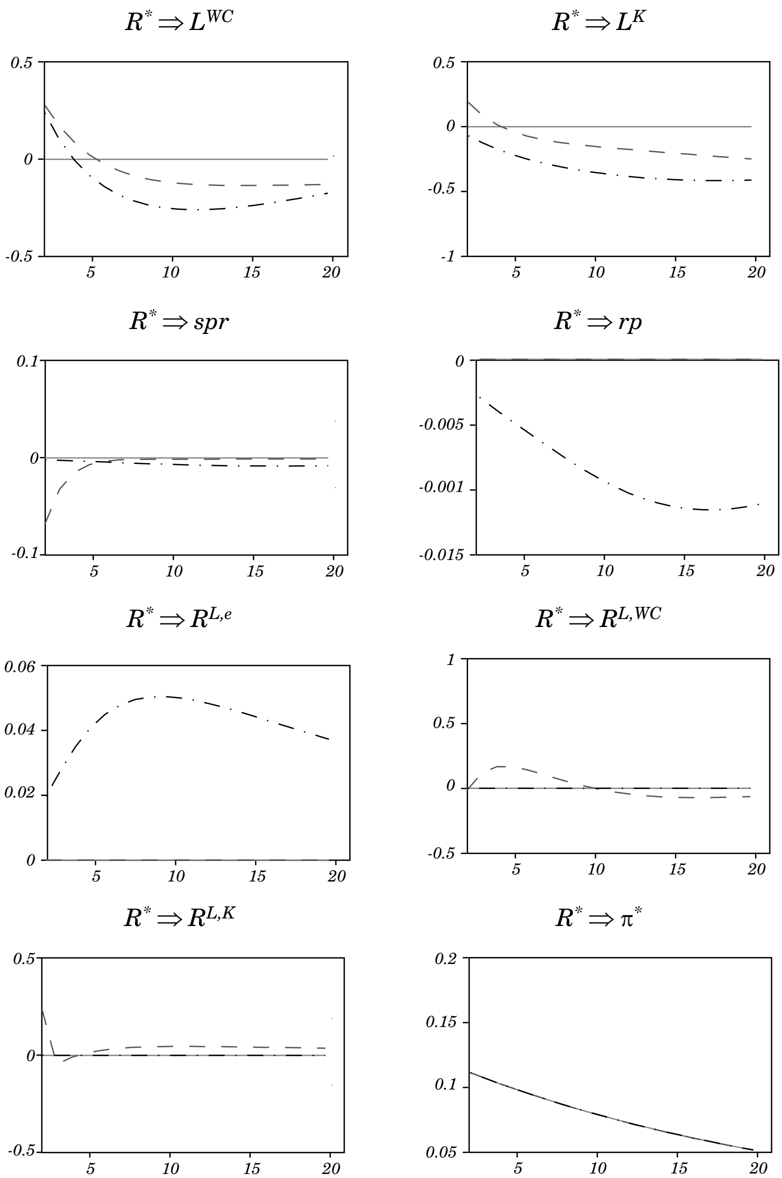


Figure 4. (continued)

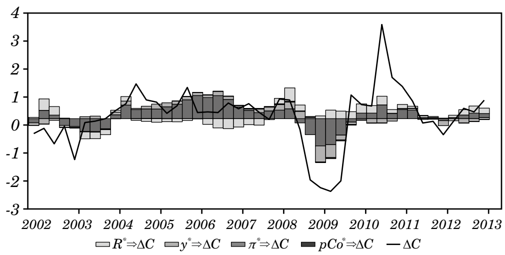


Note: See figure 2.

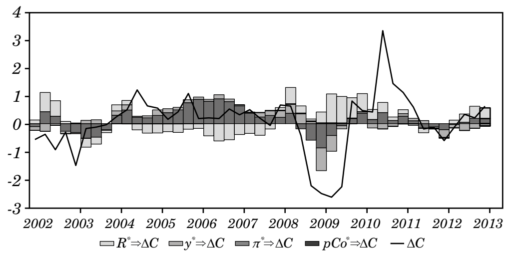
In figure 5 we display the historical decomposition for consumption growth. As expected, given the results previously analyzed, the role of external variables in explaining the evolution of consumption is amplified in the GK-BGG model, both in normal times and during the crisis. For the 2008-2009 episode, we can see how the alternative models assign different roles for international factors in explaining the contraction in consumption. In particular, according to the Base model, the drop in the price of commodities and, to a lesser extent, in foreign inflation, contributed to a drop in consumption: combined they explain more than a half of the drop in consumption growth in 2008Q4 and in 2009Q1.

Figure 5. Historical Decomposition of Consumption Growth Due to Foreign Shocks

Base



GK+BGG



Note: Historical decomposition computed at the posterior mode.

In the GK+BGG model, the contribution of the drop of commodity prices is relatively smaller, particularly in 2009Q1. In addition, the model infers that the fall in the world interest rate had an important contribution in ameliorating the effect of the recession. In particular, the drop in consumption growth would have been close to one percent larger in 2009 without the shocks to the world interest rate.[35] In contrast, the contribution of this shock is perceived as more modest in the Base model.

