AN ASYMMETRIC COUNTRY MODEL WITH FINANCIAL FRICTIONS

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Declaration of Authorship

I declare that the research presented in this thesis represents the original work that I carried out during my candidature at the Australian National University.

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Here is my best chance to sum up the nonscientific part of my Ph.D.

What does study mean, if not to reduce my ignorance about the world around and to push the boundary of knowledge forward by exploring new ideas? I would like to thank God for granting me the grit to embark on an area of research that I had no idea of at the beginning. Thanks God for leading me through all the ups and downs on the Ph.D. journey to complete this thesis. Thanks God for giving me persistence to eventually reach my goal.

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Abstract

This thesis inquires into the role of financial factors underlying domestic and cross-border business cycles in a New Keynesian Dynamic Stochastic General Equilibrium framework of two asymmetric countries. The first paper studies the role of financial frictions on the liability side of the bank balance sheet, the second conducts a thorough comparison of financial frictions between the liability side and the asset side, and the third works with the combination of financial frictions on both sides.

The 2007−2008 global financial crisis provided new impetus for the analysis of financial frictions by creating a vivid example of how financial institutions' behavior and their balance sheets can affect the real economy. In the first paper, I develop a two asymmetric-country business cycle model in which independent banking sectors are subject to asset diversion. In particular, domestic bankers are able to divert funds away from the interests of shareholders due to the presence of a moral hazard problem. The model allows for an incentive compatibility constraint on a portfolio of loans as well as financial frictions on cross-border lending and the presence of exogenous entrepreneurial net worth. Using a Bayesian likelihood approach, I estimate the model with Australian and U.S. macroeconomic and financial data. I demonstrate that a two asymmetric-country model is able to fit the standard macroeconomic and financial data very well, if one allows for financial sectors and financial frictions on a sufficiently diverse portfolio of loans. Moreover, the model with a full incentive compatibility constraint outperforms its less constrained variants and the pure trade open economy model in reproducing the cross-border synchronization of business cycles. Also consistent with this model, I find that within-country financial shocks are responsible for a substantial portion of business cycle fluctuations in each country and foreign financial shocks play a non-negligible role in cross-border spillovers.

Whilst economists have switched their focus on financial frictions to the supply side of the credit market since the 2007−2008 global financial crisis, demand-side financial frictions had already been taken into account before the crisis. In the second paper, I compare the role of financial friction approaches in a two asymmetric-country model that provides a microfounded rationale for across-country business cycle analysis. To do so, I firstly develop a two asymmetric-country business cycle model without financial frictions − henceforth the pure trade open economy model − and then incorporate two financial friction approaches: A costly verification problem whereby bankers pay some cost to verify the outcome of entrepreneurial projects, and a moral hazard problem by which bankers divert some assets from the interests of shareholders. The models are brought to the empirical investigation using Bayesian methods and Australian and U.S. macroeconomic and financial data. Taking the pure trade open economy model as a benchmark, I evaluate the performance of model extensions with financial frictions and the role of each type of financial friction. I find that the presence of financial frictions improves the fit of the pure trade open economy model. The friction model versions also overcome the shortcomings of the pure trade open economy model in reproducing the cross-border synchronization of

business cycles. In addition, the empirical evidence favors the model version with financial frictions in the banking sector.

Given the results obtained in the two previous papers, the third paper evaluates a combination of two financial friction approaches, again in a two asymmetric-country framework. I develop a two asymmetric-country business cycle model that features leverage constraints on both entrepreneurial and banking balance sheets. The model allows for financial frictions on a diverse portfolio of loans as well as financial frictions on cross-border lending and the presence of important features of the open economy. The role of financial friction types is investigated by comparing models, in which neither, one or both types are turned off. The model constructed in this paper also allows me to compare the effect of a relatively large menu of financial shocks on macroeconomic and financial aggregates and to study the synchronization of business cycles. The models are estimated with Bayesian techniques using macroeconomic and financial data for Australia and the U.S. The analysis shows that the two combined financial friction approaches in the model are useful for characterizing country-specific business cycles. In addition, the simultaneous presence of two types of financial frictions amplifies the response of the spreads and the overall economy to financial shocks as compared to the model with either one of two approaches. Indeed, the additional amplification provided by a double financial accelerator effect enhances the model's ability to match the empirically observed volatility of the spreads, as well as investment and other variables. This suggests that financial friction approaches embedded in a structural, asymmetric country model are helpful in improving empirical performance, in particular at cross-border synchronization.

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Chapter 1

Introduction

Financial factors had been largely neglected in the mainstream macroeconomic literature in the last twenty years before the 2007−2008 global financial crisis (GFC). Many policy institutions around the world prior to the GFC relied on business cycle models that did not even consider explicitly the financial sector. In particular, financial market imperfections had been omitted from the pre-crisis generation of Dynamic Stochastic General Equilibrium (DSGE) models that was used as the standard workhorse in the analysis of the business cycle. This was probably a symptom reflecting the propensity to overconfidence on the efficiency of the financial market hiding the implicit acceptance of the Modigliani-Miller theorem. The latest ensuing financial turmoil served as a wakeup call, which made it clear that business cycle modeling can no longer ignore the financial market imperfection. Since then, economists in both academia and policy institutions have been working to revive this tradition by incorporating financial friction approaches into standard business cycle models.

There are two main approaches in the literature to modeling financial market imperfections in the general equilibrium framework. The first was initiated by the seminal paper of Bernanke and Gertler (1989), further developed by Carlstrom and Fuerst (1997) and later merged with the New Keynesian DSGE framework by Bernanke, Gertler, and Gilchrist (1999) in order to become the workhorse financial accelerator model − henceforth BGG. The BGG model features non-financial borrowers with constrained leverage that are the source of financial frictions in the form of a costly state verification problem (Townsend 1979). In particular, financial frictions arise from asymmetric information about the future outcome of entrepreneurial projects. While the entrepreneur learns the *ex post* outcome of his capital utilization project, the bank does not unless it pays some monitoring costs to verify. Although *de jure* the bank pays the monitoring costs, *de facto* they are passed on to the entrepreneur by charging a higher lending rate that drives a finance premium on the loan compared with the entrepreneur's internal finance costs. Much of the macroeconomic literature following the BGG approach emphasizes credit constraints on non-financial firms while treating the entire banking sector largely as a veil.

The second approach was developed by Gertler and Kiyotaki (2010, 2015) and Gertler and Karadi (2011) − hereafter GK. This approach, instead, explicitly models leverage-constrained financial intermediaries as a source of financial frictions due to the presence of a moral hazard problem. Specifically, the banker raises household deposits if their expected value is such that there is no incentive to divert banking assets, which in turn imposes an endogenous leverage constraint on the balance sheet. As a result the bank's effective rate of return on loans will be higher than the deposit rate, creating an endogenous wedge linked to the value of each loan type. The endogenous leverage constraint also implies the role of bank net worth in determining the supply of credit to the economy. In this framework disturbances that disrupt the banking sector's assets decrease lending and borrowing through increased credit costs.

The empirical macroeconomic literature on financial frictions distinguishes the two approaches depending on whether the financial friction is primarily on the side of non-financial borrowers or on the side of financial intermediaries. Both approaches, nevertheless, stem from the information asymmetry in the credit market. Accordingly, financial frictions are endogenized by introducing agency problems between lenders and borrowers.[1] Agency problems then work to introduce an endogenous wedge between the cost of external finance and the opportunity cost of internal funds, which adds to the overall credit cost that a borrower faces. As the borrower's equity stake in the outcome of a loan-funded project increases, incentive to deviate from the lender's interests declines. The spread then declines as a result. The size of the spread therefore depends on the condition of borrower balance sheets. In sum, the two approaches share a common feature: concentrating on the price of loans.[2]

A growing theoretical and empirical macroeconomic literature has explored the relevance of financial frictions and consequently leverage constraints in the propagation mechanism underlying the business cycle. The theoretical papers extend the general equilibrium class of models with financial frictions and use numerical experiments to gauge the interaction between financial and macroeconomic factors. The empirical papers employ an array of different data sources and various estimation methods to examine the role of financial frictions in the run-up to and during the 2007−2008 GFC. Bean (2010), Gertler and Kiyotaki (2010), Quadrini (2011), Brunnermeier, Eisenbach, and Sannikov (2012) and Beck, Colciago, and Pfajfar (2014), *inter alia*, provide extensive surveys about research papers that study the role of financial frictions and the impact of financial disturbances for overall macroeconomic outcomes. As a result the extended model class has become increasingly popular in academia and at central banks. In particular, a new generation of New Keynesian DSGE models with financial frictions forms the basis for construction of frameworks that explain dynamic linkages between financial stress and the business cycle.

[1]Notice that the bank plays two roles in the credit market: receiving deposits and creating loans. The agency problem therefore can occur between depositors as lenders and the bank as borrower or between the bank as lender and firms as borrowers.

[2]Another line of research concentrates on the quantity of loans rather than their price, which was introduced by the seminal paper of Kiyotaki and Moore (1997) and then incorporated into a standard business cycle model by Iacoviello (2005). Under this approach, loan collateral constraints capture the effect of quantitative restrictions generated by the banking sector.

The insights into the progress made in understanding such bilateral linkages are in turn used to evaluate the policy measures put in place to mitigate financial stability risks and propose appropriate regulatory policies.

Up to this point, however, the literature has been mostly silent about how financial frictions work in the general equilibrium framework of two asymmetric countries. Meanwhile, existing open economy business cycle models struggle in replicating the empirically observed international comovement in output and aggregate demand cycles (see e.g. Adolfson et al. 2007; Justiniano and Preston 2010). It is unclear whether this is because such quantitative models fail to take into account the role of financial frictions in the business cycle synchronization. Further the influence of U.S. disturbances abroad, as made evident by the latest GFC, also raises the question of developing macro-finance models for evaluating spillover effects of financial shocks across countries. It is in the integration of all three concerns that my thesis finds its rationale. In particular, this thesis is an attempt to contribute to the development of cross-country New Keynesian DSGE models with financial frictions. In doing so, my research strategy consists of developing a frictionless international business cycle model − I will later call it the pure trade open economy model − for two asymmetric countries based on well-established parts of renowned DSGE models in the literature and incorporating various financial frictions with the dual aim of advancing understanding of the two financial friction approaches and providing new insights into the two asymmetric-country setting by exploring their theoretical underpinnings and estimating empirical results.

This thesis's objective is to explore the role of the financial sectors, financial frictions and financial disturbances underlying business cycles in a New Keynesian DSGE model of two asymmetric countries. To do so, I have planned to incorporate the two financial friction approaches into my otherwise pure trade open economy model. As will become clear later, this plan also explains my structure for the thesis: beginning with an evaluation of financial frictions in the banking sector in Chapter 2, to making a comparison between financial frictions in the entrepreneurial sector and those in the banking sector in Chapter 3, and then finishing with a combination of financial frictions from both sectors in Chapter 4. On the empirical side, I estimate a rich set of friction and frictionless models with standard Bayesian methods using macroeconomic and financial data for Australia and the United States over the period 1993Q1−2012Q4.

The thesis consists of five chapters in which three main chapters are presented in a journal article form between a general introduction and a general conclusion. Note that the term "paper" is used interchangeably with the term "chapter" throughout each main chapter. The three papers correspond to Chapters 2 to 4. Although the three papers can be read as separate works, with their own rationale and motivation, they are part of my ongoing research program and thus share common ground. In particular, the pure trade open economy model and financial-frictionless parts of models with financial frictions are similar in all three papers; I include them nevertheless so that the presentation of each paper is self-contained. Additionally, the complete presentation fixes notation and allows me to be precise about model modifications and hence the set of models or model variants/ versions used in the analysis of each paper. The similar empirical strategy adopted and the common macroeconomic and financial datasets used are also elements that make the three papers part of a unitary thesis.

Chapter 2

Liability-side Financial Frictions in an Estimated Asymmetric Country Model

2.1 Introduction

I introduce a moral hazard problem associated with domestic banks into an otherwise two asymmetric-country model and estimate it. With this goal in mind, I develop a baseline quantitative New Keynesian DSGE model that is compatible with the business cycle framework for a pair of small-open and large-closed economies. The domestic block of the model builds on the neoclassical core of Christiano, Eichenbaum, and Evans (2005), and adds a rich array of real and nominal rigidities and disturbances as in Smets and Wouters (2007). Further, I enrich the building segment of the small-open economy described by Adolfson et al. (2007) with two additional features compared to the literature. First, I allow for differential steady-state inflation rates between the two countries in a way that would yield nominal exchange rate depreciation in steady state. Second, commodity export demand is assumed to be not only exogenous but also contingent on global economy conditions. Next, the small-open economy is linked with its large-closed counterpart through trade and finance channels.

The principal contribution of this paper is to incorporate independent banking sectors as a source of economic fluctuations into the business cycle framework of two asymmetric countries. I model the banks subject to a moral hazard problem, in the spirit of Gertler and Karadi (2011). The banking sector in my model, however, has two distinctive features. First, the banking sector's role itself as an independent source of aggregate fluctuations is disentangled from its role as an amplifier for conventional shocks originating elsewhere in the economy. Second, the banks offer loans to a diverse range of borrowers, rather than just supplying funds to non-financial firms in exchange for equity stakes.[1] Furthermore, I extend the modeling of financial frictions *à la* Gertler and Karadi (2011) in three main

[1] Banks by Gertler and Karadi (2011) effectively own non-financial firms by buying equity stakes, implying that banks and firms are essentially a single sector.

directions. First, the moral hazard problem in independent banking sectors is put in the framework of two asymmetric economies, which allows me to extend financial frictions to cross-border lending. This is a potentially important ingredient if the model is to capture the cross-border synchronization of business cycles. Second, various domestic loans are equally subject to the moral hazard problem, creating a consistent set of financial frictions among the types of funding.[2] As I will show later, bankers' incentive to divert assets does not depend on loan-specific factors and thus incentive compatibility constraint is symmetrically binding on all types of loans. Third, I bring the dynamics on the asset side of the bank balance sheet into the model featuring liability-side frictions. Because entrepreneurs are able to endow internal resources so that they can partly self-finance, the implicit assumption of capital purchases entirely financed by bank loans as originally proposed by Gertler and Karadi (2011) is unrealistic. I therefore include exogenous entrepreneurial net worth into the model while preserving the conventional notion of asset-side financial nonfriction.[3]

The financial accelerator in my model works through the bank lending channel. I endogenize financial market frictions by introducing moral hazard problems between domestic shareholders and domestic bankers. As in Gertler and Karadi (2011), the moral hazard problem works to impose an endogenous incentive constraint on the bank balance sheet. However, I consider the idea that the moral hazard problem comes from bankers' discretion to divert assets, rather than from a fear that bankers would steal. In this framework, the constraint creates friction in the flow of funds from depositors to banks, which adds some spread to the cost of loans faced by borrowers. The size of various spreads, further, depends on the condition of bank balance sheets. As bankers' incentive to divert assets for their own interests rises, the banking leverage multiple declines. Since the lending capability of banks depends on their leverage multiple, the spread increases as a result. Concerning moral hazard, when recognizing banks' impaired capital positions, risk averse shareholders force them to deleverage, with further increases in the spread and ultimately a resulting contraction in the credit flow to the real economy. In general equilibrium, a financial accelerator effect emerges. As bank balance sheets deteriorate with worse economic conditions, the spread widens, which works to enhance borrowers' spending cuts, thus enhancing the contraction. The effects between the balance sheet constraint and real economic activity are mutually reinforced along the way. My framework therefore provides an alternative understanding of the role of the banking sector in macroeconomic fluctuations.

The model is brought into the empirical investigation with macroeconomic and financial data for Australia and the U.S. over the period 1993Q1−2012Q4. Following this, I

[2]Capital working loans and of course export credits were either not considered in the original paper by Gertler and Karadi (2011) or not subject to the moral hazard problem in later papers (e.g. Rannenberg 2016).

[3]In my model bank credit is not the only financing available for entrepreneurs. Thus the transmission mechanism described later can be best ascribed to economies where equity issuance and bank credit are the primary sources of financing.

use Bayesian estimation of variants of my model to address a number of key issues. First, how does the extent of the incentive compatibility constraint on loans affects the fit of the model? Broadly speaking, a full incentive compatibility constraint on all loan types improves the model fit in relevant dimensions of the data. Second, the model with a full incentive compatibility constraint outperforms its less-constrained variants and the pure trade open economy model in reproducing the cross-border synchronization of business cycles. In particular, the model can deliver both substantial cross-country correlations in almost Australian series and substantial shares of Australian variance attributed to U.S. shocks. Finally, in order to investigate the relative empirical importance of the financial shocks, I use the estimated model with a full incentive compatibility constraint which best fits the data. Indeed, the presence of financial frictions on various loan types highlights the role of the banking sector in the transmission mechanism of financial shocks. One of my findings is that the behavior of cross-border lending and its interaction with open economy variables are key to understanding how foreign financial shocks are propagated to the small-open economy. Variance decompositions reveal that within-country financial shocks account for a significant portion of business cycle fluctuations in each country and U.S. financial shocks play a non-negligible role in cross-border spillovers.

This paper lies at the interface of the international macroeconomic literature and the financial friction literature. Firstly, the present paper is related to several attempts that have incorporated frictions in the financial intermediation sector into the open economy framework, mainly using calibrated models (Kollmann, Enders, and Müller 2011; Kollmann 2013; Dedola, Karadi, and Lombardo 2013).[4] Although my paper shares a similar direction, the structure of my estimated model is different. Moreover, I explicitly model features of the open economy, which allows me to analyze both international relative prices and trade balance dynamics in response to financial shocks. The literature, by contrast, assumes two entirely symmetric countries in order to simplify the model and thus ignores important features of the open economy such as real exchange rates and risk sharing conditions.

Secondly, I deal with the model's ability to account for the cross-border synchronization of business cycles. It is a common finding in the open economy DSGE literature that pure trade models do a pretty poor job at reproducing the macroeconomic comovement observed in the data (Justiniano and Preston, 2010). This is largely due to the failure of this class of models to deliver sufficient propagations of within-country shocks to the partner economy. Here, I focus not on the interactions between two equally sized economies, as do Kollmann, Enders, and Müller (2011), but instead on the spillovers from a large economy to a small-open economy. A previous study that is close to my paper is the work of Kamber and Thoenissen (2013), who calibrate a highly stylized international real business cycle model of two asymmetric countries to show that the magnitude of spillovers from foreign financial

[4]The latest crisis has sparked a number of papers that study how frictions arising in financial intermediaries affect economic fluctuations in the closed economy set-up. Examples include Gertler and Kiyotaki (2010), Gerali et al. (2010), Gertler and Karadi (2011), Brunnermeier and Sannikov (2014), Nuño and Thomas (2016), and Gertler, Kiyotaki, and Prestipino (2016).

shocks is proportional to the financial exposure of the small country's banking sector to the foreign economy via lending to foreign firms. My approach, nevertheless, differs from theirs in a number of important dimensions. First, I explicitly model the origin of financial frictions in the form of a moral hazard problem, while they simply assume the spread as a result of costly deviations from a prescribed bank capital-to-loans ratio *à la* Gerali et al. (2010). Second, my focus is on domestic banking sectors that are fully independent, and banks resident in a small country are unexposed to a foreign economy. Third, I consider a diverse set of borrowers and also financial frictions on cross-border lending. Fourth, the paper *estimates* a comprehensive Ney Keyesian model containing real, nominal and financial frictions as well as conventional and financial shocks in order to provide an empirical assessment of the role of the banking sector as a source of business cycle disturbances across countries.

The rest of the paper is structured as follows. In Section 2.2, I develop the theoretical model. Section 2.3 describes the data and presents the empirical strategy. Next, Section 2.4 evaluates the relative performance of model variants. The role of financial factors is analyzed in Section 2.5. The paper ends with concluding remarks. Technical details are provided in the Appendices.

2.2 The model

The model includes two countries, called Home and Foreign. Since the home country is a small-open economy that is unable to influence the foreign partner, the foreign partner is analogous to a large-closed economy. In what follows, variables referring to the foreign economy are denoted by an asterisk where applicable.

The structure of the small-open economy is as follows. There are four types of firms in the economy. First, intermediate firms produce differentiated goods that are then aggregated into a homogeneous domestic good by another layer of producers. Second, exporters sell specialized goods derived from the homogeneous domestic good to foreign retailers who in turn create a homogeneous good to sell to foreign agents. Third, importers buy a homogeneous good in the foreign market and brand it into differentiated consumption and investment goods. Fourth, final assemblers combine the homogeneous domestic good with bundles of imported goods in order to produce final consumption and investment goods sold to households. Households consume, build raw capital, and save in home and foreign assets. Workers from households supply differentiated labor services at a wage rate set by monopoly unions, while some household members specialize in capital utilization and others manage banks owned by shareholding members.

2.2.1 Firms

Domestic goods producers

Homogeneous goods producers. A representative, competitive producer aggregates intermediate goods, $Y_{j,t}, j \in [0,1]$, into a homogeneous good, Y_t, using the Dixit-Stiglitz technology:

$$(2.1)\qquad Y_t = \left[\int_0^1 Y_{j,t}^{\frac{1}{\lambda_{d,t}}} dj\right]^{\lambda_{d,t}}, \qquad 1 \le \lambda_{d,t} < \infty,$$

where $\lambda_{d,t}$ is a price markup shock. The time series representations of $\lambda_{d,t}$ and all other stochastic processes in the model will be described below.

Intermediate goods producers. The intermediate goods are produced by a monopolist using a standard production function:

$$(2.2)\quad Y_{j,t} = \begin{cases} \epsilon_t K_{j,t}^{\alpha}(z_t h_{j,t})^{1-\alpha} - \Phi z_t & \text{if } \epsilon_t K_{j,t}^{\alpha}(z_t h_{j,t})^{1-\alpha} > \Phi z_t \\ 0 & \text{otherwise} \end{cases}, \qquad 0 < \alpha < 1,$$

where $K_{j,t}$ and $h_{j,t}$ represent the services of effective capital and homogeneous labor used by the j^{th} intermediate goods producer. Also, ϵ_t is a covariance stationary technology shock and z_t is a permanent technology shock with the stationary growth rate $g_{z,t} = \Delta \log z_t$. The fixed costs in production, Φ, are indexed to the technology level so that profits are zero in steady state.

Assume that intermediate goods producers must borrow from home banks in order to finance fractions v_K and v_H of their expenditures for capital and labor services in advance of production at a nominal interest rate $R_{f,t}$. As a result, the working capital loan of the j^{th} producer is

$$(2.3)\qquad L_{jf,t} = v_K Z_{k,t} K_{j,t} + v_H W_t h_{j,t}, \qquad 0 < v_K, v_H \le 1,$$

where $Z_{k,t}$ is the rental rate on effective capital and W_t is the nominal wage rate. Cost minimization, in equilibrium, yields a common marginal cost across producers:

$$(2.4)\quad MC_t = \left(\frac{1}{\alpha}\right)^{\alpha}\left(\frac{1}{1-\alpha}\right)^{1-\alpha} \frac{\left[Z_{k,t}\left(1 + v_K\left(R_{f,t} - 1\right)\right)\right]^{\alpha}\left[W_t\left(1 + v_H\left(R_{f,t} - 1\right)\right)\right]^{1-\alpha}}{\epsilon_t z_t^{1-\alpha}}.$$

Under Calvo-style pricing, in each time period t a randomly selected fraction $1 - \xi_d$ of intermediate goods producers can reoptimize their price. The complementary fraction ξ_d follows the indexation rule

$$(2.5)\qquad P_{j,t} = (\bar{\pi}_t)^{\iota_d}(\pi_{t-1})^{1-\iota_d} P_{j,t-1}, \qquad 0 < \iota_d < 1,$$

where $\pi_{t-1} = P_{t-1}/P_{t-2}$ is the inflation of domestic goods and $\bar{\pi}_t$ is the inflation target in the monetary authority's policy rule.

Exporters

In the home country there are two export sectors, non-commodity and commodity. The total demand for exports is specified as follows:

$$(2.6)\qquad X_t = X_{non,t} + X_{com,t} \equiv \left(\frac{P_{x,t}}{P_t^*}\right)^{-\eta_*} \imath_* Y_t^* + \varepsilon_{com,t} \varsigma_* Y_t^*, \qquad \eta_* > 1,$$

where the first term on the right represents the non-commodity export[5], while the second term expresses the commodity export that I model as an exogenous demand shock contingent on the global economy conditions proxied by the foreign output Y_t^*. The presence of the scale factors, $\imath_*$ and ς_*, is required for the determination of a well-defined steady state for export demand.[6]

Non-commodity export goods, $X_{j,t}, j \in [0,1]$, are packed by a representative, competitive foreign retailer using the Dixit-Stiglitz technology:

$$(2.7) \qquad X_{non,t} = \left[\int_0^1 X_{j,t}^{\frac{1}{\lambda_{x,t}}} dj \right]^{\lambda_{x,t}}, \qquad 1 \leq \lambda_{x,t} < \infty.$$

At the beginning of period t, exporters obtain an export credit, $L_{x,t}$, from home banks to finance part of their homogeneous goods bill:

$$(2.8) \qquad L_{x,t} = \upsilon_X P_t X_t, \qquad 0 < \upsilon_X \leq 1,$$

at a nominal interest rate, $R_{x,t}$, which is discussed below. Since exporting firms can export costlessly, the marginal cost is the same across non-commodity exporters:

$$(2.9) \qquad MC_{x,t} = P_t[1 + \upsilon_X(R_{x,t} - 1)].$$

Non-commodity exporters set their price in foreign currency when selling differentiated export goods to foreign retailers. Under Calvo-style pricing, the complementary fraction ξ_x of non-commodity exporters cannot reoptimize their price, but follows the indexation rule

$$(2.10) \qquad P_{jx,t} = (\bar{\pi}_t^*)^{\iota_x} (\pi_{x,t-1})^{1-\iota_x} P_{jx,t-1}, \qquad 0 < \iota_x < 1,$$

where $\pi_{x,t-1} = P_{x,t-1}/P_{x,t-2}$ is the inflation of non-commodity export goods and $\bar{\pi}_t^*$ is the foreign inflation target.

Importers

Importers buy a homogeneous foreign good and differentiate it by branding at no cost. They face an analogous optimal problem to exporters, so an appropriate substitution for the import credit and the marginal import cost is as follows:

$$(2.11) \quad L_{m,t} = \upsilon_M P_t^* M_t \qquad \text{and} \qquad MC_{m,t} = S_t P_t^*[1 + \upsilon_M(R_{m,t}^* - 1)], \qquad 0 < \upsilon_M \leq 1,$$

where S_t denotes the nominal exchange rate defined as the home price of foreign currency and $R_{m,t}^*$ is the nominal interest rate of the foreign currency credit, $L_{m,t}$, obtained from foreign banks.

[5] I do not disentangle the non-commodity export into consumption and investment purposes because this export demand is better captured by the foreign income, Y_t^*, than by its foreign demand components, C_t^* and I_t^*.

[6] In particular, $X = X_{non} + X_{com} = \imath_* Y^* + \varsigma_* Y^*$ in steady state. Thus the value of $\imath_*$ and ς_* corresponds to the share of non-commodity and commodity export volumes in the aggregate demand abroad, which is a very small number in practice.

As with non-commodity exporters, importers are subject to Calvo-type pricing when reselling differentiated import goods to final assemblers. The complementary fraction ξ_m of importers then indexes their price according to the rule

$$P_{jm,t} = (\bar{\pi}_t)^{\iota_m} (\pi_{m,t-1})^{1-\iota_m} P_{jm,t-1}, \qquad 0 < \iota_m < 1 \qquad \text{for } m \in \{cm, im\}, \tag{2.12}$$

where $\pi_{m,t-1} = P_{m,t-1}/P_{m,t-2}$ is the inflation of consumption and investment import goods.

Final goods assemblers

A representative, competitive assembler aggregates differentiated import goods, $M_{jm,t}, j \in [0,1]$, into two homogeneous goods bundles for consumption and investment purposes, $M_{m,t} = \{C_{m,t}, I_{m,t}\}$, using the Dixit-Stiglitz technology:

$$M_{m,t} = \left[\int_0^1 M_{jm,t}^{\frac{1}{\lambda_{m,t}}} dj \right]^{\lambda_{m,t}}, \qquad 1 \leq \lambda_{m,t} < \infty. \tag{2.13}$$

To produce final consumption and investment goods, the assembler combines each bundle of import goods with homogeneous goods purchased from domestic producers according to the technologies

$$C_t + C_{b,t} = \left[(1-\omega_c)^{\frac{1}{\eta_c}} C_{d,t}^{\frac{\eta_c - 1}{\eta_c}} + \omega_c^{\frac{1}{\eta_c}} C_{m,t}^{\frac{\eta_c - 1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}}, \qquad 0 < \omega_c < 1, \eta_c > 1,$$

and

$$I_t + a(u_t)\bar{K}_t = \left[(1-\omega_i)^{\frac{1}{\eta_i}} I_{d,t}^{\frac{\eta_i - 1}{\eta_i}} + \omega_i^{\frac{1}{\eta_i}} I_{m,t}^{\frac{\eta_i - 1}{\eta_i}} \right]^{\frac{\eta_i}{\eta_i - 1}}, \qquad 0 < \omega_i < 1, \eta_i > 1,$$

where C_t and $C_{b,t}$ are consumption components of households, which are discussed below.

The assembler then supplies whatever quantity of each type of final good is demanded by households at the following competitive prices:

$$P_{c,t} = \left[(1-\omega_c) P_t^{1-\eta_c} + \omega_c P_{cm,t}^{1-\eta_c} \right]^{\frac{1}{1-\eta_c}} \varepsilon_{p_c,t} \tag{2.14}$$

and

$$P_{i,t} = \left[(1-\omega_i) P_t^{1-\eta_i} + \omega_i P_{im,t}^{1-\eta_i} \right]^{\frac{1}{1-\eta_i}}, \tag{2.15}$$

where $\varepsilon_{p_c,t}$ is an exogenous measurement error shock.[7] So the assembler maximizes profit, taking two pairs of component prices, $\{P_t, P_{cm,t}\}$ and $\{P_t, P_{im,t}\}$, as given. The supply for each category of final consumption and investment goods is

$$C_{d,t} = (1-\omega_c) \left(\frac{P_t}{P_{c,t}} \right)^{-\eta_c} (C_t + C_{b,t}), \qquad C_{m,t} = \omega_c \left(\frac{P_{cm,t}}{P_{c,t}} \right)^{-\eta_c} (C_t + C_{b,t}), \tag{2.16}$$

[7] This shock is designed in order to cope with the time-invariant weights of the CPI components, and to bring more volatility to the endogenous consumer price inflation variable since its observable counterpart is affected by some elements that are absent from the model (e.g. unprocessed food items). I refer to $\varepsilon_{p_c,t}$ as the consumption price shock whose process follows a random walk: $\varepsilon_{p_c,t} = \varepsilon_{p_c,t-1} + \mu_{p_c,t}$. Note that a shock of this kind is not included in the price index for investment goods since I do not use investment price inflation as an observable variable in the later estimation.

and

(2.17)

$$I_{d,t} = (1-\omega_i)\left(\frac{P_t}{P_{i,t}}\right)^{-\eta_i}\left(I_t + a(u_t)\bar{K}_{t-1}\right), \qquad I_{m,t} = \omega_i\left(\frac{P_{im,t}}{P_{i,t}}\right)^{-\eta_i}\left(I_t + a(u_t)\bar{K}_{t-1}\right).$$

2.2.2 Employment agencies

The model of the labor market parallels the Dixit-Stiglitz structure of goods production and follows the work of Erceg, Henderson, and Levin (2000). All workers of the representative household supply a type of specialized labor j in the economy. A representative, competitive contractor then combines specialized labor, $h_{j,t}, j \in [0,1]$, into homogeneous labor using the following technology:

$$h_t = \left[\int_0^1 h_{j,t}^{\frac{1}{\lambda_{w,t}}}\, dj\right]^{\lambda_{w,t}}, \qquad 1 \leq \lambda_{w,t} < \infty, \tag{2.18}$$

and sells labor services, h_t, to intermediate goods producers. Also, a monopoly union represents all workers of the household in order to set the nominal wage rate, $W_{j,t}$, for their labor type. Under Calvo-style frictions, the complementary fraction ξ_w of unions cannot set wages optimally, but follow the indexation rule

$$W_{j,t} = (\bar{\pi}_t)^{\iota_w}(\pi_{c,t-1})^{1-\iota_w} g_{z,t} W_{j,t-1}, \qquad 0 < \iota_w < 1. \tag{2.19}$$

Wage-setting is indexed to a technology growth factor, $g_{z,t}$, to ensure that wage grows at the economy-wide balanced growth rate.

2.2.3 Households

There is a continuum of identical and competitive households in the economy. The existence of (implicit) complete insurance ensures that in equilibrium households make identical decisions. A representative household consists of a large number of members with total measure one: a fraction of f_w workers, f_e entrepreneurs, f_b bankers, and the complementary fraction $(1-f_w-f_e-f_b)$ of shareholders.[8] Entrepreneurs earn zero profit from capital utilization while bankers make profits from the process of financial intermediation, but my discussion of these agents is postponed until the next subsections.[9]

I assign the task of raw capital production to households. To produce new raw capital, the representative household purchases undepreciated capital from entrepreneurs and investment goods from final goods assemblers. While the undepreciated capital is converted one-for-one into new raw capital, the transformation of the investment goods involves adjustment costs $F(I_t/I_{t-1}) = \frac{F}{2}\left(\frac{I_t}{I_{t-1}} - g_z\right)^2$ with $F(.) = F'(.) = 0$, $F''(.) = F > 0$. After goods production in period t, the household builds end-of-period t raw capital, $\bar{K}_{t+1}$, using

[8] I modify the large family assumption in this financial setting, which helps streamline the model presentation while the set of optimality conditions that characterize the equilibrium are the same.

[9] The presence of entrepreneurs simplifies the optimization problem of the representative household, which means that, in particular, the term corresponding to capital utilization drops out from the budget constraint (22).

the following technology:

$$\bar{K}_{t+1} = (1-\delta)\bar{K}_t + \mu_t \left[1 - F\left(\frac{I_t}{I_{t-1}}\right)\right] I_t, \qquad 0 < \delta < 1, \tag{2.20}$$

where μ_t is a shock to the marginal efficiency of investment (MEI).

The preferences of the representative household are described by the expected utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t b_t \left[\log\left(C_t - bC_{t-1}\right) - \varphi_H \int_0^1 \frac{h_{j,t}^{1+\sigma_H}}{1+\sigma_H} dj\right], \qquad 0 < \beta, b < 1, \varphi_H, \sigma_H > 0, \tag{2.21}$$

where C_t is the per-capita consumption of non-shareholder members and b_t is an intertemporal preference shock.

Budget constraint

Households are the ultimate source of the overall flow of funds for the economy. The representative household's income sources are wages from labor services $W_{j,t}h_{j,t}$, revenues from selling raw capital $Q_{\bar{K},t}\bar{K}_{t+1}$, and various lump-sum payments Π_t including domestic firm profits net of new equity purchases (discussed in the following subsections), and lump-sum government transfers net of lump-sum taxes. In addition, the household receives interest income from home and foreign assets, $R_t D_t + R_t^* \Phi_t(.) S_t D_t^*$, by depositing funds with banks and buying government bonds with a maturity of one period. While both home deposits and bonds are risk-free assets that earn the same interest and they are therefore perfect substitutes, the foreign asset holding is additionally adjusted with a country risk premium, $\Psi_t(.)$. The total income is used to finance non-shareholder consumption, to build new raw capital and to invest in home and foreign asset markets. The flow budget constraint of the household reads:

$$\begin{aligned} P_{c,t}C_t + P_{i,t}I_t + Q_{\bar{K},t}(1-\delta)\bar{K}_t + D_{t+1} + S_t D_{t+1}^* \leq & \int_0^1 W_{j,t}h_{j,t}dj + Q_{\bar{K},t}\bar{K}_{t+1} \\ & + \Pi_t + R_t D_t + R_t^* \Psi_t(.) S_t D_t^*. \end{aligned} \tag{2.22}$$

Cross-border asset market arbitrage

The household maximizes its intertemporal utility (2.21) subject to the budget constraint (2.22). As a result, the optimal position in the cross-border asset market is determined by the uncovered interest arbitrage condition as follows:

$$R_t = E_t \left\{ R_t^* \frac{S_{t+1}}{S_t} \Psi_t(.) \right\}. \tag{2.23}$$

The arbitrage condition in the steady state allows me to endogenously derive the subjective discount factor of the foreign household with respect to calibration for the home counterpart.[10] The country risk premium function of holding foreign assets takes

[10] For the detailed algorithm of steady-state computation, see Appendix D.

the form of

$$\Psi_t\left(a_t, \Delta S_t, \psi_t\right) = \exp\left\{-\phi_a(a_t - a) - \phi_s\left[\frac{E_t\{S_{t+1}\}}{S_t}\frac{S_t}{S_{t-1}} - \left(\frac{\pi}{\pi^*}\right)^2\right] + \psi_t\right\}, \tag{2.24}$$
$$\Psi_t'(.) < 0, \Psi\left(0, \frac{\pi}{\pi^*}, 0\right) = 1, a = 0, \pi > \pi^*, \phi_a > 0, 0 < \phi_s < 1,$$

where $a_t = \frac{S_t D^*_{t+1}}{P_t z_t}$ is the (real) net foreign asset position and ψ_t is a shock to the country risk premium. As in Adolfson et al. (2008), the country risk premium is a positive function of not only the net foreign asset position but also the expected home currency depreciation.[11] Further, I allow for a higher steady-state inflation in the home country than in the foreign counterpart, which yields a nominal exchange rate depreciation in steady state as implied by the theory of purchasing-power parity.

2.2.4 Entrepreneurs

I suppose there is a representative, competitive entrepreneur. At the end of period t, the entrepreneur is endowed by the net worth, $N_{e,t} \geq 0$, from the household's transfer. The entrepreneur obtains a loan, $L_{e,t}$, from its home bank and combines with its own net worth, $N_{e,t}$, to purchase raw capital, $\bar{K}_{t+1}$, at a competitive price of $Q_{\bar{K},t}$. That is,

$$L_{e,t} = Q_{\bar{K},t}\bar{K}_{t+1} - N_{e,t}. \tag{2.25}$$

I treat the entrepreneurial net worth as an exogenous process, which will generate an additional propagation channel in the model as described later.[12]

Given the period $t+1$ aggregate rental rate and price of capital, the entrepreneur determines the optimal utilization rate, u_{t+1}, which transforms its raw capital, $\bar{K}_{t+1}$, into the services of effective capital according to

$$K_{t+1} = u_{t+1}\bar{K}_t, \tag{2.26}$$

subject to a utilization cost $a(u_{t+1})\bar{K}_t$. My specification of the utilization cost function is as follows:

$$a(u_t) = (1-\zeta)\frac{Z_k}{P_i}\left(u_t^{\frac{1}{1-\zeta}} - 1\right), \tag{2.27}$$

where $0 < \zeta < 1$ is a parameter that controls the degree of convexity of cost, $a(1) = 0, a'(.) > 0, a'(1) = \frac{Z_k}{P_i}, a''(.) > 0$, and $a''(1) = a'(1)\frac{\zeta}{1-\zeta}$. Next, the entrepreneur supplies effective capital services, K_{t+1}, for the competitive rental rate $Z_{k,t+1}$, and sells undepreciated capital back to households at the price $Q_{\bar{K},t+1}$. The optimal capital utilization and the zero-profit condition are:

$$Z_{k,t+1} = P_{i,t+1}a'(u_{t+1}), \tag{2.28}$$

[11] The inclusion of the expected depreciation aims to account for the "forward premium anomaly", which means, in particular, that the home currency empirically tends to appreciate when the home nominal interest rate exceeds the foreign rate.

[12] Another reason for including entrepreneurial net worth in my model is that the role of MEI shock can be overemphasized if one neglects information on the stock market, as explored by Christiano, Motto, and Rostagno (2014) in a closed economy setup with asset-side financial frictions *à la* Bernanke, Gertler, and Gilchrist (1999).

$$R_{k,t+1} = \frac{Z_{k,t+1}u_{t+1} - P_{i,t+1}a(u_{t+1}) + (1-\delta)Q_{\bar{K},t+1}}{\omega_{\bar{K}}Q_{\bar{K},t}} - \frac{(1-\omega_{\bar{K}})Q_{\bar{K},t+1}}{\omega_{\bar{K}}Q_{\bar{K},t}}, \tag{2.29}$$

where $\omega_{\bar{K}}$ is the share of capital purchase financed by the entrepreneurial loan and $P_{i,t}a(u_t)$ is the unit utilization cost expressed in the price of investment goods. The entrepreneur breaks even, transfers all end-of-period $t+1$ net worth back to its household and hence accumulates no net worth period by period.[13]

2.2.5 Banks

I assume that competitive banks are owned by risk averse shareholders. In addition, banks frictionlessly lend to borrowers and efficiently enforce their obligations. At the end of period t, the state of a bank is summarized by its net worth, $N_{jb,t} \geq 0$. At this point, each risk neutral bank raises a nominal deposit, $D_{j,t}$, from depositors at the risk-free rate, R_t, and then proposes a menu of portfolios including three types of risk-free loans. The first type are intraperiod working capital loans, $L_{jf,t}$, to intermediate goods producers who must finance part of their expenditure for capital and labor services. The second type are also intraperiod credits, $L_{jx,t}$, to exporters for whom a fraction of the homogeneous goods bill must be financed. Both of these types of loans are due at the end of period t. Thirdly, entrepreneurial loans, $L_{je,t}$, are interperiod to purchase raw capital, which is due at the beginning of period $t+1$. The bank's balance sheet simply states that

$$L_{jt} \equiv L_{jf,t} + L_{jx,t} + L_{je,t} = N_{jb,t} + D_{j,t}.$$

The three types of loans pay out non-contingent nominal returns, $R_{f,t}$, $R_{x,t}$ and $R_{k,t}$, respectively.

Incentive constraint scheme

I assume that an exogenous random fraction, θ_t, of each bank's earnings is retained to grow the business while the complementary fraction is paid out to its shareholders as end-of-period t dividends.[14] Given my assumption, it is clear that the larger the net worth of the bank, the greater the financial resources available to its shareholders. Thus it is in the shareholders' own interests to request that their banker maximizes net worth. Also, I assume that shareholders value a particular menu of loan portfolios according to the expected future discounted value of the owned funds. The banker's job then is to solve

[13] There is some room for interpretation of my entrepreneur. The most straightforward interpretation is that of a firm in the non-financial business sector. Nevertheless, I do not unify the entrepreneur and the intermediate goods producer because I find it convenient to distinguish between entrepreneurial lending channels and working capital lending channels. Alternatively, the entrepreneur could be interpreted as a financial firm because there would be no agency problem between the bank and the entrepreneur. According to this interpretation, one can think of $R_{k,t}$ as the return that the financial firm ("bank") enjoys from purchasing securities of a non-financial firm.

[14] In the macro-finance literature, the origin of θ is technically devised to ensure the existence of agency problems. Otherwise, the agency problem would disappear if θ were to converge to 1, i.e. bankers would ultimately accumulate enough capital to the point that they became fully self-financing.

the following problem:

$$V_{j,t} \equiv \max_{\tilde{N}_{jb,t}} E_t \sum_{s=0}^{\infty} (1-\theta_{t+1})\theta_{t+1+s}\beta^{s+1}\Xi_{t,t+1+s}N_{jb,t+1+s}.$$

However, a moral hazard problem arises when bankers can discretionarily divert an exogenous time-varying fraction ϖ_t of assets on the balance sheet for their own interest.[15] Shareholders would therefore only approve the loan portfolio proposed by bankers if the present value of the expected funds was no less than the assets diverted in each period t. Then it is every banker's responsibility to ensure they conduct themselves with the following cash constraint:

$$V_{j,t} \geq \varpi_t \left(L_{jf,t} + L_{jx,t} + L_{je,t}\right), \qquad 0 < \varpi_t < 1. \tag{2.30}$$

The linearity of the banker's optimization problem implies

$$V_{j,t} = \tau_{f,t}L_{jf,t} + \tau_{x,t}L_{jx,t} + \tau_{e,t}L_{je,t} + \gamma_t N_{jb,t} \tag{2.31}$$

with

$$\tau_{f,t} = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\theta_{t+1})(R_{f,t} - R_t) + \theta_{t+1}\frac{L_{jf,t+1}}{L_{jf,t}}\tau_{f,t+1} \right] \right\} \tag{2.32}$$

$$\tau_{x,t} = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\theta_{t+1})(R_{x,t} - R_t) + \theta_{t+1}\frac{L_{jx,t+1}}{L_{jx,t}}\tau_{x,t+1} \right] \right\} \tag{2.33}$$

$$\tau_{e,t} = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\theta_{t+1})(R_{k,t} - R_t) + \theta_{t+1}\frac{L_{je,t+1}}{L_{je,t}}\tau_{e,t+1} \right] \right\} \tag{2.34}$$

$$\gamma_t = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\theta_{t+1})R_t + \theta_{t+1}\frac{N_{jb,t+1}}{N_{jb,t}}\gamma_{t+1} \right] \right\} \tag{2.35}$$

where $\tau_{f,t}$, $\tau_{x,t}$ and $\tau_{e,t}$ are the expected discounted marginal gain of loan types, and γ_t is the expected discounted marginal value of net worth.

Observe that the term on the left of (2.30) cannot be strictly greater than its right term in each time period t because in that case banks would make positive profits, which is incompatible with the competitive credit market. Thus, the cash constraint in (2.30) and perfect competitiveness jointly imply that (2.30) must hold as a strict equality in every period. Combining this fact with the linear value function (2.31), I obtain an incentive compatibility constraint for the entire banking sector,[16]

$$L_t = \phi_{b,t}N_{b,t}, \qquad \phi_{b,t} > 1, \tag{2.36}$$

$$\tau_{f,t} = \tau_{x,t} = \tau_{e,t} \equiv \tau_t \tag{2.37}$$

[15] In Gertler and Karadi's (2011) framework, ϖ_t is traditionally referred to as a time-invariant stealing fraction of assets and thus financial frictions on the liability side originally come from a fear that bankers would steal. I believe that an interpretation of asset diversion at the banker's discretion is better suited for a time-varying parameter. Therefore, following this interpretation, I present a slightly different framework in which the scheme of incentive constraint works due to the skewed nature of banks' compensation.

[16] This aggregation is possible due to risk neutrality and the constant number of bankers in the economy as well as perfect competitiveness in the credit market. Also, there exists an aggregate loan demand curve, identical for all banks. Therefore the j index has been dropped.

where $\phi_{b,t} = \frac{\gamma_t}{\varpi_t - \tau_t}$ is the leverage multiple.[17] For a given level of net worth $N_{b,t}$, a sharp rise in the divertible fraction of assets, ϖ_t, would deleverage the bank's balance sheet and deteriorate its capability to lend. Thus, the moral hazard problem imposes an endogenous incentive constraint on the bank balance sheet. I refer to this measure of divertiblity as the bank risk shock. Following an adverse shock to net worth, bankers have to cut back lending in order to satisfy their endogenous balance sheet constraint. Note also that in equilibrium all types of loans are symmetrically constrained and thus banks are indifferent to lending an additional unit among various borrowings.[18] The $(L_{f,t}, L_{x,t}, L_{e,t})$ combinations that satisfy the arbitrage condition (2.39) define an optimal loan portfolio approved by the representative household's shareholders and allocated by the banking sector to various borrowers.

Net worth evolution

Aggregating across all banks, the profit of the banking sector at the end of period t is

$$V_{b,t} = (R_{f,t} - R_t)L_{f,t-1} + (R_{x,t} - R_t)L_{x,t-1} + (R_{k,t} - R_t)L_{e,t-1} + R_t N_{b,t-1}. \tag{2.38}$$

After banks have received returns on the optimal portfolio of loans and settled their obligations to depositors, the random fraction, $\theta_{b,t}$, of aggregate profit is retained to grow the business. The complementary fraction, $1 - \theta_{b,t}$, is distributed as dividends and consumed every period. Therefore the per-capita consumption of shareholders is

$$P_{c,t} C_{b,t} = (1 - \theta_t) V_{b,t}. \tag{2.39}$$

Banks also raise exogenous additional capital, which corresponds to a fraction χ of the balanced-growth-path aggregate net worth, $n_b z_t$. After capital raising, aggregate net worth at the end of period t is

$$N_{b,t} = \theta_{b,t} V_{b,t} + \chi n_b z_t. \tag{2.40}$$

The weighted average lending-deposit spread is given by

$$spr_t = \frac{R_{f,t} L_{f,t} + R_{x,t} L_{x,t} + R_{k,t} L_{e,t}}{R_t L_t}. \tag{2.41}$$

2.2.6 Government policies and resource constraint

The monetary authority adjusts the policy rate with a Taylor rule of the form:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho} \left[\left(\frac{\pi_{c,t+1}}{\bar{\pi}_t}\right)^{r_\pi} \left(\frac{g_{gdp,t}}{g_z}\right)^{r_{\Delta_{gdp}}}\right]^{1-\rho} \varepsilon_t, 0 < \rho < 1, r_\pi, r_{\Delta_{gdp}} > 0, \tag{2.42}$$

where ε_t is a monetary policy shock and $g_{gdp,t}$ is observed quarterly growth in GDP.

[17] The incentive constraint always binds because in a neighborhood of the deterministic steady state additional raising capital only accounts for a fraction of aggregate net worth. Thus, as long as $0 < \chi < 1$, I have $\varpi > \tau$ in the neighborhood of the steady state.

[18] The arbitrage condition, however, does not imply that the expected returns are identical (not even up to first order) across loan types because the marginal gain depends on the growth rate of each loan type.

I model public spending, G_t, as:

$$G_t = z_t g_t, \tag{2.43}$$

where g_t follows a stationary stochastic process. Using the sequence of markets equilibrium, I obtain the real resource constraint as follows:

$$Y_t = G_t + C_{d,t} + I_{d,t} + X_t. \tag{2.44}$$

I measure GDP in the model as follows:

$$GDP_t = G_t + \tilde{C}_t + \tilde{I}_t + X_t - M_t, \tag{2.45}$$

with

$$\tilde{C}_t = \left[(1-\omega_c) \left(\frac{P_t}{P_{c,t}} \right)^{-\eta_c} + \omega_c \left(\frac{P_{cm,t}}{P_{c,t}} \right)^{-\eta_c} \right] C_t$$

and

$$\tilde{I}_t = \left[(1-\omega_i) \left(\frac{P_t}{P_{i,t}} \right)^{-\eta_i} + \omega_i \left(\frac{P_{im,t}}{P_{i,t}} \right)^{-\eta_i} \right] I_t.$$

The nominal resource constraint is used to pin down the (nominal) net foreign assets:

$$\begin{aligned} S_t D^*_{t+1} = R^*_t \Phi_t(.) S_t D^*_t + [1 + v_X(R_{x,t} - 1)] S_t [P_{x,t} X_{non,t} + P_{com,t} X_{com,t}] \\ - [1 + v_M(R^*_{m,t} - 1)] S_t P^*_t M_t \end{aligned} \tag{2.46}$$

where $P_{com,t}/P^*_t = p^*_{com,t}$ is the relative price of commodities in foreign currency that I model as a stationary stochastic process to capture exogenous price variations in the foreign market.

2.2.7 Foreign economy

I complete the model with a description of the foreign economy. Though optimal problems of foreign agents are similarly modeled, a large (and approximately closed) foreign economy has the following exceptions. First, final consumption and investment goods comprise a continuum of domestically produced goods, $C^*_t \equiv \int_0^1 C^*_{dj,t} dj$ and $I^*_t \equiv \int_0^1 I^*_{dj,t} dj$, because home exports account for a trivial share of aggregate foreign demand. Second, variations in the home export price have a negligible effect on the evolution of the foreign price index, implying that $P^*_{c,t} = P^*_{i,t} \equiv P^*_t$. Third, loans provided to home importers, $L_{m,t}$, form a negligible part of the total credit, it follows that $L^*_t \equiv L^*_{f,t} + L^*_{e,t}$ and $spr^*_t \equiv \frac{R^*_{f,t} L^*_{f,t} + R^*_{k,t} L^*_{e,t}}{R^*_t L^*_t}$ and that the moral hazard problem on this loan need not be analyzed. Home importers then take $R^*_{m,t} \equiv R^*_t spr^*_t$ as given. Finally, home assets are in zero net supply because the asset holdings of home households are negligible in the foreign market while there is no access to the home asset market for foreign agents.

2.2.8 Aggregate shocks and model variants

The Baseline model I estimate includes 20 aggregate shocks: $g_{z,t}, \epsilon_t, \lambda_{d,t}, \lambda_{cm,t}, \lambda_{im,t}, \lambda_{x,t}, \lambda_{w,t}, \varepsilon_{p_c,t}, b_t, \mu_t, \psi_t, \varepsilon_{com,t}, p^*_{com,t}, \varepsilon_t, \bar{\pi}_t, g_t, \theta_t, \varpi_t, n_{e,t}, \tilde{z}^*_t$ for the Home economy and 12 aggregate shocks: $g^*_{z,t}, \epsilon^*_t, \lambda^*_{p,t}, \lambda^*_{w,t}, b^*_t, \mu^*_t, \varepsilon^*_t, \bar{\pi}^*_t, g^*_t, \theta^*_t, \varpi^*_t, n^*_{e,t}$ for the Foreign economy, where $\tilde{z}^*_t = \frac{z^*_t}{z_t}$ is a stationary shock to allow for temporary asymmetry in the relative technological progress between the two economies. I model the log-deviation of each shock from its steady state as a univariate first order autoregression, except for the monetary policy shock, $\{\varepsilon_t, \varepsilon^*_t\}$, and the consumption price inflation shock, $\varepsilon_{\pi_{c,t}}$, which are assumed to be white noise. In the case of the inflation target shock, I simply fix the autoregressive parameter $\{\rho_{\bar{\pi}}, \rho_{\bar{\pi}^*}\}$ at $(0.975, 0.975)$ as my way of accommodating the low-frequency variations of inflation in the late part of the dataset.