The historical decomposition for investment is displayed in figure 6. Focusing on the 2008-2009 contraction, we can again see how the presence of domestic financial frictions implies a different story for the contribution of external shocks. In the Base model, foreign shocks appear to have a limited role in explaining the drop in investment. In contrast, in the GK+BGG model, external shocks are relatively more important.[36] In particular, the fall in commodity prices had a larger impact on the contraction of investment than in the Base model. This is in line with the above impulse-response analysis: the presence of financial frictions exacerbated the response of investment to this shock. In addition, as in the decomposition of consumption, the GK+BGG model also assigns an ameliorating role to the drop in the world interest rate during this period.

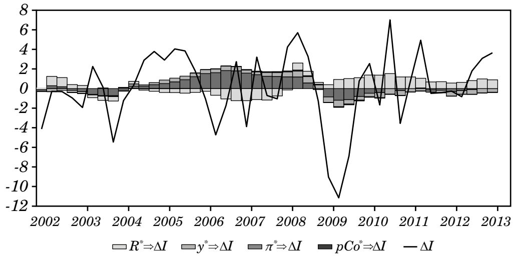
Overall, not only unconditionally as in the variance-decomposition analysis, but also in particular episodes such as during the 2008-2009 recession, accounting for domestic financial frictions seems to be particularly relevant to understand how foreign shocks propagate throughout the economy.

35. Obviously the drop in the world interest rate was produced by the expansionary monetary policy that the central banks in the developed world implemented in response to the crisis. However, as we argued in the analysis of the impulse response to shocks in the world interest rate, the impact of this world shock on consumption is exacerbated by the movement in the domestic policy rate, as the central bank is concerned by the change in inflation that this shocks generates (and this effect is large in the presence of financial frictions). Thus, the domestic central bank was also in part responsible for this countercyclical effect that the world interest rate shocks seem to have had.

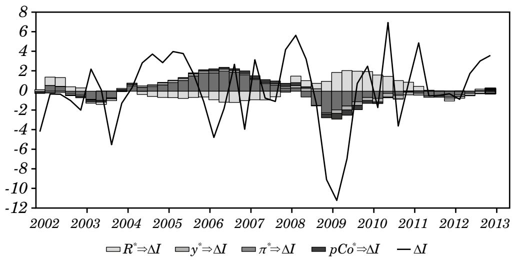
36. As can be seen in the figure, in either case, foreign shocks explain less than a quarter of the total drop in investment in that period. According to the GK+BGG model the shocks to entrepreneurs' risk ($\sigma_{w,t}$) was mainly responsible for this drop.

Figure 6. Historical Decomposition of Investment Growth Due to Foreign Shocks

Base



GK+BGG



Note: Historical decomposition computed at the posterior mode.

4. Conclusions

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

Our results showed that, because the frictions are between domestic agents, the effect of the shock on the real exchange rate is crucial to understand the amplification of external shocks. In particular, the responses of investment and, to a lesser extent, output tend to be milder in the presence of financial frictions, while the responses of consumption and inflation are exacerbated. However, we also detected that in some cases the presence of the working capital channel could also provide additional amplification for these shocks, particularly if it interacts with both financial frictions. We have also shown that in the presence of domestic financial frictions the contribution of external factors in explaining the evolution of some macro variables during the 2008-2009 recession is larger and significantly different than in a model without these frictions.

To conclude, there are several aspects of our framework that deserve to be discussed, as they can point to future improvements in the analysis. First, in our model financial frictions are always binding. In contrast, part of the literature has emphasized financial frictions that are only occasionally binding, particularly in the lending relationship between domestic and foreign agents.[37] Assuming that frictions are always binding is convenient from a computational point of view (for it allows solving the model using perturbation methods),[38] but of course we can be missing important dynamics. For instance, while we argued in the introduction that the EMBI spread for Chile has been relatively small, it still experienced a spike during the 2008 world financial crisis. A similar sudden increase could also be seen in domestic spreads. This might reflect that financial conditions became suddenly more restrictive than in normal times. Still, in that particular episode it is not easy to disentangle if this was the channel in place, since the size of the external shock was also larger than usual. Thus it might be of interest to extend our analysis by considering a model in which financial frictions bind occasionally. Nonetheless, while of course this might be relevant from a quantitative point of view; qualitatively, the analysis in this paper is still useful to understand the relevant channels that might be part of the propagation of foreign shocks.

In addition, given the highlighted relevance of 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 tradable and in that way,

37. Some examples are Mendoza (2010), Benigno et al. (2013), and Bianchi (2011).

38. Linearization not only allows to estimate the model with a likelihood approach more easily, but it also allows to consider many other potentially relevant features of the economy in the model. Global solution methods, required to solve models with occasionally binding constraints, generally require to limit significantly the size of the model (for instance, it would be quite costly to compute the model of Mendoza (2010) assuming also sticky prices and wages with indexation).

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.

Moreover, in the presence of debt denominated in foreign currency (e.g., due to liability dollarization), the movement in the real exchange rate may have an effect opposite to the one emphasized in this paper. For instance, if the real exchange rate appreciates it will lower the burden of debt denominated in dollars, and in the presence of financial frictions it will tend, *ceteris paribus*, to reduce improving the premium. While this is true conceptually, it is less clear whether it would be a relevant channel for Chile, as liability dollarization is not a widespread phenomenon.

Another relevant issue that we did not tackle in this paper is the relative importance of domestic *vis-a-vis* foreign financial frictions in propagating external shocks. To perform such a comparison, one would need to set up a model with both types of frictions at the same time. For instance, one could consider that banks obtain 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 channel.

Alternatively, one could consider that firms (at least part of them) obtain funds not only in the domestic market but also abroad (for instance through corporate debt or equity markets). In particular, this can lead to additional and relevant dynamics as emphasized, for instance, by Caballero (2002) to explain how the Asian crisis propagated to the Chilean economy. If large firms can obtain funds both domestically and abroad while smaller firms (particularly in the non-traded sector) have only access to domestic financing, a sudden stop in capital inflows will lead these large firms to turn to the domestic market for financing, crowding-out the credit available for smaller firms. Thus, in such a setup both domestic and foreign financial frictions would be relevant for the propagation of external shocks. We left these extensions for future research.

Appendix

Model Appendix

Intermediary Objective

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

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

can be expressed as

$$V_t = \rho_t^{L,WC} L_t^{WC} + \rho_t^{L,K} L_t^{K} + \rho_t^{N} N_t.$$

First, notice that

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

Thus,

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

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

and

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

In terms of ρ_t^N,

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

or,

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

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

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

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

$$\begin{aligned}\rho_t^N &= E_t\left\{(1-\omega)\beta\Xi_{t,t+1}r_{t+1} + \beta\omega\Xi_{t,t+1}\frac{N_{t+1}}{N_t}\rho_{t+1}^N\right\}\\ &= \beta E_t\left\{\Xi_{t,t+1}\left[(1-\omega)r_{t+1} + \omega\frac{N_{t+1}}{N_t}\rho_{t+1}^N\right]\right\}.\end{aligned}$$

With an analogous procedure we can obtain the expression for $\rho_t^{L,WC}$ and $\rho_t^{L,K}$.

Entrepreneurs' Optimization Problem

Using the definition for lev_t^e and (13), the Lagrangian for the optimal-contract problem can be written as,

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

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

$$E_t \left\{ \frac{[r^K_{t+1} + (1-\delta)q_{t+1}]}{q_t} h(\overline{\omega}^e_{t+1};\sigma_{\omega,t}) + \eta_{t+1} \right.$$

$$\left. \left[g(\overline{\omega}^e_{t+1};\sigma_{\omega,t}) \frac{[r^K_{t+1} + (1-\delta)q_{t+1}]}{q_t} - (lev^e_t - 1)r^L_{t+1} \right] \right\} = 0,$$

$$h'(\overline{\omega}^e_{t+1}) + \eta_{t+1} g'(\overline{\omega}^e_{t+1}) = 0.$$

Combining these to eliminate η_{t+1} and rearranging we obtain (15) in the text.

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

$$aux^1_t \equiv \frac{ln(\overline{\omega}^e_t) + .5\sigma^2_{\omega,\,t-1}}{\sigma_{\omega,\,t-1}},$$

and, letting $\Phi(\cdot)$ be the standard normal c.d.f. and $\Phi(\cdot)$ its p.d.f., we can write,[39]

$$g(\overline{\omega}^e_t;\sigma_{\omega,\,t-1}) = \overline{\omega}_t[1 - \Phi(aux^1_t)] + (1-\mu^e)\Phi(aux^1_t - \sigma_{\omega,\,t-1}),$$

$$g'(\overline{\omega}^e_t;\sigma_{\omega,t-1}) = [1 - \Phi(aux^1_t)] - \overline{\omega}^e_t \phi(aux^1_t)\frac{1}{\sigma_{\omega,t-1}}\frac{1}{\overline{\omega}^e_t}$$

$$+ (1-\mu^e)\phi(aux^1_t - \sigma_{\omega,t-1})\frac{1}{\sigma_{\omega,t-1}}\frac{1}{\overline{\omega}^e_t}$$

$$= [1 - \Phi(aux^1_t)] - \mu^e \phi(aux^1_t),$$

$$h(\overline{\omega}^e_t;\sigma_{\omega,t-1}) = 1 - \Phi(aux^1_t - \sigma_{\omega,t-1}) - \overline{\omega}^e_t[1 - \Phi(aux^1_t)],$$

$$h'(\overline{\omega}^e_t;\sigma_{\omega,\,t-1}) = -\phi(aux^1_t - \sigma_{\omega,\,t-1})\frac{1}{\sigma_{\omega,\,t-1}}\frac{1}{\overline{\omega}^e_t}$$

$$-[1 - \Phi(aux^1_t)] + \overline{\omega}^e_t \phi(aux^1_t)\frac{1}{\sigma_{\omega,\,t-1}}\frac{1}{\overline{\omega}^e_t}$$

$$= -[1 - \Phi(aux^1_t)].$$

39. See, for instance, the appendix of Devereux et al. (2006).

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 Λ_t that is multiplied by A_{t-1} (i.e., $\lambda_t \equiv \Lambda_t A_{t-1}$), for it decreases along the balanced growth path.