I consider a pure trade open economy version of my model − I call it Pure for short − in which there are no financial frictions at all. I obtain this model from my Baseline model by dropping all equations that characterize the entrepreneurial and banking sectors and adding an intertemporal Euler equation of capital accumulation in the household sector. It is, of course, necessary to delete dividend payments by banks for shareholder consumption from final private consumption. I also consider several reduced-scale financial friction variants of my Baseline model in which the incentive constraint is put on one or more of the following loans: entrepreneurial loans, working capital loans, export loans, and import loans. Technically, these variants are respectively obtained by removing one imposition at-a-time from the set: $\{R_{k,t} = R_t,\ R^*_{k,t} = R^*_t;\ R_{f,t} = R_t,\ R^*_{f,t} = R^*_t;\ R_{x,t} = R_t;\ R^*_{m,t} = R^*_t\}$. Notice that the Benchmark variant includes financial frictions only on entrepreneurial loans, $\{L_{e,t}, L^*_{e,t}\}$, and the Quasibaseline variant is the Benchmark variant with the addition of incentive compatibility constraints on working capital loans and export credit $\{L_{e,t}, L^*_{e,t}, L_{f,t}, L^*_{f,t}, L_{x,t}\}$.

2.3 Data and empirical strategy

This section describes the data used in the analysis and the empirical strategy. Next, the calibrated parameters and prior information on the structural parameters and shock processes are presented.

2.3.1 The data

Home is identified with Australia and Foreign with the United States. The model is estimated with quarterly data for the period 1993Q1−2012Q4,[19] using seven conventional time series as observable variables in both economies: real GDP, real private consumption

[19]The starting date coincides with the official commencement of inflation targeting in Australia and thus the sample period is characterized by inflation-targeting regimes in both countries. I restrict my empirical analysis to this rather short sample in order to avoid potential distortionary effects of non-inflation targeting monetary policy on the estimates. In addition, by excluding much of the post-GFC period, I want to minimize the impact of structural breaks that are said to have occurred, including the zero lower bound binding period in the U.S.

as the sum of household purchases of nondurable goods and services, real investment as the sum of gross private domestic investment plus household purchases of durable goods, nonfarm hours worked, nonfarm real wages, domestic inflation, and nominal interest rate. I augment the standard data series with seven open economy variables, including non-commodity and commodity exports, imports, real exchange rate, CPI inflation, relative price of investment goods measured as the investment goods price deflator divided by the GDP deflator, $p_{i,t} = P_{i,t}/P_t$, and relative price of commodities measured as the commodity price index divided by the U.S. GDP deflator, $p^*_{com,t} = P_{com,t}/P^*_t$.[20] In accordance with the model, overall inflation is measured as the percentage growth in the CPI and the GDP deflator for Australia and the U.S., respectively. Also, I use three financial variables in my analysis. My measure of loans, $\{L_t, L^*_t\}$, is total credit to non-financial firms taken from the Lending and Credit Aggregates dataset compiled by the Reserve Bank of Australia and the Flow of Funds database constructed by the U.S. Federal Reserve Board. I identify the indicator of entrepreneurial net worth, $\{N_{e,t}, N^*_{e,t}\}$, with the ASX All Ordinaries index and the Dow Jones Wilshire 5000 index of the stock market. The spread is measured by the difference between the 90-day loan rate and the policy rate.[21]

Prior to analysis, I transform the data as follows. Quantity variables, including financial variables, are converted in real per-capita terms by dividing their nominal values by the GDP deflator and the civilian population. Real wage is computed by dividing compensation per hour by the GDP deflator. Hours worked are also converted in per-capita terms. I take the logarithmic first difference of all these quantity variables and then remove the sample mean for both quantity and price variables. Note that my model predicts that the log of every real quantity variable to GDP ratio is stationary, while on average some series (e.g. trade and financial) grew significantly faster than GDP in my dataset. Thus, I demean separately from each real quantity variable in order for my estimation not to distort the model's inference in the relatively low business cycle frequencies due to the existence of higher business cycle frequencies.

2.3.2 Empirical strategy

The empirical strategy proceeds as follows. First, I transform the model into a stationary form. Specifically, real variables are detrended by the level of technology, $\{z_t, z^*_t\}$, and nominal variables are converted to real variables by deflating with the price index, $\{P_t, P^*_t\}$. Second, the model is written into a set of stationary equilibrium conditions. Third, I compute the nonstochastic steady state of the transformed model. Fourth, I construct a log-linear approximation of the transformed model around its nonstochastic steady state. Fifth, the transformed model is augmented with a set of measurement equations which link the observable variables in the dataset with the endogenous variables in order to form a state-space system. Finally, I estimate model variants using Bayesian methods

[20] I use the G7 trade-weighted average real exchange rate rather than the bilateral series because it is my way of introducing multilateral real-world dynamics into the two-country model through the behavior of international relative prices.

[21] The large business loan rate for Australia and the bank prime lending rate for the U.S., respectively.

(see An and Schorfheide (2007) for a survey). In particular, the posterior distribution is estimated by maximizing the log-posterior function, which combines the prior information for the parameters with the likelihood of the dataset. The Metropolis–Hastings algorithm with 500,000 replications for two chains is used to get a complete picture of the posterior distribution. Simultaneously, the marginal likelihood of the model is computed using Geweke's modied harmonic mean procedure. Then I evaluate the relative empirical performance of model variants by comparing their implications for the marginal likelihood of the common dataset.

2.3.3 Calibration

A set of parameters is simply fixed a priori. Table 2.1 reports conventional parameters. Capital share $\{\alpha, \alpha^*\}$ is set at (0.32, 0.33). The quarterly depreciation rate for capital $\{\delta, \delta^*\}$ is fixed at (1.75%, 2.5%) to match the average annual investment-capital ratio. The inverse Frisch elasticity of labor supply $\{\sigma_L, \sigma_L^*\}$ is equal to 1. I pick the disutility weight on labor $\{\varphi_H, \varphi_H^*\}$ so that the steady-state hours worked are normalized to one-third. The steady-state gross markup in the labor market $\{\lambda_w, \lambda_w^*\}$ is set to 1.2. I calibrate the growth rate of the permanent technology shock $\{\bar{g}_z, \bar{g}_z^*\}$ to (0.45%, 0.41%), consistent with the mean growth rate of per-capita real GDP over the sample period. The discount factor β is fixed at 0.9987 and β^* is endogenously determined through the uncovered interest arbitrage condition. The government spending-GDP ratio is (0.23, 0.19), which corresponds to historical values. I impose $\{v_X = v_K = v_H > v_K^* = v_H^*\}$, which reflects my finding (see below) that the credit velocity measure is smaller in Australia than in the U.S. Assuming that (real) net foreign assets are at the zero steady-state level, I set v_M so that the trade balance as a percentage of GDP is -1%, the average value for Australia during the sample period, in order to ensure a well-defined steady state in the model.[22] The weights of foreign goods in the consumption and investment composites, ω_c and ω_i, are 0.21 and 0.50, consistent with average shares of imports in the consumption basket and private investment in Australia. The export share of the commodity sector, ω_x, is set to 0.72 to reflect the sample average value.

The calibrated parameters of the financial sector are shown in Table 2.2. The steady-state payout ratio of banks $\{1-\theta,\ 1-\theta^*\}$ is equal to $1-0.955$, which is fairly close to the $1-0.972$ value used by Gertler and Karadi (2011).[23] The steady-state spread

[22]In particular, I derive the trade balance to GDP ratio, $\frac{nx}{gdp}$, with respect to the share of import bill paid in advance, v_M, as follows:

$$\frac{nx}{gdp} = \left(\frac{1 + v_M R_m^*}{1 + v_X R_x} - 1\right)\frac{m}{gdp}.$$

In this way, my model does not impose a balanced trade assumption in steady state ($nx < 0$). See Section D of the Appendix for a detailed derivation of this steady state.

[23]Traditionally, $1-\theta$ is usually referred to as the death rate of bankers. For quarterly frequency (and the framework of a single economy, whether closed or open), it has usually been set equal to $1-0.972$ in previous studies using the Gertler and Karadi (2011) framework. However, the fraction $1-\theta$ in my model corresponds to that of the bank net income, $V_{b,t}$, passed for shareholder consumption $C_{b,t}$, so the most natural interpretation of this parameter is that it is the dividend payout ratio. A similar interpretation

Table 2.1: Calibration of Conventional Parameters

Description	Parameter	Value	Parameter	Value
Discount factor	β	0.9987		
Capital share	α	0.32	α^*	0.33
Depreciation rate	δ	0.0175	δ^*	0.025
Inverse Frisch elasticity	σ_H	1	σ_H^*	1
Disutility weight on labor	φ_H	9.5	φ_H	9.5
Gross markup in the labor market	λ_w	1.2	λ_w^*	1.2
Growth rate of the economy	$\bar{g}_z$	0.45	$\bar{g}_z^*$	0.41
Government spending-GDP ratio	g/y	0.23	g^*/y^*	0.19
Share of capital rental costs paid in advance	v_K	0.70	v_K^*	0.65
Share of labor costs paid in advance	v_H	0.70	v_H^*	0.65
Share of export bill paid in advance	v_X	0.70		
Share of import bill paid in advance	v_M	0.30		
Share of import goods in consumption	ω_c	0.21		
Share of import goods in investment	ω_i	0.50		
Share of commodity sector in export	ω_x	0.72		

Table 2.2: Calibration of Financial Parameters

Description	Parameter	Value	Parameter	Value
Entrepreneurial leverage multiple	ϕ_e	1.89	ϕ_e^*	1.95
Payout ratio	$1-\theta$	$1-0.95$	$1-\theta^*$	$1-0.95$
Lending-deposit spread	spr	284 b.p	spr^*	250 b.p
Banking leverage multiple	ϕ_b	6.42	ϕ_b^*	5.65
Fraction of additional capital	χ	0.002	χ^*	0.002

between the lending and deposit rates, $\{spr, spr^*\}$, corresponds to (284, 250) basis points to match the average spread between the 90-day loan rate and the policy rate. The entrepreneurial leverage multiple is the ratio of total liabilities to total net worth in the non-financial business sector, taken from the Non-financial Corporations Balance Sheet of the Australian Bureau of Statistics and the Flow of Funds account of the Federal Reserve Board. The banking leverage multiple in steady state is total assets divided by equity capital, which roughly captures the aggregate data of the banking sector in Australia and the U.S. respectively. I set the fraction of capital raised, $\{\chi, \chi^*\}$, in order to hit my steady-state targets for the weighted spread, the banking leverage multiple, and the retention ratio. As a result, the divertible fraction of assets in steady state, $\{\varpi, \varpi^*\}$, is endogenously determined in accordance with these targets.

has been used by Gertler and Kiyotaki (2010), where θ occurs in the context of banks' equity.

2.3.4 Priors

The set of parameters is assigned values listed in Tables2.5 and 2.6. My prior belief is that parameter distributions are symmetric between the two countries. Thus, I assign the same prior assumptions to all the comparable parameters. In particular, the prior assumptions for these parameters follow those in the closed economy set-up of Smets and Wouters (2007). The priors of my parameters specific to the small-open economy are as follows. The intratemporal elasticities of substitution for the consumption and investment composites, η_c and η_i, and the elasticity of non-commodity export demand, η^*, are assumed to follow an inverse-gamma distribution with a common mean of 1.5, consistent with the typical value used in the international macroeconomics literature. In addition, I truncate the prior to exclude substitutability below unity based on economic theory. For the parameter ϕ_a governing the debt elasticity of country risk premium, I specify an inverse-gamma density with a mean of 0.01, matching the calibrated value in Benigno (2009). I set a beta distribution centered at 0.5 and with a standard deviation of 0.15 for the depreciation elasticity of country risk premium, ϕ_s.

2.4 Model fit

This section evaluates the empirical performance of the model variants estimated for Australia and the U.S. The evaluation is made along the following dimensions: (i) marginal likelihood; (ii) steady-state properties; (iii) estimated parameters; and (iv) generated business cycle moments versus those in the data.

2.4.1 What type of loans should financial frictions be placed on?

I begin by judging the relative fit of the friction models.[24] In my Baseline model, I put the incentive compatibility constraint on all types of loans and not only on entrepreneurial loans. Much of the financial frictions literature attaches incentive constraints to funding for entrepreneuers' capital acquisition. The marginal likelihood comparison in this subsection suggests that the most preferred model variant is to place financial frictions on all types of loans.

Table 2.3 reports marginal likelihood statistics. According to the first row in the table, the log marginal data density of the Benchmark variant is -4893.97. Given the Benchmark variant with financial frictions only on entrepreneurial loans, I extend the incentive constraint to other domestic loans. The second row shows that the fit of the model rises tremendously when working capital loans are also subject to the incentive

[24] The model comparison apparatus is the marginal likelihood. Let m_i be a given model with $m_i \in M$, θ the parameter vector and $p_i(\theta|m_i)$ the prior information on the parameter vector. The marginal likelihood for the model m_i and the dataset is

$$L(d|m_i) = \int_\theta L(d|\theta, m_i)p_i(\theta|m_i)d\theta,$$

where $L(d|\theta, m_i)$ is the likelihood function of the data conditional on the parameter vector of the model and $L(d|m_i)$ is the marginal data density.

Table 2.3: Log Marginal Data Density

Model Variants	Marginal Data Density
Benchmark	−4893.97
Benchmark Plus	−4772.96
Quasibaseline	−4733.02
Baseline	−4659.10

Note: The log marginal data densities are computed from the posterior draws using a Geweke (1999) modified harmonic mean. The computations are based on a Monte Carlo Markov chain of length 500,000 for each model variant.

constraint. In particular, the log marginal data density increases roughly 120 log points. Next, I consider the Quasibaseline variant where incentive constraint is placed on export credits as well. That adds 40 additional log points to the fit beyond the Benchmark Plus scenario.

Next, while keeping incentive constraint on all types of domestic loans I allow for financial frictions on cross-border lending. Accordingly, placing financial frictions on import loans raises an even larger amount to fit (a substantial amount to fit) for the Baseline model. In particular, it adds 74 log points to fit compared to the Quasibaseline variant. Further, the log marginal likelihood of the Baseline model increases roughly 235 additional log points to fit above what is achieved by the Benchmark variant where incentive constraint is put on entrepreneurial loans alone, in the spirit of Gertler and Karadi (2011). Table 2.3 shows that the Baseline model where I place financial frictions on all types of loans adds more to model fit than one way or another of extending incentive constraint.

I infer two results from the findings in Table 2.3. First, financial friction extension has the potential to substantially improve the econometric fit of the model. Second, if one wants to incorporate liability-side financial frictions only, then placing the incentive compatibility constraint on all types of loans simultaneously is the better option because it adds the most to model fit.

2.4.2 Steady state

I now evaluate the impact of the estimated parameter values on the nonstochastic steady state. Table 2.4 reports the steady-state properties of two models (Pure and Baseline) when parameters are set to their posterior mode. The table also reports the empirical counterparts computed from the data.

Overall, the models successfully capture many of these key features of the data. One discrepancy lies in the steady-state interest rate of the U.S., which is lower in the data. This can be explained by a monetary policy regime switch since the GFC, with policy rates close to zero for an extended period of time. It is therefore not surprising that the models don't perform well in this dimension. Another exception that shows that deterioration is quantitatively negligible is the capital stock-GDP ratio, which is a little lower in the

Table 2.4: Steady-state Properties, Models at Posteriors versus Data

Variable	Australia			United States		
	Pure	Baseline	Data	Pure	Baseline	Data
Discount factor				0.9983	0.9983	
Investment to GDP ratio	0.27	0.28	0.26	0.28	0.27	0.25
Consumption to GDP ratio	0.53	0.51	0.52	0.52	0.53	0.56
Government spending to GDP ratio	0.21	0.22	0.23	0.20	0.20	0.19
Export to GDP ratio	0.20	0.20	0.20			
Import to GDP ratio	0.21	0.21	0.21			
Capital stock to GDP ratio[1]	10.87	9.23	12.1	9.87	8.45	10.3
Inflation (APR)	2.48	2.50	2.58	2.16	2.24	2.19
Short-term risk-free rate (APR)	4.76	4.75	4.80	4.44	4.49	3.92
Credit velocity[2]		1.20	1.20		1.56	1.63
Banking leverage multiple		6.53	6.42		5.80	5.65
Divertible fraction of assets		0.140			0.169	

[1] Capital stock includes private non-residential and residential fixed assets, stock of private inventories, and stock of consumer durables (*Source*: ABS and BEA).

[2] Credit velocity is computed as annual nominal GDP over total credit, where total credit in each economy is respectively defined as credit market instruments liabilities of non-financial corporations (*Source*: Finance and Wealth Accounts, ABS) and the sum of credit market instruments liabilities of non-financial corporate sector plus credit market instruments liabilities of noncorporate sector (*Source*: Flow of Funds Accounts, FRB).

Baseline model. The relatively low stock of capital partly results from the effect of financial frictions on capital accumulation, possibly even more so than in the home economy where foreign financial frictions impact on investment goods via import credit. I deliberately do not include the data's relevant ratios in computing the posterior distribution of the model parameters because I want to make a comparison between the pure trade model and the financial friction model on a level playing field. Data on divertible asset rates is scarce and also poses considerable problems of interpretation. Additionally, the empirical figure for asset diversion is directly incomparable with the value obtained from the Baseline model as my theoretical framework does not take cost per lending unit into account. There is also no empirical evidence of the feasible value range of divertible asset fraction in the literature. Therefore it suffices to say that a relatively low value is broadly in line with my interpretation of this parameter as an asset fraction for discretionary diversion.[25]

2.4.3 Posteriors

I report the posterior modes of my models for Australia and the U.S. in Tables 2.5 and 2.6. Most comparable parameters are remarkably similar across the friction variants within the economy and between the two economies. Notably, the standard deviation of the posterior is often less than half of the standard deviation of the prior in three friction variants, implying that there is a reasonable amount of information in the macro-finance dataset about most economic parameters. Since parameter estimates for the models are reasonable, I quickly pin down the salient ones.

The estimate for the elasticity of capital utilization $\{\zeta, \zeta^*\}$ in three friction variants favors relatively high values, suggesting a costly change to the utilization of capital in the financial friction environment. As capital adjustment costs are high, the price of capital responds to shocks to a greater extent, with direct effects on entrepreneurial net worth and thus on the spread through demand for loans. Higher values of capital utilization elasticity also imply larger marginal depreciation costs and thus less variation in capital utilization. Consistent with these, the investment adjustment costs parameter $\{F'', F''^*\}$ is higher in the financial friction variants than in the Pure model, which it is not surprising due to interaction between investment costs and financial frictions. High adjustment costs make investment goods production more costly and therefore investment is less responsive to shocks. However, $\{F'', F''^*\}$ slightly decrease in the Quasibaseline and Baseline variants as financial frictions themselves on working capital and export loans take away, to some extent, the financial accelerator effect. The larger estimates for the Taylor inflation coefficient in the financial friction environment are indications of financial accelerator effects at work, especially in the U.S. baseline economy. Specifically, the presence of the financial accelerator amplifies and propagates the impact of markup shocks on nominal variables, since markup shocks are more persistent. Therefore, monetary authorities have to put stronger focus on nominal stabilization to undo the effects of nominal rigidities than they

[25] Gertler and Karadi (2011) calibrated this parameter to a value of 0.381, which they interpret as the fraction of stolen assets.

Table 2.5: Structural Parameters of Model Variants: Home Economy

Para.	Description	Prior			Posterior							
					Pure		Benchmark		Quasibaseline		Baseline	
		Dist.	Mean	SD	Mode	SD	Mode	SD	Mode	SD	Mode	SD
Panel A. Economic parameters												
ξ_w	Calvo, wage	B	0.5	0.1	0.47	0.08	0.41	0.08	0.44	0.08	0.44	0.08
ξ_d	Calvo, domestic price	B	0.5	0.1	0.84	0.03	0.85	0.03	0.87	0.03	0.87	0.03
ξ_{cm}	Calvo, import cons. price	B	0.5	0.1	0.91	0.02	0.55	0.07	0.55	0.08	0.57	0.08
ξ_{im}	Calvo, import inv. price	B	0.5	0.1	0.77	0.02	0.79	0.02	0.80	0.02	0.80	0.02
ξ_x	Calvo, export price	B	0.5	0.1	0.68	0.06	0.69	0.06	0.69	0.06	0.69	0.06
ι_w	Indexation, wage	B	0.5	0.15	0.40	0.16	0.42	0.16	0.41	0.16	0.41	0.16
ι_d	Indexation, domestic price	B	0.5	0.15	0.71	0.13	0.79	0.08	0.77	0.09	0.76	0.11
ι_{cm}	Indexation, import cons. price	B	0.5	0.15	0.89	0.04	0.89	0.05	0.89	0.05	0.89	0.05
ι_{im}	Indexation, import inv. price	B	0.5	0.15	0.79	0.08	0.80	0.08	0.80	0.08	0.80	0.08
ι_x	Indexation, export price	B	0.5	0.15	0.83	0.07	0.83	0.07	0.84	0.07	0.84	0.07
λ_d	Markup, domestic	N	1.2	0.12	1.78	0.09	1.86	0.09	1.86	0.09	1.86	0.09
λ_{cm}	Markup, import cons.	N	1.2	0.12	1.07	0.04	1.20	0.05	1.21	0.05	1.22	0.06
λ_{im}	Markup, import inv.	N	1.2	0.12	1.53	0.09	1.52	0.10	1.51	0.10	1.50	0.11
F''	Investment adjustment cost	N	4	1.5	4.97	1.19	7.28	1.20	7.03	1.32	6.65	1.04
ζ	Capital utilization rate	B	0.5	0.15	0.35	0.11	0.59	0.09	0.59	0.07	0.56	0.15
b	Habit formation	B	0.5	0.1	0.57	0.07	0.56	0.17	0.54	0.15	0.55	0.16
ρ	Taylor rule smoothing	B	0.75	0.1	0.89	0.02	0.86	0.02	0.88	0.02	0.88	0.02
r_π	Taylor rule on inflation	N	1.5	0.25	1.62	0.21	1.63	0.13	1.66	0.15	1.66	0.15
$r_{\triangle_{gdp}}$	Taylor rule on GDP growth	N	0.25	0.1	0.30	0.08	0.19	0.06	0.19	0.06	0.19	0.06
η_c	Elasticity of subst., cons.	$\mathrm{I}_{>1}$	1.5	4	3.73	0.57	5.41	1.21	5.39	1.33	5.55	1.47
η_i	Elasticity of subst., inv.	$\mathrm{I}_{>1}$	1.5	4	1.38	0.06	1.38	0.06	1.37	0.06	1.37	0.06
η_x	Elasticity of subst., export	$\mathrm{I}_{>1}$	1.5	4	1.49	0.12	1.49	0.12	1.49	0.12	1.49	0.12
ϕ_a	Elasticity of premium-debt	I	0.01	1	0.002	0.0006	0.002	0.0007	0.002	0.0007	0.002	0.0007
ϕ_s	Elasticity of premium-depre.	B	0.5	0.15	0.17	0.04	0.16	0.04	0.16	0.04	0.16	0.05
Panel B. Autocorrelation of the shocks												
ρ_{g_z}	Persistent technology	B	0.5	0.2	0.49	0.27	0.51	0.29	0.51	0.29	0.51	0.29
$\rho_{\tilde{z}^*}$	Asymmetric technology	B	0.5	0.2	0.50	0.27	0.50	0.27	0.50	0.27	0.50	0.27
ρ_ϵ	Transitory technology	B	0.5	0.2	0.98	0.01	0.91	0.03	0.89	0.04	0.89	0.04
ρ_w	Wage markup	B	0.5	0.2	0.17	0.09	0.15	0.08	0.15	0.08	0.16	0.08
ρ_d	Domestic price markup	B	0.5	0.2	0.10	0.10	0.06	0.05	0.06	0.06	0.06	0.06

Para.	Description	Prior			Posterior							
					Pure		Benchmark		Quasibaseline		Baseline	
		Dist.	Mean	SD	Mode	SD	Mode	SD	Mode	SD	Mode	SD
ρ_{cm}	Import cons. price markup	B	0.5	0.2	0.05	0.03	0.95	0.01	0.95	0.01	0.95	0.01
ρ_{im}	Import inv. price markup	B	0.5	0.2	0.08	0.06	0.11	0.08	0.11	0.08	0.11	0.08
ρ_x	Export price markup	B	0.5	0.2	0.09	0.07	0.08	0.06	0.08	0.06	0.08	0.06
ρ_{pco}	Commodity relative price	B	0.5	0.2	0.92	0.02	0.93	0.01	0.93	0.01	0.93	0.01
ρ_{xco}	Commodity demand	B	0.5	0.2	0.78	0.05	0.79	0.05	0.79	0.05	0.79	0.05
ρ_ψ	Country risk premium	B	0.5	0.2	0.68	0.07	0.65	0.07	0.68	0.07	0.68	0.07
ρ_g	Government spending	B	0.5	0.2	0.62	0.09	0.71	0.09	0.71	0.09	0.69	0.09
ρ_μ	Marginal efficiency of investment	B	0.5	0.2	0.15	0.09	0.92	0.03	0.94	0.03	0.96	0.05
ρ_b	Intertemporal preference	B	0.5	0.2	0.42	0.16	0.79	0.14	0.65	0.27	0.63	0.29
ρ_{ne}	Entrepreneurial net worth	B	0.5	0.2	–	–	0.98	0.007	0.98	0.007	0.98	0.007
ρ_{θ_b}	Banking net worth	B	0.5	0.2	–	–	0.98	0.007	0.99	0.004	0.99	0.005
ρ_γ	Banking risk	B	0.5	0.2	–	–	0.78	0.03	0.79	0.03	0.79	0.03
Panel C. Standard deviations of the innovations												
σ_{g_z}	Persistent technology	I	0.05	2	0.02	0.009	0.02	0.010	0.02	0.010	0.02	0.010
$\sigma_{\tilde{z}^*}$	Asymmetric technology	I	0.05	2	0.02	0.009	0.02	0.009	0.02	0.009	0.02	0.009
σ_ϵ	Transitory technology	I	0.1	2	0.33	0.032	0.51	0.052	0.56	0.056	0.56	0.057
σ_w	Wage markup	I	0.1	2	0.56	0.068	0.59	0.071	0.58	0.070	0.58	0.069
σ_d	Domestic price markup	I	0.1	2	0.72	0.068	0.75	0.066	0.73	0.065	0.73	0.066
σ_{cm}	Import cons. price markup	I	0.1	2	2.11	0.318	2.99	1.108	3.05	1.170	2.98	1.285
σ_{im}	Import inv. price markup	I	0.1	2	1.33	0.137	1.24	0.128	1.24	0.127	1.23	0.127
σ_x	Export price markup	I	0.1	2	4.54	0.724	4.48	0.703	4.47	0.700	4.47	0.702
σ_{pco}	Relative commodity price	I	0.1	2	5.73	0.457	5.71	0.453	5.72	0.456	5.72	0.457
σ_{xco}	Commodity demand	I	0.1	2	5.02	0.391	5.01	0.390	5.01	0.390	5.01	0.390
σ_ψ	Country risk premium	I	0.1	2	0.96	0.231	0.87	0.212	0.80	0.217	0.81	0.216
σ_{π_c}	Consumption price inflation	I	0.1	2	0.91	0.074	0.89	0.070	0.89	0.071	0.89	0.071
σ_ε	Monetary policy	I	0.1	2	0.11	0.009	0.11	0.010	0.11	0.010	0.11	0.010
$\sigma_{\bar{\pi}}$	Inflation target	I	0.05	2	0.04	0.012	0.02	0.010	0.02	0.011	0.02	0.012
σ_g	Government spending	I	0.1	2	0.62	0.050	0.69	0.057	0.70	0.058	0.70	0.058
σ_μ	Marginal efficiency of investment	I	0.1	2	1.28	0.138	0.47	0.069	0.44	0.068	0.42	0.078
σ_b	Intertemporal preference	I	0.1	2	0.54	0.066	0.66	0.187	0.58	0.142	0.57	0.130
σ_{ne}	Entrepreneurial net worth	I	0.1	2	–	–	6.42	0.498	6.41	0.497	6.41	0.496
σ_{θ_b}	Banking net worth	I	0.1	2	–	–	1.30	0.136	1.19	0.127	1.17	0.139
σ_ϖ	Banking risk	I	0.1	2	–	–	6.11	0.664	5.47	0.604	5.41	0.605

Note: Estimated parameters are based on two independent metropolis chains with 500,000 draws after a burn-in period of 200,000 draws.

Table 2.6: Structural Parameters of Model Variants: Foreign Economy

Para.	Description	Prior			Posterior					
					Pure		Benchmark		Baseline	
		Dist.	Mean	SD	Mode	SD	Mode	SD	Mode	SD
Panel A. Economic parameters										
ξ_w^*	Calvo, wage	B	0.5	0.1	0.55	0.08	0.47	0.07	0.51	0.07
ξ_p^*	Calvo, price	B	0.5	0.1	0.89	0.02	0.80	0.02	0.83	0.02
ι_w^*	Indexation, wage	B	0.5	0.15	0.51	0.17	0.46	0.17	0.47	0.17
ι_p^*	Indexation, price	B	0.5	0.15	0.67	0.12	0.81	0.08	0.85	0.06
λ_p^*	Markup, price	N	1.2	0.12	1.79	0.09	1.88	0.09	1.91	0.09
F''^*	Investment adjustment cost	N	4	1.5	4.64	1.27	6.14	1.06	5.97	0.97
ζ^*	Capital utilization rate	B	0.5	0.15	0.51	0.10	0.61	0.08	0.59	0.07
b^*	Habit formation	B	0.5	0.1	0.69	0.06	0.84	0.04	0.80	0.04
ρ^*	Taylor rule smoothing	B	0.75	0.1	0.84	0.02	0.84	0.02	0.84	0.02
r_{π^*}	Taylor rule on inflation	N	1.5	0.25	1.56	0.20	2.13	0.15	2.15	0.16
$r_{\triangle_{gdp}^*}$	Taylor rule on GDP growth	N	0.25	0.1	0.41	0.08	0.18	0.07	0.27	0.07
Panel B. Autocorrelation of the shocks										
$\rho_{g_z^*}$	Persistent technology	B	0.5	0.2	0.49	0.27	0.50	0.27	0.50	0.27
ρ_{ϵ^*}	Transitory technology	B	0.5	0.2	0.96	0.01	0.96	0.02	0.96	0.02
ρ_w^*	Wage markup	B	0.5	0.2	0.23	0.11	0.10	0.07	0.10	0.07
ρ_p^*	Price markup	B	0.5	0.2	0.21	0.16	0.95	0.02	0.92	0.02
ρ_g^*	Government spending	B	0.5	0.2	0.94	0.01	0.95	0.02	0.94	0.02
ρ_{μ^*}	Marginal efficiency of investment	B	0.5	0.2	0.66	0.08	0.98	0.01	0.99	0.01
ρ_b^*	Intertemporal preference	B	0.5	0.2	0.62	0.13	0.60	0.11	0.69	0.12
ρ_{ne}^*	Entrepreneurial net worth	B	0.5	0.2	–	–	0.97	0.008	0.97	0.008
$\rho_{\theta_b}^*$	Banking net worth	B	0.5	0.2	–	–	0.98	0.005	0.98	0.005
ρ_γ^*	Banking risk	B	0.5	0.2	–	–	0.79	0.02	0.79	0.02
Panel C. Standard deviations of the innovations										
$\sigma_{g_z}^*$	Persistent technology	I	0.05	2	0.02	0.009	0.02	0.009	0.02	0.009
σ_ϵ^*	Transitory technology	I	0.1	2	0.34	0.031	0.28	0.029	0.28	0.035
σ_w^*	Wage markup	I	0.1	2	0.49	0.059	0.50	0.050	0.50	0.052
σ_p^*	Price markup	I	0.1	2	0.08	0.013	0.05	0.008	0.04	0.007
σ_ε^*	Monetary policy	I	0.1	2	0.12	0.011	0.10	0.009	0.10	0.009
$\sigma_{\bar{\pi}}^*$	Inflation target	I	0.05	2	0.04	0.012	0.02	0.007	0.03	0.013
σ_g^*	Government spending	I	0.1	2	0.44	0.034	0.46	0.036	0.46	0.036
σ_μ^*	Marginal efficiency of investment	I	0.1	2	0.45	0.071	0.32	0.057	0.48	0.128
σ_b^*	Intertemporal preference	I	0.1	2	0.15	0.021	0.12	0.020	0.12	0.018
σ_{ne}^*	Entrepreneurial net worth	I	0.1	2	–	–	6.77	0.523	6.77	0.524
$\sigma_{\theta_b}^*$	Banking net worth	I	0.1	2	–	–	1.76	0.158	1.58	0.140
σ_ϖ^*	Banking risk	I	0.1	2	–	–	8.03	0.733	7.19	0.657

Note: Estimated parameters are based on two independent metropolis chains with 500,000 draws after a burn-in period of 200,000 draws. For the foreign economy, the posterior distribution in the Quasibaseline variant is not shown because it is exactly the same as in the Baseline variant.

would if there were no financial frictions at all.

For most shocks, the posterior modes of the autocorrelations are quite large. The exception is the autocorrelations of some markup shocks in both friction and frictionless models. These are nearly zero, so that the shocks are roughly random walks. In the Pure model, one notable difference is a much lower persistence of the MEI shock in Australia than in the U.S. due to the relative price volatility of investment goods with respect to the open economy setting. The high persistence of the MEI and financial stochastic processes in the friction variants implies that those shocks will account for most of the variance of the real and financial variables at long horizons. The growth rate of the persistent component of technology and its volatility are stable across both friction and frictionless models, suggesting that the demeaned financial series closely follow the stochastic growth path of the economy.

There is also substantial information in the dataset about most parameters of the shock processes, particularly financial process parameters, as indicated by the small size of the posterior standard deviation relative to the prior standard deviation. The exceptions are the intertemporal preference shock in Australia and the asymmetric technology shock in both countries, whose the posterior standard deviation is larger than the prior value. Open economy specific shocks are all plausibly characterized by relatively large volatility, whether in the frictionless or friction environment. The large standard deviation of financial processes, coupled with a larger Taylor rule coefficient for inflation, seems to suggest that incorporating financial frictions gives more prominence to the role played by inflation targeting monetary policy. Interestingly, financial shocks in the U.S. are significantly more volatile than in Australia, implying that U.S. financial frictions are relatively strong.

2.4.4 Business cycle statistics

I now consider to what extent the performance of my models is consistent with the empirical moments? The most important result from Table 2.7 is that friction variants help improve the goodness of fit of second moments, particularly in the Baseline variant.

Overall, both frictionless and friction models perform well in terms of matching macroeconomic moments. In particular, they are able to generate a low volatility of GDP despite slightly overpredicting this moment, as well as the volatility of consumption. As in the data, investment and consumption in both types of models are more volatile than GDP, though a bit more so than their empirical counterparts. In addition, the procyclicality of investment in all four models is in line with the data. The positive correlations are also reproduced by all the models in the case of hours worked and wages with GDP, though their value is largely higher than the empirical counterparts. The only exception here is the case of the U.S. hours worked, for which generated correlation signs are at odds with the data. Nevertheless, the models capture well the negative comovement of the interest rate and real exchange rate with GDP. Further, they largely replicate the behavior of exports and imports as well, both in terms of their volatility and procyclicality.

The presence of financial frictions is preferable in the data compared to the frictionless

Table 2.7: Second Moments: Data and Model Variants

Variable	By Data				By Models															
	SD	AC	CO	CR	SD				AC				CO				CR			
Australia																				
GDP	0.11	0.96	1	0.98	0.35	0.22	0.15	0.14	0.87	0.90	0.88	0.91	1				0.85	0.75	0.83	0.95
I	0.14	0.94	0.94	0.95	0.23	0.20	0.18	0.17	0.90	0.92	0.88	0.91	0.89	0.88	0.90	0.89	0.83	0.86	0.89	0.92
C	0.11	0.96	0.99	0.98	0.21	0.15	0.15	0.15	0.91	0.90	0.94	0.94	0.92	0.85	0.83	0.80	0.93	0.84	0.90	0.93
H	0.02	0.88	0.54	0.61	0.15	0.11	0.10	0.05	0.79	0.80	0.76	0.89	0.20	0.19	0.17	0.45	0.21	0.30	0.28	0.50
W	0.09	0.95	0.98	0.95	0.17	0.20	0.15	0.11	0.91	0.90	0.92	0.93	0.93	0.87	0.91	0.94	0.86	0.83	0.85	0.91
R	0.27	0.90	-0.38	-0.29	0.34	0.42	0.31	0.29	0.88	0.83	0.91	0.91	-0.19	-0.23	-0.27	-0.32	-0.10	-0.17	-0.15	-0.22
π_c	0.19	0.50	0.24	0.27	0.28	0.35	0.22	0.22	0.41	0.52	0.47	0.49	0.26	0.12	0.17	0.26	0.41	0.22	0.34	0.32
X	0.17	0.93	0.90	0.88	0.28	0.14	0.19	0.19	0.92	0.89	0.91	0.92	0.61	0.70	0.75	0.78	0.82	0.85	0.85	0.89
M	0.16	0.94	0.96	0.97	0.22	0.09	0.23	0.21	0.91	0.85	0.90	0.91	0.71	0.80	0.82	0.83	0.70	0.84	0.87	0.95
RER	0.18	0.94	-0.79	-0.70	0.21	0.27	0.26	0.21	0.93	0.97	0.96	0.96	-0.61	-0.63	-0.82	-0.77	-0.41	-0.82	-0.79	-0.78
N_e	0.17	0.89	0.34	0.49	–	0.57	0.40	0.31	–	0.98	0.96	0.93	–	0.16	0.25	0.28	–	0.18	0.23	0.37
L	0.36	0.97	0.97	0.95	–	0.52	0.43	0.40	–	0.72	0.80	0.94	–	0.81	0.90	0.96	–	0.70	0.83	0.90
Spr	0.17	0.88	-0.11	-0.21	–	0.52	0.34	0.23	–	0.61	0.70	0.86	–	-0.03	-0.07	-0.10	–	-0.05	-0.14	-0.19
United States																				
GDP^*	0.09	0.96	1		0.21	0.14	0.15	0.12	0.93	0.93	0.94	0.95	1							
I^*	0.12	0.95	0.61		0.23	0.18	0.17	0.14	0.81	0.91	0.93	0.94	0.52	0.83	0.91	0.82				
C^*	0.11	0.97	0.98		0.22	0.19	0.21	0.15	0.94	0.95	0.96	0.97	0.92	0.87	0.84	0.82				
H^*	0.07	0.98	-0.50		0.25	0.15	0.19	0.11	0.91	0.91	0.95	0.92	0.10	0.29	0.28	0.23				
W^*	0.10	0.97	0.97		0.30	0.23	0.19	0.16	0.91	0.94	0.96	0.95	0.86	0.93	0.97	0.96				
R^*	0.55	0.97	-0.46		0.36	0.63	0.58	0.57	0.73	0.88	0.91	0.96	-0.21	-0.35	-0.40	-0.43				
π^*	0.20	0.57	0.12		0.28	0.26	0.18	0.19	0.50	0.45	0.47	0.50	0.18	0.16	0.17	0.14				
N_e^*	0.30	0.94	0.82		–	0.58	0.45	0.36	–	0.81	0.89	0.92	–	0.65	0.79	0.84				
L^*	0.17	0.97	0.96		–	0.31	0.24	0.20	–	0.85	0.94	0.96	–	0.80	0.89	0.93				
Spr^*	0.46	0.94	-0.32		–	0.67	0.51	0.43	–	0.88	0.90	0.95	–	-0.17	-0.21	-0.30				

Note: SD – standard deviation, AC – autocorrelation, CO – correlation with country-specific GDP, CR – cross-country correlation with U.S. GDP. Results in each second moment are presented in the following way: the first entry is generated by the Pure model, the second entry by the Benchmark variant, the third entry by the Quasibaseline variant, and the fourth entry by the Baseline variant.

model. The comparison of the standard deviations of variables shows that the friction model variants fit the real macroeconomic aggregates better than the Pure model. In particular, the Pure model performs poorly in reproducing the standard deviations of investment. The friction models also do a better job in matching the autocorrelation shown in the data, particularly the Baseline variant. However, they perform slightly worse in terms of the comovement of (household) consumption with GDP due to the presence of shareholder consumption by construction. For example, the consumption correlation in the Baseline variant is as low as (0.83,0.84), as opposed to (0.99, 0.98) in the data. Although the friction models don't perform well in this dimension, other empirical moments that I try to match are closer to what are achieved in the friction models. The cross-correlations implied by the Baseline model correspond best to their empirical counterparts. Compared to the Pure model, the friction variants are better able to capture the cross-border comovement between investment and GDP.

I take a closer look at the relative performance among the competing friction variants. The Baseline variant improves on the other variants in terms of replicating the dynamics of macroeconomic series for both economies. Further, financial dimensions are best replicated by the Baseline variant. Accordingly it matches well the volatility and autocorrelation of three financial time series. In both economies, this variant is also able to better reproduce the within- and cross-country procyclicality of Australian credit and entrepreneurial net worth, as well as the countercyclicality of country-specific spreads.

To sum up, this goodness-of-fit analysis leads to two main results. First, financial frictions can help to improve the model's ability to match the observed macroeconomic variables in most dimensions. The Pure model, by contrast, generally performs less satisfactorily, especially its performance in matching the cross-border dynamics of variables. Second, the Baseline variant outperforms the other two friction variants in replicating the behavior of both macroeconomic and financial data. These results illustrate that a model of two asymmetric countries in which the banking sector's leverage multiple is endogenously constrained by a moral hazard problem serves well in accounting for the main business cycle patterns. Notice that various statistics of the cross-country correlation, taken together, suggest fairly strong business cycle comovement of Australia with the U.S. In next subsection, I explore whether and to what extent competing models can similarly capture these international linkages.

2.4.5 Accounting for the influence of foreign disturbances

The real test of the model structure is to what extent models can account for the spillover effect of foreign disturbances on the Home economy. This subsection presents the cross-border causes of Australian business cycles, showing that U.S. shocks tend to play a relatively larger role in three friction models, especially in the Baseline variant.

Table 2.8 decomposes the estimated contribution of all purely foreign disturbances to the variability of Australian unconditional variances. For each of the four models, I document the importance of foreign stationary shocks by presenting the sum of their

Table 2.8: Variance Shares of Australian Series Attributed to U.S. Shocks (*Percent*)

Series \ Model Variants	Pure	Benchmark	Quasibaseline	Baseline
GDP	5	4 | 5 | 9	8 | 6 | 14	10 | 8 | 18
Investment	3	5 | 3 | 8	6 | 3 | 9	9 | 5 | 14
Consumption	2	3 | 3 | 6	5 | 3 | 8	6 | 4 | 10
Hours	2	1 | 2 | 3	2 | 3 | 5	2 | 5 | 7
Wage	1	2 | 2 | 4	2 | 4 | 6	3 | 5 | 8
Interest rate	5	3 | 5 | 8	5 | 6 | 11	7 | 8 | 15
Inflation	11	3 | 10 | 13	4 | 11 | 15	7 | 11 | 18
Export	15	2 | 15 | 17	4 | 16 | 20	12 | 15 | 27
Import	21	7 | 18 | 25	11 | 16 | 27	23 | 12 | 35
Real exchange rate	16	2 | 17 | 19	3 | 17 | 20	12 | 14 | 26
Credit	–	7 | 4 | 11	12 | 8 | 20	15 | 7 | 22
Spread	–	5 | 2 | 7	12 | 3 | 15	15 | 3 | 18

Note: Unconditional variance decomposition is generated by each model evaluated at the posterior mode. For the friction variants, the contribution of the U.S. shocks is presented in the following way: the first entry is the sum of the "financial" shocks, the second entry is the sum of the "other" shocks, and the third entry is the total contribution of both the financial and other shocks. "Financial" represents entrepreneurial net worth, banking risk and banking net worth shocks. "Other" includes non-financial shocks, the country risk premium shock, and the degree of technology asymmetry. The only entry in the Pure model corresponds to the total contribution of the "other" shocks.

contributions under three categories: financial shocks, non-financial shocks, and all shocks. Overall, the purely foreign stationary shocks matter for the home business cycles in the Pure model. A structural variance decomposition reveals that the conventional shocks, taken together, have effects of at least 2% on the home variables, except regarding real wages. In particular, U.S. shocks combined can explain 5% of the variability in Australian GDP, 5% in interest rates and 11% in inflation. Moreover, it is evident that the foreign dimensions are needed to capture the substantial importance of the observed open economy variables: exports, imports and real exchange rate. However, the frictionless model is unable to account for macroeconomic comovement, though foreign shocks explain non-negligible fractions of the home variance. Cross-border trade flows and financial-frictionless lending are not sufficiently important to generate strong spillover effects, consistent with the cross-country correlation evidence in Subsection 2.4.4.

The focal point is the competing friction variants' ability to generate the share of the business cycle variance in Australian series attributable to U.S. shocks. Putting the incentive compatibility constraint on entrepreneurial loans alone − Benchmark variant − has a negligible effect on the variance decomposition of hours and real wages, but helps improve the foreign share in open economy variables. Meanwhile, the fraction of the variance in Australian GDP, investment and consumption due to all U.S. shocks rises significantly. This result suggests that the macroeconomic comovement observed in the data can be significantly increased by including domestic banking sectors with financial frictions. With the incentive compatibility constraint also on capital working and export loans, the Quasibaseline variant raises the foreign contribution to home variability. For example, the variance share of Australian GDP explained by all U.S. shocks is 5% higher than that achieved in the Benchmark variant. Additionally more than half of the variance in the real aggregates is now attributed to U.S. financial shocks. However, the variance shares of the Australian series due to all U.S. disturbances still fall short of those observed in the data.

A comparison with the last column makes it clear that the Baseline variant is better for explaining spillover effects than any of the previous friction variants. Indeed, the largest increase in the share of GDP variability explained by all U.S. shocks occurs with financial frictions also on import loans, and in this case up to 18% of GDP fluctuations. The portion of variance attributable to foreign financial shocks is also now larger, particularly for GDP and interest rate. These shocks account for 11% of GDP, 9% of investment, 6% of consumption, and 7% of the interest rate or inflation. Further, the portion of the variation in Australian credit and spread due to U.S. shocks combined climbs to 22% and 18% respectively, of which financial disturbances are particularly important. Foreign credit to importers therefore proves to be one important financial channel through which foreign business cycle fluctuations were transmitted to the home economy, as made evident by the last column of Table 2.8. This is why the Baseline variant in Subsection 2.4.4 − which allows for financial frictions on all types of loans − was best able to reproduce the empirically observed synchronization.

To sum up, my empirical evidence supports the performance of friction models: the share of the business cycle variance in the Australian series due to shocks originating in the U.S. economy is substantial. This finding is clearly consistent with the model-implied cross-country correlations in Section 2.4.4. More importantly, the baseline model with financial frictions on all types of loans does the best job in reproducing the synchronization in business cycles, both for financial and standard macroeconomic variables.

2.5 The role of financial factors

In this section, I analyze the prominent role that the banking sector and financial frictions play in economic fluctuations across countries, with a focus on the Baseline model. I first analyze the impulse responses of variables to financial shocks in order to highlight how financial frictions on all loan types affect the transmission mechanism of the shocks and the movement of variables. This selective analysis is motivated by the fact that financial shocks are contributors of particular interest to business cycle fluctuations after the GFC. Finally, I quantify the contributions of various shock groups to business cycle variation.

2.5.1 Impulse response functions

In the following subsection, I analyze the impulse response functions of main macroeconomic and financial variables to within-country financial shocks and then explore how cross-border financial shocks impact on the home economy. All of the shocks are set to produce a downturn.

Figure 2.5.1 jointly displays the impulse responses in the Baseline model to three temporary shocks: entrepreneurial net worth, banking net worth and bank risk. An entrepreneurial net worth shock actually fundamentally captures volatilities in the stock

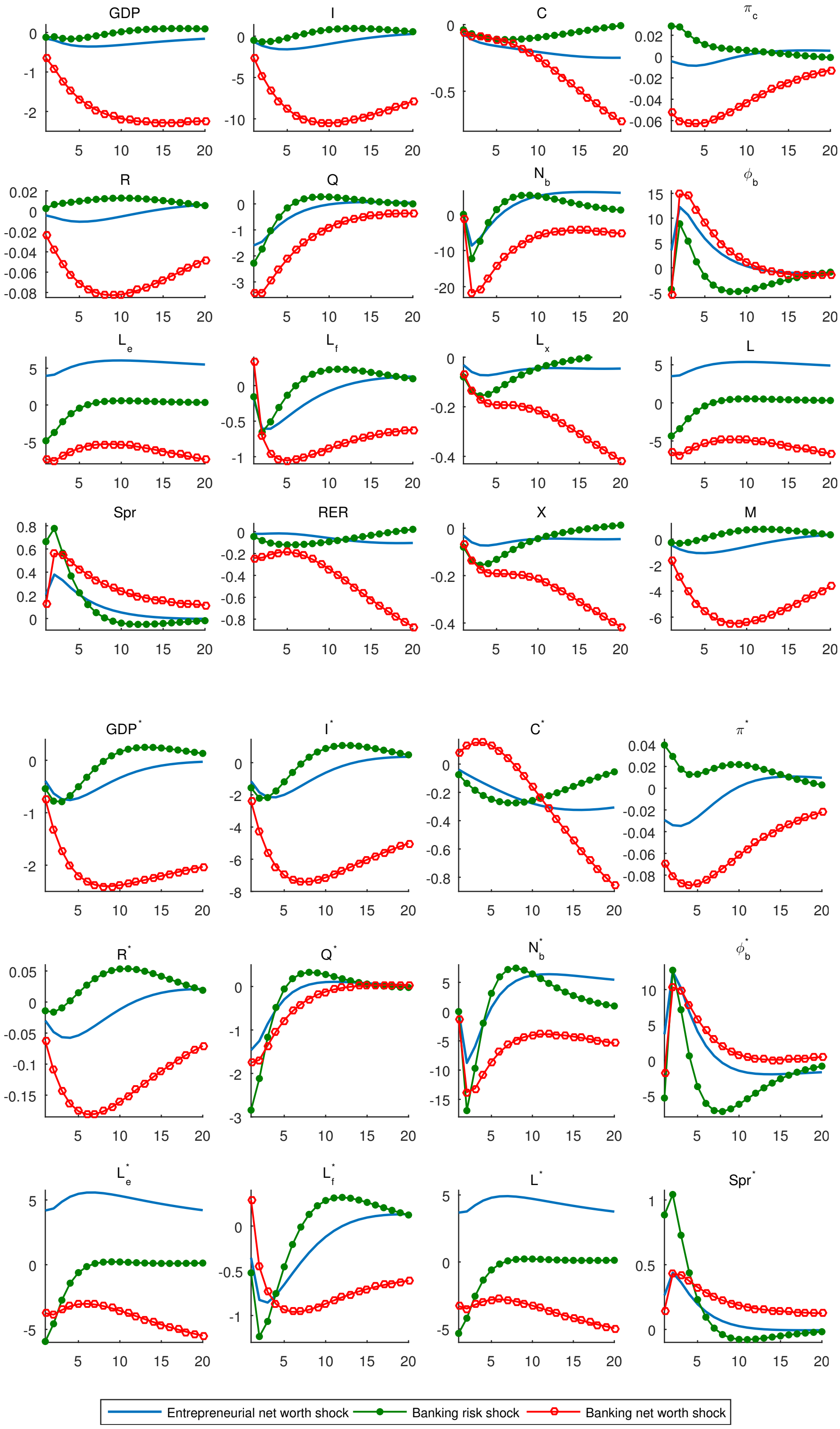

Figure 2.5.1: IRFs to financial shocks – Australia (upper panel) and the U.S. (lower panel).

market value. A decline in entrepreneurial net worth leads to a reduction in capital purchases because entrepreneurs endow less financial wealth. This, in turn, produces a fall in capital production by households which results in a fall in the price of capital. Entrepreneurial net worth continues to fall as declines in the price of capital enhance the initial decline in the value of entrepreneurial financial wealth. The falling capital demand decreases investment and GDP. Following the lower capital demand, the demand for entrepreneurial loans also drops, worsening banking profit and net worth while raising the banking leverage multiple. The reduction in entrepreneurial net worth, however, also increases demand for entrepreneurial loans, since the entrepreneurs need to borrow more to fund their capital purchases. As a result, spread and credit rise. The resulting rise of the spread helps banks quickly recover their net worth. Meanwhile, the implied increase in financing costs causes a decline in borrowers' spending, thus further contracting economic activity. Compared to the closed economy, the contraction phase is less persistent in the open economy because net exports decrease, due mainly to the increased cost of import credit.

The shock to banking net worth captures sudden exogenous volatilities in the value of assets on the bank balance sheet.[26] With exogenous declines in banking net worth, the expected value of the received funds is discounted at a higher rate, which implies that the value of an additional unit of loan declines and thus enhance the initial decline in banking net worth. This leads to financial accelerator type effects. The decline in banking net worth, meanwhile, increases the leverage multiple of the bank. Shareholders require higher profitability from an increased leverage multiple, so banks raise lending rates. The implied increase in the spread causes a drop in credit and reduces demand for entrepreneurial loans. Entrepreneurs have fewer financial resources to purchase capital. Therefore capital demand from entrepreneurs falls, which pushes down the price of capital. In addition, falling capital prices reduce entrepreneurial net worth, and this magnifies the impact of the decline in banking net worth through standard accelerator effects. The decline in capital demand leads to lower investment expenditure, so GDP declines. Note that an adverse banking net worth shock is defined in my model as a decrease in the retained profit rate, implying higher dividends to shareholder consumption. The initial decline in GDP is partially offset by an increase in shareholder consumption, and household consumption in response to the drop in the policy rate caused by the economic downturn. Therefore, the resulting contraction of GDP persists mainly due to a long-lasting decline in investment. Meanwhile, the contraction of GDP leads to a fall in costs, and thus inflation is reduced (not shown).