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

$$\{\lambda_t, c_t, h_t, h_t^d, w_t, \tilde{w}_t, mc_t^W, f_t^W, \text{”}_t^W, i_t, k_t, r_t^K, q_t, y_t, y_t^C, y_t^F, y_t^H, x_t^{C,F}, x_t^{C,H},$$
$$x_t^{I,F}, x_t^{I,H}, x_t^{I,F}, x_t^{I,H}, x_t^{H*}, R_t, \xi_t, \pi_t, \pi_t^S, rer_t, p_t^H, \tilde{p}_t^H, p_t^F, \tilde{p}_t^F, p_t^Y, p_t^G, p_t^I, mc_t^H,$$
$$f_t^H, \text{”}_t^H, mc_t^F, f_t^F, \text{”}_t^F, b_t^*, m_t, tb_t, u_t, l_t, l_t^{WC}, l_t^{WC}, d_t, n_t, \rho_t^L, \rho_t^N, lev_t, r_t^{L,K}, r_t^{L,e},$$
$$r_t^{L,WC}, R_t^{L,e}, R_t^{L,WC}, spr_t, \bar{\omega}_t, n_t^e, rp_t, lev_t^e\}_{t=0}^{\infty},$$

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

$$\{v_t, \varpi_t, z_t, a_t, \zeta_t, \varepsilon_t^R, R_t^*, \pi_t^*, p_t^{Co*}, y_t^{Co}, y_t^*, g_t, \mu_t, \sigma_{\omega,t}\}_{t=0}^{\infty},$$

the following conditions are satisfied. Households:

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

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

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

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

$$f_t^W = mc_t^W \bar{w}_t^{-\varepsilon_W} h_t^d + \beta\theta_W E_t \left\{ \frac{\upsilon_{t+1}}{\upsilon_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_W} \pi^{1-\vartheta_W}}{\pi_{t+1}} \right)^{-\varepsilon_W} \left(\frac{\bar{w}_t}{\bar{w}_{t+1}} \right)^{-\varepsilon_W} \left(\frac{w_t}{w_{t+1}} \right)^{-1-\varepsilon_W} f_{t+1}^W \right\}, \tag{5}$$

$$f_t^W = \bar{w}_t^{1-\varepsilon_W} h_t^d \left(\frac{\varepsilon_W - 1}{\varepsilon_W} \right) + \beta\theta_W E_t \left\{ \frac{\upsilon_{t+1}}{\upsilon_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_W} \pi^{1-\vartheta_W}}{\pi_{t+1}} \right)^{1-\varepsilon_W} \left(\frac{\bar{w}_t}{\bar{w}_{t+1}} \right)^{1-\varepsilon_W} \left(\frac{w_t}{w_{t+1}} \right)^{-\varepsilon_W} f_t^W \right\}, \tag{6}$$

$$1 = (1-\theta_W)\tilde{w}_t^{1-\varepsilon_W} + \theta_W \left(\frac{w_{t-1}}{w_t} \frac{\pi_{t-1}^{\vartheta_W} \pi^{1-\vartheta_W}}{\pi_t} \right)^{1-\varepsilon_W}, \tag{7}$$

$$\Delta_t^W = (1-\theta_W)\bar{w}_t^{-\varepsilon_W} + \theta_W \left(\frac{w_{t-1}}{w_t} \frac{\pi_{t-1}^{\vartheta_W} \pi^{1-\vartheta_W}}{\pi_t} \right)^{-\varepsilon_W} \Delta_{t-1}^W, \tag{8}$$

$$h_t = h_t^d \Delta_t^W. \tag{9}$$

Composite final goods:

$$y_t^C = \left[(1-o_C)^{\frac{1}{\eta_C}} (x_t^{C,H})^{\frac{\eta_C - 1}{\eta_C}} + o_C^{\frac{1}{\eta_C}} (x_t^{C,F})^{\frac{\eta_C - 1}{\eta_C}} \right]^{\frac{\eta_C}{\eta_C - 1}}, \tag{10}$$

$$i_t = \left[(1-o_I)^{\frac{1}{\eta_I}} (x_t^{I,H})^{\frac{\eta_I - 1}{\eta_I}} + o_I^{\frac{1}{\eta_I}} (x_t^{I,F})^{\frac{\eta_I - 1}{\eta_I}} \right]^{\frac{\eta_I}{\eta_I - 1}}, \tag{11}$$

$$g_t = \left[(1-o_G)^{\frac{1}{\eta_G}} (x_t^{G,H})^{\frac{\eta_G - 1}{\eta_G}} + o_G^{\frac{1}{\eta_G}} (x_t^{G,F})^{\frac{\eta_G - 1}{\eta_G}} \right]^{\frac{\eta_G}{\eta_G - 1}}, \tag{12}$$

$$x_t^{C,H} = (1-o_C)(p_t^H)^{-\eta_C} y_t^C, \tag{13}$$

$$x_t^{C,F} = o_C (p_t^F)^{-\eta_C} y_t^C, \tag{14}$$

$$x_t^{I,H} = (1-o_I)\left(\frac{p_t^H}{p_t^I}\right)^{-\eta_I} i_t, \tag{15}$$

$$x_t^{I,F} = o_I\left(\frac{p_t^F}{p_t^I}\right)^{-\eta_I} i_t, \tag{16}$$

$$x_t^{G,H} = (1-o_G)\left(\frac{p_t^H}{p_t^G}\right)^{-\eta_G} g_t, \tag{17}$$

$$x_t^{G,F} = o_G\left(\frac{p_t^F}{p_t^G}\right)^{-\eta_G} g_t. \tag{18}$$

Home goods:

$$mc_t^H = \frac{1}{\alpha^\alpha (1-\alpha)^{1-\alpha}} \frac{(r_t^K)^\alpha w_t^{1-\alpha}[1+\alpha_L^{WC}(R_t^{L,WC}-1)]}{p_t^H z_t a_t^{1-\alpha}}, \tag{19}$$

$$\frac{u_t k_{t-1}}{h_t^d} = a_{t-1}\frac{\alpha}{1-\alpha}\frac{w_t}{r_t^K}, \tag{20}$$

$$l_t^{WC} = \alpha_L^{WC}\left(w_t h_t^d + r_t^K u_t \frac{k_{t-1}}{a_{t-1}}\right), \tag{21}$$

$$f_t^H = \left(\tilde{p}_t^H\right)^{-\varepsilon_H} y_t^H mc_t^H + \beta\theta_H E_t \left\{\frac{v_{t+1}}{v_t}\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\pi_t^{\vartheta_H}\pi^{1-\vartheta_H}}{\pi_{t+1}}\right)^{-\varepsilon_H}\left(\frac{\tilde{p}_t^H}{\tilde{p}_{t+1}^H}\right)^{-\varepsilon_H}\left(\frac{p_t^H}{p_{t+1}^H}\right)^{-1-\varepsilon_H} f_{t+1}^H\right\}, \tag{22}$$

$$f_t^H = \left(\tilde{p}_t^H\right)^{1-\varepsilon_H} y_t^H \left(\frac{\varepsilon_H - 1}{\varepsilon_H}\right) + \beta\theta_H E_t \left\{\frac{v_{t+1}}{v_t}\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\pi_t^{\vartheta_H}\pi^{1-\vartheta_H}}{\pi_{t+1}}\right)^{1-\varepsilon_H}\left(\frac{\tilde{p}_t^H}{\tilde{p}_{t+1}^H}\right)^{1-\varepsilon_H}\left(\frac{p_t^H}{p_{t+1}^H}\right)^{-\varepsilon_H} f_{t+1}^H\right\}, \tag{23}$$

$$y_t^H \Delta_t^H = z_t \left(\frac{u_t k_{t-1}}{a_{t-1}} \right)^{\alpha} (a_t h_t^d)^{1-\alpha}, \tag{24}$$

$$1 = \theta_H \left(\frac{p_{t-1}^H}{p_t^H} \frac{\pi_{t-1}^{\vartheta_H} \pi^{1-\vartheta_H}}{\pi_t} \right)^{1-\varepsilon_H} + (1-\theta_H)(\tilde{p}_t^H)^{1-\varepsilon_H}, \tag{25}$$

$$\Delta_t^H = (1-\theta_H)(\tilde{p}_t^H)^{-\varepsilon_H} + \theta_H \left(\frac{p_{t-1}^H}{p_t^H} \frac{\pi_{t-1}^{\vartheta_H} \pi^{1-\vartheta_H}}{\pi_t} \right)^{-\varepsilon_H} \Delta_{t-1}^H. \tag{26}$$

Capital accumulation:

$$k_t = (1-\delta) \frac{k_{t-1}}{a_{t-1}} + \left[1 - \frac{\gamma}{2} \left(\frac{i_t}{i_{t-1}} a_{t-1} - \bar{a} \right)^2 \right] \varpi_t i_t, \tag{27}$$

$$\begin{aligned} \frac{p_t^I}{q_t} = & \left[1 - \frac{\gamma}{2} \left(\frac{i_t}{i_{t-1}} a_{t-1} - \bar{a} \right)^2 - \gamma \left(\frac{i_t}{i_{t-1}} a_{t-1} - \bar{a} \right) \frac{i_t}{i_{t-1}} a_{t-1} \right] \varpi_t \\ & + \frac{\beta}{a_t} \gamma E_t \left\{ \frac{\upsilon_{t+1}}{\upsilon_t} \frac{\lambda_{t+1}}{\lambda_t} \frac{q_{t+1}}{q_t} \left(\frac{i_{t+1}}{i_t} a_t - \bar{a} \right) \left(\frac{i_{t+1}}{i_t} a_t \right)^2 \varpi_{t+1} \right\}. \end{aligned} \tag{28}$$