Banking risk shocks occur when bankers pursue goals that have a high profile.[27] A rise in asset diversion for private interest directly raises the leverage multiple. Concerning moral hazard, shareholders require banks not to be overleveraged and thus bankers are forced to reduce lending. The reduction in the lending volume makes the incentive compatibility constraint tighter, leading to a higher spread. As explained above, the resulting

[26] Upheavals in financial markets during the 2007−2008 financial crisis appear to reflect adverse disturbances of this type, as indicated by heavy losses in assets and dramatic declines in profits of banks. In particular, the collapse of Lehman Brothers may be considered a world-wide common shock. Other examples of such disturbances in normal economic conditions include a tax on bank capital, a raise in minimum capital requirements, an increase in the Base adequacy ratio, and a change to the classification of Tier 1 and Tier 2 capital.

[27] Bankers can, for example, relax lending criteria for undesirable big projects or increase discretionary expenditure on perks. In this way, they give insights into prestige, job security and power.

rise of the spread has the effect of reducing demand for loans, leading to a contraction in real economic activity and a decline in banking net worth as a result of lower profitability. The decline in banking net worth is larger in percentage terms than the decline in credit, so the leverage multiple then increases. The higher lending rate also forces importers to lower import volumes, which reduces the decline of the home GDP. This increase of spread, meanwhile, mitigates the initial drop in banking net worth, and then contributes to the quick recovery of the banking net worth and a fall in the leverage multiples follows. The impact of this shock through accelerator effects on financial variables is quite strong, but the overall impact is relatively much smaller compared to the banking net worth shock.

A natural next step is to ask, What are the spillover effects of foreign financial shocks to the home economy? Figure 2.5.2 jointly displays the Australian economy's consequential responses to three U.S. financial shocks. Similar to within-country effects, the cross-border magnitude of a banking net worth shock on home activity is quantitatively larger than those of the other two shocks. So consider an adverse shock to the net worth of the U.S. banking sector. Broadly speaking, not only do the responses have different characteristics to those from the respective home shock, but the transmission mechanisms are also different. These are because the effects of a net worth shock leak to the home economy through international trade and financial channels.

The foreign shock firstly propagates to the Australian real economy by the reduction of export demand due to the U.S. economic downturn. Foreign inflation decreases, leading to a drop in the relative price of foreign goods and thus a rise in home imports. Note that the shock indirectly raises the cost of financing imports as the rise of U.S. spread outweighs the drop in the FED's policy rate, but cross-border lending still rises as a result of the strongly increased demand for imports. In addition, falling foreign inflation results in an appreciation in the real exchange rate. Declining real interest rates in the foreign economy also support real exchange rate appreciation, via the UIP. The total appreciation of the real exchange rate discourages exports and encourages imports, leading to a contraction in net exports. Meanwhile, the return increases due to interaction between the real appreciation and financial frictions, leading to a substantial expansion in investment. Consumption, similarly, rises. All in all, the home economy experiences a decline in aggregate demand due to the deterioration in the trade balance despite home absorption increases, which pulls down on home GDP and inflation. As a result, the shock leads to GDP comovement across the two economies. Although the GDP response in Australia is small and less persistent compared to the U.S., the effectiveness of the home macroprudential policy would be substantially affected by cross-border disturbances. Since the FED lowers the policy rate to cope with the U.S. economic downturn, home households divert savings toward domestic assets to enjoy the relatively high home return. This increases the availability of home credit as well as the home leverage multiple, and a lower weighted spread follows. In equilibrium, the increase in home credit is only mild.

The foreign banking net worth shock produces contractionary effects on the Australian economy similar to those generated by a home banking net worth shock, but the crucial

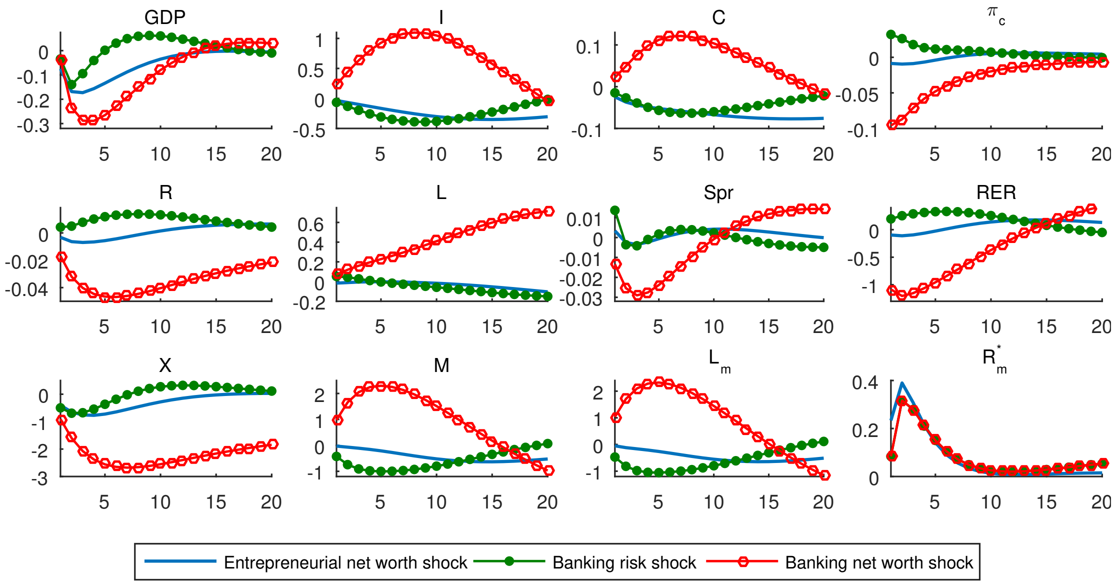

Figure 2.5.2: Australian IRFs to U.S. financial shocks

difference is that the import increases here because the real appreciation generated by the foreign shock reduces importers' burden of liabilities in the home currency while with the home shock the effect is the opposite. The specific role of the cross-border lending channel is demonstrated through loans offered by foreign banks to home importers. This result is important since an adverse foreign shock in terms of national macroprudential policy such as a raise in minimum capital requirements or an increase in the capital adequacy ratio from the FED can have sizable side-effects on the home economy through cross-border lendings, suggesting coordinated policy responses that aims at dampening these undesirable cross-border leakages.

2.5.2 Financial shocks in business cycles

Table 2.9 reports the percentage of business cycle variance in the level of variables contributed by different shocks in my Baseline model. The overall picture is very similar for Australia and the U.S. Country-specific financial disturbances account for a significant portion of business cycle fluctuations within each country, though the highest share of variation in standard macroeconomic variables is driven by conventional shocks. As regards financial variables, within-country financial disturbances are even more important, accounting for at least one-third of variances. One notable difference is the relatively high importance of country-specific financial shocks for dynamics of both financial and standard macroeconomic variables in the U.S. This is because external and foreign shocks partly take over the role of financial disturbances in Australia, in which the contribution of U.S. financial shocks is non-negligible as found in Subsection 2.5.2. The impulse response and variance decomposition analyses, taken together, quantify the sense in which financial shocks in the Baseline model generate dynamics that resemble the business cycle. This is the principal reason my empirical analysis assigns such an important role to financial shocks in their account of fluctuations.

Table 2.9: Variance Decomposition in the Baseline Model (*Percent*)

Series \ Shock	Financial	MEI	Technology	Markup	Money. Policy	Preference	Gov. Spending	External	Foreign
Australia									
GDP	17 | 13 | 4	15	12	15	3	6	2	11	18
Investment	34 | 25 | 9	42	0	4	1	0	0	5	14
Consumption	28 | 28 | 0	2	2	22	3	29	2	2	10
Hours	17 | 11 | 6	29	4	20	2	11	3	7	7
Wage	10 | 8 | 2	3	42	35	1	0	0	0	8
Interest rate	16 | 14 | 2	10	11	18	17	11	0	2	15
Inflation	12 | 11 | 1	3	18	34	2	10	1	1	18
Export	19 | 18 | 1	2	5	1	1	0	5	40	27
Import	15 | 15 | 0	5	5	19	5	0	0	15	35
Real exchange rate	11 | 11 | 0	12	5	0	2	0	0	43	26
Credit	50 | 43 | 7	2	3	11	0	1	0	11	22
Spread	53 | 49 | 4	19	0	0	7	0	0	3	18
United States									
GDP	26 | 19 | 7	19	16	6	7	18	8		
Investment	40 | 28 | 12	49	3	4	2	2	0		
Consumption	16 | 16 | 0	11	3	19	2	46	3		
Hours	19 | 12 | 7	18	18	7	7	22	9		
Wage	10 | 9 | 1	2	54	30	1	2	1		
Interest rate	17 | 16 | 1	4	21	24	13	19	2		
Inflation	11 | 11 | 0	4	24	41	4	13	2		
Credit	73 | 61 | 12	6	6	5	8	2	0		
Spread	74 | 66 | 8	17	0	0	8	0	0		

Note: For each variable in the first column, unconditional variance decompositions are generated by the baseline model evaluated at the posterior mode. The "financial" category contains the banking net worth shock, the banking risk shock and the entrepreneurial net worth shock, $\{\theta_t, \varpi_t, ne_t; \theta_t^*, \varpi_t^*, ne_t^*\}$. The "external" category includes the country risk premium shock, commodity demand shock, commodity relative price shock and asymmetric technology shock. Numbers in each row may not add up to 100 due to rounding. The table does not display results for the inflation target shock, $\bar{\pi}_t$ and $\bar{\pi}_t^*$, and the consumption price inflation shock, $\varepsilon_{\pi_{c,t}}$, whose contribution is less than 1/2 of 1 percent. In the exceptional case, the consumption price inflation shock accounts for roughly 5 percent of the variance of the Australian inflation. The contribution of the financial shocks is presented in the following way: the first entry is the contribution of all three shocks, the second entry is the contribution of shocks to banking net worth and risk $\{\theta_t, \varpi_t; \theta_t^*, \varpi_t^*\}$, and the third entry is the contribution of the entrepreneurial net worth shock $\{ne_t; ne_t^*\}$.

2.6 Concluding remarks

In this paper, I have developed a model of two asymmetric countries with domestic banking sectors that can divert a proportion of funds from the interests of shareholders due to the presence of moral hazard. The model allows for an incentive compatibility constraint on a diverse portfolio of loans as well as financial frictions on cross-border lending and the presence of exogenous entrepreneurial net worth. Using a Bayesian approach, I have estimated the model for Australian and U.S. macroeconomic and financial data over the period 1993−2012. To evaluate the credibility of my model, I make comprehensive comparisons of the Baseline model, with financial frictions on a full set of various loans, to its smaller financial variants and the pure trade open economy model.

This paper demonstrates that a modern model of two asymmetric countries is able to fit the standard macroeconomic and financial data very well, if one allows for financial sectors and financial frictions on a sufficiently diverse portfolio of loans. The Baseline model does well on almost all dimensions, indicating that the financial frictions embedded in the structural model of two asymmetric countries are helpful in improving the empirical performance, in particular at cross-border synchronization. My finding shows that an estimated, structural asymmetric country model with financial frictions can explain the substantial influence of foreign-sourced disturbances. I infer that its implications from incorporating the foreign financial dimensions offer new insight into analyzing the cross-border synchronization of business cycles in this type of two-country models. I also find that within-country financial shocks account for a significant portion of business cycle fluctuations in each country, and foreign financial shocks play a non-negligible fraction in cross-border spillovers. This finding suggests that banks' decisions over the size of their credit are critical for the behavior of the economy.

There are several natural extensions of the current work. First, a straightforward extension is to introduce a moral hazard problem between entrepreneurs and bankers that also imposes endogenous incentive constraints on the entrepreneurial balance sheet, allowing financial frictions be implemented without appealing to the costly state verification problem of Bernanke et al. (1999). Of course, it would be worthwhile to explore the possibility of introducing the costly state verification problem that also affects lending relationships between banks and entrepreneurs. Finally, a model featuring within-country financial frictions *à la* both Bernanke et al. (1999) and Gertler and Karadi (2011) could improve the model fit. Examples of how a combination of the two types of financial frictions that may match relevant dimensions of the data are explored by Rannenberg (2016) in a simple closed economy setting and by the third paper in the asymmetric country framework.

Chapter 3

Financial Factors in an Estimated Asymmetric Country Model: A Bayesian Evaluation

3.1 Introduction

I compare the role of each type of financial friction in an asymmetric country model that provides a microfounded rationale for international and domestic business cycle analysis. I do so by introducing agency problems associated with either entrepreneurs or banks into an otherwise standard business cycles model for a pair of small-open and large-closed economies and estimate it.

I begin by developing a frictionless business cycle model that allows for features prevalent in conventional quantitative closed economy New Keynesian DSGE models (e.g. Christiano, Eichenbaum, and Evans 2005; Smets and Wouters 2007) in order to clarify the importance of later financial factors. My frictionless business cycle model, however, is extended to the framework of two asymmetric countries. I build the open-economy segment of the model based on Adolfson et al. (2007) and enrich it with two additional distinctive features compared to the literature. First, I allow for inflation rate differential between the two countries such that nominal exchange rate depreciation exists in steady state. Second, commodity export demand is assumed to be not only exogenous but also contingent on global economic conditions. The pure trade model of two asymmetric countries then is obtained by connecting the small-open economy with its large-closed counterpart via trade and finance channels.

Next, financial frictions are incorporated into the pure trade open economy model following two approaches. The first features entrepreneurs with constrained leverage that are the source of financial frictions (Bernanke, Gertler, and Gilchrist 1999 − henceforth BGG).[1] Financial frictions arise because verifying the realized return of the project is costly, which drives an endogenous wedge between the cost of external finance and the

[1] This approach was initiated by the seminal paper of Bernanke and Gertler (1989) and further developed by Carlstrom and Fuerst (1997) and latterly merged with the New Keynesian DSGE framework by Bernanke, Gertler, and Gilchrist (1999) in order to become the workhorse financial accelerator model.

opportunity cost of financing the project with internal resources of the entrepreneur. The financial frictions literature following the first direction emphasizes credit constraints on non-financial borrowers while treating the banking sector largely as a frictionless "veil". The second direction, in contrast, accentuates banks as a source of financial frictions (Gertler and Kiyotaki 2010, 2015; Gertler and Karadi 2011 − hereafter GK). The focus of this approach is leverage constraint binding the banker's asset diversion ability due to moral hazard. The constraint, in turn, creates an endogenous wedge between the lending rate and the deposit rate, which affects non-financial borrowers' credit conditions.

My choice of these two modeling strategies for financial frictions is explained by the following reasons. First, these are competing approaches. While the BGG approach was well-established in the financial friction literature, financial frictions in the banking sector have been emphasized since the latest global financial crisis. Second, the two approaches share a common feature: concentrating on prices of loans.[2] That is, the agency problem works to introduce a spread, which adds to the overall cost of credit that borrowers face. The size of the external finance premium, further, depends on the borrowers' balance sheets condition, whether entrepreneurs or banks. As such, I restrict my modeling of financial frictions to these two approaches because I want to preserve comparability between the two model versions with financial frictions.

Since I am interested in comparing the resulting business cycle properties from incorporating financial frictions, I keep the model versions identical in all aspects but the financial sector. In particular, the two financial extensions are characterized by different types of frictions: the External Finance Premium (EFP) version includes financial frictions originating from entrepreneurs due to the costly state verification problem, while the Incentive Compatibility Constraint (ICC) version includes financial frictions in banks because of a moral hazard problem, and so do the transmission mechanisms of financial shocks. Therefore, to ensure empirical comparability between the two financial extensions (and with the literature), I keep all three model versions subject to the same non-financial shocks and include comparable financial shocks into the two friction versions. Further, I retain the same prior distribution of non-financial structural parameters and set the financial parameters to hit steady-state properties affected by the presence of financial frictions before bringing the model versions to the data.

The economic intuition underlying the essence of the financial accelerator effect in the two model extensions is simple. Following a reduction in financial wealth, the increased leverage multiple causes a rise in the external finance premium. Entrepreneurs respond by borrowing less and therefore there are fewer financial resources to purchase new capital. As a result capital demand from entrepreneurs falls, which pushes down the price of capital. Entrepreneurial net worth continues to fall as declines in the price

[2] Another line of research concentrates on quantities of loans instead. This was introduced in the seminal paper by Kiyotaki and Moore (1997) and then incorporated into the standard business cycle model by Iacoviello (2005).

of capital reduce the value of entrepreneurs' financial wealth. The decline in banking net worth, meanwhile, raises the leverage multiple. This increases the spread, since increased banking leverage requires higher profitability. A rise in lending costs decreases the demand for credit, with the net effect that earnings drop. This further lowers banking assets. The financial accelerator effect therefore works through the (entrepreneurial or banking) balance sheet channel, reducing the price of capital and thus leading to a contraction of investment and GDP.

I examine model versions quantitatively with Bayesian techniques using Australian and U.S. macroeconomic and financial data over the period 1993Q1−2012Q4. Next, I assess and explain the similarities and differences between the two modeling approaches using the following analytical tools: marginal likelihood, steady-state property, estimated parameter, second moments, impulse responses and variance decomposition. The findings of the present paper can be summarized as follows. First, the incorporation of financial frictions improves the pure trade open economy model's performance, suggesting that these frictions are empirically relevant. Second, the ICC version outperforms the EFP version. The analysis shows that the banking sector acts as a powerful amplifier for the financial shocks hitting the economy. As disruptions in the credit market lead to a rise in the spread and the resulting decline in entrepreneurial net worth, banks benefit from the rising spread thanks to its positive effects on banking net worth. This mechanism therefore produces a higher rise in the spread of the ICC version with more severe effects on investment and GDP compared to the EFP version. In addition, the additional amplification from the 'bank lending channel' allows the ICC version to better match the empirically observed volatility of the spread, as well as investment and other variables. The smaller role that the financial shocks play in the EFP version also provides another reason for the better empirical performance of the ICC version.

There is an existing literature on estimated models containing one or both of the approaches that I incorporate, primarily in closed economy models. Brzoza-Brzezina and Kolasa (2013) assess the relative ability of a standard New Keynesian DSGE model and its two alternative extensions that only consider constrained non-financial firms as the source of financial frictions. Specifically, they set up the original Smets and Wouters (2007) economy as a frictionless benchmark model and extend it to include Kiyotaki and Moore (1997) and BGG (1999)-type constraints. The first constraint type affects the quantities of loans by requiring collateral-in-advance from borrowers, while the second type adds an external finance premium to the prices of loans. The two model extensions are tweaked in a way that allows comparisons. Also, shocks specific to the financial frictions literature differ by construction in their model extensions and so are not fully comparable. All model versions are estimated with the U.S. quarterly macroeconomic data over the period 1973–2008. The analysis shows that neither of the financial friction versions improves definitely on the empirical performance of the frictionless benchmark, either in terms of goodness-of-fit or impulse response functions.

Villa (2016) performs a similar empirical exercise by comparing a Smets and Wouters (2007)-type benchmark model with two alternative frameworks. The first is the benchmark model with financial frictions *à la* BGG (1999) while the second framework is again the benchmark model augmented with financial frictions *à la* GK (2011). However, in this study there is no role for shocks merely originating in the financial sectors in the dynamics of the propagation mechanism. In particular, capital quality shock only enters the capital accumulation and merely corresponds to a "physical" destruction of the economy's capital stock. The way the quality shock is entered therefore rules out its qualitative effect on the asset-side of bank balance sheets through the change in collateral value in the GK spirit. All model versions are estimated using Euro Area and U.S. quarterly macroeconomic data covering the period 1983–2008. The key finding is that the model version with frictions arising in financial intermediaries generates a series of the spread more correlated with its proxy but no friction model version dominates the other in terms of forecasting performance.

There are other papers incorporating a BGG financial accelerator mechanism into the Smets and Wouters (2007)-type model (e.g. De Graeve 2008; Queijo von Heideken 2009; Gelain 2010) or into other standard closed economy models (e.g. Christensen and Dib 2008; Nolan and Thoenissen 2009; Christiano, Motto, and Rostagno 2014). In the small-open economy set-up, Fernandez and Gulan (2012) embed this mechanism into an otherwise stylized real business cycle model and then take their model to the data of emerging economies. Some studies, on the other hand, augment the Smets and Wouters (2007)-type model with GK financial frictions in order to study the source of business cycle disturbances (e.g. Villa and Yang 2011). Further, other studies augment international business cycle models with financial frictions of this type (e.g. Kollmann, Enders, and Müller 2011; Dedola, Karadi, and Lombardo 2013). Up to this point, however, the literature has been silent about incorporating the two approaches into an asymmetric country model in particular and comparing the resulting incorporation in the international business cycle framework in general.

The present paper is a continuation of the existing literature on evaluating competing approaches to financial frictions. In the comparison of two mechanisms, it is most related to Villa (2016), but my model works in a macroeconomic setting of two countries. Moreover, compared to Villa (2016) I explicitly model the origin of financial frictions and bring in a set of shocks specific to the financial friction literature. Virtually no study has jointly assessed quantitatively the two approaches within a dynamic general equilibrium framework of two asymmetric countries. My contribution is a thorough empirical evaluation of the relative role of financial friction approaches in a standard New Keynesian DSGE framework of two asymmetric economies. An interesting feature of the analysis in this paper therefore is to compare to what extent the financial frictions and financial shocks differ between the two model versions and between the small-open and large-closed economies. I think this gap in the literature is important because the two approaches need to be evaluated in a cross-country setting, which will support the process of developing international business cycle models that match the macro-financial data and economic intuition. My work aims to fill this gap.

This paper is divided into six sections apart from this introduction. The next section describes the pure trade open economy model for a pair of small-open and large-closed economies. I take this benchmark business cycle model to the two versions of a financial sector in Section 3.3. The data and empirical strategy are presented in Section 3.4. Next, Section 3.5 compares empirical properties of models. Concluding remarks are given in Section 3.6. The Appendices provide further technical details.

3.2 The pure trade open economy model

This section provides a brief overview of the pure trade open economy model. The model is composed of a home country and a foreign partner. As the home country is assumed to be small relative to the foreign country, the influence of the former is negligible and thus the latter is analogous to a large-closed economy. In what follows, I present the model from the home country's point of view, which I refer to as a small-open economy. Whenever notation is associated with the foreign economy, a star exponent (*) is used.

3.2.1 Households

The economy is composed of a continuum of identical atomistic households. Households are the agents which consume, build raw capital, supply differentiated labor services, set wages and save in home and foreign assets. There exist state-contingent securities which ensure that in equilibrium households choose identical plans for decision problems.

The representative household maximizes the utility function

$$(3.1)\quad E_0 \sum_{t=0}^{\infty} \beta^t b_t \left[\log\left(C_t - bC_{t-1}\right) - \varphi_H \int_0^1 \frac{h_{j,t}^{1+\sigma_H}}{1+\sigma_H} dj \right], \qquad 0 < \beta, b < 1, \varphi_H, \sigma_H > 0,$$

where C_t is the per-capita consumption of household members and b_t is an intertemporal preference shock.

Capital production

The household purchases undepreciated capital from other households and investment goods from final assemblers in competitive markets. The undepreciated capital is then converted one-for-one into raw capital while the transformation of the investment goods incurs adjustment costs $F(I_t/I_{t-1}) = \frac{F}{2}\left(\frac{I_t}{I_{t-1}} - g_z\right)^2$ with $F(.) = F'(.) = 0$, $F''(.) = F > 0$. The representative household builds raw capital, $\bar{K}_t$, using a standard technology

$$(3.2)\qquad \bar{K}_t = (1-\delta)\bar{K}_{t-1} + \mu_t \left[1 - F\left(\frac{I_t}{I_{t-1}}\right)\right] I_t, \qquad 0 < \delta < 1,$$

where μ_t is a shock to the marginal efficiency of investment (MEI).

In addition to its investment decisions, the representative household also transforms raw capital $\bar{K}_{t-1}$ into effective capital K_t according to

$$K_t = u_t \bar{K}_{t-1}, \tag{3.3}$$

subject to adjustment costs $a(u_t)\bar{K}_t$ arising from the capital utilization rate, u_t. My cost function $a(u_t) = (1-\zeta)\frac{Z_k}{P_i}\left(u_t^{\frac{1}{1-\zeta}} - 1\right)$ has the properties that $a'(.) > 0$, $a'(1) = \frac{Z_k}{P_i}$, $a''(.) > 0$, and $a''(1) = a'(1)\frac{\zeta}{1-\zeta}$. The value of the parameter, $\zeta \in (0,1)$, has no impact on the steady state of the model, but it does affect its dynamics. Next, effective capital is rented to intermediate goods producers at the rate $Z_{k,t}$.

Wage setting

I assume that all workers of the representative household supply a type of specialized labor j in the economy. Along the lines of Erceg, Henderson, and Levin (2000), this assumption implies that the representative household can set its own wage when it sells that labor type to competitive contractors. Next, a representative contractor combines a continuum of specialized labor $h_t(j), j \in [0,1]$, into a homogeneous block of labor, h_t, sold to intermediate goods producers, according to the Dixit-Stiglitz technology

$$h_t = \left[\int_0^1 h_t(j)^{\frac{1}{\lambda_{w,t}}} dj\right]^{\lambda_{w,t}}, \qquad 1 \leq \lambda_{w,t}. \tag{3.4}$$

The household sets the nominal wage rate, $W_{j,t}$, for its labor type, subject to Calvo-style stickiness. Every period a fraction ξ_w of households cannot choose its wage optimally, but simply indexes it according to the rule

$$W_t(j) = (\bar{\pi}_t)^{\iota_w}(\pi_{c,t-1})^{1-\iota_w} g_{z,t} W_{t-1}(j), \qquad 0 < \iota_w < 1. \tag{3.5}$$

The presence of the technology growth rate in wage-setting ensures that wage-setting frictions are not distortionary along a balanced growth path of the economy.

Budget constraint

The representative household receives wage income from labor services $W_{j,t}h_{j,t}$, capital income $Z_{k,t}u_t\bar{K}_{t+1}$ diminished by utilization costs in units of investment goods $P_{i,t}a(u_t)\bar{K}_{t+1}$, revenue from selling raw capital $Q_{\bar{K},t}\bar{K}_{t+1}$, as well as returns on home and foreign assets $R_tD_t + R_t^*\Phi_t(.)S_tD_t^*$ (S_t is the nominal exchange rate[3]), and various lump-sum payments Π_t including profits from domestic firms, transfers from entrepreneurs or bankers (discussed in the following subsections), and lump-sum transfers from the government net of lump-sum taxes. The total income is used to finance worker consumption, to build new raw capital and to trade home and foreign bonds. As a result, the household

[3]Here S_t is defined as the home price of foreign currency, implying that an increase in the nominal exchange rate corresponds to a depreciation in the home currency.

faces the flow budget constraint

$$P_{c,t}C_t + P_{i,t}I_t + Q_{\bar{K},t}(1-\delta)\bar{K}_{j,t} + D_{t+1} + S_t D^*_{t+1} \leq \int_0^1 W_t(j)h_t(j)dj + \left[Z_{k,t}u_t - P_{i,t}a(u_t)\right]\bar{K}_{t+1} + Q_{\bar{K},t}\bar{K}_{t+1} + R_t D_t + R^*_t \Psi_t(.) S_t D^*_t + \Pi_t. \quad (3.6)$$

Cross-border bond market arbitrage

The household enjoys an endogenous risk premium on foreign bond holdings, $\Psi_t(.)$, of the following form:

$$\Psi_t\left(a_t, \Delta S_t, \psi_t\right) = \exp\left\{-\phi_a(a_t - a) - \phi_s\left[\frac{E_t\{S_{t+1}\}}{S_t}\frac{S_t}{S_{t-1}} - \left(\frac{\pi}{\pi^*}\right)^2\right] + \psi_t\right\}, \quad (3.7)$$
$$\Psi_t^{'}(.) < 0, \Psi\left(0, \frac{\pi}{\pi^*}, 0\right) = 1, a = 0, \pi > \pi^*, \phi_a > 0, 0 < \phi_s < 1,$$

where $a_t = \frac{S_t D^*_{t+1}}{P_t z_t}$ is the (real) net foreign bond position and ψ_t is a country risk premia shock. Here the country risk premium is a positive function of the net foreign bond position and expected home currency depreciation as in Adolfson et al. (2008).[4] In addition, I allow for a relatively high steady-state inflation rate in the home country, which yields nominal depreciation in steady state as predicted by the theory of purchasing power parity.

The household saves by investing their financial wealth in the home and foreign bond markets. Therefore, the optimal position in the cross-border bond market is determined by the uncovered interest rate parity (UIP) condition:

$$R_t = E_t\left\{R^*_t \frac{S_{t+1}}{S_t}\Psi_t(.)\right\}. \quad (3.8)$$

The UIP condition in steady state allows me to endogenously derive the subjective discount factor of the foreign household with respect to the calibrated value of the home counterpart.[5]

3.2.2 Firms

The four types of firms are articulated as follows. Intermediate firms produce differentiated types of domestic goods, which are then aggregated by homogeneous goods producers. Next, exporters buy part of the homogeneous domestic goods to create specialized goods prior selling them to foreign retailers. Meanwhile, importers convert a homogeneous foreign good into differentiated goods. Finally, assemblers use part of the homogeneous domestic goods and bundles of homogeneous import goods in order to produce consumption and investment goods to be sold to households.

[4]The inclusion of the expected depreciation aims to account for the "forward premia anomaly", according to which the home currency empirically tends to appreciate when the home nominal interest rate exceeds the foreign rate.

[5]See Appendix D for the detailed algorithm of steady-state computation.

Domestic goods producers

Homogeneous goods producers. A representative, competitive producer aggregates a continuum of intermediate goods $Y_t(j), j \in [0,1]$, into a homogeneous good, Y_t, according to the technology

$$(3.9) \qquad Y_t = \left[\int_0^1 Y_t(j)^{\frac{1}{\lambda_{d,t}}} dj \right]^{\lambda_{d,t}}, \qquad 1 \leq \lambda_{d,t} < \infty,$$

where $\lambda_{d,t}$ is a price markup shock.

Intermediate goods producers. The j^{th} intermediate goods are produced by a monopolist using the following production function:

$$(3.10) \qquad Y_t(j) = \max \left\{ \epsilon_t K_t(j)^{\alpha} (z_t h_t(j))^{1-\alpha} - \Phi z_t; 0 \right\}, \qquad 0 < \alpha < 1,$$

where $K_t(j)$ and $h_t(j)$ represent the services of effective capital and homogeneous labor. The scalar Φ is fixed costs of production, which are proportional to the technology level so that profits are zero in steady state. Also, ϵ_t is a covariance stationary technology shock and z_t denotes the persistent component of technology with the stationary growth rate $g_{z,t} = \Delta \log z_t$.

Intermediate goods producers confront a rental rate, $Z_{k,t}$, on effective capital services and a nominal wage rate, W_t, of labor services in economy-wide factor markets. Each producer must pay a fraction v_K of their rental cost of capital and a fraction v_H of their wage bill in advance of production at a nominal interest rate R_t. Thus the nominal marginal cost of producing one unit of intermediate output $Y_t(j)$ is:

$$(3.11) \quad MC_t = \left(\frac{1}{\alpha}\right)^{\alpha} \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \frac{\left[Z_{k,t}\left(1+v_K\left(R_t-1\right)\right)\right]^{\alpha}\left[W_t\left(1+v_H\left(R_t-1\right)\right)\right]^{1-\alpha}}{\epsilon_t z_t^{1-\alpha}}.$$

Intermediate goods producers are subject to Calvo-price stickiness. Every period a fraction ξ_d of producers cannot set its price optimally, but simply indexes it according to the rule

$$(3.12) \qquad P_t(j) = (\bar{\pi}_t)^{\iota_d} (\pi_{t-1})^{1-\iota_d} P_{t-1}(j), \qquad 0 < \iota_d < 1,$$

where $\pi_{t-1} = P_{t-1}/P_{t-2}$ is the inflation of domestic goods and $\bar{\pi}_t$ is the target inflation rate of the monetary authority, which is a shock.

Exporters

There are non-commodity and commodity sectors in home country exports. Total demand for exports is therefore given by

$$(3.13) \qquad X_t = \left(\frac{P_{x,t}}{P_t^*}\right)^{-\eta_*} \imath_* Y_t^* + \varepsilon_{com,t} \varsigma_* Y_t^*, \qquad \eta_* > 1,$$

where the first term on the right represents the non-commodity export, $X_{non,t}$,[6] while the second term expresses the commodity export, $X_{com,t}$. Note that my $X_{com,t}$ appears

[6] I do not disentangle the non-commodity export into consumption and investment purposes because this export demand is better captured by the foreign income, Y_t^*, than by its foreign demand components, C_t^* and I_t^*.

in the form of an exogenous process contingent on global economy conditions proxied by foreign output Y_t^*. The presence of the scale factors, $\imath_*$ and ς_*, which correspond to export shares in aggregate demand abroad, helps obtain the well-defined steady-state level of export demand.

Non-commodity exporters sell their specialized export goods to competitive foreign retailers. A representative foreign retailer packs a continuum of non-commodity export goods $X_{non,t}(j), j \in [0,1]$, into a homogenous good, $X_{non,t}$, according to the technology:

$$X_{non,t} = \left[\int_0^1 X_t(j)^{\frac{1}{\lambda_{x,t}}} dj \right]^{\lambda_{x,t}}, \qquad 1 \leq \lambda_{x,t} < \infty, \tag{3.14}$$

and resells it to foreign agents.

Since exporting firms can export costlessly, the marginal cost is the same across non-commodity exporters:

$$MC_{x,t} = P_t[1 + v_X(R_t - 1)], \qquad 0 < v_X \leq 1, \tag{3.15}$$

where v_X is the share of advance payment on the export goods bill.

Non-commodity exporters set their price in foreign currency subject to Calvo stickiness. Every period a fraction ξ_x of non-commodity exporters simply indexes its price according to the rule

$$P_{x,t}(j) = (\bar{\pi}_t^*)^{\iota_x} (\pi_{x,t-1})^{1-\iota_x} P_{x,t-1}(j), \qquad 0 < \iota_x < 1, \tag{3.16}$$

where $\pi_{x,t-1} = P_{x,t-1}/P_{x,t-2}$ is export inflation and $\bar{\pi}_t^*$ is the target inflation rate of the foreign monetary authority.

Importers

Importers purchase a homogeneous good from abroad and convert it costlessly into differentiated goods, $M_{jm,t}, j \in [0,1]$. The marginal cost of importers is given by

$$MC_{m,t} = S_t P_t^* [1 + v_M(R_t^* - 1)], \qquad 0 < v_M \leq 1 \tag{3.17}$$

where v_M is the share of the import bill that must be paid in advance at a foreign nominal interest rate, R_t^*.

Importers are also subject to Calvo-price stickiness when they resell differentiated import goods to final assemblers. Every period a fraction ξ_m of importers indexes its price according to the rule

$$P_{m,t}(j) = (\bar{\pi}_t)^{\iota_m} (\pi_{m,t-1})^{1-\iota_m} P_{m,t-1}(j), \qquad 0 < \iota_m < 1, \tag{3.18}$$

where $\pi_{m,t-1} = P_{m,t-1}/P_{m,t-2}$ is the inflation of consumption and investment import goods, with $m = \{cm, im\}$.

Final goods assemblers

A representative, competitive assembler aggregates a continuum of differentiated import goods into two homogeneous bundles of goods for consumption and investment purposes, $M_{m,t} = \{C_{m,t}, I_{m,t}\}$, according to the technology

$$M_{m,t} = \left[\int_0^1 M_{m,t}(j)^{\frac{1}{\lambda_{m,t}}} dj\right]^{\lambda_{m,t}}, \qquad 1 \leq \lambda_{m,t} < \infty. \tag{3.19}$$

Next, the representative assembler combines each bundle of import goods with the homogeneous domestic good to produce final consumption and investment goods, using the following technologies:

$$C_t = \left[(1-\omega_c)^{\frac{1}{\eta_c}} C_{d,t}^{\frac{\eta_c-1}{\eta_c}} + \omega_c^{\frac{1}{\eta_c}} C_{m,t}^{\frac{\eta_c-1}{\eta_c}}\right]^{\frac{\eta_c}{\eta_c-1}}, \qquad 0 < \omega_c < 1, \eta_c > 1,$$

and

$$I_t + a(u_t)\bar{K}_t = \left[(1-\omega_i)^{\frac{1}{\eta_i}} I_{d,t}^{\frac{\eta_i-1}{\eta_i}} + \omega_i^{\frac{1}{\eta_i}} I_{m,t}^{\frac{\eta_i-1}{\eta_i}}\right]^{\frac{\eta_i}{\eta_i-1}}, \qquad 0 < \omega_i < 1, \eta_i > 1.$$

Given pairs of input prices $\{P_t, P_{cm,t}\}$ and $\{P_t, P_{im,t}\}$, the profit maximization problem of the assembler yields optimal demand compositions for each type of goods:

$$C_{d,t} = (1-\omega_c)\left(\frac{P_t}{P_{c,t}}\right)^{-\eta_c} C_t, \qquad C_{m,t} = \omega_c \left(\frac{P_{cm,t}}{P_{c,t}}\right)^{-\eta_c} C_t, \tag{3.20}$$

and

$$I_{d,t} = (1-\omega_i)\left(\frac{P_t}{P_{i,t}}\right)^{-\eta_i} \left(I_t + a(u_t)\bar{K}_{t-1}\right), \qquad I_{m,t} = \omega_i \left(\frac{P_{im,t}}{P_{i,t}}\right)^{-\eta_i} \left(I_t + a(u_t)\bar{K}_{t-1}\right). \tag{3.21}$$

and subsequently, the price index of each goods type is respectively given by

$$P_{c,t} = \left[(1-\omega_c)P_t^{1-\eta_c} + \omega_c P_{cm,t}^{1-\eta_c}\right]^{\frac{1}{1-\eta_c}} \varepsilon_{p_c,t} \tag{3.22}$$

and

$$P_{i,t} = \left[(1-\omega_i)P_t^{1-\eta_i} + \omega_i P_{im,t}^{1-\eta_i}\right]^{\frac{1}{1-\eta_i}}, \tag{3.23}$$

where $\varepsilon_{p_c,t}$ is a consumption price shock.[7]

[7] In particular, the consumption price shock process is a random walk: $\varepsilon_{p_c,t} = \varepsilon_{p_c,t-1} + \mu_{p_c,t}$. This shock is designed to cope with the time-invariant weights of the CPI components, and to bring more volatility to the endogenous consumer price inflation variable since its observable counterpart is affected by some elements that are absent from the model (e.g. unprocessed food items). However, a shock of this kind is not included in the price index for investment goods since I do not use investment price inflation as an observable variable in the later estimation.

3.2.3 Monetary policy and resource constraint

The monetary authority sets the nominal policy rate following a (linearized) feedback rule:

$$R_t - R = \rho(R_{t-1} - R) + (1-\rho)\left[r_\pi\left(\pi_{c,t+1} - \bar{\pi}_t\right) + r_{\Delta_{gdp}}\frac{1}{4}(g_{gdp,t} - g_z)\right] + \varepsilon_t, \tag{3.24}$$

$$0 < \rho < 1, r_\pi, r_{\Delta_{gdp}} > 0,$$

where ε_t is a monetary policy shock. The expression $R_t - R$ indicates the deviation of the net quarterly nominal policy rate from its steady state. Similarly, $\pi_{c,t+1} - \bar{\pi}_t$ indicates the deviation of anticipated quarterly consumer price inflation from the inflation target and $g_{gdp,t} - g_z$ is the observed annual growth rate of real GDP in deviation from its steady-state level.

Public spending, G_t, is modeled as:

$$G_t = z_t g_t, \tag{3.25}$$

where g_t is a government-spending shock.

Combining the equilibrium conditions in markets and the budget constraint of households, I obtain the real resource constraint:

$$Y_t = G_t + C_{d,t} + I_{d,t} + X_t. \tag{3.26}$$

I measure GDP in the model as follows:

$$GDP_t = G_t + \tilde{C}_t + \tilde{I}_t + X_t - M_t, \tag{3.27}$$

with

$$\tilde{C}_t = \left[(1-\omega_c)\left(\frac{P_t}{P_{c,t}}\right)^{-\eta_c} + \omega_c\left(\frac{P_{cm,t}}{P_{c,t}}\right)^{-\eta_c}\right] C_t$$

and

$$\tilde{I}_t = \left[(1-\omega_i)\left(\frac{P_t}{P_{i,t}}\right)^{-\eta_i} + \omega_i\left(\frac{P_{im,t}}{P_{i,t}}\right)^{-\eta_i}\right] I_t.$$

The evolution of (nominal) net foreign assets is given by

$$S_t D^*_{t+1} = R^*_t \Phi_t(.) S_t D^*_t + [1 + \upsilon_X(R_{x,t} - 1)] S_t [P_{x,t} X_{non,t} + P_{com,t} X_{com,t}] - [1 + \upsilon_M(R^*_{m,t} - 1)] S_t P^*_t M_t \tag{3.28}$$

where $P_{com,t}$ is the price of commodities measured in foreign currency. I model $P_{com,t}/P^*_t = p^*_{com,t}$ as a stationary stochastic process, which is referred to as the relative price of the commodity shock in the foreign market.

3.3 Financial frictions

Credit transactions do not assign any role to banks in the pure trade open economy framework, despite banks being a traditional intermediation sector that channel funds from savers to borrowers. Thus, now, within the representative household with a large number of members, I assume there are fractions of f_w workers, f_i entrepreneurs or bankers ($i = e, b$), and the complementary fraction $(1 - f_w - f_i)$ of shareholders.[8] Households save not only by holding bonds but also by depositing funds in home and foreign banks. Within-country government bonds and bank deposits are riskless assets in nominal terms with one-period maturity and thus perfect substitutes.

In the External Finance Premium version, entrepreneurs utilize capital and pay out dividends to shareholders while competitive bankers earn zero profit from financial intermediation. In addition, there is no agency problem between depositors and banks. By contrast, competitive entrepreneurs earn zero profit from capital utilization while bankers make profits from the process of financial intermediation and pay out dividends to shareholders in the Incentive Compatibility Constraint version. Also, there are no agency problems between banks and entrepreneurs.[9]

3.3.1 External finance premium version

Entrepreneurs

Assume that risk neutral entrepreneurs utilize capital in the competitive market. At the end of period t, entrepreneur j is endowed by the household with a net worth, $N_{e,t}(j) \geq 0$. Entrepreneurs obtain an aggregate loan, $L_{e,t}$, from home banks, and combine this with their own net worth, $N_{e,t}$, to purchase raw capital, $\bar{K}_{t+1}$, at a competitive price of $Q_{\bar{K},t}$. That is,

$$L_{e,t} = Q_{\bar{K},t}\bar{K}_{t+1} - N_{e,t}. \tag{3.29}$$

I have dropped out the j index because the equilibrium value of the objective variables is independent of $N_{e,t}$ (see below). After purchasing raw capital, entrepreneurs experience an idiosyncratic risk, ω, to the project of capital utilization, with $\log(\omega) \sim N\left(-\sigma_{e,t}^2/2, \sigma_{e,t}^2\right)$ across time and across entrepreneurs so that $E(\omega) = 1$. The standard deviation, $\sigma_{e,t}$, is the realization of stochastically time-varying volatilities in the cross-sectional dispersion of ω, which I refer to below as the entrepreneurial risk shock as in Christiano, Motto and Rostagno (2014).

Given period $t + 1$ aggregate rates of return and prices, entrepreneurs utilize their effective raw capital, $\omega\bar{K}_{t+1}$, to yield the services of effective capital, K_{t+1}, using the

[8] I modify the large family assumption in this financial setting in order to streamline the model presentation while the equations that define the equilibrium are the same.

[9] The presence of entrepreneurs simplifes the optimization problem of the representative household in the two variants with financial frictions. In particular, the term related to capital utilization drops out from the budget constraint (3.6).

following technology:

$$K_{t+1} = u_{t+1}\omega \bar{K}_t. \tag{3.30}$$

The cost function for capital utilization by entrepreneurs is the analog of the cost function $a(u_t)$ faced by households. Next, they supply effective capital services, K_{t+1}, for the competitive rental rate $Z_{k,t+1}$, and sell undepreciated capital back to households at the price $Q_{\bar{K},t+1}$. The rate of return on capital across entrepreneurs is as follows

$$R_{k,t+1} = \frac{Z_{k,t+1}u_{t+1} - P_{i,t+1}a(u_{t+1}) + (1-\delta)Q_{\bar{K},t+1}}{Q_{\bar{K},t}}, \tag{3.31}$$

where $P_{i,t}a(u_t)$ is the unit utilization cost expressed in the price of investment goods.

Entrepreneurs' total assets in period $t+1$ are given by $\omega R_{k,t+1}\bar{K}_t Q_t$. The threshold value of ω for separating bankrupt and solvent entrepreneurs, $\bar{\omega}_{t+1}$, is defined by the following expression:

$$\bar{\omega}_{t+1}R_{k,t+1}Q_{\bar{K},t}\bar{K}_{t+1} = R_{b,t+1}L_{e,t}, \tag{3.32}$$

where $R_{b,t}$ is the nominal lending rate on entrepreneurial loans. For any given threshold value of $\bar{\omega}_{t+1}$, a mean-preserving rise in the entrepreneurial risk shock, $\sigma_{e,t+1}$, implies an increase in the probability of default.

Bankers

I assume that an exogenous random fraction, $\theta_{e,t+1}$, of entrepreneurial earnings is retained to grow the business while the complementary fraction is paid out to shareholders as dividends at the end of period $t+1$. Entrepreneurs comply with their shareholders' net worth maximizing request in exchange for perfect consumption insurance. In doing so, entrepreneurs select the loan contract according to the period $t+1$ expected net worth:

$$\max_{\{\bar{\omega}_{t+1},\tilde{L}_{e,t}\}} E_t \left\{ \int_{\bar{\omega}_{t+1}}^{\infty} \left[\bar{\omega} R_{k,t+1}Q_{\bar{K},t}\bar{K}_{t+1} - R_{b,t+1}L_{e,t}\right] dF(\omega,\sigma_{e,t}) \right\}$$
$$= \max_{\{\bar{\omega}_{t+1},\phi_{e,t}\}} E_t \left[1-\Gamma(\bar{\omega}_{t+1})\right] R_{k,t+1}\phi_{e,t}N_{e,t},$$

where $\phi_{e,t} = \frac{Q_{\bar{K},t}\bar{K}_{t+1}}{N_{e,t}}$ is the entrepreneurial leverage multiple, $\Gamma(\bar{\omega}_{t+1}) = \left[1 - F(\bar{\omega}_{t+1})\right]\bar{\omega}_{t+1} + G(\bar{\omega}_{t+1})$ and $G(\bar{\omega}_{t+1}) = \int_0^{\bar{\omega}_{t+1}} \omega \; dF(\omega, \sigma_{e,t})$.

The realization of ω idiosyncratic risk is private information of entrepreneurs. In the presence of the costly state verification problem, risk-averse bankers have to incur monitoring costs to learn this value. If entrepreneurs draw $\omega \leq \bar{\omega}_{t+1}$, they go bankrupt and their remaining assets, $\omega_{t+1}R_{k,t+1}Q_{\bar{K},t}\bar{K}_{t+1}$, are seized by the bank. While the *ex ante* lending interest rate, $R_{b,t}$, is known at the contract signing time, the *ex post* return obtained by the bank is instead state-contingent. Therefore, the banker would only be willing to lend to the entrepreneur if the revenues net of monitoring costs received in each $t+1$ state of nature from the entrepreneurial loan are no less than the funds paid to depositors in period t. Accordingly, the following cash constraint must hold state by state:

$$[1 - F(\bar{\omega}_{t+1})]\, R_{b,t+1} L_{e,t} + (1-\mu) R_{k,t+1} Q_{\bar{K},t} \bar{K}_{t+1} \int_0^{\bar{\omega}_{t+1}} \omega \; dF(\omega, \sigma_{e,t}) \geq R_t L_{e,t}, \quad 0 < \mu < 1, \tag{3.33}$$

where μ is the proportion of the assets of bankrupt entrepreneurs expended for monitoring activities.

Optimal loan contract

The competitive banking sector earns zero profit in equilibrium with free entry. Thus the cash constraint in (3.33) must hold with strict equality in every $t+1$ aggregate state. Using this fact as well as the expressions of the default threshold and the entrepreneurial loan, I derive a single zero-profit condition for the banking sector:

$$\Gamma(\bar{\omega}_{t+1}) - \mu G(\bar{\omega}_{t+1}) = \frac{R_t}{R_{k,t+1}} \frac{(\phi_{e,t} - 1)}{\phi_{e,t}}, \qquad \phi_{e,t} > 1. \tag{3.34}$$

Banks offer a menu of $t+1$ state-contingent standard loan contracts that is defined by a set of $\{\bar{\omega}_{t+1}, \phi_{e,t}\}$ combinations satisfying (3.34). It is clear also from (3.34) that the standard loan contract depends solely on economy-wide variables, and thus all entrepreneurs choose the same $\{\bar{\omega}_{t+1}, \phi_{e,t}\}$ regardless of individual-specific net worth.

Net worth evolution and modified resource constraint

Summing across all entrepreneurs gives the following expression for end-of-period t entrepreneurial profit:

$$V_{e,t} = [1 - \Gamma(\bar{\omega}_t)]\, R_{k,t} Q_{\bar{K},t-1} \bar{K}_t. \tag{3.35}$$

After entrepreneurs have collected capital rental receipts and settled their obligations to banks, the complementary fraction, $1 - \theta_{e,t}$, of all entrepreneurs' earnings is paid out as dividends and consumed within the period. Therefore the per-capita consumption of shareholders is

$$P_{c,t} C_{e,t} = (1 - \theta_{e,t}) V_{e,t}. \tag{3.36}$$

Entrepreneurs raise an amount of exogenous additional capital, which corresponds to a fraction χ_e of the balanced-growth-path aggregate net worth, $n_e z_t$. Thus, after capital raising, aggregate net worth at the end of period t is

$$N_{e,t} = \theta_{e,t} V_{e,t} + \chi_e n_e z_t. \tag{3.37}$$

The spread between borrowing and risk-free interest rates is given by:

$$spr_{e,t} = \frac{R_{b,t}}{R_t}. \tag{3.38}$$

The resource constraint from the Pure model is now modified as

$$\frac{1}{g_t} Y_t = \tilde{C}_{d,t} + I_{d,t} + X_t + \mu R_{k,t} Q_{\bar{K},t-1} \bar{K}_t \int_0^{\bar{\omega}_t} \omega \; dF(\omega, \sigma_{e,t}), \tag{3.39}$$

with

$$\tilde{C}_{d,t} = (1 - \omega_c) \left(\frac{P_t}{P_{c,t}} \right)^{-\eta_c} (C_t + C_{e,t}) \qquad \text{and} \qquad \tilde{C}_{m,t} = \omega_c \left(\frac{P_{cm,t}}{P_{c,t}} \right)^{-\eta_c} (C_t + C_{e,t}).$$

3.3.2 Incentive compatibility constraint version

Entrepreneurs

Suppose there is a single, representative competitive entrepreneur. At the end of period t, the entrepreneur is endowed with a net worth, $N_{e,t} \geq 0$, from the household's transfer. The entrepreneur obtains a loan, $L_{e,t}$, from home banks, and combines with its own net worth, $N_{e,t}$, in order to purchase raw capital, $\bar{K}_{t+1}$, at a competitive price of $Q_{\bar{K},t}$. That is,

$$L_{e,t} = Q_{\bar{K},t} \bar{K}_{t+1} - N_{e,t}. \tag{3.40}$$

Given period $t + 1$ aggregate rates of return and prices, the entrepreneur chooses the utilization rate, u_{t+1}, which transforms its raw capital, $\bar{K}_{t+1}$, into the services of effective capital according to

$$K_{t+1} = u_{t+1} \bar{K}_t, \tag{3.41}$$

subject to the same utilization cost $a(u_{t+1})$ as in the EFP version. The entrepreneur also supplies effective capital services, K_{t+1}, for the competitive rental rate $Z_{k,t+1}$, and sells undepreciated capital back to households at the price $Q_{\bar{K},t+1}$. The optimal capital utilization and the zero profit condition are as follows:

$$Z_{k,t+1} = P_{i,t+1} a'(u_{t+1}), \tag{3.42}$$

$$R_{k,t} = \frac{Z_{k,t+1} u_{t+1} - P_{i,t+1} a(u_{t+1}) + (1 - \delta) Q_{\bar{K},t+1}}{\omega_{\bar{K}} Q_{\bar{K},t}} - \frac{(1 - \omega_{\bar{K}}) Q_{\bar{K},t+1}}{\omega_{\bar{K}} Q_{\bar{K},t}}, \tag{3.43}$$

where $\omega_{\bar{K}}$ is the share of aggregate capital purchase financed by the aggregate entrepreneurial loan and $P_{i,t} a(u_t)$ is the unit utilization cost denominated in the price of investment goods. The entrepreneur breaks even every period, transfers all net worth back to its household and hence accumulates no net worth state by state.

Bankers

I assume the presence of a competitive banking sector that efficiently monitors various borrowers and enforces their obligations. Thus risk neutral banks frictionlessly lend available funds to borrowers. At the end of period t, the state of a bank is summarized by its net worth, $N_{b,t}(j) \geq 0$. At this point, each bank raises a nominal deposit, $D_t(j)$, from households at the risk-free rate, R_t, and then extends three types of risk-free loans. The first type is working capital loans, $L_{f,t}(j)$, to intermediate goods producers who must finance part of their expenditures for capital and labor services:

$$L_{f,t}(j) = \upsilon_K Z_{k,t} K_t(j) + \upsilon_H W_t h_t(j). \tag{3.44}$$

The second type is credit, $L_{x,t}(j)$, to exporters who must finance a fraction of their homogeneous goods bill:

$$L_{x,t}(j) = \upsilon_X P_t X_t(j). \tag{3.45}$$

Both these types of intraperiod loans are due at the end of period t. The third loan type is interperiod loans to entrepreneurs, $L_{e,t}(j)$, who need to purchase raw capital. This type of loan is due at the beginning of period $t+1$. The bank's balance sheet simply states that

$$L_t(j) \equiv L_{f,t}(j) + L_{x,t}(j) + L_{e,t}(j) = N_{b,t}(j) + D_t(j).$$

The three types of loans pay out the non-contingent norminal returns, $R_{f,t}$, $R_{x,t}$ and $R_{k,t}$, respectively.