Imported goods:

$$mc_t^F = rer_t / p_t^F, \tag{29}$$

$$\begin{aligned} f_t^F = & \left(\tilde{p}_t^F \right)^{-\varepsilon_F} y_t^F mc_t^F + \beta \theta_F E_t \\ & \left\{ \frac{\upsilon_{t+1}}{\upsilon_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_F} \pi^{1-\vartheta_F}}{\pi_{t+1}} \right)^{-\varepsilon_F} \left(\frac{\tilde{p}_t^F}{\tilde{p}_{t+1}^F} \right)^{-\varepsilon_F} \left(\frac{p_t^F}{p_{t+1}^F} \right)^{-1-\varepsilon_F} f_{t+1}^F \right\}, \end{aligned} \tag{30}$$

$$\begin{aligned} f_t^F = & \left(\tilde{p}_t^F \right)^{1-\varepsilon_F} y_t^F \left(\frac{\varepsilon_F - 1}{\varepsilon_F} \right) + \beta \theta_F E_t \\ & \left\{ \frac{\upsilon_{t+1}}{\upsilon_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_F} \pi^{1-\vartheta_F}}{\pi_{t+1}} \right)^{1-\varepsilon_F} \left(\frac{\tilde{p}_t^F}{\tilde{p}_{t+1}^F} \right)^{1-\varepsilon_F} \left(\frac{p_t^F}{p_{t+1}^F} \right)^{-\varepsilon_F} f_{t+1}^F \right\}, \end{aligned} \tag{31}$$

$$1 = \theta_F \left(\frac{p_{t-1}^F}{p_t^F} \frac{\pi_{t-1}^{\vartheta_F} \pi^{1-\vartheta_F}}{\pi_t} \right)^{1-\varepsilon_F} + (1-\theta_F)(\tilde{p}_t^F)^{1-\varepsilon_F}. \tag{32}$$

$$m_t = y_t^F \Delta_t^F, \tag{33}$$

$$\Delta_t^F = (1-\theta_F)(\tilde{p}_t^F)^{-\varepsilon_F} + \theta_F \left(\frac{p_{t-1}^F}{p_t^F} \frac{\pi_{t-1}^{\vartheta_F} \pi^{1-\vartheta_F}}{\pi_t} \right)^{-\varepsilon_F} \Delta_{t-1}^F. \tag{34}$$

Entrepreneurs:

$$r_t^K = r^K \exp[\phi_u (u_t - 1)], \tag{35}$$

$$l_{t-1}^K r_t^{L,K} = g(\bar{\omega}_t; \sigma_{\omega,\, t-1})[r_t^K u_t - \phi(u_t) + (1-\delta) q_t] k_{t-1}, \tag{36}$$

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

$$E_t \left\{ r_{t+1}^{L,K} \frac{h'(\bar{\omega}_{t+1}^e; \sigma_{\omega,t})}{g'(\bar{\omega}_{t+1}^e; \sigma_{\omega,t})} \right\}, \tag{37}$$

$$r_{t-1}^{L,e} = \bar{\omega}_t [r_t^K u_t - \phi(u_t) + (1-\delta) q_t] \frac{k_{t-1}}{l_{t-1}^K}, \tag{38}$$

$$n_t^e = \frac{\upsilon}{a_{t-1}} \left\{ [r_t^K u_t - \phi(u_t) + (1-\delta) q_t] k_{t-1} h(\bar{\omega}_t^e; \sigma_{\omega,t-1}) \right\} + \iota^e n^e, \tag{39}$$

$$l_t^K = q_t k_t - n_t^e, \tag{40}$$

$$rp_t = \frac{E_t \left\{ \frac{[r_{t+1}^K u_{t+1} - \phi(u_{t+1}) + (1-\delta) q_{t+1}]}{q_t} \right\}}{E_t \left\{ r_{t+1}^{L,K} \right\}}, \tag{41}$$

$$lev_t^e = \frac{q_t k_t}{n_t^e}, \tag{42}$$

$$r_{t-1}^{L,e} = \frac{R_{t-1}^{L,e}}{\pi_t}. \tag{43}$$

Banks:

$$\rho_t^L = \frac{\beta}{a_t} E_t \left\{ \frac{\upsilon_{t+1}}{\upsilon_t} \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\omega)(r_{t+1}^{L,WC} - r_{t+1}) + \omega \frac{l_{t+1}^{WC}}{l_t^{WC}} a_t \rho_{t+1}^L \right] \right\}, \tag{44}$$

$$\rho_t^L = \frac{\beta}{a_t} E_t \left\{ \frac{\upsilon_{t+1}}{\upsilon_t} \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\omega)(r_{t+1}^{L,K} - r_{t+1}) + \omega \frac{l_{t+1}^{K}}{l_t^{K}} a_t \rho_{t+1}^L \right] \right\}, \tag{45}$$

$$\rho_t^N = \frac{\beta}{a_t} E_t \left\{ \frac{\upsilon_{t+1}}{\upsilon_t} \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\omega) r_{t+1} + \omega \frac{n_{t+1}}{n_t} a_t \rho_{t+1}^N \right] \right\}, \tag{46}$$

$$lev_t = \frac{\rho_t^N}{\mu_t - \rho_t^L}, \tag{47}$$

$$l_t = lev_t n_t, \tag{48}$$

$$l_t = l_t^K + l_t^{WC}, \tag{49}$$

$$d_t = l_t - n_t, \tag{50}$$

$$n_t = \frac{\omega}{a_{t-1}} \left[(r_t^{L,WC} - r_t) l_{t-1}^{WC} + (r_t^{L,K} - r_t) l_{t-1}^K + r_t n_{t-1} \right] + \iota n, \tag{51}$$

$$spr_t = \frac{(R_t^{L,WC} l_t^{WC} + R_t^{L,e} l_t^K)}{l_t} \frac{1}{R_t}, \tag{52}$$

$$r_t^{L,WC} = \frac{R_{t-1}^{L,WC}}{\pi_t}. \tag{53}$$

Rest of the world:

$$x_t^{H*} = o^* \left(\frac{p_t^H}{rer_t} \right)^{-\eta^*} y_t^*, \tag{54}$$

$$\xi_t = \bar{\xi} \exp\left[-\psi \frac{rer_t b_t^* - rer \times \bar{b}^*}{rer \times \bar{b}^*} + \frac{\zeta_t - \zeta}{\zeta} \right]. \tag{55}$$