Optimal credit allocation

I also assume that an exogenous random fraction, $\theta_{b,t}$, of the banking earnings is retained to grow the business while the complementary fraction is paid out to shareholders as dividends at the end of period t. Given my assumption, it is clear that the larger the net worth of the bank, the greater the financial resources available to its shareholders. Thus it is in the interests of shareholders to request that their bankers maximize net worth. Also, I assume that shareholders value a particular portfolio of loans proposed by bankers according to the expected future discounted value of the owned funds. Formally, the banker solves the following problem:

$$\max_{\tilde{N}_{b,t+1}(j)} E_t \left\{ \sum_{s=0}^{\infty} (1-\theta_{b,t+1}) \theta_{b,t+1+s} \beta^{s+1} \Xi_{t,t+1+s} N_{b,t+1+s}(j) \right\} = V_t(j)$$

However, a moral hazard problem arises when bankers can discretionarily divert an exogenous time-varying fraction ϖ_t of assets on the balance sheet for their own interest.[10] Shareholders would therefore only approve the project of loan allocations proposed by bankers if the discounted funds owned from each $t+1$ period were no less than the assets diverted in the period t. Therefore the following cash constraint

$$V_t(j) \geq \varpi_t \left(L_{f,t}(j) + L_{x,t}(j) + L_{e,t}(j) \right), \qquad 0 < \varpi_t < 1. \tag{3.46}$$

[10]In Gertler and Karadi's (2011) framework, ϖ_t is traditionally referred to as a time-invariant stealing fraction of assets and thus financial frictions on the liability side originally come from a fear that bankers would steal. I believe that an interpretation of asset diversion at the banker's discretion is better suited for a time-varying parameter. Therefore, following this interpretation, I present a slightly different framework in which the scheme of incentive constraint works due to the skewed nature of banks' compensation.

must be satisfied in each period t. The linearity of the banker's optimization problem implies

$$V_t(j) = \tau_{f,t} L_{f,t}(j) + \tau_{x,t} L_{x,t}(j) + \tau_{e,t} L_{e,t}(j) + \gamma_t N_{b,t}(j), \tag{3.47}$$

with

$$\tau_{f,t} = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\theta_{b,t+1})(R_{f,t} - R_t) + \theta_{b,t+1} \frac{L_{f,t+1}(j)}{L_{f,t}(j)} \tau_{f,t+1} \right] \right\} \tag{3.48}$$

$$\tau_{x,t} = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\theta_{b,t+1})(R_{x,t} - R_t) + \theta_{b,t+1} \frac{L_{x,t+1}(j)}{L_{x,t}(j)} \tau_{x,t+1} \right] \right\} \tag{3.49}$$

$$\tau_{e,t} = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\theta_{b,t+1})(R_{k,t} - R_t) + \theta_{b,t+1} \frac{L_{e,t+1}(j)}{L_{e,t}(j)} \tau_{e,t+1} \right] \right\} \tag{3.50}$$

$$\gamma_t = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\theta_{b,t+1}) R_t + \theta_{b,t+1} \frac{N_{b,t+1}(j)}{N_{b,t}(j)} \gamma_{t+1} \right] \right\} \tag{3.51}$$

where $\tau_{f,t}$, $\tau_{x,t}$ and $\tau_{e,t}$ are the expected discounted marginal gains of various loans, while γ_t is the expected discounted marginal value of net worth.

Observe that the left term in (3.46) cannot be strictly greater than the term on the right in each time period t. Otherwise, banks would make positive profits, which is incompatible with the competitive credit market. Thus the perfect competitiveness and the cash constraint in (3.46) jointly imply that (3.46) must hold as a strict equality in every period. Combining this fact with the linear value function (3.47), I obtain the aggregate incentive compatibility constraint for the banking sector,[11]

$$L_t = \phi_{b,t} N_{b,t}, \qquad \phi_{b,t} > 1, \tag{3.52}$$

$$\tau_{f,t} = \tau_{x,t} = \tau_{e,t} \equiv \tau_t \tag{3.53}$$

where $\phi_{b,t} = \frac{\gamma_t}{\varpi_t - \tau_t}$ is the banking leverage multiple. The time-varying divertible fraction of assets, ϖ_t, directly affects the bank's balance sheet and its capability to lend, which I refer to below as the bank risk shock.[12] Thus the moral hazard problem imposes an endogenous incentive constraint on the bank's balance sheet. Note that in equilibrium the incentive constraint is symmetric across all types of loans and thus banks are indifferent to lending an additional unit among various borrowings.[13] The $(L_{f,t}(j), L_{x,t}(j), L_{e,t}(j))$ combinations that satisfy the (3.53) arbitrage condition define an optimal loan portfolio approved by the representative household's shareholders and allocated by j^{th} banker to various borrowers.

[11] This aggregation is possible due to the constant number of bankers in the economy as well as their risk neutrality and perfect competitiveness. Also, there exists one aggregate loan demand curve that is identical for all bankers. Therefore the j index has been dropped.

[12] Shocks of this kind occur when bankers pursue goals which have a high profile. Bankers can, for example, relax lending criteria for undesirable big projects or increase discretionary expenditure on perks. In this way, they give insights into prestige, job security and power.

[13] The arbitrage condition, however, does not imply that the expected returns from various loans are identical (not even up to first order) as the marginal gain for each type of loan depends on the growth rate of each loan type.

Net worth evolution and modified resource constraint

Aggregating across all banks yields the following expression for end-of-period t banking profit:

$$V_{b,t} = (R_{f,t} - R_t)L_{f,t-1} + (R_{x,t} - R_t)L_{x,t-1} + (R_{k,t} - R_t)L_{e,t-1} + R_t N_{b,t-1}. \tag{3.54}$$

After bankers have received returns on the optimal portfolio of loans and settled their obligations to depositors, the complementary fraction, $1 - \theta_{b,t}$, is paid out as dividends and consumed within the period. Therefore the per-capita consumption of shareholders is

$$P_{c,t} C_{b,t} = (1 - \theta_{b,t}) V_{b,t}. \tag{3.55}$$

Banks also raise exogenous additional capital, which corresponds to a fraction χ_b of the balanced-growth-path aggregate net worth, $n_b z_t$. Thus, after capital raising, aggregate net worth at the end of period t is

$$N_{b,t} = \theta_{b,t} V_{b,t} + \chi n_b z_t. \tag{3.56}$$

Disturbances to the retention ratio $\theta_{b,t}$ would cause sudden volatilities in the value of assets on the bank balance sheet, which in turn would impact on the lending capacity of the bank.[14]

The weighted average lending-deposit spread is given by

$$spr_{b,t} = \frac{R_{f,t} L_{f,t} + R_{x,t} L_{x,t} + R_{k,t} L_{e,t}}{R_t L_t}. \tag{3.57}$$

The resource constraint from the Pure model is modified as follows:

$$\frac{1}{g_t} Y_t = \tilde{C}_{d,t} + I_{d,t} + X_t, \tag{3.58}$$

with

$$\tilde{C}_{d,t} = (1 - \omega_c) \left(\frac{P_t}{P_{c,t}} \right)^{-\eta_c} (C_t + C_{b,t}) \qquad \text{and} \qquad \tilde{C}_{m,t} = \omega_c \left(\frac{P_{cm,t}}{P_{c,t}} \right)^{-\eta_c} (C_t + C_{b,t}).$$

3.3.3 Foreign economy, exogenous disturbances and comparable perturbations

The optimal problems of foreign agents are similarly modeled, with the following exceptions noted for a large (and approximately closed) economy. First, final private consumption and investment goods comprise a continuum of domestically produced goods, $C_t^* \equiv \int_0^1 C_{d,t}^*(j)dj$ and $I_t^* \equiv \int_0^1 I_{d,t}^*(j)dj$, because home exports account for a trivial share

[14] Upheavals in financial markets during the 2007−2008 financial crisis appear to reflect adverse disturbances of this type, as indicated by heavy losses in assets and dramatic declines in profits of banks. In particular, the collapse of Lehman Brothers may be considered a world-wide common shock. Other examples of such disturbances in normal economic conditions include a tax on bank capital, a raise in regulatory capital requirement, an increase in the capital adequacy ratio, and a change to the classification of Tier 1 and Tier 2 capital.

of aggregate foreign demand. Second, variations in the home export price have a negligible effect on the evolution of the foreign price index, implying that $P^*_{c,t} = P^*_{i,t} \equiv P^*_t$. Third, loans provided to home importers, $L_{m,t}$, form a negligible part of total credit; it follows that $L^*_t \equiv L^*_{f,t} + L^*_{e,t}$, $spr^*_{e,t} = \frac{R^*_{b,t}}{R^*_t}$ and $spr^*_{b,t} \equiv \frac{R^*_{f,t}L^*_{f,t}+R^*_{k,t}L^*_{e,t}}{R^*_t L^*_t}$. Home importers then take the foreign borrowing costs $R^*_{m,t} \equiv R^*_t spr^*_{b,t}$ as given. Finally, home assets are in zero net supply because the asset holdings of home households are negligible in the foreign market while there is no access to the home asset market for foreign agents.

The Pure model includes 17 shocks in the Home economy: $g_{z,t}, \epsilon_t, \lambda_{d,t}, \lambda_{cm,t}, \lambda_{im,t}, \lambda_{x,t}, \lambda_{w,t}, \varepsilon_{p_c,t}, b_t, \mu_t, \psi_t, \varepsilon_{com,t}, p^*_{com,t}, \varepsilon_t, \bar{\pi}_t, g_t, \tilde{z}^*_t$ and 9 shocks in the Foreign economy: $g^*_{z,t}, \epsilon^*_t, \lambda^*_{p,t}, \lambda^*_{w,t}, b^*_t, \mu^*_t, \varepsilon^*_t, \bar{\pi}^*_t, g^*_t$, where $\tilde{z}^*_t = \frac{z^*_t}{z_t}$ is a stationary shock capturing temporary asymmetry in permanent technological progress between two countries. I add two pairs of financial shocks $\{\theta_{e,t}, \theta^*_{e,t}; \sigma_{e,t}, \sigma^*_{e,t}\}$ in the EFP version and $\{\theta_{b,t}, \theta^*_{b,t}; \varpi_t, \varpi^*_t\}$ in the ICC version. Each shock follows a first-order univariate autoregressive process, except that the monetary policy shock, $\{\varepsilon_t, \varepsilon^*_t\}$, and the consumption price inflation shock, $\varepsilon_{\pi_{c,t}}$, are assumed to be *iid*. For the inflation target shock, I simply set the autoregressive parameter $\{\rho_{\pi^c}, \rho_{\pi^*}\}$ to $(0.975, 0.975)$, which accommodates the fact that the inflation trend is downward in the late part of my dataset.

To promote reasonable comparability, I consider the two perturbations. First, the ICC model with financial frictions only on the entrepreneurial loan, in the spirit of Gertler and Karadi (2011), will serve as a main counterpart with the EFP model in the later comparable empirical exercise. Although my theoretical development of financial frictions on all types of loans is plausible, putting the incentive constraint on the entrepreneurial loan alone would give the EFP model a fair chance in the fitness race. Technically, this ICC model variant is obtained by setting a set of simultaneous impositions: $\{R_{x,t} = R_t; R_{f,t} = R_t, R^*_{f,t} = R^*_t; L_{e,t} = \phi_{b,t}N_{b,t}, L^*_{e,t} = \phi^*_{b,t}N^*_{b,t}; spr_t = \frac{R_{k,t}}{R_t}, spr^*_t = \frac{R^*_{k,t}}{R^*_t}\}$. Second, I use the same series of financial observables in the two friction variants. In particular, I include data on the credit supply and the stock market value in the estimation exercise of the EFP and ICC models, respectively. Also, the presence of these financial data brings extensive unmodeled dynamics of the other side of the financial market into each friction variant.

3.4 Empirical methodology

This section describes the model solution, the data used in the estimation, the calibrated parameters, and the priors for model parameters.

3.4.1 Model solution

The solution for the model proceeds as follows. In a first step, I cast the model versions into a stationary form. Specifically, real variables are detrended by the level of technology, $\{z_t, z^*_t\}$, and nominal variables are converted to real variables by deflating with the price index, $\{P_t, P_t^*\}$. Second, the models are written into a set of stationary equilibrium conditions. Third, I compute the nonstochastic steady state of the transformed models. Fourth, I log-linearly approximate the transformiere models around this steady state. Finally, the transformed models are augmented with a set of measurement equations which link the observable variables in the dataset with the endogenous variables in order to form a state-space system.

3.4.2 The data

The two countries in my empirical analysis are Australia as the small-open home economy and the United States as the large-closed foreign economy. The seven country-specific macroeconomic time series used in the estimation procedure are real GDP, real private consumption as the sum of household purchases of nondurable goods and services, real investment as the sum of gross private domestic investment plus household purchases of durable goods, nonfarm hours worked, nonfarm real wages, domestic inflation, and nominal policy rate. To these fourteen variables I add seven open economy series, being non-commodity and commodity exports, imports, real exchange rate, CPI inflation, relative price of investment goods measured as the investment good price deflator divided by the GDP deflator, $p_{i,t} = P_{i,t}/P_t$, and relative price of commodities measured as the commodity price index divided by the U.S. GDP deflator, $p^*_{com,t} = P_{com,t}/P^*_t$.[15] In accordance with the model, overall inflation is measured as percentage growth in the CPI and the GDP deflator for Australia and the U.S. respectively. Also, I use four financial variables in the analysis. My indicators of entrepreneurial net worth, $\{N_{e,t}, N^*_{e,t}\}$, are the ASX All Ordinaries index and the Dow Jones Wilshire 5000 index. I compute the entrepreneurial spread of Australia as a weighted average of spreads between corporate bond yield relative to government bond yield and large business loan rate relative to government bond yield of corresponding maturities. For the U.S., the entrepreneurial spread is measured by the difference in yield between the corporate bond and government bond. My measure of loans, $\{L_t, L_t^*\}$, is total credit to non-financial firms sourced from the Lending and Credit Aggregates dataset of the Reserve Bank of Australia and the Flow of Funds database of the U.S. Federal Reserve Board. I use the 90-day loan rate[16] minus the policy rate as my measure of the banking spread. Details of the data are in the Appendix G. The estimation period starts in 1993 Q1 and ends in 2012 Q4.[17]

Prior to analysis, I transform the quarterly data as follows. Quantity variables, including financial variables, are converted in real per-capita terms by dividing their

[15] I use the G7 trade-weighted average real exchange rate rather than the bilateral measure because it is my way of introducing a multi-country real world into my two-country model through the behavior of multilateral relative prices.

[16] The large business loan rate for Australia and the bank prime lending rate for the U.S., respectively.

[17] I concentrate on this period because it is characterized by inflation-targeting regimes in both countries. The starting date corresponds to the official commencement of inflation targeting in Australia in order to avoid potential distortionary effects of non-inflation targeting monetary policy on the estimates of the nominal interest rate.

nominal values by the GDP deflator and the civilian population. Real wage is calculated as compensation per hour divided by the GDP deflator. Hours worked are also converted in per capita terms. I take the logarithmic first difference of all these quantity variables and then remove the sample mean for both quantity and price variables. Note that my model predicts that the log of every real quantity variable to GDP ratio is stationary, while on average some series (e.g. trade and financial) grew significantly faster than GDP in my dataset. Thus I demean separately from each real quantity variable, which helps prevent low business cycle frequencies from having counterfactual implications for the higher frequencies.

3.4.3 Calibration

A set of parameters is simply fixed a priori. Table 3.1 reports parameters common to the three models. Capital share $\{\alpha,\ \alpha^*\}$ is set to (0.32, 0.33). The quarterly depreciation rate for capital $\{\delta,\ \delta^*\}$ is fixed at (1.75%, 2.5%) to match the average annual investment to capital ratio. The inverse Frisch elasticity of labor supply $\{\sigma_H,\ \sigma_H^*\}$ is set to 1. I choose the disutility weight on labor $\{\varphi_H,\ \varphi_H^*\}$ so that hours worked is normalized to one-third in steady state. The steady-state gross markup in the labor market $\{\lambda_w, \lambda_w^*\}$ is set to 1.2. I set the growth rate of the permanent technology shock $\{\bar{g}_z, \bar{g}_z^*\}$ to (0.45%, 0.41%), consistent with the mean per-capita real GDP growth rate over my sample. I set the home discount factor β at 0.9987 and β^* is endogenously determined through the uncovered interest arbitrage condition. The share of public demand in GDP is (0.23, 0.19) to match its average share in the data. I assign $\{v_K = v_H > v_K^* = v_H^*\}$, which reflects my later finding that the credit velocity measure is smaller in Australia than in the U.S. I force $v_M = 0.30$ following the presence of debt denominated in foreign currency on the balance sheet of Australian non-financial firms. Next, I set v_X in order to ensure both balanced trade and a well-defined level of net foreign assets in steady state.[18] The parameters governing the weight of import goods in consumption and investment, ω_c and ω_i, as well as the export share of the commodity sector, ω_x, are respectively set to 0.21, 0.50, and 0.72 to reflect the average values over the sample period in Australia.

I turn to calibrated parameters specific to financial frictions in Table 3.2. The steady-state dividend payout ratio of both sectors, $\{\theta_i,\ \theta_i^*\}$, is set equal to 0.95, which is fairly close to the 0.972 value used in BGG and GK.[19] The spread between the borrowing and risk-free rates, $\{spr_e,\ spr_e^*\}$, is set to match the average spread of (105, 100) basis points

[18] In particular, $v_X = v_M \frac{R^*-1}{R-1}$ in the Pure and EFP models and $v_X = v_M \frac{R_m^*-1}{R_x-1}$ in the ICC model. See Section D of the Appendix for details of the derivation.

[19] Traditionally, $1-\theta_i$ (for $i = \{e, b\}$) is usually referred to as the death rate of entrepreneurs or bankers. For quarterly frequency (and the framework of a single economy, whether closed or open), it has usually been set equal to $1-0.972$ in studies using the framework of BGG and GK. However, the fraction $1-\theta_i$ in my model corresponds to that of the net income, $V_{i,t}$, passed for shareholder consumption $C_{i,t}$, so the most natural interpretation of this parameter is "the dividend payout ratio". Similar interpretations have been used by Fernández and Gulan (2015) and Gertler and Kiyotaki (2010), where θ_i occurs in the context of the firms' value and banks' equity respectively.

Table 3.1: Calibration of Common Parameters

Description	Parameter	Value	Parameter	Value
Discount factor	β	0.9987		
Capital share	α	0.32	α^*	0.33
Capital depreciation rate	δ	0.0175	δ^*	0.025
Inverse Frisch elasticity	σ_H	1	σ_H^*	1
Disutility weight on labor	φ_H	9.5	φ_H	9.5
Gross markup in the labor market	λ_w	1.2	λ_w^*	1.2
Growth rate of the economy	$\bar{g}_z$	0.45	$\bar{g}_z^*$	0.41
Government spending-GDP ratio	g/y	0.23	g^*/y^*	0.19
Share of capital rental costs paid in advance	υ_K	0.70	υ_K^*	0.65
Share of labor costs paid in advance	υ_H	0.70	υ_H^*	0.65
Share of import bill paid in advance	υ_M	0.30		
Share of import goods in consumption	ω_c	0.21		
Share of import goods in investment	ω_i	0.50		
Share of commodity sector in export	ω_x	0.72		

Table 3.2: Calibration of Model-specific Financial Parameters

Description	Parameter	Value	Parameter	Value
Payout ratio	$1-\theta_i$	$1-0.95$	$1-\theta_i^*$	$1-0.95$
Borrowing-riskless spread	spr_e	105 b.p	spr_e^*	100 b.p
Entrepreneurial leverage multiple	ϕ_e	1.89	ϕ_e^*	1.95
Fraction of additional capital	χ_e	0.005	χ_e^*	0.005
Entrepreneurial risk shock	σ_e	0.33	σ_e^*	0.35
Lending−deposit spread	spr_b	284 b.p	spr_b^*	250 b.p
Banking leverage multiple	ϕ_b	6.42	ϕ_b^*	5.65
Fraction of additional capital	χ_b	0.002	χ_b^*	0.002

in my data. The steady-state entrepreneurial leverage multiple is the total liabilities to total net worth ratio of the non-financial business sector, taken from the Non-financial Corporations Balance Sheet of the Australian Bureau of Statistics and the Flow of Funds account of the Federal Reserve Board. I calibrate the steady-state value of the entrepreneurial risk shock $\{\sigma_e, \sigma_e^*\}$ so that the steady-state leverage multiple of the non-financial business sector meets my target value. The fraction of additional capital, $\{\chi_e, \chi_e^*\}$, is calibrated to meet targets for the spread, the entrepreneurial leverage multiple, and the payout ratio, $1-\theta_e$, in steady state.

I set the steady-state spread between the lending and deposit rates, $\{spr_b, spr_b^*\}$, to (284, 250) basis points, which corresponds to the average difference between the 90-day loan and policy rates. The steady-state banking leverage multiple is total assets divided by equity capital, which roughly captures the aggregate data of the banking sector in Australia and the U.S. respectively. The fraction of additional capital, $\{\chi_b, \chi_b^*\}$, is calibrated to meet targets for the retention ratio, the spread and the banking leverage multiple in steady state. Thus the divertible fraction of assets in steady state, $\{\varpi, \varpi^*\}$, is endogenously determined in accordance with these targets.

3.4.4 The priors

The set of parameters to be assigned values is listed in Tables3.5 and 3.6. My prior belief is that parameter distributions are symmetric between the two countries. Thus the same priors are assigned to all comparable parameters. In particular, I adopt the prior assumptions of the parameters that correspond to those in the closed economy set-up from Smets and Wouters (2007). For open economy-specific parameters, I impose the following prior distributions. The elasticities of substitution between imported and domestic goods, η_c and η_i, and the elasticity of non-commodity export demand, η^*, follow an inverse-gamma distribution with mean 1.5, in keeping with much of the international macroeconomics literature. In addition, I truncate the prior in order to exclude substituability below unity, based on economic theory. The depreciation elasticity of country risk premium, ϕ_s, is beta distributed around 0.5 with standard deviation 0.15. The parameter driving the debt elasticity of risk premium, ϕ_a, is subject to an inverse gamma density with mean 0.01, matching the calibrated value in Benigno (2009).

I turn to parameters pertaining to the entrepreneurial sector. To estimate the steady-state probability of default, I let the variance of $\{\log(\omega), \log(\omega^*)\}$ be the function of $\{F(\bar{\omega}), F(\bar{\omega}^*)\}$ and the relevant parameters of the model. The mean of my prior beta distribution for $\{F(\bar{\omega}), F(\bar{\omega}^*)\}$ is 0.008, between the 0.0075 value used in BGG and the 0.0097 percent value used by Fisher (1999). For the monitoring costs $\{\mu,\ \mu^*\}$, I set a beta distribution with mean 0.275 and standard deviation 0.125, within the range of 0.20–0.36 that Carlstrom and Fuerst (1997) propose as empirically relevant.

To characterize the posterior distribution of the model parameters, I use Bayesian procedures surveyed by An and Schorfheide (2007). Accordingly, the posterior distribution is estimated by maximizing the log-posterior function, which combines prior information on the structural parameters with the likelihood of the data. The Metropolis-Hastings algorithm with 500,000 replications for two chains is used to get a complete picture of the posterior distribution.

3.5 Model comparison

In this section, I evaluate the relative performance of the model versions with a comparative focus between the EFP and ICC extensions that are the novel part of the present paper. The empirical comparison is made along the following dimensions: (i) marginal likelihood; (ii) steady-state properties; (iii) estimated parameters; (iv) business cycle moments; (v) impulse response functions; and (vi) ability to account for comovement.

3.5.1 Marginal likelihood

I firstly evaluate the relative empirical performance of the model versions by comparing their implications for the marginal likelihood of the dataset. According to the first row in Table 3.3, the log marginal likelihood of my Pure model is -4332.80. The second

Table 3.3: Log Marginal Likelihood

Model Versions	Marginal Likelihood
Pure	−4332.80
EFP	−4292.74
ICC with financial frictions on all types of loan	−4253.07
EFP with lending-deposit spread series	−4313.10
ICC with financial frictions on entrepreneurial loan alone	−4267.85

Note: For model versions estimated with different datasets, I evaluate the marginal data density at the posterior mode using a Laplace approximation. By contrast, model versions with the same dataset are compared by the marginal data density computing with Geweke (1999) modified harmonic mean. The computations are based on a Monte Carlo Markov chain of length 500,000 for each model version.

and third rows show that when I incorporate financial frictions into the Pure model, the fit of the model versions increases significantly. In particular, the marginal likelihood rises roughly 40 and 80 log points for the EFP and ICC versions, respectively. The greater improvement in fit comes from augmenting the Pure model with financial frictions between depositors and banks. Financial frictions on this relation add 30 additional log points to fit above what is achieved by incorporating financial frictions between entrepreneurs and banks.

Using different proxies for the financial frictions may affect the goodness of fit. Thus I want to give the EFP version a second chance in the competition of the fit. So I use lending−deposit spread instead of borrowing−riskless spread in the re-estimation of the EFP version. That attempt adds less to model fit than using the external finance premium series did. In particular, the marginal likelihood falls roughly 20 log points. Because the literature on demand-side financial frictions focuses solely on funding for entrepreneurs' capital purchases, I also give the financial frictions on the supply side a fair competition chance. So, I consider the case where only the entrepreneurial loan is subject to the moral hazard problem, in the spirit of Gertler and Karadi (2011). That reduces roughly 15 log points compared to the case of all types of loans subject to the moral hazard problem in the ICC version, while still 25 points higher than the log marginal likelihood of the best EFP version.

In sum, a comparison between the two friction variants provides clear evidence in favor of incorporating financial frictions *à la* GK into the Pure model. Further, if one wants to consider scenarios of financial frictions on bank loans (as I do, for a fair comparison), then putting the incentive compatibility constraint on all types of loans simultaneously is the better choice because it adds more to the model fit.

3.5.2 Steady-state properties

I next examine the impact of the estimated parameter values on the nonstochastic steady state. Table 3.4 reports the steady-state properties of the models when parameters are evaluated at their posterior mode. The table also reports the empirical counterparts in

Table 3.4: Steady-state Properties, Models at Posteriors versus Data

Variable	Australia				United States			
	Pure	EFP	ICC	Data	Pure	EFP	ICC	Data
Discount factor					0.9983	0.9983	0.9983	
Investment to GDP ratio	0.25	0.28	0.27	0.26	0.27	0.28	0.27	0.25
Consumption to GDP ratio	0.54	0.51	0.52	0.52	0.52	0.51	0.52	0.56
Government spending to GDP ratio	0.21	0.21	0.21	0.23	0.21	0.21	0.21	0.19
Export to GDP ratio	0.22	0.21	0.21	0.20				
Import to GDP ratio	0.22	0.21	0.21	0.21				
Capital stock to GDP ratio[1]	10.85	8.67	10.21	12.10	9.86	7.96	9.45	10.30
Inflation (APR)	2.45	2.47	2.50	2.58	2.11	2.15	2.20	2.19
Short-term risk free rate (APR)	4.72	4.73	4.77	4.80	4.41	4.40	4.38	3.92
Credit velocity[2]		1.38	1.35	1.20		1.41	1.44	1.63
Entrepreneurer leverage multiple		1.96		1.89		2.05		1.95
Elasticity of the external finance premium		0.01				0.012		
Banking leverage multiple			6.65	6.42			5.86	5.65
Divertible fraction of assets			0.19				0.21	

[1] Capital stock includes private nonresidential and residential fixed assets, stock of private inventories, and stock of consumer durables (*Source*: ABS and BEA).

[2] Credit velocity is computed as annual nominal GDP over total credit, where total credit in each economy is respectively defined as credit market instruments liabilities of non-financial corporations (*Source*: Finance and Wealth Accounts, ABS) and the sum of credit market instruments liabilities of non-financial corporate sector plus credit market instruments liabilities of noncorporate sector (*Source*: Flow of Funds Accounts, FRB).

the data. Overall, the friction models better match the data than the Pure model. One exception to the goodness of fit is the ratio of capital stock to GDP, which is little low in the model extensions with financial frictions. I regard this relatively low stock of capital as preliminary evidence of the effects of financial frictions, and even more so in the EFP version due to the strong effect of a positive external finance premium on the capital stock. I deliberately do not include the data's relevant ratios in computing the posterior distribution of the model parameters because I want to make a fair comparison between the two extensions and with the Pure model.

Interestingly, the Australian non-financial business sector has a lower leverage multiple and, simultaneously, a smaller elasticity of the external finance premium with respect to the leverage multiple compared to its U.S. counterpart, implying that U.S. firms rely more on the external finance associated with higher costs. It follows that an entrepreneurial sector can obtain loan contracts with a higher leverage multiple which requires, *ceteris paribus*, paying a higher external finance premium. This is because, with a higher leverage multiple, entrepreneurs impose greater monitoring costs on the banking sector in the event of default. There is no empirical evidence of the feasible value range of divertible banking asset fraction, so it suffices to say that my relatively low value is broadly in line with my interpretation of this parameter as a fractional asset diverted for discretionary spending.[20]

3.5.3 Estimated parameters

Tables 3.5 and 3.6 report the estimated posterior modes of my model versions for Asutralia and the U.S. Since most parameters are remarkably similar across the three models, I quickly pin down the salient ones. We see, from comparing prior and posterior standard deviations, that there is a fair amount of information about the steady-state default probability, $\{F(\bar{\omega}), F(\bar{\omega}^*)\}$, and somewhat less about the monitoring cost, $\{\mu, \mu^*\}$, in my data. The estimated monitoring cost fraction μ of 0.214 for the Australian economy is smaller, albeit with a lower rate of bankcrupcy, than the value of 0.312 estimated for the U.S.[21] A proxy for direct monitoring costs is the average cost of closing a business (expressed as a percent of estate) found in the Doing Business database of the World Bank, which shows a value of 7.38% for a sample of small-open developed economies.

The estimated bankruptcy costs of both economies are well within the 0.20–0.36 range of Carlstrom and Fuerst (1997), in which the estimate for the U.S. is in the upper-value range compared to some previous studies focusing on this economy. For example, Christiano, Motto, and Rostagno (2014) obtain the value 0.215 from Bayesian estimation for the period 1985Q1−2010Q2. My relatively high estimate of μ_i can be considered as a broad indicator of financial frictions at work in advanced economies, possibly even more so in the U.S. economy where the degree of competition is relatively higher. As argued by Carlstrom and Fuerst (1997), high monitoring costs should be regarded in a broader sense

[20]This parameter is interpreted as the fraction of stolen assets in Gertler and Karadi (2011), where it is calibrated up to 0.381.

[21]The bankruptcy rates for Australia and the U.S. are (2.62, 3.38) percent per year, respectively. The number for the U.S. is in line with those seen in some previous studies, e.g., 3 percent annualized in BGG (1999).

Table 3.5: Priors and Posteriors of Structural Parameters for Home Economy

Para.	Description	Prior			Posterior					
					Pure		EFP		ICC	
		Distr.	Mean	SD	Mode	SD	Mode	SD	Mode	SD
Panel A. Economic parameters										
ξ_w	Stickiness, wage	B	0.5	0.1	0.41	0.07	0.44	0.08	0.45	0.09
ξ_d	Stickiness, domestic price	B	0.5	0.1	0.53	0.07	0.87	0.03	0.87	0.04
ξ_{cm}	Stickiness, import cons. price	B	0.5	0.1	0.47	0.08	0.57	0.08	0.56	0.09
ξ_{im}	Stickiness, import inv. price	B	0.5	0.1	0.82	0.03	0.80	0.03	0.77	0.02
ξ_x	Stickiness, export price	B	0.5	0.1	0.70	0.06	0.70	0.06	0.68	0.07
ι_w	Indexation, wage	B	0.5	0.15	0.38	0.16	0.42	0.16	0.47	0.17
ι_d	Indexation, domestic price	B	0.5	0.15	0.89	0.06	0.76	0.11	0.75	0.13
ι_{cm}	Indexation, import cons. price	B	0.5	0.15	0.88	0.06	0.89	0.06	0.88	0.05
ι_{im}	Indexation, import inv. price	B	0.5	0.15	0.81	0.08	0.81	0.08	0.79	0.08
ι_x	Indexation, export price	B	0.5	0.15	0.83	0.08	0.84	0.08	0.82	0.08
λ_d	Markup, domestic	N	1.2	0.12	1.45	1.26	1.87	0.10	1.86	0.10
λ_{cm}	Markup, import cons.	N	1.2	0.12	1.22	1.15	1.23	0.07	1.24	0.09
λ_{im}	Markup, import inv.	N	1.2	0.12	1.64	1.47	1.51	0.12	1.49	0.13
$F(\bar{\omega})$	SS probability of default	B	0.008	0.004	–	–	0.0056	0.0019	–	–
μ	Monitoring cost	B	0.275	0.15	–	–	0.214	0.118	–	–
F''	Investment adjustment cost	N	4	1.5	4.76	1.11	6.76	1.57	6.65	1.05
ζ	Capital utilization rate	B	0.5	0.15	0.35	0.12	0.57	0.15	0.55	0.16
b	Habit formation	B	0.5	0.1	0.78	0.07	0.56	0.16	0.57	0.20
ρ	Taylor rule smoothing	B	0.75	0.1	0.85	0.02	0.88	0.02	0.88	0.03
r_π	Taylor rule on inflation	N	1.5	0.25	1.62	0.21	1.66	0.19	1.67	0.20
$r_{\triangle_{gdp}}$	Taylor rule on GDP growth	N	0.25	0.1	0.34	0.08	0.20	0.07	0.19	0.07
η_c	Elasticity of subst., consumption	$I_{>1}$	1.5	0.4	4.36	0.89	5.53	1.45	5.56	1.52
η_i	Elasticity of subst., investment	$I_{>1}$	1.5	0.4	1.37	0.07	1.38	0.07	1.37	0.07
η_x	Elasticity of subst., export	$I_{>1}$	1.5	0.4	1.47	0.11	1.49	0.13	1.49	0.12
ϕ_a	Elasticity of risk premium-debt	I	0.01	1	0.003	0.0006	0.003	0.0007	0.003	0.0008
ϕ_s	Elasticity of risk premium-depre.	B	0.5	0.15	0.15	0.04	0.17	0.05	0.17	0.06
Panel B. Autocorrelation of the shocks										
ρ_{g_z}	Persistent technology	B	0.5	0.2	0.50	0.27	0.52	0.29	0.51	0.29
$\rho_{\tilde{z}^*}$	Asymmetric technology	B	0.5	0.2	0.50	0.27	0.50	0.28	0.50	0.27
ρ_ϵ	Transitory technology	B	0.5	0.2	0.99	0.01	0.89	0.04	0.89	0.04
ρ_w	Wage markup	B	0.5	0.2	0.16	0.08	0.15	0.08	0.16	0.08
ρ_d	Domestic price markup	B	0.5	0.2	0.10	0.10	0.07	0.06	0.07	0.06

Para.	Description	Prior			Posterior					
					Pure		EFP		ICC	
		Distr.	Mean	SD	Mode	SD	Mode	SD	Mode	SD
ρ_{cm}	Import cons. price markup	B	0.5	0.2	0.98	0.01	0.95	0.02	0.96	0.03
ρ_{im}	Import inv. price markup	B	0.5	0.2	0.10	0.07	0.11	0.08	0.12	0.07
ρ_{x}	Export price markup	B	0.5	0.2	0.09	0.07	0.09	0.07	0.09	0.07
ρ_{pcom}	Commodity relative price	B	0.5	0.2	0.92	0.02	0.93	0.02	0.93	0.02
ρ_{xcom}	Commodity export demand	B	0.5	0.2	0.77	0.05	0.80	0.05	0.79	0.07
ρ_{ψ}	Country risk premium	B	0.5	0.2	0.72	0.09	0.69	0.07	0.68	0.07
ρ_{g}	Government spending	B	0.5	0.2	0.91	0.06	0.70	0.09	0.69	0.11
ρ_{μ}	Marginal efficiency of investment	B	0.5	0.2	0.23	0.10	0.96	0.05	0.97	0.07
ρ_{b}	Intertemporal preference	B	0.5	0.2	0.34	0.11	0.63	0.29	0.62	0.36
ρ_{θ_e}	Entrepreneurial net worth	B	0.5	0.2	–	–	0.99	0.006	–	–
ρ_{σ_e}	Entrepreneurial risk	B	0.5	0.2	–	–	0.80	0.05	–	–
ρ_{θ_b}	Banking net worth	B	0.5	0.2	–	–	–	–	0.98	0.007
ρ_{ϖ}	Banking risk	B	0.5	0.2	–	–	–	–	0.79	0.03
Panel C. Standard deviations of the innovations										
σ_{g_z}	Persistent technology	I	0.05	2	0.03	0.009	0.02	0.010	0.02	0.009
$\sigma_{\tilde{z}^*}$	Asymmetric technology	I	0.05	2	0.03	0.010	0.02	0.009	0.02	0.009
σ_{ϵ}	Transitory technology	I	0.1	2	0.33	0.029	0.56	0.058	0.57	0.060
σ_{w}	Wage markup	I	0.1	2	0.58	0.073	0.59	0.076	0.57	0.068
σ_{d}	Domestic price markup	I	0.1	2	0.85	0.239	0.73	0.066	0.74	0.069
σ_{cm}	Import cons. price markup	I	0.1	2	3.67	1.446	2.94	1.237	3.05	1.681
σ_{im}	Import inv. price markup	I	0.1	2	1.21	0.125	1.24	0.127	1.23	0.128
σ_{x}	Export price markup	I	0.1	2	4.52	0.696	4.47	0.702	4.43	0.704
σ_{pcom}	Commodity relative price	I	0.1	2	5.75	0.461	5.73	0.457	5.70	0.460
σ_{xcom}	Commodity demand	I	0.1	2	5.05	0.394	5.02	0.391	5.11	0.349
σ_{ψ}	Country risk premium	I	0.1	2	0.52	0.204	0.81	0.216	0.82	0.219
σ_{π_c}	Consumption price inflation	I	0.1	2	0.90	0.071	0.89	0.071	0.88	0.072
σ_{ε}	Monetary policy	I	0.1	2	0.12	0.011	0.11	0.009	0.10	0.010
$\sigma_{\bar{\pi}}$	Inflation target	I	0.05	2	0.03	0.010	0.03	0.012	0.04	0.013
σ_{g}	Goverment spending	I	0.1	2	0.92	0.071	0.71	0.059	0.70	0.056
σ_{μ}	Marginal efficiency of investment	I	0.1	2	1.30	0.162	0.40	0.078	0.42	0.094
σ_{b}	Intertemporal preference	I	0.1	2	0.39	0.058	0.58	0.129	0.56	0.137
σ_{θ_e}	Entrepreneurial net worth	I	0.1	2	–	–	1.08	0.074	–	–
σ_{σ_e}	Entrepreneurial risk	I	0.1	2	–	–	0.02	0.004	–	–
σ_{θ_b}	Banking net worth	I	0.1	2	–	–	–	–	1.18	0.163
σ_{ϖ}	Banking risk	I	0.1	2	–	–	–	–	5.18	0.569

Note: Estimated parameters are based on two Metropolis–Hastings chains of 500,000 iterations, with a 20 percent burn-in.

Table 3.6: Priors and Posteriors of Structural Parameters for Foreign Economy

Para.	Description	Prior			Posterior					
					Pure		EFP		ICC	
		Distr.	Mean	SD	Mode	SD	Mode	SD	Mode	SD
Panel A. Economic parameters										
ξ_w^*	Stickiness, wage	B	0.5	0.1	0.54	0.08	0.51	0.08	0.52	0.07
ξ_p^*	Stickiness, price	B	0.5	0.1	0.83	0.02	0.83	0.02	0.83	0.03
ι_w^*	Indexation, wage	B	0.5	0.15	0.52	0.17	0.48	0.17	0.50	0.17
ι_p^*	Indexation, price	B	0.5	0.15	0.81	0.08	0.86	0.07	0.85	0.06
λ_p^*	Markup, price	N	1.2	0.12	1.45	1.26	1.91	0.10	1.90	0.09
$F(\bar{\omega}^*)$	SS probability of default	B	0.008	0.004	–	–	0.0060	0.0018	–	–
μ^*	Monitoring cost	B	0.275	0.15	–	–	0.312	0.174	–	–
F''^*	Investment adjustment cost	N	4	1.5	4.37	1.34	6.25	1.02	5.97	0.98
ζ^*	Capital utilization rate	B	0.5	0.15	0.52	0.11	0.59	0.08	0.59	0.07
b^*	Habit formation	B	0.5	0.1	0.83	0.05	0.80	0.05	0.80	0.04
ρ^*	Taylor rule smoothing	B	0.75	0.1	0.85	0.02	0.85	0.02	0.85	0.02
r_π^*	Taylor rule on inflation	N	1.5	0.25	1.93	0.20	2.15	0.17	2.21	0.16
$r_{\triangle_{gdp}^*}$	Taylor rule on GDP growth	N	0.25	0.1	0.34	0.08	0.26	0.08	0.27	0.07
Panel B. Autocorrelation of the shocks										
$\rho_{g_z}^*$	Persistent technology	B	0.5	0.2	0.49	0.27	0.50	0.28	0.50	0.27
ρ_ϵ^*	Transitory technology	B	0.5	0.2	0.97	0.01	0.97	0.02	0.96	0.03
ρ_w^*	Wage markup	B	0.5	0.2	0.11	0.07	0.10	0.07	0.11	0.07
ρ_p^*	Price markup	B	0.5	0.2	0.87	0.05	0.93	0.03	0.92	0.02
ρ_g^*	Government spending	B	0.5	0.2	0.96	0.01	0.95	0.02	0.94	0.03
ρ_μ^*	Marginal efficiency of investment	B	0.5	0.2	0.70	0.06	0.96	0.01	0.98	0.01
ρ_b^*	Intertemporal preference	B	0.5	0.2	0.51	0.12	0.70	0.13	0.71	0.14
$\rho_{\theta_e}^*$	Entrepreneurial net worth	B	0.5	0.2	–	–	0.98	0.005	–	–
$\rho_{\sigma_e}^*$	Entrepreneurial risk	B	0.5	0.2	–	–	0.81	0.02	–	–
$\rho_{\theta_b}^*$	Banking net worth	B	0.5	0.2	–	–	–	–	0.98	0.006
ρ_ϖ^*	Banking risk	B	0.5	0.2	–	–	–	–	0.78	0.02
Panel C. Standard deviations of the innovations										
$\sigma_{g_z}^*$	Persistent technology	I	0.05	2	0.03	0.010	0.02	0.009	0.02	0.010
σ_ϵ^*	Transitory technology	I	0.1	2	0.33	0.032	0.28	0.036	0.29	0.035
σ_w^*	Wage markup	I	0.1	2	0.53	0.058	0.54	0.060	0.50	0.052
σ_p^*	Price markup	I	0.1	2	0.05	0.010	0.05	0.008	0.04	0.007
σ_ε^*	Monetary policy	I	0.1	2	0.12	0.010	0.11	0.009	0.10	0.009
$\sigma_{\bar{\pi}}^*$	Inflation target	I	0.05	2	0.03	0.011	0.04	0.012	0.03	0.014
σ_g^*	Government spending	I	0.1	2	0.62	0.049	0.46	0.040	0.46	0.036
σ_μ^*	Marginal efficiency of investment	I	0.1	2	0.46	0.074	0.47	0.128	0.49	0.129
σ_b^*	Intertemporal preference	I	0.1	2	0.14	0.019	0.12	0.019	0.12	0.020
$\sigma_{\theta_e}^*$	Entrepreneurial net worth	I	0.1	2	–	–	1.20	0.140	–	–
$\sigma_{\sigma_e}^*$	Entrepreneurial risk	I	0.1	2	–	–	0.03	0.005	–	–
$\sigma_{\theta_b}^*$	Banking net worth	I	0.1	2	–	–	–	–	1.59	0.175
σ_ϖ^*	Banking risk	I	0.1	2	–	–	–	–	6.88	0.622

Note: Estimated parameters are based on two Metropolis−Hastings chains of 500,000 iterations, with a 20 percent burn-in.

of also including other indirect costs.

The estimated value in both friction versions favors the large investment adjustment cost parameter, suggesting high costs of capital utilization, in line with the empirical literature of financial frictions. The somewhat higher estimate for Australia is likely to arise from the fact that agents in the open economy smooth capital production less effectively due to their dependence on imported investment goods. Indeed, a larger adjustment cost parameter is consistent with observed investment fluctuations from the impulse response function, which indicates that Australian investment is reduced by a greater extent in response to an adverse net worth shock (see below). The relatively high estimated mode of capital utilization rate is an additional piece of evidence showing financial frictions at work in the friction versions. The presence of financial frictions increases the importance of the monetary policy reaction to inflation but reduces its response magnitude to GDP growth, compared to the economy without financial frictions. The estimates of the parameter measuring the Taylor rule reaction to inflation and growth rate are also in line with earlier discussion of financial frictions across the two versions, with higher values in the ICC version. Additionally there is evidence of a stronger reaction to both inflation and growth rate in the U.S compared to Australia.

Turning to the exogenous processes, all shocks are quite persistent except for the markup shocks. The presence of financial frictions increases the persistence of shocks to the MEI, intertemporal preference and import consumption markup but reduces the long-horizon importance of the government spending shock. The estimates of the shock processes are generally similar between the two model extensions, but the MEI shock has lower autocorrelation and volatility in the EFP version than in the ICC version. The mode of the standard errors of the comparable conventional shocks, especially for the intertemporal preference shock, is higher for Australia, reflecting larger volatility in the small-open economy. By contrast, financial shocks are significantly more volatile than in the U.S. economy.

3.5.4 Second moments

Now I evaluate the performance of models along the empirical moments. Table 3.7 documents important business cycle features of the models and the second moments observed in the data. It is clear that both friction extensions improve upon the Pure model in terms of replicating the volatility, though all three models tend to overestimate the standard deviation of most real aggregates. In contrast to the ICC version, the EFP version raises the volatilities of some variables substantially. In particular, it generates fluctuations in trade variables and the real exchange rate that exceed those in the data. The model-implied financial volatility is also different between the two friction extensions in which the ICC framework fits the data better.

There are further differences across the models with respect to autocorrelations. The EFP version generally decreases the persistence of macroeconomic variables compared to the Pure model, while the ICC version brings this moment closer to those in the data.

Table 3.7: Business Cycle Properties

Variables	By Data				By Models											
	SD	AC	CO	CR	SD			AC			CO			CR		
Australia																
GDP	0.11	0.96	1	0.98	0.35	0.21	0.12	0.87	0.88	0.97	1			0.85	0.87	0.94
I	0.14	0.94	0.94	0.95	0.23	0.24	0.19	0.90	0.81	0.96	0.89	0.90	0.92	0.83	0.89	0.91
C	0.11	0.96	0.99	0.98	0.21	0.18	0.16	0.91	0.80	0.96	0.92	0.82	0.81	0.93	0.91	0.92
H	0.02	0.88	0.54	0.61	0.14	0.20	0.07	0.78	0.81	0.93	0.15	0.45	0.45	0.21	0.40	0.41
W	0.09	0.95	0.98	0.95	0.17	0.23	0.12	0.91	0.82	0.93	0.93	0.84	0.93	0.86	0.81	0.89
R	0.27	0.90	-0.38	-0.29	0.34	0.33	0.32	0.88	0.78	0.92	-0.21	-0.32	-0.32	-0.10	-0.21	-0.22
π_c	0.19	0.50	0.24	0.27	0.28	0.25	0.25	0.41	0.41	0.56	0.26	0.22	0.20	0.41	0.21	0.25
X	0.17	0.93	0.90	0.88	0.28	0.26	0.14	0.92	0.91	0.94	0.71	0.81	0.84	0.82	0.86	0.87
M	0.16	0.94	0.96	0.97	0.22	0.22	0.14	0.91	0.94	0.93	0.71	0.79	0.85	0.70	0.81	0.96
RER	0.18	0.94	-0.79	-0.70	0.21	0.25	0.16	0.93	0.66	0.96	-0.61	-0.61	-0.84	-0.41	-0.80	-0.76
N_e	0.17	0.89	0.34	0.49	–	0.23	0.42	–	0.73	0.45	–	0.27	0.10	–	0.40	0.21
Spr_e	0.22	0.87	-0.37	-0.52	–	0.32	–	–	0.71	–	–	-0.24	–	–	-0.45	–
L	0.36	0.97	0.97	0.95	–	0.66	0.40	–	0.61	0.94	–	0.75	0.95	–	0.81	0.91
Spr_b	0.17	0.88	-0.11	-0.21	–	–	0.23	–	–	0.86	–	–	-0.09	–	–	-0.18
United States																
GDP^*	0.09	0.96	1		0.21	0.16	0.15	0.93	0.94	0.95	1					
I^*	0.12	0.95	0.61		0.23	0.17	0.15	0.81	0.90	0.95	0.52	0.61	0.59			
C^*	0.11	0.97	0.98		0.23	0.14	0.14	0.94	0.97	0.97	0.92	0.95	0.97			
H^*	0.07	0.98	-0.50		0.18	0.13	0.15	0.92	0.98	0.99	0.53	0.36	0.60			
W^*	0.10	0.97	0.97		0.30	0.28	0.14	0.95	0.95	0.98	0.86	0.88	0.95			
R^*	0.55	0.97	-0.46		0.36	0.46	0.62	0.73	0.87	0.97	-0.21	-0.31	-0.37			
π^*	0.20	0.57	0.12		0.28	0.16	0.18	0.50	0.43	0.46	0.18	0.12	0.12			
N_e^*	0.30	0.94	0.82		–	0.42	0.59	–	0.92	0.79	–	0.77	0.60			
Spr_e^*	0.20	0.89	-0.59		–	0.36	–	–	0.81	–	–	-0.40	–			
L^*	0.17	0.97	0.96		–	0.51	0.23	–	0.64	0.95	–	0.52	0.93			
Spr_b^*	0.46	0.94	-0.32		–	–	0.38	–	–	0.91	–	–	-0.27			

Note: SD – standard deviation, AC – autocorrelation, CO – correlation with country-specific GDP, CR – cross-country correlation with U.S. GDP. Results in each second moment are presented in the following way: the first entry is generated by the Pure model, the second entry by the EFP version, and the third entry by the ICC version.

The most notable is lower autocorrelation of most macroeconomic aggregates in the EFP version than in the data and usually substantially higher persistence of these cases in the ICC version than in the data. Likewise, the financial series are moderately autocorrelated in the EFP version while they are close to the data in the ICC version.

Important differences between the models and the data also concern cyclicalities of the variables. All in all, the financial friction frameworks fit the data better than the Pure model in terms of correlations of the main macroeconomic variables with country-specific GDP. For example, the Pure model implies far too low procyclicality of Australian hours worked while both model extensions improve upon it in this respect. However, both the EFP and ICC versions clearly underestimate the procyclicality of consumption. Interestingly, the two friction extensions are able to replicate the procyclicality of entrepreneurial net worth and credit as well as the countercyclicality of two spread series.

Finally, the cross-country correlations generated by the financial friction frameworks correspond well to what is observed empirically. In particular, both friction versions are better able to capture the cross-correlations of Australian GDP, investment and open economy variables with U.S. GDP. Further, the ICC version does a somewhat better job than the EFP version in terms of replicating cross-country correlations of consumption, inflation, and interest rate, though the results are fairly similar. A similar picture emerges with respect to the financial series, which indicates that the EFP and ICC versions can reproduce the cross-country correlations, and the latter performs better.

In sum, the comparisons in this subsection show that the estimated friction versions can successfully account for many of the documented business cycle features in the two asymmetric-country setting. More importantly, the behavior of variables is best replicated by augmenting the pure trade open economy model with financial frictions in the banking sector, in particular the dynamics of open economy variables and financial series.

3.5.5 Impulse response functions

In this subsection, I inspect the response functions of the model extensions in order to explain why the presence of financial frictions in the banking sector is favored by the data. Since comparing impulse responses of key macroeconomic aggregates to conventional shocks in the two friction specifications is well-documented in the literature (see Villa 2016), I only focus on comparing responses to shocks that are of novel parts in the present paper. In particular, I will highlight different responses between the EFP and the ICC versions to networth and risk shocks. I particularly emphasize both the magnitude and the persistence of the responses of GDP, investment, consumption, leverage, credit and spread. All the shocks are set to produce a downturn.

Net worth shocks

I first discuss the effects of shocks that cause exogenous declines in the net worth of entrepreneurs or banks. Figure 3.5.1 jointly displays the response to two shocks of this

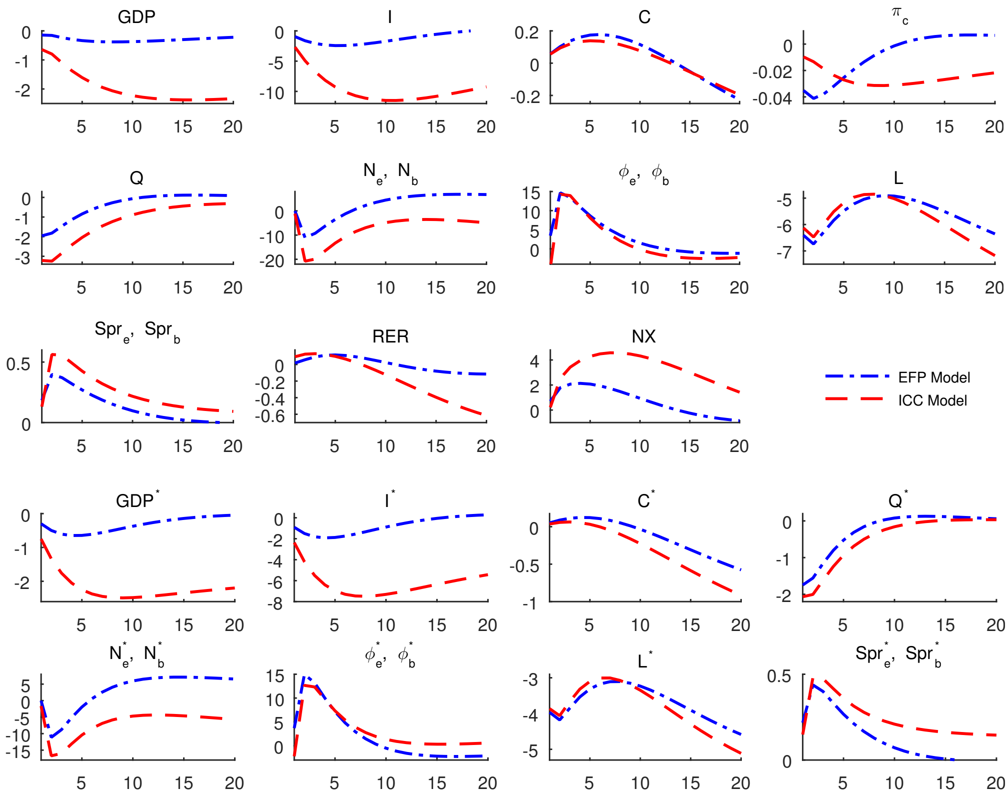

Figure 3.5.1: IRFs to two net worth shocks – Australia (upper panel) and the U.S. (lower panel).

type in the EFP and the ICC versions, respectively.[22] Two net worth shocks act like a classic demand shock: they drive down investment, consumption, GDP and inflation. Also, the shocks cause the real exchange rate to appreciate and net exports to decrease due to domestic demand outpacing supply in the open economy. Note that according to my theoretical framework, an adverse net worth shock is defined as a decrease in the retained profit rate, which corresponds to a higher dividend payout to shareholder consumption. Thus the initial decrease of GDP is offset by an increase in both shareholder consumption (not shown) and household consumption in response to the drop of the policy rate caused by the economic downturn. The resulting contraction of GDP persists mainly due to a decline in investment.

A reduction in the retention ratio of entrepreneurial earnings means that there are fewer financial resources to purchase new capital. Capital demand from entrepreneurs declines, which pushes down the price of capital. The drop in the price of capital subtracts from entrepreneurial net worth, leading to a higher external finance premium. Simultaneously, the decline in capital demand translates into weaker investment expenditure, which results in a decline in GDP and consumption. Furthermore, the decline in GDP leads to a fall in inflation due to reduced costs. Banking credit falls less than entrepreneurial net worth because there is a partial offsetting effect on credit. In particular, entrepreneurs need to borrow more to fund capital purchases as their net worth drops. The resulting higher

[22] This type of shock has been used in closed economy models with BGG-type financial frictions by many authors (e.g. Nolan and Thoenissen 2009; Christiano, Motto, and Rostagno 2010).

demand for external finance raises banking loans. In equilibrium, the net impact of all these effects on banking credit is negative but the decline is muted.

The story behind the response of the ICC version to a banking net worth shock differs in several vital aspects. First, following an adverse shock, the expected net worth of banks is discounted at a higher rate and thus the value of an additional unit of loan decreases, which in turn enhances the initial decline in banking net worth. In addition, banks increase lending rates as shareholders require higher profitability from an increased leverage multiple. The implied increase in the spread causes a decrease in demand for entrepreneurial loans, translating into a drop in the price of capital and consequently a decline in investment and then GDP. The second striking difference between the two model extensions concerns the magnitude of responses. Compared to the EFP version, the GDP decline is much greater than in the ICC version. Additionally, the responses of GDP and investment are more pronounced and persistent in the latter than in the former, although the instant responses of the two models are similar. The ICC version also shows that banks' balance sheets (and so lending conditions) only improve gradually as the increasing credit contributes to the recovery of banking net worth. The speed of reversion to the steady state is much slower in this version, in contrast to the relatively quick recovery of entrepreneurial balance sheets in the EFP version.

Risk shocks

In Figure 3.5.2, I compare the impact of a risk shock between the two model versions. Recall that an adeverse risk shock in the EFP framework implies a rise in the probability of default, while a risk shock in the ICC framework coresponds to an increase in the divertibility of assets. Therefore, entrepreneurial risk shocks directly impact on the cost of loans while banking risk shocks indirectly affect the cost of loans through their availablity. Although the definitions of these two shocks are not fully equivalent, there are some similarities between them. First, the two risk shocks decrease the asset side of the balance sheet of both entrepreneurs and bankers. Second, by raising spreads both shocks resemble a cost-push shock, driving GDP and inflation in opposite directions. As can be seen from the response of spread, the degree of comparability between these two shocks is very high.

Again, the main difference between the two versions lies in the propagation mechanisms. In the EFP framework, there are two effects associated with a temporary rise in entrepreneurial risk. First, a jump in idiosyncratic risk raises the probability of entrepreneurial default. Banks react by raising the lending rate charged on entrepreneurial loans to cover monitoring costs. Entrepreneurs borrow less and consequently lending declines. Capital demand from entrepreneurs decreases because it is more costly to obtain funds to purchase new capital, which pushes down the price of capital. In addition, the falling price of capital lowers entrepreneurial net worth, and this magnifies the impact of the jump in idiosyncratic risk through standard accelerator effects. Second, the decline in funds associated with the initial drop of the entrepreneurial leverage multiple leads to a reduction in capital purchases. This contracts the production of capital by households,

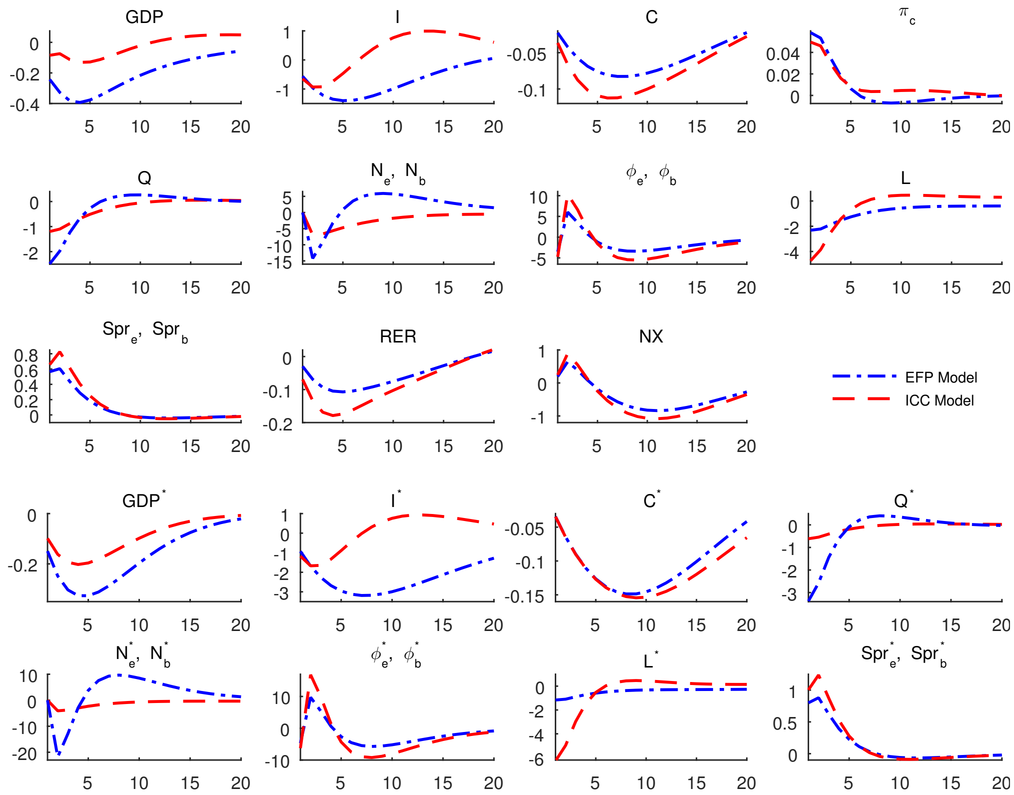

Figure 3.5.2: IRFs to two risk shocks – Australia (upper panel) and the U.S. (lower panel).

which results in further fall in its price. The resulting lower demand for capital leads to weaker demand for investment and thus a decline in GDP and consumption.

The story in the ICC framework is different. A rise in asset diversion raises the banking leverage multiple. Concerning moral hazard, shareholders require bankers not to be overleveraged and thus banks are forced to cut back lending. The decline in the lending volume causes the spread to increase. As a result, capital purchases, investment and GDP decline. The second difference between the two versions concerns to what extent the responses will be magnified over time. The rise of the banking spread from its steady state is much larger in the ICC version, compared with the entrepreneurial spread in the EFP version. Entrepreneurs observe a larger rise in borrowing costs, so they reduce more their demand for capital. As a result the decline in investment is much more pronounced in the ICC version.

In general, the impulse response analysis shows important differences in the propagation mechanism and the response magnitude between the two friction versions. The banking sector provides a powerful endogenous mechanism of amplification for financial shocks hitting the economy. Following an adverse shock, the rise of the spread is stronger in the ICC model, which leads to a more pronounced decline in investment and GDP. The response of the economy to the risk shock is small and less persistent compared to the net worth shock, which is also likely to explain the weaker response of the EFP model itself.

3.5.6 International comovement

To show the relative role played by all purely foreign stationary shocks across models, I decompose the cross-border causes of the Australian unconditional variances in Table 3.8. For each of the models, I present the sum of contributions by foreign shocks under three categories: financial shocks, non-financial shocks, and all shocks.

The Pure model's relatively poor ability to account for macroeconomic comovement is confirmed. Virtually all volatility of the home macroeconomic aggregates can be negligibly attributable to purely foreign disturbances. In particular, the U.S. stationary conventional shocks have very limited effects ($\leq 5\%$) on the business cycle variance of the Australian real macroeconomic series, except the observed open economy variables. As usual in the open-economy DSGE literature, my standard trade model struggles to generate significant cross-border spillover effects. This is no longer the case once I incorporate financial frictions following either of two approaches into the pure trade open economy framework.

It is worth noting that the overall picture is very similar for the EFP and ICC extensions. The first similarity is that purely foreign disturbances are important. Toward the third column of each friction version, I survey the overall role of shocks sourced from the U.S. For the EFP version, the U.S. shocks combined can explain more than 9% and 7% of the variability in Australian GDP and investment respectively. Meanwhile, the share of the variance in these macroeconomic aggregates attributable to all U.S. shocks climbs to 18% and 13% in the ICC specification. Second, the highest share of variation in standard macroeconomic variables is driven by U.S. financial shocks. In the EFP version these shocks, taken together, explain 4% of investment while the contribution of conventional shocks is 3%. The explanatory power of two groups of shocks is quite diverse in the ICC version: 8% attributed to financial disturbances but only 5% due to conventional shocks. Foreign financial disturbances are even more important for the volatility of home financial variables. Shocks originating in the U.S. entrepreneurial sector account for a large proportion of the volatility of Australian entrepreneurial net worth (31%). Likewise, a substantial variance share of the Australian credit (20%) is explained by shocks arising in the U.S. banking sector. These results suggest that cross-border financial linkages are significantly responsible for the presence of comovement.

One important difference is the relatively low importance of foreign financial disturbances for the volatility of home investment in the EFP version. In the ICC version, instead, the financial shocks are the strong foreign driver of home investment fluctuations. Note that bank loans are the main source of external finance for the Australian corporate sector and therefore unsurprisingly foreign financial shocks transmitted through cross-border lending channels have a relative strong impact on real activity in the ICC framework. This finding is clearly consistent with my impulse response analysis in Subsection 3.5.5 that shows the stronger response of Australian investment and GDP in the ICC version than in the EFP version. Another notable difference across the two model extensions concerns the role of U.S. financial shocks to the variability of the Australian spread: they only account for 11% of variance of the entrepreneurial spread, whereas shocks of this

Table 3.8: Variance Shares of Australian Series due to U.S. Shocks (*Percent*)

Model	Pure	EFP			ICC		
Series \ Shocks	Total	Financial	Other	Total	Financial	Other	Total
GDP	5	5	4	9	10	8	18
Investment	3	4	3	7	8	5	13
Consumption	2	2	3	5	7	3	10
Hours	2	1	1	2	2	5	7
Wage	1	2	4	6	3	5	8
Interest rate	5	7	7	14	7	8	15
Inflation	11	4	7	11	7	11	18
Export	14	3	23	26	11	16	27
Import	20	4	20	24	22	11	33
Real exchange rate	15	8	19	27	12	14	26
Entrepreneurial net worth	–	25	6	31	–	–	–
Entrepreneurial spread	–	11	6	17	–	–	–
Credit	–	–	–	–	14	6	20
Banking spread	–	–	–	–	15	2	17

Note: Unconditional variance decompositions are generated by each model evaluated at the posterior mode. "Financial" is the sum of the foreign entrepreneurial risk and net worth shocks in the EFP version, while it is the sum of foreign banking risk and net worth shocks in the ICC version. "Others" represents the sum of foreign non-financial shocks, the country risk premium shock, and the degree of technology asymmetry.

kind are responsible for up to 15% of variation in the banking spread, as is evident from Table 3.8. By construction, the banking spread and foreign borrowing in the ICC version are strongly driven by foreign financial shocks, but these variables are hardly affected by foreign financial shocks in the EFP specification.

Summing up, this subsection documents the central results of the comparison exercise: my model extensions with financial frictions are better able to account for international comovement than the Pure model. Further, the pure trade open economy framework augmented with financial frictions in the banking sector is best able to account for the influence of purely foreign disturbances. Financial frictions on cross-border lending also help to generate significant spillovers across the home economy. These findings are consistent with the reduced-form empirical evidence in the same data displayed in Table 3.7 of Subsection 3.5.4.

3.5.7 Shock groups in business cycles

Now I use the results of the variance decomposition to quantify the relative importance of different shock categories across the friction versions. Table 3.9 reports the percentage of business cycle variance due to various groups of shocks in the friction versions.

The overall picture is very similar for Australia and the U.S. The group of within-country financial shocks explains a substantial portion of business cycle fluctuations in each of the countries, although conventional shocks account for the highest proportion of variability in standard macroeconomic variables. As regards financial variables, the financial shock group is even more important, accounting for at least one-third of fluctuations. Notably, the contribution of financial shocks is relatively high for both financial and standard macroeconomic variables in the U.S compared to Australia. This is not

Table 3.9: Variance Decomposition by Country (*Percent*)

<table>
<tr><th>Country</th><th colspan="4">Australia</th><th colspan="3">United States</th></tr>
<tr><th>Series \ Shock Category</th><th>Supply</th><th>Demand</th><th>External</th><th>Financial</th><th>Supply</th><th>Demand</th><th>Financial</th></tr>
<tr><td>GDP</td><td>27 | 23</td><td>29 | 29</td><td>32 | 32</td><td>12 | 16</td><td>40 | 36</td><td>43 | 42</td><td>17 | 22</td></tr>
<tr><td>Investment</td><td>10 | 12</td><td>45 | 30</td><td>18 | 26</td><td>27 | 32</td><td>20 | 18</td><td>50 | 43</td><td>30 | 39</td></tr>
<tr><td>Consumption</td><td>11 | 10</td><td>48 | 44</td><td>14 | 16</td><td>27 | 30</td><td>8 | 10</td><td>70 | 65</td><td>22 | 25</td></tr>
<tr><td>Hours</td><td>60 | 59</td><td>14 | 12</td><td>16 | 18</td><td>10 | 11</td><td>70 | 68</td><td>16 | 16</td><td>14 | 16</td></tr>
<tr><td>Wage</td><td>48 | 45</td><td>17 | 14</td><td>19 | 21</td><td>16 | 20</td><td>60 | 64</td><td>20 | 17</td><td>20 | 19</td></tr>
<tr><td>Interest rate</td><td>8 | 7</td><td>45 | 33</td><td>30 | 38</td><td>17 | 22</td><td>20 | 18</td><td>55 | 52</td><td>25 | 30</td></tr>
<tr><td>Inflation</td><td>40 | 36</td><td>25 | 20</td><td>17 | 19</td><td>18 | 25</td><td>39 | 42</td><td>46 | 37</td><td>15 | 21</td></tr>
<tr><td>Export</td><td>18 | 11</td><td>9 | 2</td><td>60 | 67</td><td>13 | 20</td><td></td><td></td><td></td></tr>
<tr><td>Import</td><td>8 | 6</td><td>31 | 21</td><td>52 | 59</td><td>9 | 14</td><td></td><td></td><td></td></tr>
<tr><td>Real exchange rate</td><td>3 | 2</td><td>8 | 11</td><td>79 | 72</td><td>10 | 15</td><td></td><td></td><td></td></tr>
<tr><td>Entrepreneurial net worth</td><td>22 | [–]</td><td>11 | [–]</td><td>27 | [–]</td><td>30 | [–]</td><td>24 | [–]</td><td>28 | [–]</td><td>48 | [–]</td></tr>
<tr><td>Entrepreneurial spread</td><td>21 | [–]</td><td>12 | [–]</td><td>28 | [–]</td><td>39 | [–]</td><td>25 | [–]</td><td>25 | [–]</td><td>50 | [–]</td></tr>
<tr><td>Credit</td><td>[–] | 12</td><td>[–] | 17</td><td>[–] | 31</td><td>[–] | 40</td><td>[–] | 23</td><td>[–] | 17</td><td>[–] | 60</td></tr>
<tr><td>Banking spread</td><td>[–] | 14</td><td>[–] | 15</td><td>[–] | 29</td><td>[–] | 42</td><td>[–] | 25</td><td>[–] | 20</td><td>[–] | 55</td></tr>
</table>

Note: Unconditional variance decompositions are generated by each model evaluated at the posterior mode. The “supply” category contains technology shocks and shocks to the markups. The “demand” category includes shocks to intertemporal preference, marginal efficiency of investment, government spending, monetary policy and inflation target. The “external” category includes country risk premium, commodity demand and relative commodity price shocks, degree of technology asymmetry, foreign financial and non-financial shocks. The “financial” category includes domestic risk and net worth shocks. The first entry refers to the EFP version whereas the second corresponds to the ICC version.

surprising given that, in the Australian open economy, the role of external shocks goes at the cost of domestic financial shocks, among which the contribution of U.S. financial disturbances is non-negligible as analyzed in Subsection 3.5.6.

One notable difference is the relative importance of within-country financial shocks across the model extensions. In particular, the role played by these shocks is greater in the ICC version than in the EFP version, confirming the result obtained from the impulse response analysis that the financial accelerator effects are more pronounced in the former. The impulse response and variance decomposition analyses, taken together, show that financial shocks in the estimated ICC extension better generate dynamics that resemble the business cycle. This is the principal reason that the ICC version generally outperforms the EFP version in the relevant dimensions as compared throughout Section 3.5.

3.6 Concluding remarks

In this paper, I have evaluated the resulting properties of incorporating two competing financial friction approaches into the pure trade open economy framework of two asymmetric countries. To make the model versions comparable, I set them up to be identical in all aspects except agency problems. Next, I compared the performance across the model versions with the following tools: marginal likelihoods, steady-state properties, estimated parameters, implied moments, impulse response and variance decomposition.

The main result is that the incorporation of financial frictions into either approach improves the fit of the standard pure trade open economy model. In addition, financial friction modelings improve upon the pure trade framework in bringing the moments of standard macroeconomic variables closer to the data. While the two friction versions have similar performance in characterizing the dynamics of macroeconomic variables, the behaviour of financial series is better explained by the ICC version. The friction versions also overcome the shortcomings of the pure trade open economy model in reproducing the cross-border synchronization of business cycles, even better so with the ICC version. All in all, the empirical evidence favors the model extension with financial frictions in the banking sector.

Of course, the model extensions compared remain stylized and should be further developed. An interesting extension would be to expand cross-border financial linkages where home entrepreneurs and banks obtain funds from abroad which were subject to the similar types of home financial frictions. This would help compare the relative importance of home vis-à-vis foreign financial frictions in propagating external shocks and might better explain the cross-border importance of U.S. disturbances. Additional work on the transmission mechanisms of foreign financial shocks could also improve the performance of the friction model versions with respect to business cycle synchronization. I hope to have shown, however, that my comparison using Bayesian techniques in this paper offers effective model extensions with financial frictions for the framework of international business cycles.

Chapter 4

Financial Frictions and Leverage Constraints in an Estimated Asymmetric Country Model

4.1 Introduction

Cross-country DSGE models with comprehensively structured financial sectors would improve our understanding of domestic and international business cycle fluctuations. In this paper, I incorporate the microeconomics of a financial friction framework into an otherwise business cycle model of two asymmetric countries and estimate my model by standard Bayesian methods, using data spanning the 1993−2012 period for Australia and the United States.

To that end, I develop a quantitative DSGE model for a pair of small-open and large-closed economies. The domestic block is a medium-scale version of the New Keynesian paradigm, in the spirit of Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007). The open-economy segment of the model is built on Adolfson et al. (2007) and differs from the literarure in two main aspects. First, I allow for inflation rate differential between the two countries in order to yield nominal exchange rate depreciation in steady state. Second, the small-open economy exports an exogenous endowment of a commodity good, which is contingent on global economy conditions. Next, the small-open economy is linked with the large-closed counterpart through different channels of trade and finance.

I simultaneously introduce two agency problems in the credit market into the two asymmetric-country model − I call it the baseline model. The first is a costly verification problem for entrepreneurs' project outcomes along the lines of Bernanke, Gertler, and Gilchrist (1999) and the second problem involves moral hazard due to bankers' ability to divert part of funds in the spirit of Gertler and Karadi (2011). In my model the optimal loan contract is between the entrepreneur and the bank while the optimal loan portfolio is between the bank and its shareholders. Also, banks extend risky loans to entrepreneurs for capital purchases and riskless loans to other borrowers for working capital. The agency problems work to add some spread to the overall cost of credit that diverse borrowers face. The size of various spreads, further, depends on the condition of entrepreneurial and banking balance sheets. Because both entrepreneurs and banks are leverage-constrained, the financial accelerator effect is enhanced due to endogenous developments in the entrepreneurial net worth as well as in the banking net worth. Consequently, the entrepreneurerial and banking net worth jointly constitute the borrowing and lending constraints in the credit market, and therefore determine the aggregate economic activity.

The objectives of the paper are threefold. First, the incorporation of two types of financial frictions raises the question of which friction type is empirically important. The role of friction types is demonstrated by comparing models, in which none, one or both friction types are turned off. I find that the baseline model outperforms models with either type of financial friction. These results are confirmed by a relative measure in terms of the marginal likelihood, as well as by second moments, which shows that the baseline model explains the main features of Australian and U.S. macroeconomic and financial data well. My finding also shows that rich interactions between the real and financial sectors, as in the baseline model, is a useful way to match the volatility of both non-financial and financial observables. This finding is consistent with those obtained by Christiano, Motto, and Rostagno (2014) and FuentesAlbero (2012), who rely on closed economy models with the Bernanke, Gertler, and Gilchrist (1999) approach.

Second, as financial frictions are incorporated into a standard business cycle model of two asymmetric countries, it is important to verify whether they help in improving the models' ability to account for macroeconomic synchronization. I find that the financial friction models better deliver both cross-country correlations and shares of home variance due to foreign shocks. In particular, two pieces of evidence support this result. First, cross-country correlations in some series implied by the models are remarkably far away from zero. Second, cross-border variance decompisition reveals that shocks sourced in the U.S. explain a substantial share of variation in the Australian economy. Further, financial variables are better explained by the baseline model, though all three financial friction models have similar performance in explaining macroeconomic variables. This finding is consistent with the reduced-form empirical evidence in terms of the model-implied cross-country correlations.

Finally, I use the estimated baseline model to address a number of key issues in business cycle analysis. First, how do different types of financial frictions affect the propagation of financial shocks? I compare the responses in various models that include (or exclude) frictions on the demand and/ or supply of credit. I find that combining two types of financial frictions not only amplifies the within- and cross-border responses to financial shocks but also increase their persistence. Second, U.S. financial shocks are transmitted to the Australian economy mainly via international trade channels; but the financial channels, cross-border lending in particular, are also important. Finally, my analysis shows that within-country financial shocks explains a significant portion of business cycle fluctuations across countries and U.S. financial shocks play a very non-negligible role in cross-border spillovers.

The present paper is at the crossroads of three research strands of the macroeconomic literature. First, my work is a continuation of the emerging research program developing DSGE models with leverage constraints in both the banking and non-financial firm sectors. On the both mechanisms I am related to Rannenberg (2016), who works with a closed economy model. Because Rannenberg aims to obtain analytical results, his calibrated model is a fairly simplified version of the New Keynesian DSGE model. My work, by contrast, emphasizes quantitative results using a more complex model that accounts for more details of the roles of both non-financial and financial factors. In particular, I allow for the incentive compatibility constraint on a diverse portfolio of loans and a rich set of financial shocks.[1] Furthermore, my modeling is in the comprehensive setting of two countries in which there are financial frictions also associated with cross-border lending.

The second strand attempts to incorporate financial frictions in an open economy framework. Fernandez and Gulan (2012) embed the financial accelerator of Bernanke, Gertler, and Gilchrist (1999) into a very stylized business cycle model of the small-open economy in order to assess the role of financial frictions between home and foreign agents in propagating external shocks to emerging economies. Kollmann, Enders, and Müller (2011) abstract various real and nominal frictions from a quantitative two-country business cycle model, but focus on the international transmission channel in the presence of financial frictions in a global bank that faces a capital requirement. In a related contribution, Dedola, Karadi, and Lombardo (2013) augment a two-country model with financial frictions *à la* Gertler and Karadi (2011) to study the international dimension of unconventional policies; in contrast to my paper, these authors do not investigate the sources of business cycle disturbances. These authors also simplify the model by assuming two entirely symmetric countries and thus ignoring important features of the open economy including risk sharing conditions and international relative prices.

The third relates to the international business cycle models' ability to account for macroeconomic synchronization. It is well-documented in the international macroeconomic literature that DSGE models in the framework of two countries or a single small-open economy struggle in replicating the observed international comovement in output and aggregate demand cycles (see e.g. Justiniano and Preston 2010; Adolfson et al. 2007). This is because the models of this class fail to deliver sufficient propagations of foreign shocks to the partner economy. Here I focus not on the interactions between two equally sized economies as in Kollmann, Enders, and Müller (2011), but focus instead on

[1] Capital working loans and (export loans, of course) were either not considered in the original paper by Gertler and Karadi (2011) or not subject to the moral hazard problem in later papers (e.g. Rannenberg 2016).

the spillovers arising from a large economy, on the one hand, to a small-open partner, on the other. A close study to my paper is Kamber and Thoenissen (2013), who calibrate a much stylized international real business cycle model of two asymmetric countries to show that the magnitude of spillovers from foreign financial shocks is proportional to the financial exposure of the home economy's banking sector to the foreign large partner via lending to foreign firms. My approach, nevertheless, differs from theirs in a number of important dimensions. First, I explicitly model the origin of financial frictions from the agency problems while they simply assume the financial frictions as a result of costly deviations from a prescribed ratio of bank capital to loans *à la* Gerali et al. (2010). Second, in my model domestic banking sectors are fully independent and banks resident in the small-open economy are unexposed to the foreign economy. Third, I consider a diverse set of borrowers and financial frictions also on cross-border lending. Fourth, the paper here *estimates* comprehensive models containing a rich set of shocks and frictions in order to provide an empirical assessment of the role of entrepreneurial and banking sectors as sources of shocks and as transmission channels, as well as cross-border propagations of financial shocks.

The plan of this paper is as follows. In Section 4.2, I develop the baseline asymmetric-country model with financial frictions and then outline satellite models. Section 4.3 describes the data and the empirical strategy. The relative performance of the models is assessed in Section 4.4. In Section 4.5, I use the estimated baseline model to investigate the importance of financial factors for business cycles. Finally, Section 4.6 contains the concluding remarks. Technical details are provided in the Appendices.

4.2 The baseline model

The model consists of two economies of asymmetric size. In what follows, I present the model from the small-open economy's perspective, which I refer to as the home country. Foreign variables and parameters are indicated with an asterisk where needed.

The small-open economy is populated by six classes of agents: firms, employment agencies, households, entrepreneurs, banks, and a government. The goods production sector is made up of three layers of firms. First, intermediate firms produce differentiated types of goods. Second, aggregators convert differentiated intermediate goods into a homogeneous good for domestic and export purposes. The third layer of firms – called final assemblers – combine the homogeneous domestic good with bundles of import goods in order to produce final consumption and investment goods sold to households. In the international trade sector, exporters buy the homogeneous domestic goods and differentiate them to sell to foreign retailers, while importers buy a homogeneous foreign good and brand it into differentiated consumption and investment goods. Households consume, build raw capital, and save in home and foreign assets. Within each household, there are various types of members. Workers supply differentiated labor services at a wage rate set by an employment agency, while shareholders receive dividends from risky projects run by entrepreneurs and lending activities managed by bankers.

4.2.1 Goods production

Domestic goods producers

A representative competitive firm produces a homogeneous good Y_t from a continuum of intermediate goods $Y_{j,t}, j \in [0,1]$, using the Dixit-Stiglitz aggregator:

$$Y_t = \left[\int_0^1 Y_{j,t}^{\frac{1}{\lambda_{d,t}}} dj\right]^{\lambda_{d,t}}, \qquad 1 \leq \lambda_{d,t} < \infty, \tag{4.1}$$

where $\lambda_{d,t}$ is a price markup shock. I elaborate the time series representations of $\lambda_{d,t}$ and other stochastic processes in the model later on.

A monopolist produces the j^{th} intermediate good according to the production function

$$Y_{j,t} = \max\left\{\epsilon_t K_{j,t}^{\alpha}(z_t h_{j,t})^{1-\alpha} - \Phi z_t; 0\right\}, \qquad 0 < \alpha < 1, \tag{4.2}$$

where $K_{j,t}$ and $h_{j,t}$ denote the services of effective capital and homogeneous labor, respectively. Also, ϵ_t is a covariance stationary technology shock and z_t is a shock whose stationary growth rate is $g_{z,t} = \Delta \log z_t$. The technology variable z_t drives $\frac{Y_t}{z_t}$ to converge to a constant along a nonstochastic, steady-state growth path. The non-negative scalar Φ parameterizes fixed production costs, and is indexed to the technology variable to ensure zero steady-state profit.

I assume that producers have to finance part of their expenditures for capital and labor services in advance by bank loans at a non-contingent nominal interest rate, $R_{f,t}$. The working capital loan of producer j is given by

$$L_{jf,t} = v_K Z_{k,t} K_{j,t} + v_H W_t h_{j,t}, \qquad 0 < v_K, v_H \leq 1, \tag{4.3}$$

where $Z_{k,t}$ is the rental rate on effective capital services and W_t is the nominal wage rate. As a result, the equilibrium marginal cost is

$$MC_t = \left(\frac{1}{\alpha}\right)^{\alpha}\left(\frac{1}{1-\alpha}\right)^{1-\alpha} \frac{\left[Z_{k,t}\left(1 + v_K\left(R_{f,t} - 1\right)\right)\right]^{\alpha}\left[W_t\left(1 + v_H\left(R_{f,t} - 1\right)\right)\right]^{1-\alpha}}{\epsilon_t z_t^{1-\alpha}}. \tag{4.4}$$

The monopoly producer of intermediate good $Y_{j,t}$ sets its price, $\tilde{P}_{j,t}$, subject to a Calvo mechanism. In each time period t a fraction of intermediate goods producers, $1 - \xi_d$, chooses its price optimally while the remaining fraction resets its current price according to the indexation rule

$$P_{j,t} = (\bar{\pi}_t)^{\iota_d}(\pi_{t-1})^{1-\iota_d} P_{j,t-1}, \qquad 0 < \iota_d < 1, \tag{4.5}$$

where $\pi_{t-1} = P_{t-1}/P_{t-2}$ is the inflation in the domestic sector and $\bar{\pi}_t$ is the inflation target in the monetary authority's policy rule.

Final goods assemblers

A representative competitive assembler aggregates differentiated import goods, $M_{jm,t}, j \in [0,1]$, into two homogeneous good bundles for use in consumption or investment, $M_{m,t} = \{C_{m,t}, I_{m,t}\}$, using the Dixit-Stiglitz technology:

$$M_{m,t} = \left[\int_0^1 M_{jm,t}^{\frac{1}{\lambda_{m,t}}} dj\right]^{\lambda_{m,t}}, \qquad 1 \leq \lambda_{m,t} < \infty. \tag{4.6}$$

Next, two bundles of import goods are used in combination with the homogeneous domestic good to produce final consumption and investment goods according to respective technologies

$$C_t + C_{e,t} + C_{b,t} = \left[(1-\omega_c)^{\frac{1}{\eta_c}} C_{d,t}^{\frac{\eta_c-1}{\eta_c}} + \omega_c^{\frac{1}{\eta_c}} C_{m,t}^{\frac{\eta_c-1}{\eta_c}}\right]^{\frac{\eta_c}{\eta_c-1}}, \qquad 0 < \omega_c < 1, \eta_c > 1,$$

and

$$I_t + a(u_t)\bar{K}_t = \left[(1-\omega_i)^{\frac{1}{\eta_i}} I_{d,t}^{\frac{\eta_i-1}{\eta_i}} + \omega_i^{\frac{1}{\eta_i}} I_{m,t}^{\frac{\eta_i-1}{\eta_i}}\right]^{\frac{\eta_i}{\eta_i-1}}, \qquad 0 < \omega_i < 1, \eta_i > 1,$$

where $C_t, C_{e,t}$ and $C_{b,t}$ are consumption components of households, which are discussed below.

The assembler takes relevant input prices, $P_t, P_{cm,t}$ and $P_{im,t}$, as given. Profit maximization leads to optimal demand compositions of each good type as follows:

$$C_{d,t} = (1-\omega_c)\left(\frac{P_t}{P_{c,t}}\right)^{-\eta_c}(C_t + C_{e,t} + C_{b,t}), \qquad C_{m,t} = \omega_c\left(\frac{P_{cm,t}}{P_{c,t}}\right)^{-\eta_c}(C_t + C_{e,t} + C_{b,t}) \tag{4.7}$$

and

$$I_{d,t} = (1-\omega_i)\left(\frac{P_t}{P_{i,t}}\right)^{-\eta_i}\left(I_t + a(u_t)\bar{K}_{t-1}\right), \qquad I_{m,t} = \omega_i\left(\frac{P_{im,t}}{P_{i,t}}\right)^{-\eta_i}\left(I_t + a(u_t)\bar{K}_{t-1}\right). \tag{4.8}$$

Final consumption and investment goods are then sold to households at the following competitive prices:

$$P_{c,t} = \left[(1-\omega_c)P_t^{1-\eta_c} + \omega_c P_{cm,t}^{1-\eta_c}\right]^{\frac{1}{1-\eta_c}} \varepsilon_{p_c,t} \tag{4.9}$$

and

$$P_{i,t} = \left[(1-\omega_i)P_t^{1-\eta_i} + \omega_i P_{im,t}^{1-\eta_i}\right]^{\frac{1}{1-\eta_i}}, \tag{4.10}$$

where $\varepsilon_{p_c,t}$ is a consumption price shock.[2]

[2]In particular, the consumption price shock process is a random walk: $\varepsilon_{p_c,t} = \varepsilon_{p_c,t-1} + \mu_{p_c,t}$. This shock is designed to cope with the time-invariant weights of the CPI components, and to bring more volatility to the endogenous consumer price inflation variable since its observable counterpart is affected by some elements that are absent from the model (e.g. unprocessed food items). Note that a shock of this kind is not included in the price index for investment goods since I do not use investment price inflation as an observable variable in the later estimation.

4.2.2 International trade

Exporters

The home country has two export sectors, including commodity and non-commodity. I model the total export demand as:

$$(4.11) \qquad X_t = X_{non,t} + X_{com,t} \equiv \left(\frac{P_{x,t}}{P_t^*}\right)^{-\eta_*} \imath_* Y_t^* + \varepsilon_{com,t} \varsigma_* Y_t^*, \qquad \eta_* > 1,$$

where the commodity export, $X_{com,t}$, is an exogenous demand shock contingent on global economy conditions proxied by foreign output Y_t^*. The presence of the scale factors, $\imath_*$ and ς_*, which correspond to export shares in aggregate demand abroad, helps obtain the well-defined steady-state level of the export demand.[3]

Non-commodity export goods are packed by a representative competitive foreign retailer using the Dixit-Stiglitz technology:

$$(4.12) \qquad X_{non,t} = \left[\int_0^1 X_{j,t}^{\frac{1}{\lambda_{x,t}}} dj\right]^{\lambda_{x,t}}, \qquad 1 \leq \lambda_{x,t} < \infty.$$

At the beginning of period t, exporters obtain an export credit, $L_{x,t}$, from home banks to finance part of their homogeneous goods bill:

$$(4.13) \qquad L_{x,t} = \upsilon_X P_t X_t, \qquad 0 < \upsilon_X \leq 1,$$

at a non-contingent nominal interest rate, $R_{x,t}$, which is discussed below. Since exporting firms can export costlessly, the marginal cost is the same across non-commodity exporters:

$$(4.14) \qquad MC_{x,t} = P_t[1 + \upsilon_X(R_{x,t} - 1)].$$

Non-commodity exporters are subject to a Calvo mechanism when they set their price in foreign currency for differentiated export goods sold to foreign retailers. The remaining fraction ξ_x of non-commodity exporters does not choose prices optimally but resets its current price according to the indexation rule

$$(4.15) \qquad P_{jx,t} = (\bar{\pi}_t^*)^{\iota_x} (\pi_{x,t-1})^{1-\iota_x} P_{xj,t-1}, \qquad 0 < \iota_x < 1,$$

where $\pi_{x,t-1} = P_{x,t-1}/P_{x,t-2}$ is the inflation in the non-commodity export sector and $\bar{\pi}_t^*$ is the foreign inflation target.

Importers

Importers purchase a homogeneous good in the foreign market and brand it at no cost into differentiated goods. As with exporters, importers face similar decision problems and thus the import credit and the marginal import cost is as follows:

$$(4.16) \quad L_{m,t} = \upsilon_M P_t^* M_t \qquad \text{and} \qquad MC_{m,t} = S_t P_t^*[1+\upsilon_M(R_{m,t}^* - 1)], \qquad 0 < \upsilon_M \leq 1,$$

[3] I do not disentangle the non-commodity export into consumption and investment purposes because this export demand is better captured by the foreign income, Y_t^*, than by its foreign demand components, C_t^* and I_t^*.

where S_t denotes the nominal exchange rate[4] and $R^*_{m,t}$ is the non-contingent nominal interest rate of a credit, $L_{m,t}$, extended by foreign banks, as discussed below.

Importers are also subject to a Calvo mechanism when setting their price for differentiated import goods resold to final assemblers. The remaining fraction of importers, ξ_m, then resets its current price according to the indexation rule

$$P_{jm,t} = (\bar{\pi}_t)^{\iota_m}(\pi_{m,t-1})^{1-\iota_m} P_{jm,t-1}, \qquad 0 < \iota_m < 1 \qquad \text{with } m = \{cm, im\}, \tag{4.17}$$

where $\pi_{m,t-1} = P_{m,t-1}/P_{m,t-2}$ is the inflation in the consumption and investment import sectors.

4.2.3 Labor market

The labor market is modeled along the line of Erceg, Henderson, and Levin (2000) and adopts the Dixit-Stiglitz structure in a way similar to the goods market. All workers of the representative household supply a type of specialized labor j in the economy. A representative competitive contractor then pools specialized labor, $h_{j,t}, j \in [0,1]$, into homogeneous labor with the following technology:

$$h_t = \left[\int_0^1 h_{j,t}^{\frac{1}{\lambda_{w,t}}}\, dj\right]^{\lambda_{w,t}}, \qquad 1 \leq \lambda_{w,t}, \tag{4.18}$$

and sells labor services, h_t, to intermediate goods producers. Also, a monopoly union represents all workers of the household in order to set the nominal wage rate, $W_{j,t}$, for their labor type, subject to a Calvo mechanism. The remaining fraction ξ_w of unions does not choose wages optimally but resets its current wage according to the indexation rule

$$W_{j,t} = (\bar{\pi}_t)^{\iota_w}(\pi_{c,t-1})^{1-\iota_w} g_{z,t} W_{j,t-1}, \qquad 0 < \iota_w < 1. \tag{4.19}$$

The indexing scheme in wage-setting implies that the final output is independent of the wage inflation in steady state.

4.2.4 Households

There is a competitive sector of identical households in the economy. Within the representative household with a large number of members, there are fractions of f_w workers, f_b bankers, f_e entrepreneurs, and the complementary fraction $(1 - f_w - f_b - f_e)$ of shareholders.[5] Entrepreneurs run projects of capital utilization and bankers channel funds, but I defer my discussion of these agents to the following subsections.[6]

[4] Note that S_t is defined as the home price of foreign currency, so that a rise in the nominal exchange rate represents a depreciation of the home currency.

[5] I modify the large family assumption in this financial setting, which helps streamline the model presentation while the set of optimality conditions that characterize the equilibrium are the same.

[6] The presence of entrepreneurs simplifies the optimization problem of the representative household, which means that the term related to capital utilization drops out from the budget constraint (22).

Households are the agents who build raw capital.[7] To produce new raw capital, the representative household purchases undepreciated capital from entrepreneurs and investment goods from final assemblers. While the undepreciated capital is converted one-for-one into new raw capital, the transformation of the investment goods is subject to quadratic adjustment costs $F(I_t/I_{t-1}) = \frac{F}{2}\left(\frac{I_t}{I_{t-1}} - g_z\right)^2$ with $F(.) = F'(.) = 0$, $F''(.) = F > 0$. After goods production in period t, the household builds end-of-period t raw capital, $\bar{K}_{t+1}$, using the standard technology:

$$\bar{K}_{t+1} = (1-\delta)\bar{K}_t + \mu_t \left[1 - F\left(\frac{I_t}{I_{t-1}}\right)\right] I_t, F\left(\frac{I}{K}\right) = \delta, F'\left(\frac{I}{K}\right) = 1, 0 < \delta < 1 \tag{4.20}$$

where μ_t is a marginal efficiency of investment (MEI) shock.

Each household also consumes final goods under perfect consumption insurance. The preferences of the representative household are given by

$$E_0 \sum_{t=0}^{\infty} \beta^t b_t \left[\log\left(C_t - bC_{t-1}\right) - \varphi_H \int_0^1 \frac{h_{j,t}^{1+\sigma_H}}{1+\sigma_H} dj\right], \qquad 0 < \beta, b < 1, \varphi_H, \sigma_H > 0, \tag{4.21}$$

where C_t is the per-capita consumption of non-shareholder members of the household and b_t is an intertemporal preference shock.

Budget constraint

The representative household maximizes its intertemporal utility (4.21) with respect to the period-by-period budget constraint

$$\begin{aligned} P_{c,t}C_t + P_{i,t}I_t + Q_{\bar{K},t}(1-\delta)\bar{K}_t + D_{t+1} + S_t D^*_{t+1} \leq \int_0^1 W_{j,t}h_{j,t}dj + Q_{\bar{K},t}\bar{K}_{t+1} \\ + R_t D_t + R^*_t \Psi_t(.) S_t D^*_t + \Pi_t. \end{aligned} \tag{4.22}$$

Accordingly, the household allocates funds to non-shareholder consumption, raw capital building, and home and foreign asset investment. The household's sources of funds are wage income from labor services $W_{j,t}h_{j,t}$, revenues from selling raw capital $Q_{\bar{K},t}\bar{K}_{t+1}$, as well as returns on home and foreign assets $R_t D_t + R^*_t \Phi_t(.) S_t D^*_t$, and various lump-sum payments Π_t including profits from domestic firms, transfers from entrepreneurs and bankers net of equity injections (discussed in the following subsections), and net lump-sum transfers from the government.

Financial assets

The household saves by investing their financial wealth in the home and foreign asset markets. The within-country bank deposits and government bonds are risk-free assets in

[7] For the sake of minimizing the number of agents, I assign the task of raw capital production to households instead of a competitive capital goods producer.

nominal terms with one-period maturity and thus perfectly substitute. The optimal position in the cross-border asset market is determined by the uncovered interest arbitrage condition:

$$R_t = E_t \left\{ R_t^* \frac{S_{t+1}}{S_t} \Psi_t(.) \right\}. \tag{4.23}$$

From the arbitrage condition in steady state, I can endogenously derive the subjective discount factor of the foreign household with respect to the calibrated counterpart of the home household.[8] The country risk premium function of holding foreign assets, $\Psi_t(.)$, takes the form of

$$\Psi_t\left(\frac{A_t}{z_t}, \Delta S_t, \psi_t\right) = \exp\left\{-\phi_a(a_t - a) - \phi_s\left[\frac{E_t\{S_{t+1}\}}{S_t}\frac{S_t}{S_{t-1}} - \left(\frac{\pi}{\pi^*}\right)^2\right] + \psi_t\right\}, \tag{4.24}$$
$$\Psi_t^{'}(.) < 0, \Psi\left(0, \frac{\pi}{\pi^*}, 0\right) = 1, a = 0, \pi > \pi^*, \phi_a > 0, 0 < \phi_s < 1,$$

where $A_t = \frac{S_t D_{t+1}^*}{P_t}$ is the (real) net foreign asset position and ψ_t is a country risk premium shock. Following Adolfson et al. (2008), the country risk premium is a positive function of the net foreign asset position and expected home currency depreciation.[9] In addition, I allow for the home economy's relatively high inflation rate in steady state, which yields steady-state nominal depreciation as implied by the purchasing power parity theory.

4.2.5 Entrepreneurs

Risk neutral entrepreneurs utilize capital in the competitive market. At the end of period t, entrepreneur j is endowed by a net worth, $N_{ej,t} \geq 0$. Entrepreneurs obtain aggregate loans, $L_{e,t}$, from home bankers, which is combined with their own aggregate net worth, $N_{e,t}$, to purchase raw capital, $\bar{K}_{t+1}$, at a competitive price of $Q_{\bar{K},t}$. That is,

$$L_{e,t} = Q_{\bar{K},t}\bar{K}_{t+1} - N_{e,t}. \tag{4.25}$$

I have dropped out the j index because the equilibrium value of the objective variables is independent of $N_{e,t}$ (see below). After purchasing raw capital, entrepreneurs experience idiosyncratic risk, ω, to the project of capital utilization, with $\log(\omega) \sim N\left(-\sigma_{e,t}^2/2, \sigma_{e,t}^2\right)$ over time and across entrepreneurs so that ω has unit mean. Exogenous changes in the standard deviation $\sigma_{e,t}$ characterize the extent of cross-sectional volatility in ω. I refer to this measure of volatility as the entrepreneurial riskiness shock, which proxies for a sudden and dramatic re-appreciation of general market risk.[10]

[8]The detailed algorithm of steady-state computation is described in Appendix D.

[9]The inclusion of expected exchange rate depreciation aims to account for the "forward premium anomaly", according to which the home currency empirically tends to appreciate when the home nominal interest rate exceeds the foreign rate.

[10]A recent macro-finance literature argues that exogenous disturbances in cross-sectional idiosyncratic uncertainty are key in order to understand aggregate fluctuations (see, e.g., Bloom (2009); Kiley and Sim (2011); Bloom et al. (2012); Arellano, Bai, and Kehoe (2012); Christiano, Motto, and Rostagno (2014); and Nuño and Thomas (2017)). Christiano, Motto, and Rostagno (2014) label such disturbances "risk shocks", whereas Nuño and Thomas (2017) interpret them as "volatility shocks". My specification of entrepreneurial riskiness shocks is most closely related to Christiano, Motto, and Rostagno (2014).

After observing the period $t+1$ aggregate rate of return and price, entrepreneurs determine the utilization rate u_{t+1} to transform their effective raw capital, $\omega \bar{K}_{t+1}$, into the services of effective capital according to

$$K_{t+1} = u_{t+1} \omega \bar{K}_t. \tag{4.26}$$

The capital utilization involves adjustment costs $a(u_{t+1})\bar{K}_t$ where

$$a(u_t) = (1-\zeta)\frac{Z_k}{P_i}\left(u_t^{\frac{1}{1-\zeta}} - 1\right), \qquad 0 < \zeta < 1 \tag{4.27}$$

is a cost function with the following properties: $a(1) = 0, a'(.) > 0, a'(1) = \frac{Z_k}{P_i}, a''(.) > 0, a''(1) = a'(1)\frac{\zeta}{1-\zeta}$ and its only parameter, ζ, controls the local curvature of the cost function.

Entrepreneurs supply effective capital services, K_{t+1}, for the competitive rental rate $Z_{k,t+1}$, and sell undepreciated capital back to households at the price $Q_{\bar{K},t+1}$. The rate of return on capital across entrepreneurs is as follows:

$$R_{k,t+1} = \frac{Z_{k,t+1}u_{t+1} - P_{i,t+1}a(u_{t+1}) + (1-\delta)Q_{\bar{K},t+1}}{Q_{\bar{K},t}}, \tag{4.28}$$

where $P_{i,t}a(u_t)$ reflects the unit utilization cost expressed in the price of investment goods.

Entrepreneurs' total assets in period $t+1$ are given by $\omega R_{k,t+1}\bar{K}_t Q_t$. The cut-off value of ω for separating bankrupt and solvent entrepreneurs, $\bar{\omega}_{t+1}$, is defined by the following expression:

$$\bar{\omega}_{t+1} R_{k,t+1} Q_{\bar{K},t} \bar{K}_{t+1} = R_{b,t} L_{e,t}, \tag{4.29}$$

where $R_{b,t}$ is the contractual lending rate on the entrepreneurial loan.

Costly state verification problem

I assume that shareholders allow their entrepreneur to retain an exogenous random fraction, $\theta_{e,t+1}$, of the entrepreneurial earnings in order to grow the business while the complementary fraction is paid out as dividends at the end of period $t+1$.[11] Then, entrepreneurs comply with the net worth maximizing objective set by shareholders in exchange for perfect consumption insurance. A representative entrepreneur therefore must select the loan contract according to the expected net worth in period $t+1$:

$$\max_{\{\bar{\omega}_{t+1}, \tilde{L}_{e,t}\}} E_t \left\{ \int_{\bar{\omega}_{t+1}}^{\infty} \left[\bar{\omega}_{t+1} R_{k,t+1} Q_{\bar{K},t} \bar{K}_{t+1} - R_{b,t} L_{e,t}\right] dF(\omega, \sigma_{e,t}) \right\}$$
$$= \max_{\{\bar{\omega}_{t+1}, \phi_{e,t}\}} E_t \left[1 - \Gamma(\bar{\omega}_{t+1})\right] R_{k,t+1} \phi_{e,t} N_{e,t},$$

[11] The shocks to entrepreneurial net worth actually fundamentally capture volatilities in stock market value, which reflect an "asset bubble" or "irrational exuberance" hitting the entrepreneurial sector.

where $\phi_{e,t} = \frac{Q_{\bar{K},t}\bar{K}_{t+1}}{N_{e,t}}$ is the entrepreneurial leverage multiple, $\Gamma(\bar{\omega}_{t+1}) = [1 - F(\bar{\omega}_{t+1})]\,\bar{\omega}_{t+1}$ $+ G(\bar{\omega}_{t+1})$ and $G(\bar{\omega}_{t+1}) = \int_0^{\bar{\omega}_{t+1}} \omega\ dF(\omega, \sigma_{e,t})$.

The realization of ω idiosyncratic risk is private information of entrepreneurs. In the presence of the costly state verification problem, risk-averse bankers have to pay monitoring costs to learn this value, which accounts for the proportion μ of the remaining assets of bankrupt entrepreneurs.[12] Entrepreneurs with $\omega \leq \bar{\omega}_{t+1}$ declare bankruptcy and turn over their assets, $\omega_{t+1}R_{k,t+1}Q_{\bar{K},t}\bar{K}_{t+1}$, to the bank. While the *ex ante* lending interest rate, $R_{b,t}$, is known at the contract signing time, the *ex post* return accrued by the banker, $R_{e,t+1}$, is instead state-contingent. Therefore, the banker would only be willing to lend to the entrepreneur if the revenues net of monitoring costs received in every period $t + 1$ state of nature from the entrepreneurial loan are no less than the funds requested by shareholders in the same period. Thus the following cash constraint

$$[1 - F(\bar{\omega}_{t+1})]\,R_{b,t}L_{e,t} + (1-\mu)R_{k,t+1}Q_{\bar{K},t}\bar{K}_{t+1}\int_0^{\bar{\omega}_{t+1}} \omega\ dF(\omega, \sigma_{e,t}) \geq R_{e,t+1}L_{e,t}, \qquad 0 < \mu < 1. \tag{4.30}$$

must hold in each realized $t + 1$ state of nature.

Optimal loan contract

Competitive banks earn zero profit in equilibrium with free entry. Thus the cash constraint in (4.30) must hold as a strict equality in every $t+1$ aggregate state. Using this fact as well as the expressions of the cut-off value and the entrepreneurial loan, I derive a single zero-profit condition for the banking sector:

$$\Gamma(\bar{\omega}_{t+1}) - \mu G(\bar{\omega}_{t+1}) = \frac{R_{e,t+1}}{R_{k,t+1}}\frac{(\phi_{e,t}-1)}{\phi_{e,t}}, \qquad \phi_{e,t} > 1, \tag{4.31}$$

Bankers offer a menu of $t + 1$ state-contingent loan contracts, which includes a set of $\{\bar{\omega}_{t+1}, \phi_{e,t}\}$ combinations satisfying (4.31). As clear from (4.31) the menu of loan contracts depends solely on economy-wide variables, and thus the optimal loan contract is homogeneous and standardized across entrepreneurs.