Monetary policy:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\bar{\pi}}\right)^{\alpha_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{\alpha_y}\right]^{1-\rho_R} \exp(\varepsilon_t^R). \tag{56}$$

Market clearing and definitions:

$$y_t^H = x_t^{C,H} + x_t^{G,H} + x_t^{G,H} + x_t^{H*}, \tag{57}$$

$$\frac{rer_t}{rer_{t-1}} = \frac{\pi_t^S \pi_t^*}{\pi_t}, \tag{58}$$

$$y_t = c_t + i_t + g_t + x_t^{H*} + y_t^{Co} - m_t, \tag{59}$$

$$tb_t = p_t^H x_t^{H*} + rer_t p_t^{Co*} y_t^{Co} - rer_t m_t, \tag{60}$$

$$rer_t b_t^* = rer_t \frac{b_{t-1}^*}{a_{t-1}\pi_t^*} R_{t-1}^* \xi_{t-1} + tb_t - (1-\chi) rer_t p_t^{Co*} y_t^{Co}, \tag{61}$$

$$p_t^Y y_t = c_t + p_t^I i_t + p_t^G g_t + tb_t. \tag{62}$$

$$y_t^F = x_t^{C,F} + x_t^{G,F} + x_t^{G,F}, \tag{63}$$

$$y_t^C = c_t + \frac{r^K}{\phi_u}\{\exp[\phi_u(u_t - 1)] - 1\}\frac{k_{t-1}}{a_{t-1}} + \mu^e[r_t^K u_t - \phi(u_t) + (1-\delta)q_t]\frac{k_{t-1}}{a_{t-1}} \text{ ¦ } (aux_t^1 - \sigma_{\omega,t-1}). \tag{64}$$

The exogenous processes are

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

$x = \{\upsilon, \varpi, z, a, \zeta, R^*, \pi^*, p^{Co*}, y^{Co}, y^*, g, \mu, \sigma_\omega\}$, where the ε_t^x are n.i.d. shocks (including also ε_t^R).

Steady State

We show how to compute the steady state for given values of R, $h, p^H, s^{tb}= tb/(p^Y y), s^g= p^G g/(p^Y y), s^{Co}= rer \text{x} p^{Co*} y^{Co}/(p^Y y), \Gamma \equiv r^{L,e} / r, lev$, ι, rp, υ, lev^e and μ^e. The parameters β, $\bar{\pi}^*$, κ, o^*, $\bar{g}$, $\bar{y}^{Co}$, $\bar{\mu}$, ω, $\bar{\sigma}_\omega$ and ι^e are determined endogenously while the values of the remaining parameters are taken as given.

From the exogenous processes for $v_t, u_t, z_t, a_t, y_t^{Co}, R_t^*, y_t^*$ and p_t^{Co*}, $v = \bar{v}$, $u = \bar{u}$, $z = \bar{z}$, $a = \bar{a}$, $y^{Co} = \bar{y}^{Co}$, $\zeta = \bar{\zeta}$, $R^* = \bar{R}^*$, $y^* = \bar{y}^*$, $p^{Co*} = \bar{p}^{Co*}$, From (55), $\xi = \bar{\xi}$.

From (56), $\pi = \bar{\pi}$.

From (3), $\beta = a\pi / R$.

From (35), u=1,

which implies that monitoring costs $\phi(u)$ are zero in steady state. From (4), $\pi^S = a\pi / (\beta R^* \xi)$.

From (58) and the exogenous process for π_t^*, $\pi^* = \bar{\pi}^* = \pi / \pi^S$.

Also, from (36), (37), (41) and (42),

$$rp\left[h'(\bar{\omega}^e;\sigma_\omega) g(\bar{\omega}^e;\sigma_\omega) - h(\bar{\omega}^e;\sigma_\omega) g'(\bar{\omega}^e;\sigma_\omega) \right] = h'(\bar{\omega}^e;\sigma_\omega),$$

$$\frac{lev^e - 1}{lev^e} = g(\bar{\omega}^e;\sigma_\omega) rp.$$

These two equation can be solved numerically to obtain $\bar{\omega}^e$ and σ_ω. Then, from the definition of Γ,

$$R^{L,e} = \Gamma R,$$

and combining (36) and (38),

$$R^{L,K} = \frac{R^{L,e}}{rp} \frac{lev^e - 1}{lev^e \bar{\omega}^e}, \quad r^{L,K} = R^{L,K} / \pi.$$