Net worth evolution

Summing across all entrepreneurs, I get the aggregate entrepreneurial profit at the end of period t:

$$V_{e,t} = [1 - \Gamma(\bar{\omega}_t)]\,R_{k,t}Q_{\bar{K},t-1}\bar{K}_t. \tag{4.32}$$

After entrepreneurs have collected capital rental receipts and settled their end-of-period t contractual obligations to banks, the complementary fraction, $1 - \theta_{e,t}$, of all

[12]This can be interpreted as legal costs that the banks have to pay in the case of borrowers' default.

entrepreneurs' earnings is paid out as dividends for within-period consumption. Therefore the per-capita consumption of shareholders is

$$P_{c,t}C_{e,t} = (1 - \theta_{e,t})V_{e,t}. \tag{4.33}$$

In addition, entrepreneurs raise exogenous capital, which corresponds to a fraction χ_e of the balanced-growth-path aggregate net worth, $n_e z_t$. After capital raising, aggregate net worth at the end of period t is

$$N_{e,t} = \theta_{e,t}V_{e,t} + \chi_e n_e z_t. \tag{4.34}$$

The borrowing-riskless spread is given by:[13]

$$spr_{e,t} = \frac{R_{b,t}}{R_t}. \tag{4.35}$$

4.2.6 Banks

Competitive, risk-neutral banks are owned by risk-averse shareholders. At the end of period t, the state of a bank is summarized by its net worth, $N_{jb,t} \geq 0$. At this point, each bank raises a nominal deposit, $D_{j,t}$, from depositors at the risk-free rate, R_t, and then grants three classes of loans: working capital loans $L_{jf,t}$, export credits $L_{jx,t}$ and entrepreneurial loans $L_{je,t}$. The first two classes of intraperiod loans are riskless and due at the end of period t, while the third is risky interperiod loans that are due at the begining of period $t+1$. The bank's balance sheet reads:

$$L_{jt} \equiv L_{jf,t} + L_{jx,t} + L_{je,t} = N_{jb,t} + D_{j,t}.$$

The three types of loans pay out non-contingent norminal returns, $R_{f,t}$, $R_{x,t}$, and state-contingent norminal returns, $R_{e,t+1}$, respectively.

Moral hazard problem

As with entrepreneurs, each banker is allowed to retain an exogenous random fraction, $\theta_{b,t}$, of the banking earnings for growing the business while the complementary fraction is paid out to shareholders as dividends at the end of period t.[14] Given my assumptions, financial resources available to shareholders would be greater if the net worth of the bank were larger. Therefore it is in shareholders' own interest to request that their

[13] Although $\frac{R_{k,t+1}}{R_t}$ is an appropriate measure of the external finance cost (see e.g., Nolan and Thoenissen 2009), it is an unobservable variable. At time t the *ex post* return on capital, $R_{k,t+1}$, is not known, as the idiosyncratic risk has not yet been realized. I therefore use the spread between the *ex ante* lending rate at the contract signing time t which entrepreneurs expect to pay in the event of non-default and the policy rate (see also Christiano, Motto and Rostagno 2014; Rannenberg 2016).

[14] It is the banking net worth shock which captures exogenous sudden volatilities in the value of the assets on the bank balance sheet. Upheavals in financial markets, characterized by growing asset losses and dramatic declines in profits of banks, during the 2007−2008 financial crisis appear to reflect adverse disturbances of this kind. Other examples of such disturbances include a tax on bank capital, a raise in minimum capital requirements, an increase in the capital adequacy ratio, and a change to the classification of Tier 1 and Tier 2 capital.

banker maximize expected net worth. Also, I assume that shareholders value a particular portfolio of loans according to the expected discounted funds owned in period $t+1$. Then the banker's job is to solve the following problem:

$$\max_{\tilde{N}_{jb,t+1}} E_t \left\{ \sum_{s=0}^{\infty} (1-\theta_{b,t+1})\theta_{b,t+1+s}\beta^{s+1}\Xi_{t,t+1+s}N_{jb,t+1+s} \right\} = V_{jb,t}$$

However, a moral hazard problem arises when bankers can discretionarily divert an exogenous time-varying fraction ϖ_t of assets on the balance sheet for their own interest.[15] Shareholders would therefore only approve the project of loan allocations proposed by bankers if the expected discounted funds received in each period t were no less than the assets diverted in that period. Thus the following cash constraint:

$$V_{jb,t} \geq \varpi_t \left(L_{jf,t} + L_{jx,t} + L_{je,t}\right), \qquad 0 < \varpi_t < 1 \tag{4.36}$$

must be satisfied in each period t. The linearity of the banker's optimization problem implies

$$V_{jb,t} = \tau_{f,t}L_{jf,t} + \tau_{x,t}L_{jx,t} + \tau_{e,t}L_{je,t} + \gamma_t N_{jb,t}, \tag{4.37}$$

with

$$\tau_{f,t} = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\theta_{b,t+1})(R_{f,t} - R_t) + \theta_{b,t+1}\frac{L_{jf,t+1}}{L_{jf,t}}\tau_{f,t+1} \right] \right\} \tag{4.38}$$

$$\tau_{x,t} = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\theta_{b,t+1})(R_{x,t} - R_t) + \theta_{b,t+1}\frac{L_{jx,t+1}}{L_{jx,t}}\tau_{x,t+1} \right] \right\} \tag{4.39}$$

$$\tau_{e,t} = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\theta_{b,t+1})(R_{e,t+1} - R_t) + \theta_{b,t+1}\frac{L_{je,t+1}}{L_{je,t}}\tau_{e,t+1} \right] \right\} \tag{4.40}$$

$$\gamma_t = \beta E_t \left\{ \Xi_{t,t+1} \left[(1-\theta_{b,t+1})R_t + \theta_{b,t+1}\frac{N_{jb,t+1}}{N_{jb,t}}\gamma_{t+1} \right] \right\} \tag{4.41}$$

where $\tau_{f,t}$, $\tau_{x,t}$ and $\tau_{e,t}$ are the expected discounted marginal gain of various loans, while γ_t is the expected discounted marginal value of net worth.

Optimal loan portfolio

Observe that the right term in (4.36) cannot be strictly greater than the term on the left in each time period t, otherwise banks would make positive profits in the competitive credit market. Thus perfect competitiveness coupled with the cash constraint in (4.36) imply that (4.36) must hold as a strict equality in every state of nature. Combining this fact with the linear value function (4.37), I obtain the incentive compatibility constraint for the entire banking sector,[16]

$$L_t = \phi_{b,t}N_{b,t}, \qquad \phi_{b,t} > 1, \tag{4.42}$$

[15] In Gertler and Karadi's (2011) framework, ϖ_t is traditionally referred to as a time-invariant stealing fraction of assets and thus financial frictions on the liability side originally comes from a fear that bankers would steal. I believe that an interpretation of asset diversion at bankers' discretion is better suited for a time-varying parameter. Therefore, following this interpretation, I present a slightly different framework in which the scheme of incentive constraint works due to the skewed nature of banks' compensation.

[16] This aggregation is possible due to the constant number of bankers in the economy as well as their risk neutrality and perfect competitiveness. Also, there exists one aggregate loan demand curve, identical for all bankers. Therefore the j index has been omitted.

(4.43) $$\tau_{f,t} = \tau_{x,t} = \tau_{e,t} \equiv \tau_t$$

where $\phi_{b,t} = \frac{\gamma_t}{\varpi_t - \tau_t}$ is the banking leverage multiple.[17] For a given level of net worth $N_{jb,t}$, increased divertibility of assets, ϖ_t, would deleverage the bank's balance sheet and cause a decline in the availablity of funding. Thus the moral hazard problem imposes an endogenous incentive constraint on the bank's balance sheet. I refer to this measure of divertiblity as the bank riskiness shock.[18] Also, shocks to banking net worth, which capture sudden exogenous volatilities in the value of the assets on the bank balance sheet,[19] would deteriorate banks' capability to lend. Note also that in equilibrium banks are indifferent to lending an additional unit among various borrowings since the incentive constraint is symmetric across all types of loans.[20] The $(L_{jf,t}, L_{jx,t}, L_{je,t})$ combinations that satisfy the (4.43) arbitrage condition define an optimal portfolio of loans approved by the representative household's shareholders and allocated by each banker to various borrowers.

Net worth evolution

Aggregating across all banks, I obtain the total banking profits at the end of period t:

(4.44) $$V_{b,t} = (R_{f,t} - R_t)L_{f,t-1} + (R_{x,t} - R_t)L_{x,t-1} + (R_{e,t} - R_t)L_{e,t-1} + R_t N_{b,t-1}.$$

After receiving returns on the optimal portfolio of loans and then meeting their end-of-period t deposit obligations, banks pay out the complementary fraction, $1 - \theta_{b,t}$, as dividend for within-period consumption. Therefore the per-capita consumption of shareholders is

(4.45) $$P_{c,t}C_{b,t} = (1 - \theta_{b,t})V_{b,t}.$$

Similarly to entrepreneurs, banks raise exogenous additional capital, which corresponds to a fraction χ_b of the balanced-growth-path aggregate net worth, $n_b z_t$. After capital raising, aggregate net worth at the end of period t is

(4.46) $$N_{b,t} = \theta_{b,t}V_{b,t} + \chi_b n_b z_t.$$

[17] My assumption of self-interest diversion implies that the banker expands lending as long as the marginal gain to the banker from diversion remains larger than the marginal gain to shareholders from lending. The incentive constraint always binds at the non-stochastic steady state, $\varpi > \tau$, since $\gamma > 0$.

[18] Shocks of this kind occur when bankers pursue goals which have a high profile. Bankers can, for example, relax lending criteria to undesirable big pjojects or increase discretionary expenditure on perks. In this way, they give insights into prestige, job security and power.

[19] Upheavals in financial markets during the 2007−2008 financial crisis appear to reflect adverse disturbances of this type, as indicated by heavy losses in assets and dramatic declines in profits of banks. In particular, the collapse of Lehman Brothers may be considered a world-wide common shock. Other examples of such disturbances in normal economic conditions include a tax on bank capital, a raise in minimum capital requirements, an increase in the capital adequacy ratio, and a change to the classification of Tier 1 and Tier 2 capital.

[20] The arbitrage condition, however, does not imply that the expected returns from various loans are identical (not even up to first order) because the marginal gain from each type of loan depends on the loan type-specific growth rate.

I define the lending-deposit spread as the weighted average of contractual loan rates:

$$spr_{b,t} = \frac{R_{f,t}L_{f,t} + R_{x,t}L_{x,t} + R_{b,t}L_{e,t}}{R_t L_t}. \tag{4.47}$$

4.2.7 Government policies and general equilibrium

The monetary authority's policy rule is expressed directly in the following linearized form:

$$R_t - R = \rho(R_{t-1} - R) + (1-\rho)\left[r_\pi\left(\pi_{c,t+1} - \bar{\pi}_t\right) + r_{\Delta_{gdp}}(g_{gdp,t} - g_z)\right] + \varepsilon_t, \quad 0 < \rho < 1, r_\pi, r_{\Delta_{gdp}} > 0, \tag{4.48}$$

where ε_t is a monetary policy shock. The expression $R_t - R$ is the deviation of the net quarterly riskless interest rate from its steady state. Similarly, $\pi_{c,t+1} - \bar{\pi}_t$ is the deviation of anticipated quarterly consumer price inflation from the inflation target and $g_{gdp,t} - g_z$ is the observed quarterly growth rate of real GDP in deviation from its steady state.

I model government consumption, G_t, as:

$$G_t = z_t g_t, \tag{4.49}$$

where g_t is treated as an exogenous process. Goods market clearing dictates that the homogenous output goods are allocated among alternative uses as follows:

$$Y_t = G_t + C_{d,t} + I_{d,t} + X_t + \mu R_{k,t} Q_{\bar{K},t-1}\bar{K}_t \int_0^{\bar{\omega}_t} \omega \; dF(\omega, \sigma_{e,t}). \tag{4.50}$$

I measure GDP in the model as follows:

$$GDP_t = G_t + \tilde{C}_t + \tilde{I}_t + X_t - M_t, \tag{4.51}$$

with

$$\tilde{C}_t \equiv \left[(1-\omega_c)\left(\frac{P_t}{P_{c,t}}\right)^{-\eta_c} + \omega_c\left(\frac{P_{cm,t}}{P_{c,t}}\right)^{-\eta_c}\right] C_t$$

and

$$\tilde{I}_t \equiv \left[(1-\omega_i)\left(\frac{P_t}{P_{i,t}}\right)^{-\eta_i} + \omega_i\left(\frac{P_{im,t}}{P_{i,t}}\right)^{-\eta_i}\right] I_t.$$

The dynamics of the (nominal) net foreign asset position are driven by the international trade balance:

$$S_t D^*_{t+1} = R^*_t \Phi_t(.) S_t D^*_t + [1 + v_X(R_{x,t} - 1)] S_t [P_{x,t} X_{non,t} + P_{com,t} X_{com,t}] - [1 + v_M(R^*_{m,t} - 1)] S_t P^*_t M_t \tag{4.52}$$

where $P_{com,t}$ is the commodity price denominated in foreign currency. I model the relative price of commodities, $P_{com,t}/P^*_t$, as a stationary stochastic process.

4.2.8 Foreign economy

The optimal problems in the foreign economy are similarly described. However, the foreign country approximates a closed economy because the home partner is a small-open economy that is unable to influence. Therefore there are exceptions for modeling a large-closed foreign economy. First, final consumption and investment goods comprise a continuum of domestically produced goods, $C_t^* \equiv \int_0^1 C_{dj,t}^* dj$ and $I_t^* \equiv \int_0^1 I_{dj,t}^* dj$, due to a negligible share of home exports in aggregate foreign demand. Second, variations in the home export price have a trivial effect on the evolution of the foreign price index, implying that $P_{c,t}^* = P_{i,t}^* \equiv P_t^*$. Third, negligible credits for home importers, $L_{m,t}$ and $L_{eF,t}$, need not be taken into account and thus $L_t^* \equiv L_{f,t}^* + L_{e,t}^*$, $spr_{e,t}^* = \frac{R_{b,t}^*}{R_t^*}$, $spr_{b,t}^* \equiv \frac{R_{f,t}^* L_{f,t}^* + R_{b,t}^* L_{e,t}^*}{R_t^* L_t^*}$. Home importers then take $R_{m,t}^* \equiv R_t^* spr_{b,t}^*$ as given. Finally, home assets are in zero net supply because the asset holdings of home households are negligible in the foreign market while there is no access to the home asset market for foreign agents.

4.2.9 Satellite models, model solution and fundamental shocks

For comparison purposes, I also consider three smaller satellite models. The first is a model without financial frictions between bankers and depositors, called the External Finance Premium (EFP) model. In the EFP model, entrepreneurs run capital utilization projects and pay dividends to thier shareholders while competitive bankers earn zero profit from financial intermediation. Technically, this satellite model is derived from the baseline model by: (1) dropping the moral hazard problem between bankers and shareholders, $\varpi_t = 0$; (2) deleting banking shareholder consumption from final private consumption, $C_{b,t} = 0$; (2) adjusting the lending rate on period t risky entrepreneurial loans after the realization of period $t+1$ shocks in order to ensure that the bank receives a risk-free return, $R_{e,t+1} = R_t$; and (4) allowing riskless loans to be made at the risk-free rate, $R_{f,t} = R_{x,t} = R_t$ and $R_{m,t}^* = R_t^*$. Thus I obtain an always binding constraint,

$$L_{e,t} = \phi_{b,t} N_{b,t}. \tag{4.53}$$

while the spread remains unchanged

$$spr_{e,t} = \frac{R_{b,t}}{R_t}. \tag{4.54}$$

In this model, the banking sector raises non-friction deposits. Such a shadow banking sector, however, still has impact on the dynamics of the returns on entrepreneurial loans and the real economy due to the presence of credit supply data in my estimation exercise. In addition, the presence of a shadow banking sector will be helpful for comparing responses to the same shocks between the EFP model and other friction models with $\varpi_t > 0$.

By contrast, bankers manage the financial intermediary and pay dividends to their shareholders while competitive entrepreneurs earn zero profit from capital utilization in the Incentive Compatibility Constraint (ICC) model. In this model, there are no frictions in the bank−entrepreneur relationship. Technically, this satellite model is extracted from the baseline model by: (1) dropping the costly state verification problem between bankers and entrepreneurs, $\mu = 0$ and $\omega_t = 1$; (2) deleting project shareholder consumption from final private consumption, $C_{e,t} = 0$; (3) assuming that entrepreneurial loans are state-contingent so that the interest rate on entrepreneurial loans equals the expected return on capital, $R_{b,t+1} = R_{e,t+1} = R_{k,t+1}$; and (4) forcing the share of aggregate capital purchase financed by entrepreneurial loans, $\omega_{\bar{K}}$, to be the same as in the EFP model. I define the weighted average lending-deposit spread as:

$$spr_{b,t} = \frac{R_{f,t}L_{f,t} + R_{x,t}L_{x,t} + R_{k,t}L_{e,t}}{R_t L_t}, \tag{4.55}$$

and the zero profit condition of the entrepreneurial sector:

$$R_{k,t+1} = \frac{Z_{k,t+1}u_{t+1} - P_{i,t+1}a(u_{t+1}) + (1-\delta)Q_{\bar{K},t+1}}{\omega_{\bar{K}}Q_{\bar{K},t}} - \frac{(1-\omega_{\bar{K}})Q_{\bar{K},t+1}}{\omega_{\bar{K}}Q_{\bar{K},t}}. \tag{4.56}$$

Entrepreneurs manage capital accumulation but accumulate no net worth and thus break even state by state in this model. However, the presence of such a passive entrepreneurial sector has impact on the dynamics of non-risky returns and real activities through the volatilities of the stock market index. Further, it helps in understanding how differently the economy responds to shocks once $\mu > 0$ and $\omega_t \neq 1$ as in the baseline and EFP models.

In the absence of the financial sector, the structure of my baseline model collapses back to a pure trade open economy model − I call it Pure for short. To obtain this Pure model from the baseline model, I drop all equations that characterize the financial sector and add an intertemporal Euler equation corresponding to household capital accumulation. It is of course also necessary to delete shareholder consumptions from final private consumption and monitoring costs from the resource constraint.

The two economies evolve along two stochastic growth paths in every model. Therefore, the overall solution across models involves the following steps. First, I transform the models into a stationary form. Specifically, real variables are detrended by the level of technology, $\{z_t, z_t^*\}$, and nominal variables are converted to real variables by deflating with the price index, $\{P_t, P_t^*\}$. Second, the models are written into a set of stationary equilibrium conditions. Third, non-linear equilibrium conditions are log-linearized and solved using first-order approximation methods. Fourth, the log-linearized version of models is augmented by a set of measurement equations which link the observable variables in the dataset with the endogenous variables of the theoretical model.

The stochastic behavior of the system of linear rational expectations equations in the Baseline model is driven by 20 fundamental shocks: $g_{z,t}, \epsilon_t, \lambda_{cm,t}, \lambda_{im,t}, \lambda_{x,t}, \lambda_{w,t}, \varepsilon_{pc,t}, b_t, \mu_t, \psi_t, \varepsilon_{com,t}, p^*_{com,t}, \varepsilon_t, \bar{\pi}_t, g_t, \theta_{e,t}, \theta_{b,t}, \varpi_t, \sigma_{e,t}, \tilde{z}^*_t$ for the Home economy and 12 fundamental shocks: $g^*_{z,t}, \epsilon^*_t, \lambda^*_{p,t}, b^*_t, \mu^*_t, \varepsilon^*_t, \bar{\pi}^*_t, g^*_t, \theta^*_{e,t}, \theta^*_{b,t}, \varpi^*_t, \sigma^*_{e,t}$ for the Foreign economy, where $\tilde{z}^*_t = \frac{z^*_t}{z_t}$ is a stationary shock capturing the degree of asymmetry in the trend levels of technology between the two economies. With two exceptions, I model the log-deviation of each shock from its steady state as a univariate first-order autoregressive process. The autoregressive parameter of the inflation target shock, $\{\rho_{\bar{\pi}}, \rho_{\bar{\pi}^*}\}$ is set at $(0.975, 0.975)$ in order to accommodate the downward inflation trend in the late part of the dataset. The two exceptions are the monetary policy shock, $\{\varepsilon_t, \varepsilon_t^*\}$, and the consumption price inflation shock, $\varepsilon_{\pi_{c,t}}$, which are assumed to be white noise.

4.3 Bayesian Inference

This section first describes the data used in the analysis as well as the calibrated parameters and then discusses the priors and posteriors for the estimated parameters. Finally, I compare the models in terms of goodness-of-fit using various measures, including likelihood race, steady-state properties and business cycle moments.

4.3.1 The data

Home is identified with Australia and Foreign with the United States. The models are estimated with quarterly data that cover the period 1993Q1 to 2012Q4.[21] The dataset contains seven conventional standard time series as observable variables in each economy: real GDP, real private consumption as the sum of household purchases of nondurable goods and services, real investment as the sum of gross private domestic investment plus household purchases of durable goods, nonfarm hours worked, nonfarm real wages, domestic inflation, and nominal interest rate. I extend this dataset to seven typical open economy variables: non-commodity and commodity exports, imports, real exchange rate, CPI inflation, relative price of investment measured as the investment deflator divided by the GDP deflator, $p_{i,t} = P_{i,t}/P_t$, and relative price of commodities measured as the commodity price index divided by the U.S. GDP deflator, $p^*_{com,t} = P_{com,t}/P^*_t$.[22] In accordance with the model, overall inflation is measured as the percentage growth of the CPI and the GDP deflator for Australia and the U.S., respectively. Also, I use four financial observables in my analysis. For my measure of loans, $\{L_t, L_t^*\}$, I use data on total credit to the non-financial sector taken from the Lending and Credit Aggregates dataset compiled by the Reserve Bank of Australia and the Flow of Funds database constructed by the U.S. Federal Reserve Board. My indicator of entrepreneurial net worth, $\{N_{e,t}, N^*_{e,t}\}$, is the ASX All Ordinaries index and the Dow Jones Wilshire 5000 index. I compute the entrepreneurial spread of Australia as a weighted average of spreads between corporate bond yield relative to government bond yield and large business loan rate relative to government bond yield of corresponding maturities. For the U.S.,

[21] This period is characterized by inflation-targeting regimes in both countries. Therefore I concentrate on this period to ensure that the policy follows a time-invariant rule for the entire sample.

[22] I use the G7 trade-weighted average real exchange rate rather than the bilateral measure as my way of introducing multilateral real-world dynamics into the two-country model through the behavior of international relative prices.

the entrepreneurial spread is measured by the yield difference between corporate and government bonds. The banking spread is measured by the difference between the 90-day loan and policy rates.[23] Details of the data are in Appendix G.

All real variables are expressed in per capita terms, dividing them by the civilian population, and in quarter-on-quarter growth rates. Hours worked are also divided by the civilian population. Note that I demean not only nominal variables but also real variables. This is because on average trade and financial series grew at significantly higher rates than GDP in the dataset, while my model predicts that the log of ratio of GDP to these real variables is stationary. Therefore removing sample means separately from each real variable prevents the high business cycle frequencies from causing counterfactual implications of the estimated model for the low frequencies.

4.3.2 Calibration

I partition the model parameters into two subsets. The first subset contains the conventional and financial parameters that control the steady state. I simply borrow the values of some of these parameters from the literature and set the values of the other parameters so that the model reproduces key sample averages in the data. Table 4.1 lists conventional parameters. Capital share $\{\alpha,\ \alpha^*\}$ is fixed at (0.32, 0.33). I set the quarterly depreciation rate of capital $\{\delta,\ \delta^*\}$ to (1.75%, 2.5%), which is around the average value of this parameter in the Australian and the U.S. national accounts. The inverse of the Frisch labor supply elasticity $\{\sigma_H,\ \sigma_H^*\}$ is set to 1. I adjust the disutility weight on labor $\{\varphi_H,\ \varphi_H^*\}$ so that the steady-state working time is one-third of total time endowment. The parameter governing the gross wage markup $\{\lambda_w, \lambda_w^*\}$ is set at 1.2. The growth rate of the permanent technology shock $\{\bar{g}_z, \bar{g}_z^*\}$ is consistent with the mean per capita real GDP growth rate in my sample (0.45%, 0.41%). The discount factor β is fixed at 0.9987 and β^* is then endogenously determined through the uncovered interest arbitrage condition. The ratio of government spending to GDP is (0.23, 0.19) in steady state, which corresponds with the historical averages over my sample. I assign $\{v_X = v_K = v_H > v_K^* = v_H^*\}$, which reflects my later finding that the credit velocity measure is smaller in Australia than in the U.S. Assuming that (real) net foreign assets are at a zero steady-state level, I set v_M so that the trade balance as a percentage of GDP is -1%, i.e. the average value for Australia during the sample period, in order to ensure that the model's steady state is well defined.[24] I set the openness parameters,

[23]The 90-day loan rate corresponds to the large business loan rate for Australia and the bank prime lending rate for the U.S., respectively.

[24]In particular, I derive the trade balance to GDP ratio, $\frac{nx}{gdp}$, with respect to the share of import bill paid in advance, v_M, as follows:

$$\frac{nx}{gdp} = \left(\frac{1 + v_M R_m^*}{1 + v_X R_x} - 1\right) \frac{m}{gdp}.$$

In this way, I do not impose a steady-state balanced trade condition, $nx = 0$, on the model. See Section D of the Appendix for further details of this steady-state derivation.

Table 4.1: Calibration of Conventional Parameters

Description	Parameter	Value	Parameter	Value
Discount factor	β	0.9987		
Effective capital share	α	0.32	α^*	0.33
Depreciation rate	δ	0.0175	δ^*	0.025
Inverse Frisch elasticity	σ_H	1	σ_H^*	1
Disutility weight on labor	φ_H	9.5	φ_H	9.5
Gross markup in the labor market	λ_w	1.2	λ_w^*	1.2
Growth rate of the economy	$\bar{g}_z$	0.45	$\bar{g}_z^*$	0.41
Government spending-GDP ratio	g/y	0.23	g^*/y^*	0.19
Share of capital rental costs paid in advance	v_K	0.70	v_K^*	0.65
Share of labor costs paid in advance	v_H	0.70	v_H^*	0.65
Share of export bill paid in advance	v_X	0.70		
Share of import bill paid in advance	v_M	0.30		
Share of import goods in consumption	ω_c	0.21		
Share of import goods in investment	ω_i	0.50		
Share of commodity sector in export	ω_x	0.72		

Table 4.2: Calibration of Financial Parameters

Description	Parameter	Value	Parameter	Value
Payout ratio	$1-\theta_i$	$1-0.95$	$1-\theta_i^*$	$1-0.95$
Spread between borrowing and risk-free rates	spr_e	105 b.p	spr_e*	100 b.p
Entrepreneurial leverage multiple	ϕ_e	1.95	ϕ_e^*	1.89
Additional capital raise	χ_e	0.005	χ_e^*	0.005
Entrepreneurial riskiness shock	σ_e	0.32	σ_e^*	0.33
Lending−deposit spread	spr_b	284 b.p	spr_b^*	250 b.p
Banking leverage multiple	ϕ_b	6.42	ϕ_b^*	5.65
Additional capital raise	χ_b	0.002	χ_b^*	0.002

ω_c and ω_i, at 0.21 and 0.50 to match the average import share of consumption and investment goods in Australia. The export share of the commodity sector, ω_x, is set to 0.72 to reflect the average value over the sample period.

I turn to calibrated parameters specific to financial frictions in Table 4.2. The steady-state dividend payout ratio of both sectors, $\{\theta_i, \theta_i^*\}$, is set equal to 0.95, which is fairly close to the 0.972 value used in BGG and GK.[25] The steady-state entrepreneurial spread, $\{spr_e, spr_e^*\}$, is set to match the average wedge of (105, 100) basis points in my data. The target for the entrepreneurial leverage multiple is the ratio between total liabilities and total net worth of the non-financial business sector, taken from the Non-financial Corporations Balance Sheet of the Australian Bureau of Statistics and the Flow of Funds

[25]Traditionally, $1-\theta_i$ (for $i = \{e, b\}$) is usually referred to as the death rate of entrepreneurs or bankers. For quarterly frequency (and the framework of a single economy, whether closed or open), it has usually been set equal to $1-0.972$ in previous studies using the framework of BGG and GK. However, the fraction $1-\theta_i$ in my model corresponds to that of the net income, $V_{i,t}$, passed for shareholder consumption $C_{i,t}$, so the most natural interpretation of this parameter is "the dividend payout ratio". Similar interpretations have been used by Fernández and Gulan (2015) and Gertler and Kiyotaki (2010), where θ_i occurs in the context of the firms' value and banks' equity, respectively.

account of the Federal Reserve Board. Standard deviation of the idiosyncratic risk $\{\sigma, \sigma^*\}$ is calibrated such that the steady-state leverage multiple of the non-financial business sector meets the target value. The additional capital raise, $\{\chi_e,\ \chi_e^*\}$, is calibrated to meet targets for the entrepreneurial spread, the entrepreneurial leverage multiple, and the payout ratio, $1 - \theta_e$, in steady state.

The steady-state banking spread, $\{spr,\ spr^*\}$, is set to (284, 250) basis points, which corresponds to the average difference between the 90-day loan and policy rates. The banking leverage multiple in steady state is total assets divided by equity capital, which roughly captures the aggregate data of the banking sector in Australia and the U.S. respectively. I calibrate the additional capital raise, $\{\chi_b,\ \chi_b^*\}$, in order to meet my targets for the payout ratio, the banking spread, and the banking leverage multiple in steady state. Thus the divertible fraction of assets in steady state, $\{\varpi,\ \varpi^*\}$, is endogenously determined in accordance with these targets.

4.3.3 Priors and posteriors

The second subset of parameters to be estimated is listed in Tables 4.5 and 4.6. The prior belief is that parameter distributions are symmetric between the two economies. Thus, I assign the same priors to all comparable parameters. The locations of the prior mean are borrowed from the closed economy set-up of Smets and Wouters (2007). The priors of my parameters specific to the small-open economy are as follows. The elasticities of substitution between home and foreign goods in consumption and investment, η_c and η_i, and the elasticity of non-commodity export demand, η^*, are assumed to follow an inverse-gamma distribution with a mean of 1.5, consistent with the typical value used in the international macroeconomics literature. Based on economic theory, I also truncate the prior in order to exclude substituability below unity. For the parameter ϕ_a governing the elasticity of risk premium with respect to the net foreign indebtedness, I specify an inverse gamma density with mean 0.01, matching the calibrated value in Benigno (2009). I set a beta distribution centered at 0.5 and with a standard error of 0.15 for the depreciation elasticity of country risk premium, ϕ_s.

I turn to parameters pertaining to the entrepreneurial sector. To estimate the steady-state probability of default, I let the variance of $\{\log(\omega), \log(\omega^*)\}$ be the function of $\{F(\bar{\omega}), F(\bar{\omega}^*)\}$ and the other parameters. The mean of my prior beta distribution for $\{F(\bar{\omega}), F(\bar{\omega}^*)\}$ is 0.008, between the 0.0075 value used in BGG and the 0.0097 percent value used by Fisher (1999). The monitoring cost $\{\mu,\ \mu^*\}$ is beta distributed around 0.275 with standard error 0.125, within the range of 0.20–0.36 that Carlstrom and Fuerst (1997) propose as empirically relevant.

I estimate the second subset using the Bayesian procedures discussed in An and Schorfheide (2007). Accordingly, the likelihood of the data is combined with the prior information on the parameters to obtain the posterior distribution. Markov Chain Monte Carlo methods are implemented in a Metropolis–Hastings algorithm of 500,000 replica-

Table 4.3: Priors and Posteriors for Home Economy

Para.	Description	Prior			Posterior							
					Pure		EFP		ICC		Baseline	
		Dist.	Mean	SD	Mode	SD	Mode	SD	Mode	SD	Mode	SD
Panel A. Economic parameters												
ξ_w	Calvo, wage	B	0.5	0.1	0.47	0.08	0.44	0.08	0.45	0.06	0.46	0.05
ξ_d	Calvo, domestic price	B	0.5	0.1	0.84	0.03	0.87	0.03	0.87	0.03	0.88	0.01
ξ_{cm}	Calvo, import cons. price	B	0.5	0.1	0.91	0.02	0.57	0.08	0.57	0.08	0.78	0.07
ξ_{im}	Calvo, import inv. price	B	0.5	0.1	0.77	0.03	0.80	0.02	0.80	0.02	0.84	0.02
ξ_x	Calvo, export price	B	0.5	0.1	0.68	0.06	0.69	0.06	0.69	0.06	0.71	0.06
ι_w	Indexation, wage	B	0.5	0.15	0.40	0.16	0.41	0.16	0.41	0.16	0.38	0.13
ι_d	Indexation, domestic price	B	0.5	0.15	0.71	0.13	0.75	0.11	0.76	0.11	0.73	0.09
ι_{cm}	Indexation, import cons. price	B	0.5	0.15	0.89	0.04	0.89	0.05	0.88	0.05	0.89	0.05
ι_{im}	Indexation, import inv. price	B	0.5	0.15	0.79	0.08	0.79	0.08	0.80	0.08	0.80	0.08
ι_x	Indexation, export price	B	0.5	0.15	0.83	0.07	0.82	0.08	0.84	0.07	0.84	0.07
λ_d	Markup, domestic	N	1.2	0.12	1.78	0.09	1.86	0.10	1.86	0.09	1.60	0.06
λ_{cm}	Markup, import cons.	N	1.2	0.12	1.07	0.04	1.23	0.09	1.22	0.07	1.26	0.09
λ_{im}	Markup, import inv.	N	1.2	0.12	1.53	0.09	1.50	0.11	1.49	0.10	1.69	0.13
μ	Monitoring cost	B	0.275	0.15	–	–	0.235	0.098	–	–	0.214	0.079
$F(\bar{\omega})$	SS probability of default	B	0.008	0.004	–	–	0.0054	0.0021	–	–	0.0059	0.0026
F''	Investment adjustment cost	N	4	1.5	4.97	1.19	5.29	1.22	6.65	1.04	6.39	0.99
ζ	Capital utilization rate	B	0.5	0.15	0.35	0.11	0.57	0.15	0.56	0.15	0.57	0.06
b	Habit formation	B	0.5	0.1	0.57	0.07	0.55	0.16	0.56	0.16	0.64	0.18
ρ	Taylor rule smoothing	B	0.75	0.1	0.89	0.02	0.88	0.02	0.88	0.02	0.87	0.02
r_π	Taylor rule on inflation	N	1.5	0.25	1.62	0.21	1.65	0.15	1.67	0.15	1.69	0.17
$r_{\triangle gdp}$	Taylor rule on GDP growth	N	0.25	0.1	0.30	0.08	0.19	0.07	0.19	0.06	0.19	0.06
η_c	Elasticity of subst., cons.	$I_{>1}$	1.5	4	3.73	0.57	5.53	1.45	5.55	1.47	4.51	1.03
η_i	Elasticity of subst., inv.	$I_{>1}$	1.5	4	1.38	0.06	1.39	0.07	1.37	0.06	1.41	0.08
η_x	Elasticity of subst., export	$I_{>1}$	1.5	4	1.49	0.12	1.51	0.13	1.49	0.12	1.49	0.13
ϕ_a	Elast. premium-debt	I	0.01	1	0.003	0.0006	0.002	0.0007	0.002	0.0004	0.004	0.003
ϕ_s	Elasticity of premium-depre.	B	0.5	0.15	0.17	0.04	0.18	0.06	0.16	0.05	0.16	0.04
Panel B. Autocorrelation of the shocks												
ρ_{g_z}	Persistent technology	B	0.5	0.2	0.49	0.27	0.51	0.29	0.51	0.29	0.50	0.27
$\rho_{\tilde{z}^*}$	Asymmetric technology	B	0.5	0.2	0.50	0.27	0.50	0.27	0.50	0.27	0.50	0.27
ρ_ϵ	Transitory technology	B	0.5	0.2	0.98	0.01	0.89	0.04	0.89	0.04	0.91	0.02
ρ_w	Wage markup	B	0.5	0.2	0.16	0.08	0.15	0.07	0.16	0.08	0.16	0.07
ρ_d	Domestic price markup	B	0.5	0.2	0.10	0.10	0.06	0.06	0.07	0.06	0.98	0.07

Para.	Description	Prior			Posterior							
					Pure		EFP		ICC		Baseline	
		Dist.	Mean	SD	Mode	SD	Mode	SD	Mode	SD	Mode	SD
ρ_{cm}	Import cons. price markup	B	0.5	0.2	0.05	0.03	0.94	0.02	0.05	0.04	0.95	0.01
ρ_{im}	Import inv. price markup	B	0.5	0.2	0.08	0.06	0.11	0.08	0.11	0.07	0.15	0.10
ρ_{x}	Export price markup	B	0.5	0.2	0.09	0.07	0.08	0.06	0.08	0.06	0.09	0.06
ρ_{pco}	Relative commodity price	B	0.5	0.2	0.92	0.02	0.93	0.02	0.93	0.02	0.94	0.02
ρ_{xco}	Commodity demand	B	0.5	0.2	0.78	0.05	0.78	0.07	0.79	0.05	0.78	0.05
ρ_{ψ}	Country risk premium	B	0.5	0.2	0.68	0.07	0.63	0.07	0.68	0.07	0.85	0.03
ρ_{g}	Government spending	B	0.5	0.2	0.62	0.09	0.70	0.09	0.70	0.09	0.71	0.08
ρ_{μ}	Marginal efficiency of investment	B	0.5	0.2	0.15	0.09	0.95	0.05	0.96	0.05	0.98	0.01
ρ_{b}	Intertemporal preference	B	0.5	0.2	0.42	0.16	0.63	0.29	0.63	0.29	0.67	0.13
ρ_{θ_e}	Entrepreneurial net worth	B	0.5	0.2	–	–	0.99	0.006	–	–	0.98	0.07
ρ_{σ_e}	Entrepreneurial riskiness	B	0.5	0.2	–	–	0.79	0.02	–	–	0.78	0.06
ρ_{θ_b}	Banking net worth	B	0.5	0.2	–	–	–	–	0.99	0.005	0.98	0.003
ρ_{ϖ}	Banking riskiness	B	0.5	0.2	–	–	–	–	0.78	0.02	0.77	0.03
Panel C. Standard deviations of the innovations												
σ_{g_z}	Persistent technology	I	0.05	2	0.02	0.009	0.02	0.010	0.02	0.009	0.02	0.009
$\sigma_{\tilde{z}^*}$	Asymmetric technology	I	0.05	2	0.02	0.009	0.02	0.009	0.02	0.009	0.02	0.009
σ_{ϵ}	Transitory technology	I	0.1	2	0.33	0.032	0.56	0.057	0.56	0.058	0.63	0.062
σ_{w}	Wage markup	I	0.1	2	0.57	0.068	0.58	0.071	0.57	0.068	0.57	0.065
σ_{d}	Domestic price markup	I	0.1	2	0.72	0.068	0.73	0.066	0.73	0.064	0.66	0.059
σ_{cm}	Import cons. price markup	I	0.1	2	2.11	0.318	2.94	1.236	2.64	1.223	2.52	1.068
σ_{im}	Import inv. price markup	I	0.1	2	1.33	0.137	1.23	0.127	1.22	0.127	1.18	0.128
σ_{x}	Export price markup	I	0.1	2	4.54	0.724	4.47	0.702	4.48	0.701	4.39	0.697
σ_{pco}	Relative commodity price	I	0.1	2	5.73	0.457	5.72	0.456	5.70	0.452	5.68	0.450
σ_{xco}	Commodity demand	I	0.1	2	5.02	0.391	5.01	0.390	5.01	0.390	5.02	0.391
σ_{ψ}	Country risk premium	I	0.1	2	0.96	0.231	0.81	0.216	0.82	0.219	0.38	0.070
σ_{π_c}	Consumption price inflation	I	0.1	2	0.91	0.074	0.89	0.071	0.88	0.071	0.88	0.070
σ_{ε}	Monetary policy	I	0.1	2	0.11	0.009	0.11	0.010	0.11	0.010	0.11	0.009
$\sigma_{\bar{\pi}}$	Inflation target	I	0.05	2	0.04	0.012	0.02	0.012	0.02	0.012	0.02	0.013
σ_{g}	Government spending	I	0.1	2	0.62	0.050	0.71	0.060	0.70	0.058	0.75	0.079
σ_{μ}	Marginal efficiency of investment	I	0.1	2	1.28	0.138	0.42	0.077	0.43	0.065	0.58	0.092
σ_{b}	Intertemporal preference	I	0.1	2	0.54	0.066	0.57	0.128	0.56	0.093	0.30	0.044
σ_{θ_e}	Entrepreneurial net worth	I	0.1	2	–	–	1.06	0.076	–	–	1.01	0.098
σ_{σ_e}	Entrepreneurial riskiness	I	0.1	2	–	–	0.03	0.004	–	–	0.03	0.005
σ_{θ_b}	Banking net worth	I	0.1	2	–	–	–	–	1.18	0.125	1.44	0.128
σ_{ϖ}	Banking riskiness	I	0.1	2	–	–	–	–	5.18	0.551	6.25	0.657

Note: Estimated parameters are based on two independent Metropolis−Hastings chains of 500,000 iterations, with a 20 percent burn-in.

Table 4.4: Priors and Posteriors for Foreign Economy

Para.	Description	Prior			Posterior							
					Pure		EFP		ICC		Baseline	
		Dist.	Mean	SD	Mode	SD	Mode	SD	Mode	SD	Mode	SD
Panel A. Economic parameters												
ξ_w^*	Calvo, wage	B	0.5	0.1	0.55	0.08	0.52	0.09	0.51	0.07	0.52	0.08
ξ_p^*	Calvo, price	B	0.5	0.1	0.89	0.01	0.83	0.02	0.83	0.02	0.84	0.01
ι_w^*	Indexation, wage	B	0.5	0.15	0.51	0.17	0.47	0.17	0.47	0.17	0.52	0.17
ι_p^*	Indexation, price	B	0.5	0.15	0.67	0.12	0.85	0.06	0.85	0.06	0.83	0.09
λ_p^*	Markup, price	N	1.2	0.12	1.79	0.09	1.90	0.09	1.91	0.09	1.60	0.06
μ^*	Monitoring cost	B	0.275	0.15	–	–	0.312	0.116	–	–	0.301	0.106
$F(\bar{\omega}^*)$	SS probability of default	B	0.008	0.004	–	–	0.0061	0.0029	–	–	0.0065	0.0031
F''^*	Investment adjustment cost	N	4	1.5	4.64	1.27	5.29	0.82	5.97	0.97	6.40	1.15
ζ^*	Capital utilization rate	B	0.5	0.15	0.51	0.10	0.59	0.07	0.59	0.07	0.60	0.09
b^*	Habit formation	B	0.5	0.1	0.69	0.06	0.80	0.05	0.80	0.04	0.79	0.03
ρ^*	Taylor rule smoothing	B	0.75	0.1	0.85	0.02	0.84	0.02	0.84	0.02	0.85	0.02
r_{π^*}	Taylor rule on inflation	N	1.5	0.25	1.56	0.20	2.11	0.17	2.15	0.16	2.22	0.19
$r_{\triangle_{gdp}^*}$	Taylor rule on GDP growth	N	0.25	0.1	0.41	0.08	0.25	0.07	0.27	0.07	0.27	0.07
Panel B. Autocorrelation of the shocks												
$\rho_{g_z^*}$	Persistent technology	B	0.5	0.2	0.49	0.27	0.50	0.27	0.50	0.27	0.50	0.27
ρ_{ϵ^*}	Transitory technology	B	0.5	0.2	0.96	0.01	0.96	0.02	0.96	0.02	0.97	0.03
ρ_w^*	Wage markup	B	0.5	0.2	0.22	0.11	0.10	0.08	0.10	0.07	0.10	0.07
ρ_p^*	Price markup	B	0.5	0.2	0.21	0.16	0.92	0.02	0.92	0.02	0.94	0.03
ρ_g^*	Government spending	B	0.5	0.2	0.94	0.02	0.94	0.02	0.94	0.02	0.95	0.02
ρ_{μ^*}	Marginal efficiency of investment	B	0.5	0.2	0.66	0.08	0.98	0.01	0.99	0.01	0.98	0.01
ρ_b^*	Intertemporal preference	B	0.5	0.2	0.62	0.13	0.69	0.12	0.69	0.12	0.67	0.12
$\rho_{\theta_e}^*$	Entrepreneurial net worth	B	0.5	0.2	–	–	0.97	0.005	–	–	0.98	0.01
$\rho_{\sigma_e}^*$	Entrepreneurial riskiness	B	0.5	0.2	–	–	0.79	0.02	–	–	0.77	0.03
$\rho_{\theta_b}^*$	Banking net worth	B	0.5	0.2	–	–	–	–	0.98	0.004	0.98	0.003
ρ_{ϖ}^*	Banking riskiness	B	0.5	0.2	–	–	–	–	0.78	0.02	0.82	0.02
Panel C. Standard deviations of the innovations												
$\sigma_{g_z}^*$	Persistent technology	I	0.05	2	0.02	0.009	0.02	0.009	0.02	0.009	0.02	0.009
σ_{ϵ}^*	Transitory technology	I	0.1	2	0.34	0.031	0.27	0.035	0.28	0.035	0.28	0.036
σ_w^*	Wage markup	I	0.1	2	0.49	0.058	0.51	0.057	0.50	0.052	0.51	0.053
σ_p^*	Price markup	I	0.1	2	0.04	0.006	0.04	0.007	0.04	0.007	0.05	0.007
σ_{ε}^*	Monetary policy	I	0.1	2	0.12	0.011	0.10	0.009	0.10	0.009	0.10	0.009
$\sigma_{\bar{\pi}}^*$	Inflation target	I	0.05	2	0.04	0.012	0.03	0.013	0.03	0.012	0.06	0.013
σ_g^*	Government spending	I	0.1	2	0.44	0.034	0.46	0.036	0.46	0.036	0.55	0.044
σ_{μ}^*	Marginal efficiency of investment	I	0.1	2	0.45	0.071	0.46	0.114	0.49	0.132	0.48	0.128
σ_b^*	Intertemporal preference	I	0.1	2	0.15	0.021	0.14	0.019	0.12	0.018	0.11	0.021
$\sigma_{\theta_e}^*$	Entrepreneurial net worth	I	0.1	2	–	–	1.12	0.087	–	–	1.16	0.118
$\sigma_{\sigma_e}^*$	Entrepreneurial riskiness	I	0.1	2	–	–	0.03	0.005	–	–	0.03	0.004
$\sigma_{\theta_b}^*$	Banking net worth	I	0.1	2	–	–	–	–	1.57	0.139	1.78	0.155
σ_{ϖ}^*	Banking riskiness	I	0.1	2	–	–	–	–	6.88	0.629	6.43	0.730

Note: Estimated parameters are based on two independent Metropolis–Hastings chains of 500,000 iterations, with a 20 percent burn-in.

tions for two chains in order to numerically find the parameters that maximize the log-posterior function.

Several features of the parameter values in Tables 4.5 and 4.6 are worth emphasizing. The most relevant results are the values taken by $\{F(\bar{\omega}), F(\bar{\omega}^*)\}$ and $\{\mu, \mu^*\}$. The prior and posterior comparison of the standard deviations shows that there is a fair amount of information about the quarterly bankruptcy rate and somewhat less about the monitoring cost fraction in my data. The empirical bankruptcy rate for Australia and the U.S. is (2.62, 3.38) percent a year. Compared to the baseline result there is a larger difference in the estimated bankruptcy rate of the EFP model with this empirical value. Whereas estimated values for Australia cannot be found in the literature, the number for the U.S. from both models is in line with those in some previous studies, e.g. 3 percent annualized in BGG (1999). Given institutional features (e.g. creditor rights and judicial efficiency) equivalent across the two countries, the empirical bankruptcy numbers are directly comparable between Australia and the U.S. The monitoring cost fractions of (0.235, 0.214) estimated for Australia are lower, albeit with lower rates of bankruptcy, than the estimates (0.312, 0.301) of the U.S. The estimates for Australia are close to the 6.46% percent of direct bankcruptcy costs that is proxied by the average cost of closing a business for a group of developed small-open economies in the Doing Business database of the World Bank. My U.S. estimates are in the upper value range of other studies working on the United States. For example, Christiano, Motto, and Rostagno (2014) obtain the 0.215 value from Bayesian estimation of a closed economy model with BGG-type financial frictions. My high monitoring cost estimates should be treated as a broad indicator that financial frictions are at work in developed economies, possibly even more so in the U.S.

The estimated elasticity of the cost of investment adjustment in the friction models is higher than assumed a priori and than that in the Pure model, suggesting a slower response of investment to changes in the value of capital. In addition, the estimated high mode of the elasticity of capital utilization cost implies that it is extremely costly to change the utilization of capital in the presence of financial frictions. The estimates of the Taylor rule suggest that the RBA and FED adjusted the nominal policy rate in response to the inflation more than proportionately in the financial friction environment so as to influence the real interest rate but placed smaller weight on the GDP growth. Turning to exogenous shock processes, all shocks are quite persistent except for the markup shocks. The estimates of the shock processes are generally similar across the friction models, but in the EFP model the MEI shock has lower autocorrelation and volatility than in the Baseline and ICC models. The mean of the standard errors of the shocks is higher in the Baseline and ICC models than in the EFP model, except for the standard deviation of shocks to technology level and inflation target.

4.3.4 Marginal likelihood

I evaluate the relative performance of the models by comparing their implication for the marginal likelihood of the common dataset. According to the first row in Table 4.5, the

Table 4.5: Log Marginal Likelihood

Model Variants	Marginal Likelihood
Baseline	−4573.15
EFP	−4884.10
ICC with financial frictions on all types of loan	−4771.97
EFP with lending−borrowing spread series	−4861.75
ICC with financial frictions on entrepreneurial loan alone	−4802.08

Note: The model variants with the same dataset are compared by the marginal likelihood, which is computed using Geweke's (1999) modified harmonic mean estimator. By contrast, for different models estimated with different sets of financial series I evaluate the marginal data density using a Laplace approximation at the posterior mode. The computations are based on a Monte Carlo Markov chain of length 500,000 for each model.

log marginal likelihood of my Baseline model is −4573.85. The second and third rows show that with financial frictions *à la* BGG or GK, the fit of the satellite models decreases significantly. In particular, the marginal likelihood drops roughly 310 and 200 log points for the EFP and ICC models, respectively. The larger deterioration in fit from dropping either of the financial frictions, comes from the model with financial frictions between banker and entrepreneur. Financial frictions on this relationship reduce 110 additional log points to the fit below what is achieved by remaining financial frictions on the household−banker relationship.

Using different proxies for the financial frictions may affect the goodness of fit. Thus I give the two satellite friction models a fair competition chance in terms of fit. Therefore I use observables for the lending−deposit spread instead of the borrowing−riskless wedge in the re-estimation of the EFP model. That attempt adds a little to model fit using entrepreneurial spread. In particular, the marginal likelihood increases roughly by 22 log points. On the other hand, the literature on demand-side financial frictions focuses solely on funding for entrepreneurs, so I force the ICC model to take a fair competition chance in terms of fit by considering the case where only entrepreneurial loans are subject to the moral hazard problem, in the spirit of Gertler and Karadi (2011). That reduces 30 log points compared to the case of all types of loans subject to the moral hazard problem in the ICC model, while it still adds 60 log points to fit beyond the second EFP model. However, all variants of the two satellite friction models achieve lower fit than the Baseline model.

To sum up, three results can be inferred from the analysis of findings in Table4.5. First, it appears that a combination of two types of financial frictions improves the ability of the model from the overall measure of goodness of fit. Second, the incorporation of financial frictions arising in the banking sector results in better performance, if one chooses one of two types of financial frictions. Third, financial frictions on all types of loans show the better performance between the two alternative GK models.

4.3.5 Steady state

I now assess which of the estimated models is the most reliable representation of the two economies by comparing their steady-state properties to the data. Table 4.6 reports selected model variables and ratios evaluated at each model's posterior mode, along with their empirical counterparts. Overall, the models and the data match well. Two discrepancies lie in the inflation rate and the short-term riskless rate, which are lower in the data. This can be explained by the zero lower bound monetary policy for an extended period of time since the latest financial crisis. It is therefore not surprising that the models don't perform well on these dimensions. Another exception to the goodness of fit is the somewhat low ratio of capital stock to GDP in the friction models, which results partly from the effects of financial frictions on capital accumulation, even more so than in the Baseline model due to the enhanced accelerator effect. I deliberately do not include the data's relevant ratios in computing the posterior distribution of the model parameters because I want to make a comparison between the pure open economy model and the friction models on a level playing field.

The leverage elasticity of external risk premium implied by the mode of my estimated EFP and Baseline models is within the range of 0.04–0.08 in other studies that work with developed countries. Interestingly, the Australian non-financial business sector has a lower leverage multiple and, simultaneously, smaller elasticity of the external finance premium to the leverage multiple compared to the U.S. counterpart, suggesting that U.S. firms rely more on external finance associated with higher costs. This is because with higher leverage the U.S. entrepreneurial sector imposes a greater cost on its banks in the event of default. Since there's no empirical evidence of the feasible value range of divertible banking asset fraction, it suffices to say that relatively low values are broadly in line with my interpretation of this parameter as a fractional asset diverted for discretionary spending.[26]

4.3.6 Business cycle properties

This subsection investigates which model better captures the statistical properties of the data by comparing the second moments generated by the models with those observed in the actual data. Table 4.7 documents the model's performance along the empirical moments.

I first consider macroeconomic variables. The standard deviation comparison shows that the friction models help to improve the goodness of fit of some moments. In particular, they do a good job in replicating the variance of GDP, particularly the Baseline model. As in the data, investment in these models is more volatile than GDP, though still a bit more than its empirical counterpart. Also, they do a fairly good job in accounting for the volatility of hours worked. The Baseline model, however, exacerbates somehow the volatility of consumption while slightly underestimating that of wages. As regards the interest rate and inflation, the Baseline model is overall as good as the ICC counterpart, while both the EFP and Pure models overpredict the variation of these variables. The ICC model implies a larger variance of exports compared to the Baseline model, though both models still undershoot that in the data. By contrast, the other two models overpredict

[26] This parameter is interpreted as the fraction of stolen assets in Gertler and Karadi (2011), where it is calibrated up to 0.381.

Table 4.6: Steady-state Properties, Models at Posteriors versus Data

Variable	Australia					United States				
	Pure	EFP	ICC	Baseline	Data	Pure	EFP	ICC	Baseline	Data
Discount factor						0.9983	0.9983	0.9983	0.9983	
Investment to GDP ratio	0.27	0.28	0.28	0.27	0.26	0.28	0.28	0.27	0.26	0.25
Consumption to GDP ratio	0.53	0.50	0.51	0.52	0.52	0.52	0.51	0.53	0.54	0.56
Government spending to GDP ratio	0.21	0.22	0.22	0.22	0.23	0.20	0.21	0.20	0.20	0.19
Export to GDP ratio	0.20	0.20	0.20	0.20	0.20					
Import to GDP ratio	0.21	0.20	0.21	0.21	0.21					
Capital stock to GDP ratio[1]	10.87	8.69	9.23	8.03	12.10	9.87	7.99	8.45	7.31	10.30
Inflation (APR)	2.48		2.50	2.55	2.58	2.16		2.24	2.26	2.19
Short-term risk-free rate (APR)	4.76		4.75	4.80	4.80	4.44		4.49	4.27	3.92
Credit velocity[2]		1.68	1.29	1.25	1.20		1.71	1.56	1.56	1.63
Entrepreneurial leverage multiple		1.98		1.95	1.89		2.01		2.08	1.95
Elasticity of the finance premium		0.07		0.05			0.08		0.06	
Banking leverage multiple			6.53	6.74	6.42			5.80	5.98	5.65
Divertible fraction of assets			0.15	0.17				0.17	0.18	

[1] Capital stock includes private nonresidential and residential fixed assets, stock of private inventories, and stock of consumer durables (*Source*: ABS and BEA).
[2] Credit velocity is computed as annual nominal GDP over total credit, where total credit in each economy is respectively defined as credit market instruments liabilities of non-financial corporations (*Source*: Finance and Wealth Accounts, ABS) and the sum of credit market instruments liabilities of non-financial corporate sector plus credit market instruments liabilities of noncorporate sector (*Source*: Flow of Funds Accounts, FRB).

this variability, particularly the Pure model. The variance of imports is somewhat smaller and closer to the data in the Baseline and ICC models, while the EFP model displays a relatively high figure similar to that in the Pure model. For the real exchange rate, the three friction models induce variance that comes close to that in the data. Meanwhile, the Pure model exacerbates the variability of this variable, which is consistently associated with its more persistent behavior in the absence of financial friction.

The Baseline, ICC and Pure models perform similarly at reproducing persistence in the data. In particular, all these models are successful at matching the autocorrelation of GDP, investment and consumption. Meanwhile, the EFP model implies lower persistence for some observables. As regards the cross-country correlation, the Baseline model either improves the performance relative to the Pure model or it has similar implications. The satellite friction models generally do a worse job than either the Baseline or Pure models. Also, they match the cross-correlation of wages but generate a far too low cross-correlation of hours worked.

I now focus on financial variables. Overall, the friction models are able to replicate the behavior of financial series, both in terms of their volatility and cyclicality. The Baseline model outperforms the satellite friction models in terms of matching the volatility and persistence of both entrepreneurial and banking spreads. The difference is most evident in the case of the entrepreneurial spread: the EFP model generates a much more volatile and less persistent series than its empirical counterpart. The failure of my EFP model to match the volatility of the entrepreneurial spread is in line with recent results of Christiano, Motto, and Rostagno (2014) and FuentesAlbero (2012) who rely on estimated closed economy models containing a BGG financial accelerator mechanism with shocks directly affecting the contracing problem between the entrepreneur and the bank in order to replicate the observed variation. A similar result is also obtained by Nolan and Thoenissen (2009). Meanwhile, with richer interactions between the real and financial sectors my Baseline model offers an alternative way to achieve this goal. The ICC model generates far too much volatility for banking spread while the Baseline model closely matches the data. The relatively low volatility of entrepreneurial net worth in the Baseline model also represents an improvement on the EFP model. However, the autocorrelation of entrepreneurial net worth is very similar across the EFP and Baseline models. The same is true for the persistence of credit in the Baseline and ICC models.

Unsurprisingly, the countercyclicality of the spread in the friction models is in line with the data. The Baseline and EFP models match the procyclicality of entrepreneurial net worth, though it is a bit too low in the latter. Simultaneously, the friction models are able to reproduce the procyclical behavior of the credit in the data. However, the Baseline and ICC models generate (somewhat less) procyclical credit, while it is much too low in the EFP model. Finally, the Baseline model performs well along the cross-country correlation of the financial variables. It better captures the negative comovement of Australian spreads with U.S. GDP, though all friction models generate more countercyclical spreads than their empirical counterpart. The procyclicality of entrepreneurial net worth is higher in the

Table 4.7: Data and Model-implied Moments

Variables	By Data				By Models															
	SD	AC	CO	CR	SD				AC				CO				CR			
Australia																				
GDP	0.11	0.96	1	0.98	0.35	0.22	0.15	0.14	0.87	0.88	0.90	0.91	1				0.85	0.75	0.83	0.95
I	0.14	0.94	0.94	0.95	0.23	0.20	0.18	0.17	0.90	0.82	0.91	0.91	0.89	0.88	0.90	0.89	0.83	0.86	0.89	0.92
C	0.11	0.96	0.99	0.98	0.21	0.18	0.16	0.26	0.91	0.90	0.94	0.93	0.92	0.80	0.83	0.95	0.93	0.84	0.90	0.93
H	0.02	0.88	0.54	0.61	0.14	0.20	0.10	0.10	0.78	0.80	0.93	0.90	0.15	0.45	0.46	0.48	0.41	0.21	0.28	0.50
W	0.09	0.95	0.98	0.95	0.17	0.20	0.15	0.06	0.91	0.82	0.92	0.93	0.93	0.87	0.93	0.94	0.86	0.83	0.85	0.91
R	0.27	0.90	-0.38	-0.29	0.34	0.42	0.31	0.29	0.88	0.83	0.91	0.91	-0.19	-0.32	-0.27	-0.32	-0.10	-0.17	-0.15	-0.22
π_c	0.19	0.50	0.24	0.27	0.28	0.27	0.22	0.22	0.41	0.42	0.47	0.49	0.26	0.22	0.20	0.26	0.41	0.22	0.34	0.32
X	0.17	0.93	0.90	0.88	0.28	0.26	0.14	0.06	0.92	0.89	0.91	0.92	0.71	0.81	0.84	0.87	0.82	0.85	0.86	0.89
M	0.16	0.94	0.96	0.97	0.22	0.14	0.23	0.14	0.92	0.85	0.93	0.94	0.71	0.80	0.86	0.93	0.70	0.84	0.95	0.97
RER	0.18	0.94	-0.79	-0.70	0.21	0.27	0.18	0.16	0.93	0.67	0.86	0.89	-0.61	-0.63	-0.82	-0.77	-0.41	-0.82	-0.79	-0.78
N_e	0.17	0.89	0.34	0.49	–	0.27	0.42	0.25	–	0.73	0.45	0.87	–	0.27	0.10	0.36	–	0.35	0.23	0.45
Spr_e	0.22	0.87	-0.37	-0.52	–	0.36	–	0.28	–	0.68	–	0.86	–	-0.26	–	-0.34	–	-0.46	–	-0.45
L	0.36	0.97	0.97	0.95	–	0.52	0.40	0.40	–	0.51	0.93	0.93	–	0.75	0.95	0.96	–	0.23	0.90	0.92
Spr_b	0.17	0.88	-0.11	-0.21	–	–	0.24	0.19	–	–	0.86	0.87	–	–	-0.09	-0.10	–	–	-0.18	-0.19
United States																				
GDP^*	0.09	0.96	1		0.21	0.14	0.15	0.12	0.93	0.93	0.94	0.95	1							
I^*	0.12	0.95	0.61		0.23	0.18	0.17	0.14	0.81	0.91	0.93	0.94	0.52	0.83	0.91	0.92				
C^*	0.11	0.97	0.98		0.23	0.19	0.21	0.22	0.94	0.95	0.96	0.97	0.92	0.90	0.94	0.96				
H^*	0.07	0.98	-0.50		0.25	0.15	0.19	0.18	0.91	0.91	0.95	0.92	0.59	0.40	0.58	0.53				
W^*	0.10	0.97	0.97		0.30	0.23	0.19	0.08	0.91	0.94	0.96	0.95	0.86	0.93	0.97	0.96				
R^*	0.55	0.97	-0.46		0.63	0.63	0.58	0.57	0.73	0.88	0.91	0.96	-0.21	-0.35	-0.40	-0.43				
π^*	0.20	0.57	0.12		0.28	0.26	0.18	0.19	0.50	0.45	0.47	0.54	0.18	0.16	0.17	0.14				
N_e^*	0.30	0.94	0.82		–	0.34	0.45	0.36	–	0.92	0.89	0.91	–	0.84	0.65	0.78				
Spr_e^*	0.20	0.89	-0.59		–	0.18	–	0.25	–	0.82	–	0.85	–	-0.42	–	-0.48				
L^*	0.17	0.97	0.96		–	0.29	0.21	0.19	–	0.88	0.94	0.95	–	0.70	0.89	0.92				
Spr_b^*	0.46	0.94	-0.32		–	–	0.43	0.50	–	–	0.95	0.95	–	–	-0.21	-0.26				

Note: SD – standard deviation, AC – autocorrelation, CO – correlation with country-specific GDP, CR – cross-country correlation with U.S. GDP. Results in each second moment are presented in the following way: the first entry is generated by the Pure model, the second entry by the EFP model, the third entry by the ICC model, and the fourth entry by the Baseline model.

Baseline and EFP models than in the data, while the Baseline and ICC models generate relatively low procyclicality in credit. However, the Baseline model still improves on the satellite friction models since its net worth and credit series are more countercyclical.

Summing up, the Baseline model is most capable of matching key business cycle moments from the real and financial sides of the Australian and U.S. economies. In contrast, both the EFP and ICC models generally perform less satisfactorily, particularly the former. These results demonstrate that the two asymmetric-country model containing two types of financial frictions serves well in accounting for some of the main business cycle features.

4.4 Applications

4.4.1 Impulse response functions

I devote this subsection to analyzing the role of types of financial frictions in the transmission mechanism and comparing the economic responses of different models to financial shocks. This financial shock presentation is motivated by the fact that financial shocks are contributors of particular interest to real and nominal fluctuations after the GFC. All shocks are set to produce a downturn.

Net worth shocks

I first examine how the two economies respond to financial shocks that cause exogenous declines in net worth of entrepreneurs and banks. Figure 4.4.1 jointly displays the responses of three friction models to these temporary shocks.

A reduction in the retention ratio of entrepreneurial earnings means that more earnings are redistributed toward shareholder consumption while there are fewer financial resources to purchase new capital. As a result capital demand from entrepreneurs falls, which pushes down the price of capital. Entrepreneurial net worth continues to fall as declines in the price of capital reduce the value of entrepreneurial net worth. This leads to standard financial accelerator effects. The spread rises in response to the declines in net worth, which results in a weaker demand for capital because it is more costly to obtain bank loans. Note that as investment goods is a key input into the production of raw capital, it follows that investment declines. With this decline in the purchase of goods, GDP and household consumption decrease as well. In equilibrium, the smaller decline in net worth than in the value of the capital stock (not shown) implies that entrepreneurs reduce borrowings from banks. In order to meet the decreased demand for loans, credit falls while leverage multiple rises.

While the same sequence of responses is present in the EFP and Baseline models, loan supply in the Baseline model is less elastic. The rise in deposits and leverage multiple of the banking sector requires higher profitability, and thus a higher weighted spread. Hence, the entrepreneurial spread rises by more in the Baseline model than in the EFP model, implying a stronger drop in the price of capital and thus a larger rise in the entrepreneurial leverage multiple, which causes a further increase in entrepreneurial spread. In addition,

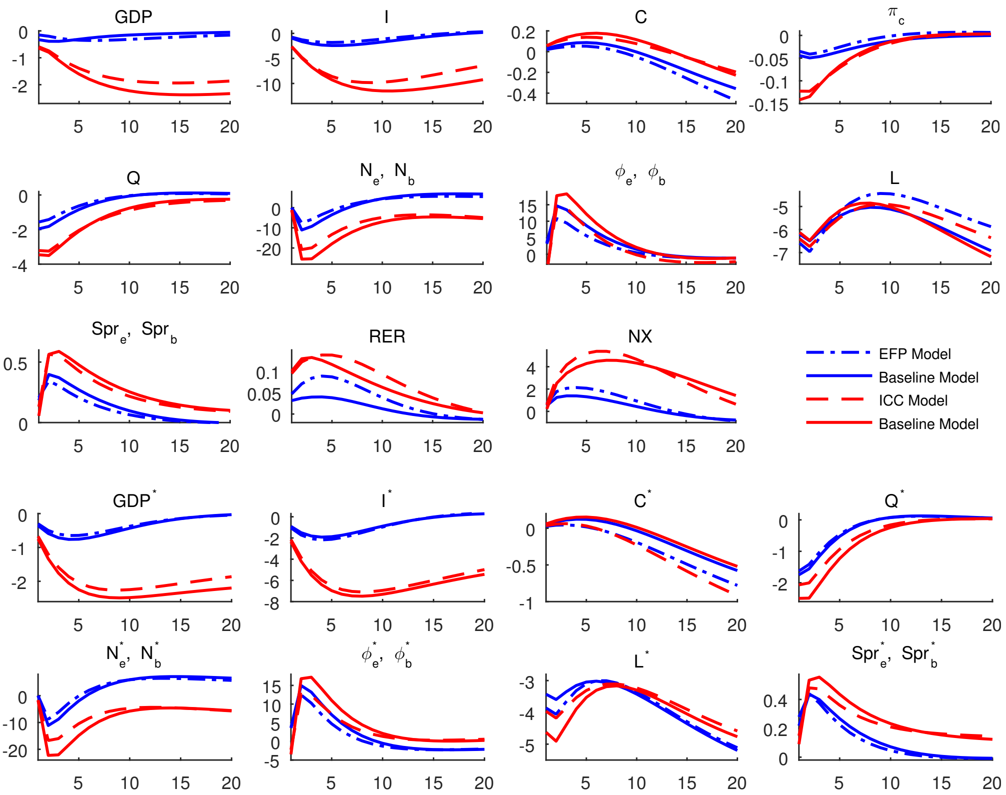

Figure 4.4.1: IRFs to four net worth shocks – Australia (upper panel) and the U.S. (lower panel).

rises in other components of the weighted spread cause a steeper increase of the banking leverage multiple in the Baseline model than in the EFP model's passive banking sector, which enhances the adverse effect from the jump in entrepreneurial spread of the former model. Therefore GDP declines more in the Baseline model as a result of stronger declines in investment and household consumption.

The exogenous shock to banking net worth increases the banking leverage multiple, leading to a higher weighted spread. A rise in borrowing costs decreases demand for capital, which in turn lowers investment and the price of capital. A drop in the price of capital results in a drop in entrepreneurial net worth. Household consumption initially tend to rise as the drop in banking net worth raises shareholder consumption (not shown), but this tendency is quickly overcompensated for by a strong decline in household consumption in response to the fall in the policy rate caused by the economic downturn. The demand for entrepreneurial loans adjusts only gradually to the decreased credit supply. As a result credit declines persistently and lags significantly behind GDP and investment. Meanwhile, the rising profitability of the banking sector implies that its net worth gradually recovers.

The contraction of investment and GDP is larger in the banking friction environment than with the environment of entrepreneurial frictions. This is because EFP entrepreneurs – bearing capital losses as the price of capital declines – are leveraged much less than ICC and Basline banks that also bear this risk. Further, the resulting contraction is always larger in the environment containing two friction types. Entrepreneurs with constrained leverage bear more loss as a result of borrowing from constrained banks, which implies a double financial accelerator effect in the Baseline model. Hence the percentage decline in investment and GDP caused by a given decline in the price of capital in the Baseline model is larger than that caused by the same decline in the price of capital in each respective satellite model.

Riskiness shocks

Figure 4.4.2 jointly displays the impulse response to an entrepreneurial riskiness shock in the EFP model, a banking riskiness shock in the ICC model, and both shocks in the Baseline model.

With a jump in idiosyncratic riskiness, the probability of a low default threshold increases. Banks therefore raise the interest rate on entrepreneurial loans to cover the resulting costs. Entrepreneurs respond by borrowing less, so lending declines. Capital demand from entrepreneurs falls due to more costly funding, which pushes down the price of capital and decreases investment demand. Entrepreneurial net worth falls too because entrepreneurs suffer the loss associated with the drop in the price of capital and because their rental income falls with the decline in economic activity. The fall in entrepreneurial net worth magnifies the impact of the jump in idiosyncratic riskiness through standard accelerator effects.[27] As a result, GDP and household consumption decline. The entrepreneurial riskiness shock therefore leads to a countercyclical spread and procyclical investment, consumption, inflation, credit, and entrepreneurial net worth. Since the lower entrepreneurial net worth raises the demand for entrepreneurial loans, there is a partial offsetting effect on credit. The net impact of all relevant effects on credit is negative but the decline is muted. In equilibrium credit falls less than entrepreneurial net worth, in percentage terms. Compared to the net worth shock, the response of the economy to the riskiness shock is small and less persistent.

4.4.2 Cross-border spillovers

The real test of the model structure is to what extent the models can account for the influence of foreign-sourced disturbances on the home economy. This subsection presents the cross-border causes of home unconditional variances, showing that foreign shocks play a relatively larger role in my friction models, especially the model with both types of financial frictions.

Table 4.8 decomposes the estimated contribution of purely U.S. stationary shocks to the variability of Australian series shares for four models. For each of three friction models, I document the importance of the U.S. disturbances by presenting the sum of their contributions under three categories: financial shocks, non-financial shocks, and all shocks. Generally the purely foreign stationary shocks matter for the variance decomposition in the Pure model. Taken together, the conventional U.S. disturbances have effects more

[27] There is another effect resulting from a temporary rise in entrepreneurial riskiness. In particular, the decline in credit associated with the initial reduction in entrepreneurial leverage multiple leads to a reduction in purchases of new capital by entrepreneurs. This, in turn, causes a decrease in capital production of households which results in a fall in the price of capital.

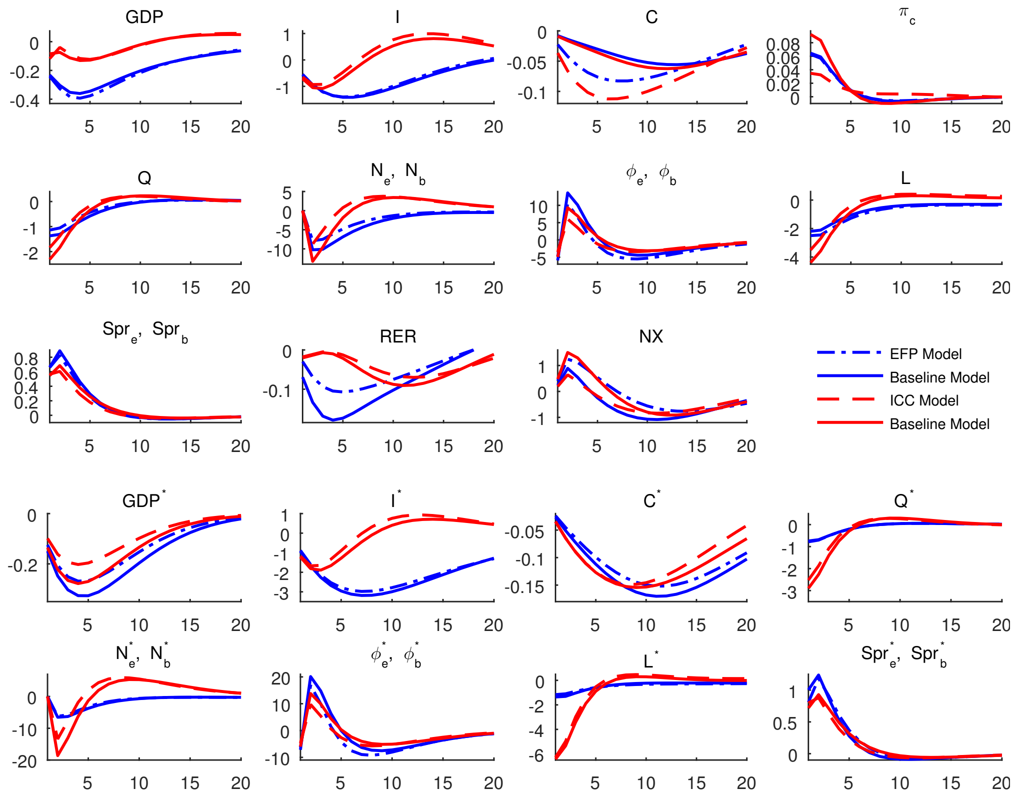

Figure 4.4.2: IRFs to four riskiness shocks – Australia (upper panel) and the U.S. (lower panel).

than 2% on the variation of the Australian series. Nevertheless the variance shares due to all conventional shocks fall short of those observed in the data, implying the Pure model's inability to account for cross-border synchronisation of business cycles.

The focal point is the friction models' ability in generating the share of Australian macroeconomic variability explained by all disturbances originating in the U.S. Frictions on non-financial firms in the EFP model (columns 3) have a limited effect on the variance decomposition of hours worked, wages, and inflation but help improve the U.S. share in GDP, investment, consumption, interest rate, and to a lesser extent open economy variables. Although the variance shares of most series attributed to all U.S. shocks are still much lower than the empirical counterparts in the data, the EFP model's cross-border spillover rises relative to the Pure model for many variables. Meanwhile, with financial frictions in the banking sector in the ICC model (columns 4), the fraction of variance in Australian GDP attributable to U.S. shocks climbs to 18%. In addition, the foreign share of trade variables and the real exchange rate increase significantly. These results reveal that the magnitude of the cross-border spillover can be significantly raised by including banking sectors with financial frictions on a range of loans.[28]

A comparison with the last column, which replicates my Baseline model, yields the central result of this subsection. The largest increase in the share of variation in home

[28] Admittedly, the inclusion of also foreign lending to home entrepreneurs and banks would be a better modeling device to capture the size of spillover effects as well as foreign borrowings of the Australian private sector.

Table 4.8: Estimated Contribution of U.S. Disturbances to the Variability of Australian Series (*Percent*)

Series \ Model	Pure	EFP	ICC	Baseline
GDP	5	4 | 5 | 9	10 | 8 | 18	14 | 6 | 20
Investment	3	5 | 3 | 8	9 | 5 | 14	12 | 4 | 16
Consumption	2	3 | 3 | 6	6 | 4 | 10	7 | 4 | 11
Hours	2	1 | 2 | 3	2 | 5 | 7	3 | 5 | 8
Wage	1	2 | 5 | 7	3 | 5 | 8	3 | 6 | 9
Interest rate	5	5 | 7 | 12	7 | 8 | 15	8 | 9 | 17
Inflation	11	5 | 7 | 12	7 | 11 | 18	8 | 10 | 18
Export	15	2 | 22 | 24	12 | 15 | 27	13 | 15 | 28
Import	21	5 | 20 | 25	23 | 12 | 35	27 | 9 | 36
Real exchange rate	16	7 | 18 | 25	12 | 14 | 26	16 | 12 | 28
Entrepreneurial net worth		26 | 5 | 31	– | – | –	27 | 6 | 33
Entrepreneurial spread		12 | 5 | 17	– | – | –	17 | 3 | 20
Credit		– | – | –	15 | 7 | 22	17 | 6 | 23
Banking spread		– | – | –	15 | 3 | 18	17 | 3 | 20

Note: Unconditional variance decompositions are generated by each model evaluated at the posterior mode. For the friction models, the contribution of the U.S. shocks is presented in the following way: the first entry is the sum of "financial" shocks, the second entry is the sum of "other" shocks, and the third entry is the total contribution of both financial and other shocks. "Financial" represents riskiness and net worth shocks in the entrepreneur sector of the EFP model or the banking sector of the ICC model, while it encompasses these four shocks in the baseline model. "Other" includes conventional shocks, the country risk premium shock, and the degree of technology asymmetry. The only entry in the Pure model corresponds to the total contribution of "other" shocks.

GDP due to foreign shocks occurs with financial frictions on both non-financial borrowers and banks, and in this case up to 20% of Australian GDP fluctuations are accounted for by all U.S. shocks. The fraction of variation attributed to U.S. financial shocks is now larger than in the other friction models, particularly for GDP, investment, and spreads. In particular, these shocks explain 14%, 12%, and 17% of fluctuations for GDP, investment, and entrepreneurial spread or banking spread. Therefore the combination of two types of foreign financial frictions increase the influence of U.S. disturbances abroad, as made evident by the last column of Table 4.8. This helps explain why the Baseline model could fully reconcile model-implied moments and empirical counterparts observed in the same data for the home economy.

To sum up, cross-border variance decompositions show that the share of variation in Australian series due to all shocks sourced in the U.S. economy is very non-negligible, particularly in the Baseline model. This finding is clearly consistent with the model-implied cross-country correlations in Subsection 4.3.6.

4.4.3 Driving forces of economic fluctuations

To examine the relative importance of shock groups, I analyze the results of the variance decomposition in the friction models. Table 4.9 reports the percentage of variance in key variables explained by my different groups of shocks.

On the whole, the picture of variance decomposition is very similar for Australia and the U.S. The group of within-country financial shocks accounts for a substantial portion

Table 4.9: Variance Decomposition by Shock Category (*Percent*)

<table>
<tr><th>Series \ Model</th><th>Pure</th><th>EFP</th><th>ICC</th><th>Baseline</th></tr>
<tr><td>Australia</td><td></td><td></td><td></td><td></td></tr>
<tr><td>GDP</td><td>40 | 42 | 18</td><td>27 | 29 | 32 | 12</td><td>23 | 29 | 32 | 16</td><td>24 | 27 | 31 | 18</td></tr>
<tr><td>Investment</td><td>17 | 52 | 31</td><td>10 | 45 | 18 | 27</td><td>12 | 30 | 26 | 32</td><td>13 | 30 | 21 | 36</td></tr>
<tr><td>Consumption</td><td>12 | 60 | 28</td><td>11 | 48 | 14 | 27</td><td>10 | 44 | 16 | 30</td><td>9 | 45 | 17 | 29</td></tr>
<tr><td>Hours</td><td>61 | 27 | 12</td><td>60 | 14 | 16 | 10</td><td>59 | 12 | 18 | 11</td><td>57 | 17 | 17 | 9</td></tr>
<tr><td>Wage</td><td>71 | 5 | 24</td><td>48 | 17 | 19 | 16</td><td>45 | 14 | 21 | 20</td><td>46 | 15 | 21 | 18</td></tr>
<tr><td>Interest rate</td><td>20 | 35 | 45</td><td>8 | 45 | 30 | 17</td><td>7 | 33 | 38 | 22</td><td>7 | 27 | 40 | 26</td></tr>
<tr><td>Inflation</td><td>26 | 51 | 23</td><td>40 | 25 | 17 | 18</td><td>36 | 20 | 19 | 25</td><td>28 | 25 | 22 | 25</td></tr>
<tr><td>Export</td><td>7 | 18 | 75</td><td>18 | 9 | 60 | 13</td><td>11 | 2 | 67 | 20</td><td>10 | 5 | 69 | 16</td></tr>
<tr><td>Import</td><td>4 | 25 | 71</td><td>8 | 31 | 52 | 9</td><td>6 | 21 | 59 | 14</td><td>5 | 24 | 57 | 14</td></tr>
<tr><td>Real exchange rate</td><td>6 | 14 | 80</td><td>3 | 8 | 79 | 10</td><td>2 | 11 | 72 | 15</td><td>3 | 9 | 78 | 10</td></tr>
<tr><td>Entrepreneurial net worth</td><td></td><td>22 | 11 | 37 | 30</td><td></td><td>8 | 21 | 31 | 40</td></tr>
<tr><td>Entrepreneurial spread</td><td></td><td>21 | 9 | 28 | 42</td><td></td><td>12 | 18 | 25 | 45</td></tr>
<tr><td>Credit</td><td></td><td></td><td>12 | 17 | 31 | 40</td><td>12 | 17 | 29 | 42</td></tr>
<tr><td>Banking spread</td><td></td><td></td><td>15 | 17 | 29 | 39</td><td>15 | 17 | 28 | 40</td></tr>
<tr><td>United States</td><td></td><td></td><td></td><td></td></tr>
<tr><td>GDP</td><td>53 | 47 | –</td><td>40 | 43 | – | 17</td><td>36 | 42 | – | 22</td><td>36 | 38 | – | 26</td></tr>
<tr><td>Investment</td><td>29 | 71 | –</td><td>20 | 50 | – | 30</td><td>18 | 43 | – | 39</td><td>17 | 31 | – | 52</td></tr>
<tr><td>Consumption</td><td>27 | 73 | –</td><td>8 | 70 | – | 22</td><td>10 | 65 | – | 25</td><td>11 | 60 | – | 29</td></tr>
<tr><td>Hours</td><td>72 | 28 | –</td><td>70 | 16 | – | 14</td><td>68 | 16 | – | 16</td><td>65 | 20 | – | 15</td></tr>
<tr><td>Wage</td><td>75 | 25 | –</td><td>60 | 20 | – | 20</td><td>64 | 17 | – | 19</td><td>57 | 25 | – | 18</td></tr>
<tr><td>Interest rate</td><td>33 | 67 | –</td><td>20 | 55 | – | 25</td><td>18 | 52 | – | 30</td><td>17 | 49 | – | 34</td></tr>
<tr><td>Inflation</td><td>39 | 61 | –</td><td>39 | 46 | – | 15</td><td>42 | 37 | – | 21</td><td>40 | 32 | – | 28</td></tr>
<tr><td>Entrepreneurial net worth</td><td></td><td>24 | 28 | – | 48</td><td></td><td>11 | 29 | – | 60</td></tr>
<tr><td>Entrepreneurial spread</td><td></td><td>25 | 25 | – | 50</td><td></td><td>15 | 27 | – | 58</td></tr>
<tr><td>Credit</td><td></td><td></td><td>23 | 17 | – | 60</td><td>18 | 18 | – | 64</td></tr>
<tr><td>Banking spread</td><td></td><td></td><td>25 | 20 | – | 55</td><td>22 | 26 | – | 52</td></tr>
</table>

Note: Unconditional variance decompositions are generated by each model evaluated at the posterior mode. In all models, the first entry corresponds to the “supply” category containing technology shocks and shocks to the markups; the second entry corresponds to the “demand” category including shocks to intertemporal preference, marginal efficiency of investment, government spending, monetary policy and inflation target; and the third entry corresponds to an “external” category including country risk premium, commodity demand, relative commodity price, asymmetric technology, foreign financial and non-financial shocks. For the friction models in particular, the fourth entry is a “financial” category which includes domestic banking riskiness and net worth shocks.

of business cycle fluctuations in each of countries, though the highest share of variance in standard macroeconomic variables is driven by conventional shocks. Consider the Baseline model. The within-country financial shocks explain more than a third of the volatility of investment in Australia and 52% of that volatility in the U.S. Regarding financial variables, the financial driving force is even more substantial, accounting for more than 40% of fluctuations. It is noteworthy that, the contributions of financial shocks to open-economy business cycles are very different from the results for the closed economy. In particular, the importance of financial shocks is relatively high for both financial and standard macroeconomic variables in the U.S. This is because external shocks crowd out the importance of domestic financial disturbances on Australian business cycles, in which U.S. financial shocks play a very non-negligible role as analyzed in Subsection 4.4.2.

In summary, the cross-border and cross-country variance decomposition analysis quantifies the sense in which financial shocks in the Baseline model generate dynamics that best resemble business cycles. This is the principal reason my empirical analysis assigns such a large role to financial shocks originating from both sides of the credit market in their account of business cycles.

4.5 Concluding remarks

This paper has sought to contribute to the growing literature on DSGE models with financial frictions by developing a macro-finance model that combines two main financial friction approaches in the business cycle framework of two asymmetric countries. The model has integrated a demand-side approach which stresses financial frictions on constrained entrepreneurs with a supply-side approach which stresses the role of banks with constrained leverage. Financial frictions in my model therefore are not only operating via entrepreneurs' balance sheets but also through changes in banks' balance sheets.

I have showed how combining two financial friction approaches is useful for characterizing country-specific business cycles. In particular, whereas all three financial friction models have similar performance in accounting for standard macroeconomic variables, financial series are better explained by the Baseline model. In addition, the additional amplification provided by a double financial accelerator effect allows the Baseline model to improve upon the satellite friction models' ability to match the volatility of the spreads in the data, as well as investment and other variables. The presence of both types of financial friction also amplifies the response of the spreads and the overall economy to financial shocks, as compared to models augmented with either BGG-type or GK-type financial accelerators. My results support the earlier findings of Rannenberg (2016), who used a calibrated model in a closed economy setting. This suggests that the financial friction approaches embedded in the structural asymmetric-country model are helpful in improving empirical performance, in particular at cross-border synchronization.

Of course, the Baseline model remains stylized and should be further developed. In particular, my analysis raises questions about the deeper determinants of the financial shocks identified as being important driving factors of within-country fluctuations and cross-country comovements. Furthermore, one could consider a model extension with home bankers and entrepreneurs subject to the same types of domestic financial frictions when also obtaining funds from abroad, which would help compare the relative importance of home *vis-à-vis* foreign financial frictions in propagating external shocks.

Chapter 5

Conclusion

This thesis has dealt with problems in financial sectors that are a source of business cycle disturbances in the framework of two asymmetric countries. My theoretical work has developed detailed structural models of those financial disturbances, which by nature incorporate and tailor financial friction approaches into an otherwise two asymmetric-country New Keynesian DSGE model. The models are brought under Bayesian extensive empirical scrutiny for Australian and U.S. macroeconomic and financial data.

The first paper worked with financial frictions on the supply side of the credit market. The model focuses on the introduction of an incentive compatibility constraint tied to the expected value of banking funds. The incentive compatibility constraint designed in this paper allows investigation of the effect of an optimal portfolio of loans on macroeconomic and financial aggregates and the role of one of the institutional characteristics of the credit market, namely the banking leverage multiple. It is well known that in pure trade open economies it may be difficult to rationalize the empirically observed international synchronization of business cycles. The presence of this kind of financial friction has important consequences for the cross-border transmission and spillover of shocks, given that the friction model variants' performance, relative to the pure trade open economy model, are better. Moreover, the friction model with full incentive compatibility constraint outperforms its less-constrained variants and the pure trade open economy model in reproducing the cross-border synchronization of business cycles. Notably, country-specific financial shocks explain a substantial portion of economic fluctuations across countries and foreign financial shocks play a non-negligible role in cross-border spillovers.

The second paper compared the resulting performance of model extensions following the extension of the pure trade open economy model with two types of financial frictions. The first model extension incorporates the approach of financial friction at non-financial borrowers in the form of a costly verification problem, while the second includes the approach of financial friction at banks due to the presence of a moral hazard problem. Simultaneously, the two model extensions allow for shocks specific, but comparable, to each financial friction approach. Taking the pure trade open economy model as a benchmark, the empirical exercise evaluates the performance of two friction model versions and the role of each type of financial friction. Comparing the results shows that the presence of financial frictions improves the econometric fit of the pure trade open economy model. The friction model versions also overcome the shortcomings of the pure trade open economy model in reproducing the cross-border synchronization of business cycles. Furthermore, the empirical evidence favors the model version with financial frictions in the banking sector.

In the third paper, the dynamics of the model are simultaneously influenced by two types of financial frictions, which originate from endogenous variations in the balance sheets of constrained entrepreneurs and banks. In particular, entrepreneurs face leverage multiple constraints and thus run up an external finance premium. Changes in idiosyncratic risk, and in net worth, then have a direct impact on entrepreneurs' borrowing conditions. Simultaneously, lending rates are affected by changes in the availablity of funding as asset divertability impairs banks' ability to provide loans. The constraint not only creates an endogenous wedge between the lending rate and deposit rate but also affects the credit supply capacity of the banking sector. This, combined with the fact that a bank's ability to extend loans to non-financial borrowers is positively related to its net worth and expected earnings, contributes to a magnification of shocks. The economic outcome of the model is therefore affected by the coexistence and interaction of different financial accelerator mechanisms. Empirically, combining financial frictions from both sides of the credit market is useful for characterizing within- and cross-country business cycles. In addition, the simultaneous presence of two types of financial frictions amplifies the response of the spreads and the overall economy to financial shocks, as compared to the models excluding either of the two types of financial frictions. Indeed, the additional amplification provided a double financial accelerator effect enhances the model's ability to match the volatility of the spreads in the data, as well as investment and other variables. This suggests that the financial frictions approaches embedded in a structural, two asymmetric-country model is helpful in improving empirical performance, in particular in cross-border synchronization.

To sum up, I have shown in this thesis that modern cross-border New Keynesian DSGE models are able to fit the main macroeconomic and financial data very well in a two asymmetric-country general equilibrium framework, if one incorporates well-developed domestic financial sectors and allows for financial frictions and a sufficient set of non-financial and financial stochastic structure. The results from my thesis support the incorporation of existing financial friction approaches into the business cycle framework in the two asymmetric-country setting. This result is largely stable to various estimations across models and their modifications. I see this robustness as suggesting that cross-border macro-finance modeling is a promising direction along which to bridge the international macroeconomic literature and the financial friction literature. I believe that the thesis makes significant contributions to the process of developing cross-border macro-finance New Keynesian DSGE models that match both data and economic intuition. This should benefit academic and policy-oriented research.

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Appendices

The Appendices contains technical details on the solution, transformation and approximation of my model, as well as the dataset and some additional information not included in the text of the thesis. In particular, I present: A) the optimization problems and FOCs; B) the scaling of variables; C) the equilibrium conditions; D) the steady state; E) the log-linearized equilibriums; F) the normalization of the shocks; G) the details of the dataset; H) the measurement equations.

Uppercase letters denote variables in levels while lowercase ones denote variables after being transformed. State states are lowercase letters without time subscript while lowercase letters with hat and time subscript are log deviations from steady state. I only present the formulation of the Foreign economy where mathematical differences exist, otherwise they take identical forms to those of the Home economy with all variables and parameters denoted by the asterisk "*".

Appendix A

Optimization problems and first order conditions

A.1 Domestic goods producers

Homogeneous goods producer. Profit maximization yields the following demand curve for the variety j:

$$Y_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\frac{\lambda_{d,t}}{\lambda_{d,t}-1}} Y_t \tag{A.1}$$

The aggregate price of the homogeneous goods is a CES aggregate of the prices of the intermediate goods

$$P_t = \left[\int_0^1 P_{j,t}^{\frac{1}{\lambda_{d,t}-1}} dj\right]^{\lambda_{d,t}-1} \tag{A.2}$$

Intermediate goods producers. The monopolist's profit is given by:

$$P_{j,t}Y_{j,t} - Z_{k,t}K_{j,t}[1 + v_K(R_{f,t} - 1)] - W_t h_{j,t}[1 + v_H(R_{f,t} - 1)] \tag{A.3}$$

$$P_{j,t}Y_{j,t} - Z_{k,t}K_{j,t}[1 + v_K(R_t - 1)] - W_t h_{j,t}[1 + v_H(R_t - 1)] \tag{A.4}$$

Cost minimization, in equilibrium, yields the following rental rate:

$$Z_{k,t} = \frac{\alpha}{1-\alpha}\frac{W_t\,[1 + v_H(R_{f,t} - 1)]}{[1 + v_K(R_{f,t} - 1)]}\frac{h_t}{K_t} \tag{A.5}$$

$$Z_{k,t} = \frac{\alpha}{1-\alpha}\frac{W_t\,[1 + v_H(R_t - 1)]}{[1 + v_K(R_t - 1)]}\frac{h_t}{K_t} \tag{A.6}$$

Note: The pair of equations (A.3) and (A.5) is derived from the Baseline model in Chapter 2, the ICC version in Chapter 3, and the Baseline model in Chapter 4. Meanwhile, the pair of equations (A.4) and (A.6) is derived from the Pure model and the EFP version in Chapter 3.

The optimal price set by the monopolist results from the following optimisation problem:

$$\max_{\tilde{P}_{j,t}} E_t \sum_{s=0}^{\infty} \xi_d^s \frac{\beta^s \Lambda_{t+s}}{\Lambda_t} \left(\tilde{P}_{j,t} \chi_{t,t+s}^d - MC_t \right) Y_{j,t+s}$$

$$\text{subject to} \qquad Y_{j,t+s} = \left(\frac{P_{j,t} \chi_{t,t+s}^d}{P_{t+s}} \right)^{-\frac{\lambda_{d,t}}{\lambda_{d,t}-1}} Y_{t+s}$$

where the term $\chi_{t,t+s}^d$ is a cumulative inflation-indexation factor given by

$$\chi_{t,t+s}^d = \begin{cases} \Pi_{l=1}^s \bar{\pi}_t^{\iota_d} \pi_{t+l-1}^{1-\iota_d} & \text{if} s \geq 1 \\ 1 & \text{if} s = 0. \end{cases}.$$

The first-order condition is given by:

$$E_t \sum_{s=0}^{\infty} \xi_d^s \beta^s \Lambda_{t+s} \tilde{Y}_{t+s} \left[\tilde{P}_t \chi_{t,t+s}^d - \lambda_{d,t+s} MC_{t+s} \right] = 0 \tag{A.7}$$

The aggregate price index for domestic goods is given by

$$P_t = \left[(1-\xi_d) \left(\tilde{P}_t \right)^{\frac{1}{\lambda_{d,t-1}}} + \xi_d \left(\bar{\pi}_t^{\iota_d} \pi_{t-1}^{1-\iota_d} P_{t-1} \right)^{\frac{1}{\lambda_{d,t-1}}} \right]^{\lambda_{d,t}-1} \tag{A.8}$$

A.2 Exporters

Profit maximization implies the demand function for variety j of non-commodity export goods

$$X_{jnon,t} = \left(\frac{P_{jx,t}}{P_{x,t}} \right)^{-\frac{\lambda_{x,t}}{\lambda_{x,t}-1}} X_{non,t} \tag{A.9}$$

The aggregate price charged by the representative, competitive retailer is

$$P_{x,t} = \left[\int_0^1 P_{jx,t}^{\frac{1}{\lambda_{x,t}-1}} dj \right]^{\lambda_{x,t}-1} \tag{A.10}$$

The first-order condition for the j^{th} non-commodity exporter is given by

$$E_t \sum_{s=0}^{\infty} \xi_x^s \beta^s \Lambda_{t+s} \tilde{X}_{non,t+s} \left[\tilde{P}_{x,t} \chi_{t,t+s}^x - \lambda_{x,t} MC_{x,t+s} \right] = 0 \tag{A.11}$$

The aggregate price index for non-commodity export goods is given by

$$P_{x,t} = \left[(1-\xi_x) \left(\tilde{P}_{x,t} \right)^{\frac{1}{\lambda_{x,t-1}}} + \xi_x \left(\bar{\pi}_t^{*\iota_x} \pi_{x,t-1}^{1-\iota_x} P_{x,t-1} \right)^{\frac{1}{\lambda_{x,t-1}}} \right]^{\lambda_{x,t}-1} \tag{A.12}$$

A.3 Importers

The optimal price set by the j^{th} retailer results from the following optimisation problem:

$$\max_{\tilde{P}_{jm,t}} E_t \sum_{s=0}^{\infty} \xi_m^s \frac{\beta^s \Lambda_{t+s}}{\Lambda_t} \left[\tilde{P}_{jm,t} \chi_{t,t+s}^m - MC_{m,t} \right] M_{jm,t+s}$$

$$\text{subject to} \qquad M_{jm,t+s} = \left(\frac{P_{jm,t}\chi^m_{t,t+s}}{P_{m,t+s}}\right)^{-\frac{\lambda_{m,t}}{\lambda_{m,t-1}}} M_{m,t+s}$$

where the term $\chi^m_{t,t+s}$ is a cumulative inflation-indexation factor given by

$$\chi^m_{t,t+s} = \begin{cases} \Pi^s_{l=1}\bar{\pi}_t^{\iota_m}\pi^{1-\iota_m}_{m,t+l-1} & \text{if} s \geq 1 \\ 1 & \text{if } s = 0. \end{cases} \tag{A.13}$$

The first-order condition is given by:

$$E_t\sum_{s=0}^{\infty}\xi^s_m\beta^s\Lambda_{t+s}\tilde{M}_{m,t+s}\left[\tilde{P}_{m,t}\chi^m_{t,t+s} - \lambda_{m,t}MC_{m,t+s}\right] = 0 \tag{A.14}$$

The aggregate price index for import goods is given by

$$P_{m,t} = \left[(1-\xi_m)\left(\tilde{P}_{m,t}\right)^{\frac{1}{\lambda_{m,t-1}}} + \xi_m\left(\bar{\pi}_t^{\iota_m}\pi^{1-\iota_m}_{m,t-1}P_{m,t-1}\right)^{\frac{1}{\lambda_{m,t-1}}}\right]^{\lambda_{m,t}-1} \tag{A.15}$$

A.4 Final goods assemblers

Profit maximization yields the following demand curve for the import variety j:

$$M_{jm,t} = \left(\frac{P_{jm,t}}{P_{m,t}}\right)^{-\frac{\lambda_{m,t}}{\lambda_{m,t-1}}} M_t \tag{A.16}$$

The aggregate price of the two bundles of import consumption and investment goods is a CES aggregate of the prices of the differentiated import goods

$$P_{m,t} = \left[\int_0^1 P_{jm,t}^{\frac{1}{\lambda_{m,t-1}}}dj\right]^{\lambda_{m,t}-1} \tag{A.17}$$

A.5 Households

Choice of Allocations. In the models with financial frictions, the FOCs for maximizing the representative household's intertemporal utility with respect to C_t, D_t, D^*_t, I_t, and h_t are give by:

$$P_{c,t}\Lambda_t = \frac{b_t}{C_t - bC_{t-1}} - \beta b E_t\frac{b_{t+1}}{C_{t+1} - bC_t} \tag{A.18}$$

$$-\Lambda_t + \beta E_t\frac{\Lambda_{t+1}}{\pi_{t+1}}R_t = 0 \tag{A.19}$$

$$\Lambda_t S_t = \beta E_t\frac{\Lambda_{t+1}}{\pi_{t+1}}\left[S_{t+1}R^*_t\Phi_t(.)\right] \tag{A.20}$$

$$\begin{aligned} P_{i,t} = Q_{\bar{K},t}\mu_t &\left[1 - \frac{F}{2}\left(\frac{I_t}{I_{t-1}}\right)^2 - F\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right] \\ &+ \beta E_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}Q_{\bar{K},t+1}\mu_{t+1}F\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right\} \end{aligned} \tag{A.21}$$

(A.22)
$$b_t\varphi_H\frac{h_t^{\sigma_H}}{\Lambda_t}=W_t$$

For the Pure model in particular, two additional FOCs for maximizing the representative household's intertemporal utility with respect to $\bar{K}_t$ and u_t are give by:

(A.23)
$$Z_{k,t}=P_{i,t}a'(u_t)$$

(A.24)
$$Q_{\bar{K},t}=\beta E_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}\left[(1-\delta)Q_{\bar{K},t+1}+Z_{k,t+1}u_{t+1}-P_{i,t+1}a(u_{t+1})\right]\right\}$$

Wage setting. Profit maximization by the representative, competitive contractor implies the labor demand function

(A.25)
$$h_{j,t}=\left(\frac{W_{j,t}}{W_t}\right)^{-\frac{\lambda_{w,t}}{\lambda_{w,t-1}}}h_t$$

where $W_{j,t}$ is the nominal wage rate received from the contractor by all workers of labor type j, while the nominal wage rate paid by intermediate good producers for their homogeneous labor services is

(A.26)
$$W_t=\left[\int_0^1 W_{j,t}^{\frac{1}{\lambda_{w,t-1}}}dj\right]^{\lambda_{w,t}-1}$$

The complementary fraction $1-\xi_w$ of unions sets an optimal nominal wage rate $W_{j,t}$ by maximizing

$$E_t\left\{\sum_{s=0}^{\infty}\xi_w^s\frac{\beta^s\Lambda_{t+s}P_t}{\Lambda_tP_{t+s}}h_{j,t+s}\left[\Xi_{t,t+s}\tilde{W}_{j,t}\chi_{t,t+s}^w-b_{t+s}\varphi_H\frac{h_{j,t+s}^{1+\sigma_H}}{1+\sigma_H}\right]\right\}$$

subject to the demand curve (20), where the term $\chi_{t,t+s}^w$ is a cumulative wage-indexation factor given by

$$\chi_{t,t+s}^d=\begin{cases}\Pi_{l=1}^s(\bar{\pi}_t)^{\iota_w}(\pi_{c,t+l-1})^{1-\iota_w} & \text{if} s\geq 1\\ 1 & \text{if } s=0.\end{cases}.$$

The FOC for this problem is

(A.27)
$$E_t\left\{\sum_{s=0}^{\infty}\xi_w^s\frac{\beta^s\Lambda_{t+s}P_t}{\Lambda_tP_{t+s}}l_{j,t+s}\left[\tilde{W}_{j,t}\chi_{t,t+s}^w-\lambda_{w,t+s}b_{t+s}\varphi_H\frac{h_{j,t+s}^{\sigma_H}}{\Xi_{t+s}}\right]\right\}=0$$

The law of motion of the nominal wage rate is given by

(A.28)
$$W_t=\left[(1-\xi_w)\tilde{W}_t^{\frac{1}{\lambda_{w,t-1}}}+\xi_w\left(\bar{\pi}_t^{\iota_w}\pi_{c,t-1}^{1-\iota_w}g_{z,t}W_{j,t-1}\right)^{\frac{1}{\lambda_{w,t-1}}}\right]^{\lambda_{w,t}-1}$$

A.6 Entrepreneurs

The strict equality of the cash constraint is

$$\left[1-F(\bar{\omega}_{t+1})\right]R_{b,t+1}L_{e,t}+(1-\mu)R_{k,t+1}Q_{\bar{K},t}\bar{K}_{t+1}\int_0^{\bar{\omega}_{t+1}}\omega\ dF(\omega,\sigma_{e,t})=R_tL_{e,t}.$$

Using the facts $R_{b,t+1}L_{e,t} = \bar{\omega}_{t+1}R_{k,t+1}Q_{\bar{K},t}\bar{K}_{t+1}$ and $L_{e,t} = Q_{\bar{K},t}\bar{K}_{t+1} - N_{e,t}$, the cash constraint is rewritten as follows:

$$R_{k,t+1}Q_{\bar{K},t}\bar{K}_{t+1}\left\{[1 - F(\bar{\omega}_{t+1})]\,\bar{\omega}_{t+1} + (1-\mu)\int_0^{\bar{\omega}_{t+1}} \omega\ dF(\omega, \sigma_{e,t})\right\}$$
$$= R_t(Q_{\bar{K},t}\bar{K}_{t+1} - N_{e,t})$$

or equivalently,

$$\phi_{e,t}R_{k,t+1}\left[\Gamma(\bar{\omega}_{t+1}) - \mu G(\bar{\omega}_{t+1})\right] = R_t\left(\phi_{e,t} - 1\right). \tag{A.29}$$

Now, the banker maximizes $E_t\{[1 - \Gamma(\bar{\omega}_{t+1})]\,R_{k,t+1}\phi_{e,t}N_{e,t}\}$ subject to (A.29) taking $N_{e,t}$ as given. The FOCs with respect to the entrepreneurial leverage multiple, lending rate and Lagrange multiplier are given by

$$(\partial\phi_{e,t}): \quad R_{k,t+1}\left[1 - \Gamma(\bar{\omega}_{t+1})\right] + \xi_t R_{k,t+1}\left[\Gamma(\bar{\omega}_{t+1}) - \mu G(\bar{\omega}_{t+1})\right] - R_t = 0 \tag{A.30}$$
$$(\partial R_{e,t}): \quad -\Gamma'(\bar{\omega}_{t+1}) + \xi_t\left[\Gamma'(\bar{\omega}_{t+1}) - \mu G'(\bar{\omega}_{t+1})\right] = 0 \tag{A.31}$$
$$(\partial\xi_t): \quad \phi_{e,t}R_{k,t+1}\left[\Gamma(\bar{\omega}_{t+1}) - \mu G(\bar{\omega}_{t+1})\right] - R_t\left(\phi_{e,t} - 1\right) = 0, \tag{A.32}$$

where ξ_t is the Lagrange multiplier associated with the cash constraint. It is straightforward to verify from the optimality conditions of the Lagrange multiplier that

$$\Gamma(\bar{\omega}_{t+1}) - \mu G(\bar{\omega}_{t+1}) = \frac{R_t}{R_{k,t+1}}\frac{(\phi_{e,t} - 1)}{\phi_{e,t}}. \tag{A.33}$$

Note: The optimization problem and the FOCs of entrepreneurs are derived from the EFP version in the Chapter 3. The deposit rate, R_t, is replaced by the *ex post* return, $R_{e,t+1}$, when the same optimization problem and the similar FOCs are applied to the Baseline model in Chapter 4.