Thus, from (44) and (45)

$$R^{L,WC} = R^{L,K}, \; r^{L,WC} = r^{L,K}.$$

From (10)-(18),

$$p^F = \left[\frac{1}{o_C} - \frac{1-o_C}{o_C}(p^H)^{1-\eta_C} \right]^{\frac{1}{1-\eta}},$$

$$p^I = [(1-o_I)(p^H)^{1-\eta_I} + o_I(p^F)^{1-\eta_I}]^{\frac{1}{1-\eta_I}},$$

$$p^G = [(1-o_G)(p^H)^{1-\eta_G} + o_G(p^F)^{1-\eta_G}]^{\frac{1}{1-\eta_G}}.$$

From (25), (32) and (7),

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

From (26), (34) and (8),

$$\Delta^H = (\tilde{p}^H)^{-\varepsilon_H}, \ \ \Delta^F = (\tilde{p}^H)^{-\varepsilon_F}, \ \ \Delta^W = \tilde{w}^{-\varepsilon_W}.$$

From (22)-(23), (30)-(31) and (5)-(6),

$$mc^H = \frac{\varepsilon_H - 1}{\varepsilon_H}\tilde{p}^H, \ \ mc^F = \frac{\varepsilon_F - 1}{\varepsilon_F}\tilde{p}^F, \ \ mc^W = \left(\frac{\varepsilon_W - 1}{\varepsilon_W}\right)\tilde{w}.$$

From (9),

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

From (28),

$$q = \frac{p^I}{\varpi}.$$

From (41),

$$r^K = q\left[rp \times r^{L,K} - (1-\delta)q\right].$$

From (19),

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

From (5),

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

From (20),

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

From (24),

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

From (22),

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

From (27),

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

From (29),

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

From (15)-(16),

$$x^{I,H} = \left(1-o_I\right)\left(\frac{p^{H}}{p^{I}}\right)^{-\eta_I} i,$$

$$x^{I,F} = o_I\left(\frac{p^{F}}{p^{I}}\right)^{-\eta_I} i.$$

Let $mon \equiv \mu^{e}[r^{K} + (1-\delta)q]\frac{k}{a}\Phi(aux^{1} - \sigma_{\omega})$ be the monitoring costs payed in steady state. From GDP equal to value added, equivalent to (62), and (33),

$$p^{Y} y = p^{H} y^{H} + p^{Y} y s^{Co} + p^{F}(1 - mc^{F}{}^{,,}{}^{F}) y^{F} - mon.$$

Using (63) and (14),

$$p^Y y = p^H y^H + p^Y y s^{Co} + p^F (1 - mc^F \Delta^F) \left[o_C (p^F)^{-\eta_C} y^C + x^{IF} + o_G \left(\frac{p^F}{p^G} \right)^{-\eta_G} g \right] - mon.$$

Using (64),

$$p^Y y = p^H y^H + p^Y y s^{Co} + p^F (1 - mc^F \Delta^F) \left[o_C (p^F)^{-\eta_C} (c + mon) + x^{IF} + o_G \left(\frac{p^F}{p^G} \right)^{-\eta_G} g \right] - mon.$$

Using (62),

$$p^Y y = p^H y^H + p^Y y s^{Co} + p^F (1 - mc^F \Delta^F) \left[o_C (p^F)^{-\eta_C} (p^Y y (1 - s^{tb} - s^g) - p^I i + mon) + x^{IF} + o_G \left(\frac{p^F}{p^G} \right)^{-\eta_G} \frac{p^Y y s^g}{p^G} \right] - mon.$$

Thus,

$$p^Y y = \frac{p^H y^H + p^F (1 - mc^F \Delta^F)[-o_C (p^F)^{-\eta_C} (p^I i - mon) + x^{IF}] - mon}{1 - s^{Co} - p^F (1 - mc^F \Delta^F) \left[o_C (p^F)^{-\eta_C} (1 - s^{tb} - s^g) + o_G \left(\frac{p^F}{p^G} \right)^{-\eta_G} \frac{s^g}{p^G} \right]}.$$

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

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

From (62),

$c = p^Y y - p^I i - p^G g - tb.$

From (64),

$y^c = c + mom.$

From (13)-(14) and (17)-(18),

$x^{C,H} = (1 - o_C)(p^H)^{-\eta_C} y^C,$

$x^{C,F} = o_C (p^F)^{-\eta_C} y^C,$

$$x^{G,H} = (1 - o_G)\left(\frac{p^H}{p^G}\right)^{-\eta_G} g,$$

$$x^{G,F} = o_G\left(\frac{p^F}{p^G}\right)^{-\eta_G} g.$$

From (57),

$x^{H*} = y^H - x^{C,H} - x^{I,H} - x^{G,H}.$

From (63),

$y^F = x^{C,F} + x^{I,F} + x^{G,F}.$

From (30),

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

From (33),

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

From (59),

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

From (62),

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

From (1),

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

From (2),

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

From (54),

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

From (61),

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

From (38),

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

From (42),

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

From (40),

$$l^{K} = qk - n^{e}.$$

From (39),

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

From (51),

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

From (46),

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

From (44),

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

From (47),

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

From (21),

$$l^{WC} = \alpha_L^{WC}\left(wh + r^K \frac{k}{a}\right).$$

From (49),

$$l = l^{WC} + l^K.$$

From (50),

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

From (50),

$$d = l - n.$$

From (52),

$$spr = \frac{(R^{L,WC} l^{WC} + R^{L,e} l^K)}{l} \frac{1}{R}.$$

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