A.7 Banks

Using the method of undetermined coefficients, I show that the banker's problem

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

can be linearly expressed as

$$V_{j,t} = \tau_{f,t}L_{jf,t} + \tau_{x,t}L_{jx,t} + \tau_{e,t}L_{je,t} + \gamma_t N_{jb,t}.$$

Firstly, the bank's net worth evolves over time as

$$\begin{aligned} N_{jb,t+1} &= R_{f,t}L_{jf,t} + R_{x,t}L_{jx,t} + R_{k,t}L_{je,t} - R_tD_{j,t} \\ &= (R_{f,t} - R_t)L_{jf,t} + (R_{x,t} - R_t)L_{jx,t} + (R_{k,t} - R_t)L_{je,t} + R_tN_{jb,t}, \end{aligned}$$

so the objective of banker can be rewritten as

$$V_{j,t} \equiv E_t \sum_{s=0}^{\infty} (1-\theta_{t+1})\theta_{t+1+s}\beta^{s+1}\Xi_{t,t+1+s}\left[(R_{f,t+s}-R_{t+s})L_{jf,t+s}\right.$$

$$\left. +(R_{x,t+s}-R_{t+s})L_{jx,t+s} + (R_{k,t+s}-R_{t+s})L_{je,t+s} + R_{t+s}N_{jb,t+s}\right]$$

or equivalently,

$$V_{j,t} \equiv E_t \sum_{s=0}^{\infty} (1-\theta_{t+1})\theta_{t+1+s}\beta^{s+1}\Xi_{t,t+1+s}\left[(R_{f,t+s}-R_{t+s})\frac{L_{jf,t+s}}{L_{jf,t}}L_{jf,t}\right. \tag{A.34}$$

$$\left. +(R_{x,t+s}-R_{t+s})\frac{L_{jx,t+s}}{L_{jx,t}}L_{jx,t} + (R_{k,t+s}-R_{t+s})\frac{L_{je,t+s}}{L_{je,t}}L_{je,t} + R_{t+s}\frac{N_{jb,t+s}}{N_{jb,t}}N_{jb,t}\right].$$

Thus,

$$\tau_{f,t} \equiv E_t \sum_{s=0}^{\infty} (1-\theta_{t+1})\theta_{t+1+s}\beta^{s+1}\Xi_{t,t+1+s}(R_{f,t+s}-R_{t+s})\frac{L_{jf,t+s}}{L_{jf,t}} \tag{A.35}$$

$$\tau_{x,t} \equiv E_t \sum_{s=0}^{\infty} (1-\theta_{t+1})\theta_{t+1+s}\beta^{s+1}\Xi_{t,t+1+s}(R_{x,t+s}-R_{t+s})\frac{L_{jx,t+s}}{L_{jx,t}} \tag{A.36}$$

$$\tau_{e,t} \equiv E_t \sum_{s=0}^{\infty} (1-\theta_{t+1})\theta_{t+1+s}\beta^{s+1}\Xi_{t,t+1+s}(R_{k,t+s}-R_{t+s})\frac{L_{je,t+s}}{L_{je,t}} \tag{A.37}$$

$$\gamma_t \equiv E_t \sum_{s=0}^{\infty} (1-\theta_{t+1})\theta_{t+1+s}\beta^{s+1}\Xi_{t,t+1+s}R_{t+s}\frac{N_{jb,t+s}}{N_{jb,t}}$$

The proof for each auxiliary variable $\tau_{f,t}$, $\tau_{x,t}$, $\tau_{k,t}$ and γ_t follows an expansion around the definition of $V_{j,t}$ in (A.34) and a straight forward notation in recursive form. I proceed with γ_t:

$$\begin{aligned}
\gamma_t &\equiv E_t\left\{\sum_{s=0}^{\infty}(1-\theta_{t+1})\theta_{t+1+s}\beta^{s+1}\Xi_{t,t+1+s}R_{t+s}\frac{N_{jb,t+s}}{N_{jb,t}}\right\} \\
&= \beta E_t\left\{(1-\theta_{t+1})\Xi_{t,t+1}R_t\right\} + E_t\left\{\sum_{s=1}^{\infty}(1-\theta_{t+1})\theta_{t+1+s}\beta^{s+1}\Xi_{t,t+1+s}R_{t+s}\frac{N_{jb,t+s}}{N_{jb,t}}\right\} \\
&= \beta E_t\left\{(1-\theta_{t+1})\Xi_{t,t+1}R_t\right\} \\
&\quad +\beta E_t\left\{\theta_{t+1}\Xi_{t,t+1}\tfrac{N_{jb,t+1}}{N_{jb,t}}\sum_{s=1}^{\infty}(1-\theta_{t+1})\theta_{t+1+s}\beta^{s}\Xi_{t+1,t+1+s}R_{t+s}\frac{N_{jb,t+s}}{N_{jb,t+1}}\right\}
\end{aligned}$$

Using the definition of γ_t evaluated at $t+1$:

$$\begin{aligned}
\gamma_{t+1} &\equiv E_t\left\{\sum_{s=0}^{\infty}(1-\theta_{t+1})\theta_{t+1+s}\beta^{s+1}\Xi_{t+1,t+1+s}R_{t+s}\frac{N_{jb,t+s}}{N_{jb,t+1}}\right\} \\
&= E_t\left\{\sum_{s=1}^{\infty}(1-\theta_{t+1})\theta_{t+1+s}\beta^{s}\Xi_{t+1,t+1+s}R_{t+s}\frac{N_{jb,t+s}}{N_{jb,t+1}}\right\}
\end{aligned}$$

Inserting γ_{t+1} into γ_t yields:

$$\begin{aligned}
\gamma_t &= \beta E_t\left\{(1-\theta_{t+1})\Xi_{t,t+1}R_t\right\} + \beta E_t\left\{\theta_{t+1}\Xi_{t,t+1}\frac{N_{jb,t+1}}{N_{jb,t}}\gamma_{t+1}\right\} \\
&= \beta E_t\left\{\Xi_{t,t+1}\left[(1-\theta_{t+1})R_t + \theta_{t+1}\frac{N_{jb,t+1}}{N_{jb,t}}\gamma_{t+1}\right.\right\}
\end{aligned} \tag{A.38}$$

The expressions of $\tau_{f,t}$, $\tau_{x,t}$, and $\tau_{e,t}$ can be obtained using an analogous procedure. Now, the banker maximizes (A.34)

$$\text{subject to} \qquad V_{j,t} \geq \varpi_t \left(L_{jf,t} + L_{jx,t} + L_{je,t}\right), \qquad 0 < \tau_t < 1,$$

taking $N_{b,t}$ as given. The FOCs with respect to optimal loans and Lagrange multiplier are given by

$$(\partial L_{f,t}): \qquad (1+\xi_t)\tau_{f,t} - \xi_t \varpi_t = 0 \tag{A.39}$$

$$(\partial L_{x,t}): \qquad (1+\xi_t)\tau_{x,t} - \xi_t \varpi_t = 0 \tag{A.40}$$

$$(\partial L_{e,t}): \qquad (1+\xi_t)\tau_{e,t} - \xi_t \varpi_t = 0 \tag{A.41}$$

$$(\partial \xi_t): \qquad \tau_{f,t} L_{f,t} + \tau_{x,t} L_{x,t} + \tau_{e,t} L_{e,t} + \gamma_t N_{b,t} - \tau_t \left(L_{f,t} + L_{x,t} + L_{e,t}\right) \geq 0$$

where ξ_t is the Lagrange multiplier associated with the incentive compatibility constraint. Notice that the first three conditions hold with equality if $\xi_t > 0$, otherwise they hold with strict positive inequality. It is straightforward to verify from the optimality conditions for types of loan that $\tau_{f,t} = \tau_{x,t} = \tau_{e,t} = \tau_t$.

Note: The optimization problem and the FOCs of banks are derived from the Baseline model in Chapter 2 and the ICC version in Chapter 3. The non-contingent return on capital, $R_{k,t}$, is replaced by the *ex post* return, $R_{e,t+1}$, when the same optimization problem and the similar FOCs are applied to the Baseline model in Chapter 4.

Appendix B

Scaling of variables

The model solution requires that the endogenous variables are stationary, so we need to transform the variables in order to induce stationary. Note that all real variables, with the exception of hours worked, in each economies share a real stochastic trend, which is the level of technology consistent with the balanced-growth property of the theoretical model. Also, all nominal variables of each economy have a nominal stochastic trend in common as the monetary authority aims to achieve the inflation target. To render the model stationary, I therefore detrend all real variables of the home and the foreign economies with the trend level of technology, $\{z_t, z_t^*\}$, and deflate all nominal variables by the price of domestic goods, $\{P_t, P_t^*\}$, respectively.

There are, however, some exceptions from the above conventions. First, since wage rate and financial variables not only have a nominal stochastic trend but also are assumed to grow in line with technology, they are scaled with both the price of domestic goods and the trend level of technology. Second, capital stock is a predetermined variable, thus it is scaled with the lagged value of technology level. Third, the marginal utility of consumption is scaled up with the trend level of technology because this marginal utility decreases as consumption increases along the balanced-growth path.

Real variables are scaled as follows:

$$\lambda = \Lambda_t z_t, \qquad y_t = \frac{Y_t}{z_t}, \qquad c_t = \frac{C_t}{z_t}, \qquad c_{d,t} = \frac{C_{d,t}}{z_t}, \qquad c_{m,t} = \frac{C_{m,t}}{z_t} \qquad c_{b,t} = \frac{C_{b,t}}{z_t}$$

$$i_t = \frac{I_t}{z_t}, \qquad i_{d,t} = \frac{I_{d,t}}{z_t}, \qquad i_{m,t} = \frac{I_{m,t}}{z_t}, \qquad \bar{k}_{t+1} = \frac{\bar{K}_{t+1}}{z_t}, \qquad k_{t+1} = \frac{K_{t+1}}{z_t}$$

$$x_t = \frac{X_t}{z_t}, \qquad x_{non,t} = \frac{X_{non,t}}{z_t}, \qquad x_{com,t} = \frac{X_{com,t}}{z_t}, \qquad m_t = \frac{M_t}{z_t}$$

$$a_t = \frac{S_t B_{t+1}^*}{z_t P_t}$$

$$y_t^* = \frac{Y_t^*}{z_t^*}$$

Prices are scaled as follows:

$$mc_t = \frac{MC_t}{P_t}, \qquad mc_{x,t} = \frac{MC_{x,t}}{P_t}, \qquad mc_{cm,t} = \frac{MC_{c,t}}{P_t}, \qquad mc_{im,t} = \frac{MC_{im,t}}{P_t}$$

$$q_t = \frac{Q_{\bar{K},t}}{P_t}, \qquad z_{k,t} = \frac{Z_{k,t}}{P_t}, \qquad w_t = \frac{W_t}{z_t P_t}$$

$$r_t = \frac{R_t}{\pi_{t+1}}, \qquad r_{k,t+1} = \frac{R_{k,t}}{\pi_{t+1}} \qquad r_{e,t+1} = \frac{R_{e,t}}{\pi_{t+1}}$$

$$r_{b,t} = \frac{R_{b,t}}{\pi_{t+1}}, \qquad r_{f,t} = \frac{R_{f,t}}{\pi_{t+1}}, \qquad r_{x,t} = \frac{R_{x,t}}{\pi_{t+1}}, \qquad r^*_{m,t} = \frac{R^*_{m,t}}{\pi^*_{t+1}}, \qquad r^*_{eF,t+1} = \frac{R^*_{eF,t}}{\pi^*_{t+1}}$$

Financial variables are scaled as follows:

$$n_{e,t} = \frac{N_{e,t}}{z_t P_t}, \qquad v_{e,t} = \frac{V_{e,t}}{z_t P_t}$$

$$l_t = \frac{L_t}{z_t P_t}, \qquad l_{e,t} = \frac{L_{e,t}}{z_t P_t}, \qquad l_{f,t} = \frac{L_{f,t}}{z_t P_t}, \qquad l_{x,t} = \frac{L_{x,t}}{z_t P_t}, \qquad l_{m,t} = \frac{L_{m,t}}{z^*_t P^*_t}, \qquad l_{eF,t} = \frac{L_{eF,t}}{z^*_t P^*_t}$$

$$n_{b,t} = \frac{N_{b,t}}{z_t P_t}, \qquad v_{b,t} = \frac{V_{b,t}}{z_t P_t}$$

Real exchange rate, rer_t, is defined by:

$$rer_t = \frac{S_t P^*_t}{P_{c,t}}$$

Scaling conventions of relative price are as follows:

$$p_{c,t} = \frac{P_{c,t}}{P_t}, \qquad p_{cm,t} = \frac{P_{cm,t}}{P_t}, \qquad p_{i,t} = \frac{P_{i,t}}{P_t}$$

$$p_{im,t} = \frac{P_{im,t}}{P_t}, \qquad p^*_{com,t} = \frac{P_{com,t}}{P^*_t}, \qquad p^*_{x,t} = \frac{P_{x,t}}{P^*_t}$$

Other conventions of relative prices used are:

$$p_{cmc,t} = \frac{P_{cm,t}}{P_{c,t}}, \qquad p_{ccm,t} = \frac{P_{c,t}}{P_{cm,t}}, \qquad p_{imi,t} = \frac{P_{im,t}}{P_{i,t}}, \qquad p_{iim,t} = \frac{P_{i,t}}{P_{im,t}}$$

Appendix C

Stationary equilibrium conditions

This appendix displays all the equilibrium conditions of the models, which are written in terms of the scaled variables.

C.1 Firms

Domestic good producers

$$y_t = \epsilon_t k_t^{\alpha} h_t^{1-\alpha} - \Phi \tag{C.1}$$

$$l_{f,t} = v_K z_{k,t} k_t + v_H w_t h_t \tag{C.2}$$

$$z_{k,t} = \frac{\alpha}{1-\alpha} \frac{w_t \left[1 + v_H (R_{f,t} - 1)\right]}{\left[1 + v_K (R_{f,t} - 1)\right]} \frac{h_t}{k_t} \tag{C.3}$$

$$mc_t = \left(\frac{1}{\alpha}\right)^{\alpha} \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \frac{\left[z_{k,t}\left(1 + v_K\left(R_{f,t} - 1\right)\right)\right]^{\alpha} \left[w_t \left(1 + v_H \left(R_{f,t} - 1\right)\right)\right]^{1-\alpha}}{\epsilon_t} \tag{C.4}$$

$$z_{k,t} = \frac{\alpha}{1-\alpha} \frac{w_t \left[1 + v_H (R_t - 1)\right]}{\left[1 + v_K (R_t - 1)\right]} \frac{h_t}{k_t} \tag{C.5}$$

$$mc_t = \left(\frac{1}{\alpha}\right)^{\alpha} \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \frac{\left[z_{k,t}\left(1 + v_K\left(R_t - 1\right)\right)\right]^{\alpha} \left[w_t \left(1 + v_H \left(R_t - 1\right)\right)\right]^{1-\alpha}}{\epsilon_t} \tag{C.6}$$

Note: The pair of equilibrium conditions (C.3-4) is written for the Baseline model in Chapter 2, the ICC version in Chapter 3, and the Baseline model in Chapter 4. Meanwhile, the pair of equilibrium conditions (C.5-6) results from the Pure model and the EFP version in Chapter 3.

$$E_t \sum_{s=0}^{\infty} \xi_d^s \frac{\beta^s \lambda_{t+s}}{\lambda_t} y_{j,t+s} \left[\tilde{p}_{j,t} \chi_{t,t+s}^d - mc_{t+s}\right] = 0 \tag{C.7}$$

$$1 = \left[(1 - \xi_d) \left(\tilde{p}_t\right)^{\frac{1}{\lambda_{d,t}-1}} + \xi_d \left(\bar{\pi}_t^{\iota_d} \pi_{t-1}^{1-\iota_d} \pi_t^{-1}\right)^{\frac{1}{\lambda_{d,t}-1}}\right]^{\lambda_{d,t}-1} \tag{C.8}$$

Exporters

(C.9) $$x_t = x_{non,t} + x_{com,t}$$

(C.10) $$x_{non,t} = (p_{x^*,t})^{-\eta^*} \zeta_* y_t^* \tilde{z}_t^*$$

(C.11) $$x_{com,t} = \varepsilon_{com,t} \xi^* y_t^* \tilde{z}_t^*$$

(C.12) $$l_{x,t} = v_X x_t$$

(C.13) $$mc_{x,t} = \frac{[1 + v_X(R_{x,t} - 1)]}{rer_t p_{c,t} p_{x,t}^*}$$

(C.14) $$mc_{x,t} = \frac{[1 + v_X(R_t - 1)]}{rer_t p_{c,t} p_{x,t}^*}$$

Note: The equilibrium condition (C.13) is written for the Baseline model in Chapter 2, the ICC version in Chapter 3, and the Baseline model in Chapter 4. Meanwhile, the equilibrium condition (C.14) results from the Pure model and the EFP version in Chapter 3.

(C.15) $$E_t \sum_{s=0}^{\infty} \xi_x^s \frac{\beta^s \lambda_{t+s}}{\lambda_t} x_{j,t+s} \left[\tilde{p}_{jx,t} \chi_{t,t+s}^x - mc_{x,t+s}\right] = 0$$

(C.16) $$1 = \left[(1 - \xi_x) \left(\tilde{p}_{x,t}\right)^{\frac{1}{\lambda_{x,t-1}}} + \xi_x \left(\bar{\pi}_t^{*\iota_x} \pi_{x,t-1}^{1-\iota_x} \pi_{x,t}^{-1}\right)^{\frac{1}{\lambda_{x,t-1}}}\right]^{\lambda_{x,t}-1}$$

Importers

(C.17) $$m_t = c_{m,t} + i_{m,t}$$

(C.18) $$l_{m,t} = v_M m_t \frac{1}{\tilde{z}_t^*}$$

(C.19) $$mc_{cm,t} = \frac{rer_t p_{c,t}}{p_{cm,t}} [1 + v_M(R_{m,t}^* - 1)]$$

(C.20) $$mc_{im,t} = \frac{rer_t p_{c,t}}{p_{im,t}} [1 + v_M(R_{m,t}^* - 1)]$$

(C.21) $$R_{m,t}^* = R_t^* spr_t^*$$

(C.22) $$R_{m,t}^* = R_t^*$$

Note: The equilibrium condition (C.21) is written for the Baseline model in Chapters 2 and 4 and the ICC version in Chapter 3 in which there are financial frictions on import credit. By contrast, the equilibrium condition (C.22) is written for models without financial frictions on cross-border lending, the Pure model and the EFP version in Chapter 3.

(C.23) $$E_t \sum_{s=0}^{\infty} \xi_m^s \frac{\beta^s \lambda_{t+s}}{\lambda_t} m_{j,t+s} \left[\tilde{p}_{jm,t} \chi_{t,t+s}^m - mc_{m,t+s} \right] = 0$$

(C.24) $$1 = \left[(1-\xi_m) \left(\tilde{p}_{m,t} \right)^{\frac{1}{\lambda_{m,t}-1}} + \xi_m \left(\bar{\pi}_t^{\iota_m} \pi_{m,t-1}^{1-\iota_m} \pi_{m,t}^{-1} \right)^{\frac{1}{\lambda_{m,t}-1}} \right]^{\lambda_{m,t}-1}$$

(C.25) $$c_{d,t} = (1-\omega_c) \left(p_{c,t} \right)^{\eta_c} \left(c_t + c_{b,t} \right)$$

(C.26) $$c_{m,t} = \omega_c \left(\frac{p_{c,t}}{p_{cm,t}} \right)^{\eta_c} \left(c_t + c_{b,t} \right)$$

(C.27) $$c_{d,t} = (1-\omega_c) \left(p_{c,t} \right)^{\eta_c} c_t$$

(C.28) $$c_{m,t} = \omega_c \left(\frac{p_{c,t}}{p_{cm,t}} \right)^{\eta_c} c_t$$

(C.29) $$\tilde{c}_{d,t} = (1-\omega_c) \left(p_{c,t} \right)^{\eta_c} \left(c_t + c_{i,t} \right) \qquad \text{for } i = \{e, b\}$$

(C.30) $$\tilde{c}_{m,t} = \omega_c \left(\frac{p_{c,t}}{p_{cm,t}} \right)^{\eta_c} \left(c_t + c_{i,t} \right) \qquad \text{for } i = \{e, b\}$$

(C.31) $$c_{d,t} = (1-\omega_c) \left(p_{c,t} \right)^{\eta_c} \left(c_t + c_{e,t} + c_{b,t} \right)$$

(C.32) $$c_{m,t} = \omega_c \left(\frac{p_{c,t}}{p_{cm,t}} \right)^{\eta_c} \left(c_t + c_{e,t} + c_{b,t} \right)$$

Note: The pair of equilibrium conditions (C.25-26) corresponds to the Baseline model in Chapter 2, (C.27-28) the Pure model in Chapter 3, (C.29-30) the EFP and the ICC versions in Chapter 3, and (C.31-32) the Baseline model in Chapter 4.

(C.33) $$i_{d,t} = (1-\omega_i) \left(p_{i,t} \right)^{\eta_i} \left(i_t + a(u_t) \frac{\bar{k}_{t-1}}{g_{z,t}} \right)$$

(C.34) $$i_{m,t} = \omega_i \left(\frac{p_{it}}{p_{im,t}} \right)^{\eta_i} \left(i_t + a(u_t) \frac{\bar{k}_{t-1}}{g_{z,t}} \right)$$

(C.35) $$p_{c,t} = \left[(1-\omega_c) + \omega_c p_{cm,t}^{1-\eta_c} \right]^{\frac{1}{1-\eta_c}}$$

(C.36) $$p_{i,t} = \left[(1-\omega_i) + \omega_i p_{im,t}^{1-\eta_i} \right]^{\frac{1}{1-\eta_c}}$$

(C.37) $$p_{ccm,t} = \left[(1-\omega_c)(p_{cm,t})^{\eta_c - 1} + \omega_c \right]^{\frac{1}{1-\eta_c}}$$

(C.38) $$p_{iim,t} = \left[(1-\omega_i)(p_{im,t})^{\eta_i - 1} + \omega_i \right]^{\frac{1}{1-\eta_i}}$$

C.2 Households

(C.39) $$p_{c,t}\lambda_t = \frac{b_t}{c_t - \frac{bc_{t-1}}{g_{z,t}}} - \beta b E_t \frac{b_{t+1}}{c_{t+1}g_{z,t+1} - bc_t}$$

(C.40) $$-\lambda_t + \beta E_t \frac{\lambda_{t+1}}{g_{z,t+1}\pi_{t+1}} R_t = 0$$

(C.41) $$R_t = R_t^* E_t \frac{rer_{t+1}}{rer_t}\frac{\pi_{c,t+1}}{\pi_{t+1}^*}\Psi_t(.)$$

(C.42) $$p_{i,t} = q_t\mu_t\left[1 - \frac{F}{2}\left(\frac{i_t}{i_{t-1}}g_{z,t} - g_z\right)^2 - F\left(\frac{i_t}{i_{t-1}}g_{z,t} - g_z\right)\frac{i_t}{i_{t-1}}g_{z,t}\right] + \frac{\beta}{g_{z,t+1}}E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}q_{t+1}\mu_{t+1}F\left(\frac{i_{t+1}}{i_t}g_{z,t+1} - g_z\right)\left(\frac{i_{t+1}}{i_t}g_{z,t+1}\right)^2\right\}$$

(C.43) $$\bar{k}_{t+1} = (1-\delta)\frac{\bar{k}_t}{g_{z,t}} + \mu_t\left[1 - \frac{F}{2}\left(\frac{i_t}{i_{t-1}}g_{z,t} - g_z\right)^2\right]i_t$$

(C.44) $$b_t\varphi_H\frac{h_t^{\sigma_H}}{\lambda_t} = w_t$$

(C.45) $$E_t\left\{\sum_{s=0}^{\infty}\xi_w^s\frac{\beta^s\lambda_{t+s}}{\lambda_t}h_{j,t+s}\left[\tilde{w}_{j,t}\chi_{t,t+s}^w - \lambda_{w,t+s}b_{t+s}\varphi_H\frac{h_{j,t+s}^{\sigma_H}}{\lambda_{t+s}}\right]\right\} = 0$$

(C.46) $$w_t = \left\{(1-\xi_w)\tilde{w}_t^{\frac{1}{\lambda_{w,t}-1}} + \xi_w\left[\left(\frac{\bar{\pi}_t}{\pi_t}\right)^{\iota_w}\left(\frac{\pi_{c,t-1}}{\pi_t}\right)^{1-\iota_w}w_{t-1}\right]^{\frac{1}{\lambda_{w,t}-1}}\right\}^{\lambda_{w,t}-1}$$

Two additional conditions for the Pure model in Chapter 3:

(C.47) $$z_{k,t} = p_{i,t}a'(u_t)$$

(C.48) $$q_t = \beta E_t\left\{\frac{\lambda_{t+1}}{\lambda_t g_{z,t+1}}\left[(1-\delta)q_{t+1} + z_{k,t+1}u_{t+1} - p_{i,t+1}a(u_{t+1})\right]\right\}$$

C.3 Entrepreneurs

(C.49) $$l_{e,t} = q_t\bar{k}_{t+1} - n_{e,t}$$

(C.50) $$k_t = u_t\frac{\bar{k}_{t-1}}{g_{z,t}}$$

(C.51) $$z_{k,t} = p_{i,t}a'(u_t)$$

Note: The equilibrium conditions (C.49-51) are written for all friction models in three chapters.

(C.52) $$r_{k,t+1} = \frac{z_{k,t+1}u_{t+1} - p_{i,t+1}a(u_{t+1}) + (1-\delta)q_{t+1}}{\omega_{\bar{K}}q_t} - \frac{(1-\omega_{\bar{K}})q_{t+1}}{\omega_{\bar{K}}q_t}$$

(C.53) $$r_{k,t+1} = \frac{z_{k,t+1}u_{t+1} - p_{i,t+1}a(u_{t+1}) + (1-\delta)q_{t+1}}{q_t}$$

Note: The equilibrium condition (C.52) is written for the Baseline model in Chapter 2 and the ICC version in Chapter 3. Meanwhile, the EFP version in Chapter 3 adopts the equilibrium condition (C.53).

(C.54) $$\bar{\omega}_{t+1}r_{k,t+1}q_t\bar{k}_{t+1} = r_{b,t+1}l_{e,t}$$

(C.55) $$\phi_{e,t} = \frac{q_{t-1}\bar{k}_t}{n_{e,t}}$$

(C.56) $$\phi_{e,t}\left[\Gamma(\bar{\omega}_{t+1}) - \mu G(\bar{\omega}_{t+1})\right] = \frac{r_t}{r_{k,t+1}}(\phi_{e,t} - 1)$$

(C.57) $$v_{e,t} = \left[1 - \Gamma(\bar{\omega}_t)\right] r_{k,t}q_{t-1}\bar{k}_t$$

(C.58) $$p_{c,t}c_{e,t} = (1-\theta_{e,t})v_{e,t}$$

(C.59) $$n_{e,t} = \theta_{e,t}v_{e,t} + \chi_e n_e$$

(C.60) $$spr_{e,t} = \frac{r_{b,t}}{r_t}$$

Note: The equilibrium conditions (C.54-60) are written for the EFP version in Chapter 3. The Baseline model in Chapter 4 adopts similar equilibrium conditions, except the real deposit rate, r_t, in equation (C.56) is replaced by the real *ex post* return, $r_{e,t+1}$.

C.4 Banks

(C.61) $$l_t = l_{f,t} + l_{x,t} + l_{e,t} \quad , \quad l_t^* = l_{f,t}^* + l_{e,t}^*$$

Note: The equilibrium condition (C.61) is used for all friction models in three chapters.

(C.62) $$r_t = \frac{R_t}{\pi_{t+1}}$$

(C.63)
$$r_{f,t} = \frac{R_{f,t}}{\pi_{t+1}}$$

(C.64)
$$r_{x,t} = \frac{R_{x,t}}{\pi_{t+1}}$$

(C.65)
$$r_{k,t+1} = \frac{R_{k,t}}{\pi_{t+1}}$$

(C.66)
$$l_t = l_{f,t} + l_{x,t} + l_{e,t} \quad , \quad l_t^* = l_{f,t}^* + l_{e,t}^*$$

(C.67)
$$\tau_{f,t} = \frac{\beta}{g_{z,t}} E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\theta_{t+1})(r_{f,t} - r_t) + \theta_{t+1} \frac{l_{f,t+1}}{l_{f,t}} g_{z,t+1} \tau_{f,t+1} \right] \right\}$$

(C.68)
$$\tau_{x,t} = \frac{\beta}{g_{z,t}} E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\theta_{t+1})(r_{x,t} - r_t) + \theta_{t+1} \frac{l_{x,t+1}}{l_{x,t}} g_{z,t+1} \tau_{x,t+1} \right] \right\}$$

(C.69)
$$\tau_{e,t} = \frac{\beta}{g_{z,t}} E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\theta_{t+1})(r_{k,t+1} - r_t) + \theta_{t+1} \frac{l_{e,t+1}}{l_{e,t}} g_{z,t+1} \tau_{e,t+1} \right] \right\}$$

(C.70)
$$\gamma_t = \frac{\beta}{g_{z,t}} E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\theta_{t+1}) r_t + \theta_{t+1} \frac{n_{b,t+1}}{n_{b,t}} g_{z,t+1} \gamma_{t+1} \right] \right\}$$

(C.71)
$$l_t = \phi_{b,t} n_{b,t}$$

(C.72)
$$v_{b,t} = \left\{ \left[(r_{f,t} - r_t) \frac{l_{f,t-1}}{l_{t-1}} + (r_{x,t} - r_t) \frac{l_{x,t-1}}{l_{t-1}} + (r_{k,t} - r_t) \frac{l_{e,t-1}}{l_{t-1}} \right] \phi_{b,t-1} + r_t \right\} \frac{n_{b,t-1}}{g_{z,t}},$$
$$v_{b,t}^* = \left\{ \left[(r_{f,t}^* - r_t^*) \frac{l_{f,t-1}^*}{l_{t-1}^*} + (r_{k,t}^* - r_t^*) \frac{l_{e,t-1}^*}{l_{t-1}^*} \right] \phi_{b,t-1}^* + r_t^* \right\} \frac{n_{b,t-1}^*}{g_{z,t}^*}$$

(C.73)
$$p_{c,t} c_{b,t} = (1-\theta_t) v_{b,t}$$

(C.74)
$$n_{b,t} = \theta_t v_{b,t} + \chi n_b$$

(C.75)
$$spr_t = \frac{r_{f,t} l_{f,t} + r_{x,t} l_{x,t} + r_{k,t+1} l_{e,t}}{r_t l_t} \quad , \quad spr_t^* = \frac{r_{f,t}^* l_{f,t}^* + r_{k,t+1}^* l_{e,t}^*}{r_t^* l_t^*}$$

Note: The equilibrium conditions (C.62-75) are written for the Baseline model in Chapter 2 and the ICC version in Chapter 3. The Baseline model in Chapter 4 adopts similar equilibrium conditions. However, the non-contingent real return on capital $r_{k,t+1}$ in (C.69) and $r_{k,t}$ in (C.72) are replaced by the real *ex post* return $r_{e,t+1}$ and $r_{e,t}$, respectively. In addition, the non-contingent real return on capital $r_{k,t+1}$ in (C.75) is replaced by the real contractual lending rate $r_{b,t}$.

C.5 Resource constraint

(C.76) $$gdp_t = g_t + \tilde{c}_t + \tilde{i}_t + x_t - m_t \quad , \quad gdp_t^* = g_t^* + c_t^* + i_t^*$$

(C.77) $$gdp_t = g_t + \tilde{c}_t + \tilde{i}_t + x_t - \tilde{m}_t$$

(C.78) $$\tilde{m}_t = \tilde{c}_{m,t} + i_{m,t}$$

Note: The equilibrium condition (C.76) is written for the Baseline model in Chapters 2 and 4 and the Pure model in Chapter 3, while the pair of equilibrium conditions (C.77-78) applies for the EFP and ICC versions in Chapter 3.

(C.79) $$y_t = g_t + c_{d,t} + i_{d,t} + x_t \quad , \quad y_t^* = g_t^* + c_t^* + c_{b,t}^* + i_t^* + a(u_t)^* \frac{\bar{k}_{t-1}^*}{g_{z,t}^*}$$

(C.80) $$y_t = g_t + c_{d,t} + i_{d,t} + x_t \quad , \quad y_t^* = g_t^* + c_t^* + i_t^* + a(u_t)^* \frac{\bar{k}_{t-1}^*}{g_{z,t}^*}$$

(C.81) $$y_t = g_t + \tilde{c}_{d,t} + i_{d,t} + x_t + \mu r_{k,t} q_{t-1} \bar{k}_t \int_0^{\bar{\omega}_t} \omega \; dF(\omega, \sigma_{e,t}),$$
$$y_t^* = g_t^* + c_t^* + i_t^* + a(u_t)^* \frac{\bar{k}_{t-1}^*}{g_{z,t}^*} + \mu^* r_{k,t}^* q_{t-1}^* \bar{k}_t^* \int_0^{\bar{\omega}_t^*} \omega^* \; dF(\omega^*, \sigma_{e,t}^*)$$

(C.82) $$y_t = g_t + \tilde{c}_{d,t} + i_{d,t} + x_t \quad , \quad y_t^* = g_t^* + c_t^* + c_{b,t}^* + i_t^* + a(u_t)^* \frac{\bar{k}_{t-1}^*}{g_{z,t}^*}$$

(C.83) $$y_t = g_t + c_{d,t} + i_{d,t} + x_t + \mu r_{k,t} q_{t-1} \bar{k}_t \int_0^{\bar{\omega}_t} \omega \; dF(\omega, \sigma_{e,t}),$$
$$y_t^* = g_t^* + c_t^* + c_{e,t}^* + c_{b,t}^* + i_t^* + a(u_t)^* \frac{\bar{k}_{t-1}^*}{g_{z,t}^*} + \mu^* r_{k,t}^* q_{t-1}^* \bar{k}_t^* \int_0^{\bar{\omega}_t^*} \omega^* \; dF(\omega^*, \sigma_{e,t}^*)$$

Note: The equilibrium condition (C.79) corresponds to the Baseline model in Chapter 2, (C.80) the Pure model, (C.81) the EFP version, (C.82) the ICC version in Chapter 3, and (C.83) the Baseline in Chapter 4.

(C.84) $$a_t = \frac{R_t}{\pi_t g_{z,t}} a_{t-1} + [1 + v_X(R_{x,t} - 1)] rer_t p_{c,t} (p_{x,t}^* x_{non,t} + p_{com,t}^* x_{com,t}) - [1 + v_M(R_{m,t}^* - 1)] rer_t p_{c,t} m_t$$

(C.85) $$a_t = \frac{R_t}{\pi_t g_{z,t}} a_{t-1} + [1 + v_X(R_t - 1)] rer_t p_{c,t} (p_{x,t}^* x_{non,t} + p_{com,t}^* x_{com,t}) - [1 + v_M(R_t^* - 1)] rer_t p_{c,t} m_t$$

The equilibrium condition (C.84) is written for the Baseline model in Chapters 2, the ICC version in Chapter 3, and the Baseline model in Chapter 4, while the equilibrium condition (C.85) applies for the Pure model and the EFP version in Chapter 3.

Appendix D

Steady state

In this Appendix, I present an algorithm for computing the steady state of the model in each chapter given calibrated and prior values of parameters.

D.1 Chapter 2 – Baseline model

I first have:

(D.1)
$$\pi = 1 + \frac{\bar{\pi}}{100} \qquad , \qquad \pi^* = 1 + \frac{\bar{\pi}^*}{100}$$

(D.2)
$$g_z = 1 + \frac{\bar{g}_z}{100} \qquad , \qquad g_z^* = 1 + \frac{\bar{g}_z^*}{100}$$

Evaluating the equilibrium condition (C.40) in steady state, I obtain

(D.3)
$$R = \frac{\pi g_z}{\beta}$$

Since $\pi_c = \pi$ in steady state, the uncovered interest arbitrage condition (C.41) immediately reduces to

(D.4)
$$R^* = R\frac{\pi^*}{\pi}$$

As a result, the subjective discount factor of the foreign household is given by

(D.5)
$$\beta^* = \frac{\pi^* g_z^*}{R^*},$$

Of course, the real interest rate are

(D.6)
$$r = \frac{g_z}{\beta} \qquad , \qquad r^* = \frac{g_z^*}{\beta^*}$$

Now, I turn to

(D.7)
$$spr = 1 + \frac{\text{basis point}}{4 \times 10000}$$

Combining the fact $\tau_f = \tau_x = \tau_e = \tau$, $r_f = r_x = r_k$ with the definition of the steady-state spread

$$spr = \frac{R_f l_f + R_x l_x + R_k l_e}{Rl} = \frac{R_f}{R} \equiv \frac{R_x}{R} \equiv \frac{R_k}{R}$$

yields

$$R_f \equiv R_x \equiv R_k = R \times spr, \qquad \text{thus} \qquad r_f \equiv r_x \equiv r_k = \frac{R_k}{\pi} \tag{D.8}$$

Additionally,

$$R_m^* = R^* spr^*, \qquad \text{thus} \qquad r_m^* = \frac{R_m^*}{\pi^*} \tag{D.9}$$

It is clear that

$$\omega_{\bar{K}} = \frac{\phi_e - 1}{\phi_e} \tag{D.10}$$

The price of capital (C.42) in steady state implies:

$$q = p_i \quad , \quad q^* = 1 \tag{D.11}$$

The rental rate on effective capital services (C.52) in steady state yields:

$$z_k = q[\omega_{\bar{K}} r_k + (1 - \omega_{\bar{K}}) - (1 - \delta)] \quad , \quad z_k^* = \omega_{\bar{K}}^* r_k^* + (1 - \omega_{\bar{K}}^*) - (1 - \delta^*) \tag{D.12}$$

Note that $\lambda_d = 1 + \frac{\Phi}{y}$. The equation (C.4) for the real marginal cost of intermediate goods producers implies

$$w = \left[\frac{\alpha^\alpha (1-\alpha)^{1-\alpha}}{\lambda_d \left[z_k (1 + v_K (R_f - 1)) \right]^\alpha \left[1 + v_H (R_f - 1) \right]^{1-\alpha}} \right]^{\frac{1}{1-\alpha}} \tag{D.13}$$

With z_k and w, I use the equation (C.3) to compute

$$\frac{k}{h} = \frac{\alpha}{1-\alpha} \frac{w \left[1 + v_H (R_f - 1) \right]}{z_k \left[1 + v_K (R_f - 1) \right]} \tag{D.14}$$

The zero profit condition for intermediate goods producers

$$\begin{aligned} & y - z_k \left[1 + v_K (R_f - 1) \right] k - w \left[1 + v_H (R_f - 1) \right] h \\ & = \left(\frac{k}{h} \right)^\alpha h - \Phi - z_k \left[1 + v_K (R_f - 1) \right] k - w \left[1 + v_H (R_f - 1) \right] h = 0 \end{aligned} \tag{D.15}$$

implies

$$\frac{\Phi}{h} = \left(\frac{k}{h} \right)^\alpha - z_k \left[1 + v_K (R_f - 1) \right] \frac{k}{h} - w \left[1 + v_H (R_f - 1) \right] \tag{D.16}$$

Therefore, I can compute

$$\frac{y}{h} = \left(\frac{k}{h} \right)^\alpha - \frac{\Phi}{h} \tag{D.17}$$

From the equation (C.43) in steady state, I get:

$$\frac{i}{h} = \left(1 - \frac{1-\delta}{g_z} \right) g_z \frac{k}{h} \tag{D.18}$$

Now I turn to the equations of relative prices (C.35-C.38) evaluated in steady state:

(D.19) $$\eta_{cm} = \frac{\lambda_{cm}}{\lambda_{cm} - 1}$$

(D.20) $$\eta_{im} = \frac{\lambda_{im}}{\lambda_{im} - 1}$$

(D.21) $$p_c = \left[(1 - \omega_c) + \omega_c \left(\frac{\eta_{cm}}{\eta_{cm} - 1}\right)^{1-\eta_c}\right]^{\frac{1}{1-\eta_c}}$$

(D.22) $$p_i = \left[(1 - \omega_i) + \omega_i \left(\frac{\eta_{im}}{\eta_{im} - 1}\right)^{1-\eta_i}\right]^{\frac{1}{1-\eta_i}}$$

(D.23) $$p_{c,cm} = \left[(1 - \omega_c) \left(\frac{\eta_{cm} - 1}{\eta_{cm}}\right)^{1-\eta_c} + \omega_c\right]^{\frac{1}{1-\eta_c}}$$

(D.24) $$p_{i,im} = \left[(1 - \omega_i) \left(\frac{\eta_{im} - 1}{\eta_{im}}\right)^{1-\eta_i} + \omega_i\right]^{\frac{1}{1-\eta_i}}$$

(D.25) $$p_c = \left[(1 - \omega_c) + \omega_c \lambda_{cm}^{1-\eta_c}\right]^{\frac{1}{1-\eta_c}}$$

(D.26) $$p_i = \left[(1 - \omega_i) + \omega_i \lambda_{im}^{1-\eta_i}\right]^{\frac{1}{1-\eta_i}}$$

(D.27) $$p_{c,cm} = \left[(1 - \omega_c)\lambda_{cm}^{\eta_c-1} + \omega_c\right]^{\frac{1}{1-\eta_c}}$$

(D.28) $$p_{i,im} = \left[(1 - \omega_i)\lambda_{im}^{\eta_i-1} + \omega_i\right]^{\frac{1}{1-\eta_i}}$$

(D.29) $$p_{cm,c} = \frac{1}{p_{c,cm}}$$

(D.30) $$p_{im,i} = \frac{1}{p_{i,im}}$$

Since $p_x^* = 1, p_{com}^* = 1$, $rer = \frac{1}{p_c}$ (using C.13), $a = 0$ in steady state, I reduce the equilibrium condition of the real net foreign asset (C.84) to

$$[1 + v_X(R_x - 1)]x = [1 + v_M(R_m^* - 1)]m,$$

equivalently

$$x = Expr \times m \tag{D.31}$$

where

$$Expr = \frac{[1 + \upsilon_M(R_m^* - 1)]}{[1 + \upsilon_X(R_x - 1)]} \tag{D.32}$$

Next, the real resource constraint (C.79) in steady state:

$$\begin{aligned}
\left(1 - \frac{g}{y}\right) y &= c_d + i_d + x \\
&= c_d + c_m + i_d + i_m + (Expr - 1)m \\
&= c_d + Expr \times c_m + i_d + Expr \times i_m \\
&= \left[(1-\omega_c)(p_c)^{\eta_c} + Expr \times \omega_c (p_{c,cm})^{\eta_c}\right] c_p + \left[(1-\omega_i)(p_i)^{\eta_i} + Expr \times \omega_i (p_{i,im})^{\eta_i}\right] i
\end{aligned}$$

Then, the steady-state ratio of total consumption to hours worked:

$$\begin{aligned}
\frac{c_p}{h} &= \frac{\left(1 - \frac{g}{y}\right)\frac{y}{h} - \left[(1-\omega_i)(p_i)^{\eta_i} + Expr \times \omega_i (p_{i,im})^{\eta_i}\right]\frac{i}{h}}{(1-\omega_c)(p_c)^{\eta_c} + Expr \times \omega_c (p_{c,cm})^{\eta_c}}, \\
\frac{c_p^*}{h^*} &= \left(1 - \frac{g^*}{y^*}\right)\frac{y^*}{h^*} - \frac{i^*}{h^*}
\end{aligned} \tag{D.33}$$

which consists of household consumption c and shareholder consumption c_b.

I have total net worth from the equation (C.74) at the steady state

$$n_b = \frac{\theta}{1-\chi} v_b \tag{D.34}$$

and the steady-state aggregate profit is given by the equation (C.72)

$$v_b = \frac{1}{g_z}[(r_k - r)\phi_b + r]n_b \tag{D.35}$$

Rearranging (D.34) after substituting out for v_b using (D.35), I obtain the steady-state leverage multiple:

$$\phi_b = \frac{g_z(1-\chi) - \theta r}{\theta(r_k - r)} \tag{D.36}$$

Given g_z, r_k, r, θ, I adjust χ to obtain the same target for ϕ_b in the friction model variants.

I have

$$\frac{l_f}{h} = \upsilon_H w + \upsilon_K z_k \frac{k}{h} \qquad \text{from (C.2)} \tag{D.37}$$

$$\frac{l_x}{h} = \upsilon_X \frac{x}{h} \qquad \text{from (C.12)} \tag{D.38}$$

with

$$\frac{x}{h} = Expr \times \frac{m}{h} \qquad \text{from (D.31)} \tag{D.39}$$

(D.40) $$\frac{m}{h} = \frac{c_m}{h} + \frac{i_m}{h} \qquad \text{from (C.17)}$$

(D.41) $$\frac{c_m}{h} = \omega_c \left(p_{c,cm}\right)^{\eta_c} \frac{c_p}{h} \qquad \text{from (C.26)}$$

(D.42) $$\frac{i_m}{h} = \omega_i \left(p_{i,im}\right)^{\eta_i} \frac{i}{h} \qquad \text{from (C.34)}$$

(D.43) $$\frac{l_e}{h} = \omega_{\bar{K}} \frac{k}{h} q \qquad \text{from (C.49) and (D.10)}$$

Next, I have

(D.44) $$\frac{l}{h} = \frac{l_f}{h} + \frac{l_x}{h} + \frac{l_e}{h} \quad , \quad \frac{l^*}{h^*} = \frac{l_f^*}{h^*} + \frac{l_e^*}{h^*} \qquad \text{from (C.61)}$$

Combining (D.35) with the equation (C.71) in steady state, I obtain

(D.45) $$\frac{v_b}{h} = \frac{1}{g_z \phi_b}[(r_k - r)\phi_b + r]\frac{l}{h}$$

The shareholder consumption (C.73) in steady state gives:

(D.46) $$\frac{c_b}{h} = (1-\theta)\frac{v_b}{h}\frac{1}{p_c} \quad , \quad \frac{c_b^*}{h^*} = (1-\theta^*)\frac{v_b^*}{h^*}$$

and thus

(D.47) $$\frac{c}{h} = \frac{c_p}{h} - \frac{c_b}{h}$$

In steady state, the equation (C.39) implies

(D.48) $$\lambda h = \frac{g_z - \beta b}{g_z - b}\left(\frac{c}{h}\right)^{-1}\frac{1}{p_c} \quad , \quad \lambda^* h^* = \frac{g_z^* - \beta^* b^*}{g_z^* - b^*}\left(\frac{c^*}{h^*}\right)^{-1}$$

Now I obtain an expression for h from (C.44):

(D.49) $$h = \left[\frac{w}{\lambda_w \varphi_H}\lambda h\right]^{\frac{1}{1+\sigma_H}}$$

It is convenient to parametrize the steady-state value of hours worked, h, with respect to the disutility weight on labor, φ_H, since this parametrization immediately implies

(D.50) $$c_p = \frac{c_p}{h}h$$

(D.51) $$c_d = (1-\omega_c)(p_c)^{\eta_c} c_p$$

(D.52) $$c_m = \frac{c_m}{h}h$$

(D.53) $$c = \frac{c}{h}h$$

(D.54) $$\tilde{c}_d = (1-\omega_c)(p_c)^{\eta_c} c$$

(D.55) $$\tilde{c}_m = \omega_c (p_{c,cm})^{\eta_c} c$$

(D.56) $$c_b = \frac{c_b}{h} h$$

(D.57) $$i = \frac{i}{h} h$$

(D.58) $$i_d = (1-\omega_i)(p_i)^{\eta_i} i$$

(D.59) $$i_m = \frac{i_m}{h} h$$

(D.60) $$x = \frac{x}{h} h$$

(D.61) $$m = \frac{m}{h} h$$

(D.62) $$y = \frac{y}{h} h$$

(D.63) $$gdp = \frac{1}{1-\frac{g}{y}}(\tilde{c}_d + \tilde{c}_m + i_d + i_m + x - m)$$ from (C.76) in steady state

Notice that

(D.64) $$\left[\frac{1+v_M(R_m^*-1)}{1+v_X(R_x-1)} - 1\right]\frac{m}{gdp} = \frac{nx}{gdp}$$

Given R_x, R_m^*, the calibrated value of v_X, and the steady-state value of m and gdp, I choose a value for v_M so that $\frac{nx}{gdp}$ meets the average value of the trade balance over the sample period.

(D.65) $$\Phi = \frac{\Phi}{h} h$$

(D.66) $$k = \frac{k}{h} h$$

(D.67) $$v_b = \frac{v_b}{h} h$$

(D.68) $$l = \frac{l}{h} h$$

(D.69) $$l_f = \frac{l_f}{h} h$$

(D.70) $$l_x = \frac{l_x}{h} h$$

(D.71) $$l_e = \frac{l_e}{h} h$$

Finally, I calculate the remaining financial values at the steady state:

(D.72) $$n_e = \frac{qk}{\phi_e} \quad , \quad n_e^* = \frac{k^*}{\phi_e^*}$$

(D.73) $$n_b = \frac{l}{\phi_b}$$

(D.74) $$\tau = \frac{\beta(1-\theta)(r_k - r)}{g_z(1-\beta\theta)}$$

(D.75) $$\gamma = \frac{\beta(1-\theta)r}{g_z(1-\beta\theta)}$$

(D.76) $$\varpi = \frac{\gamma}{\phi_b} + \tau$$

D.2 Chapter 3

D.2.1 Pure model

(D.1-6) and (D.11) in Chapter 2

The price of capital (C.48) in steady state yields

(D.77) $$z_k = [R - (1-\delta)]q$$

The equation (C.6) for the real marginal cost of intermediate goods producers implies

(D.78) $$w = \left[\frac{\alpha^\alpha (1-\alpha)^{1-\alpha}}{\lambda_d \left[z_k(1+v_K(R-1))\right]^\alpha \left[1+v_H(R-1)\right]^{1-\alpha}} \right]^{\frac{1}{1-\alpha}}$$

With z_k and w, I use the equation (C.5) to compute

(D.79) $$\frac{k}{h} = \frac{\alpha}{1-\alpha} \frac{w\left[1+v_H(R-1)\right]}{z_k\left[1+v_K(R-1)\right]}$$

The zero profit condition for intermediate goods producers

(D.80) $$\begin{aligned} y - z_k\left[1+v_K(R-1)\right]k - w\left[1+v_H(R-1)\right]h \\ = \left(\frac{k}{h}\right)^\alpha h - \Phi - z_k\left[1+v_K(R-1)\right]k - w\left[1+v_H(R-1)\right]h = 0 \end{aligned}$$

implies

(D.81) $$\frac{\Phi}{h} = \left(\frac{k}{h}\right)^{\alpha} - z_k \left[1 + v_K(R-1)\right] \frac{k}{h} - w\left[1 + v_H(R-1)\right]$$

(D.17-30) in Chapter 2

The steady-state ratio of consumption to hours worked:

(D.82) $$\frac{c}{h} = \frac{\left(1-\frac{g}{y}\right)\frac{y}{h} - \left[(1-\omega_i)\left(p_i\right)^{\eta_i} + \omega_i\left(p_{i,im}\right)^{\eta_i}\right]\frac{i}{h}}{(1-\omega_c)\left(p_c\right)^{\eta_c} + \omega_c\left(p_{c,cm}\right)^{\eta_c}}, \qquad \frac{c*}{h^*} = \left(1 - \frac{g^*}{y^*}\right)\frac{y^*}{h^*} - \frac{i^*}{h^*}$$

(D.83) $$\frac{c_m}{h} = \omega_c\left(p_{c,cm}\right)^{\eta_c}\frac{c}{h}$$

(D.84) $$\frac{i_m}{h} = \omega_i\left(p_{i,im}\right)^{\eta_i}\frac{i}{h}$$

Assume the balanced trade in steady state, so

(D.85) $$\frac{x}{h} = \frac{\tilde{m}}{h} = \frac{\tilde{c}_m}{h} + \frac{i_m}{h}$$

I reduce the equilibrium condition of the real net foreign asset (C.85) to

$$v_X(R-1) = v_M(R^*-1)$$

and thus

(D.86) $$v_X = v_M\frac{(R^*-1)}{(R-1)}$$

(D.48-49) and (D.52-53) in Chapter 2

Next,

(D.87) $$c_d = (1-\omega_c)(p_c)^{\eta_c}c$$

(D.57-63) and (D.65-66) in Chapter 2

D.2.2 EFP version

Given the prior value of the default probability, $f(\bar{\omega})$, I can compute:

(D.88) $$z_{\bar{\omega}} = Ninv\left(f(\bar{\omega})\right).$$

By calibrating the steady-state value of the risk shock, σ_e, I write the threshold value $\bar{\omega}$ as a function of σ_e:

(D.89) $$\bar{\omega} = \exp\left\{\sigma_e z_{\bar{\omega}} - \frac{1}{2}\sigma_e^2\right\}$$

(D.90)
$$F(\bar{\omega}) = Npdf\left(z_{\bar{\omega}}\right)$$

(D.91)
$$G(\bar{\omega}) = Ncdf\left(z_{\bar{\omega}} - \sigma_e\right)$$

(D.92)
$$G'(\bar{\omega}) = \frac{1}{\sigma_e} F(\bar{\omega})$$

(D.93)
$$\Gamma(\bar{\omega}) = \bar{\omega}\left[1 - f(\bar{\omega})\right] + G(\bar{\omega})$$

(D.94)
$$\Gamma'(\bar{\omega}) = 1 - f(\bar{\omega})$$

Combining the FOCs (A.30) and (A.31), I solve for the external finance premium in steady state:

(D.95)
$$\frac{R_k}{R} = \frac{1}{1 - \mu\left\{\frac{G'(\bar{\omega})}{\Gamma'(\bar{\omega})}\left[1 - \Gamma\left(\bar{\omega}\right)\right] + G\left(\bar{\omega}\right)\right\}}$$

Using the FOC (A.32), I obtain the entrepreneurial leverage multiple in steady state:

(D.96)
$$\phi_e = \frac{1}{1 - \left[\Gamma(\bar{\omega}) - \mu G(\bar{\omega})\right]\frac{R_k}{R}}$$

I choose the value of σ_e such that ϕ_e is equal to my target.

In order to compute the elasticities of external finance premium with respect to entrepreneurial leverage multiple and risk shock, I first have to compute the following relevant elasticities:

(D.97)
$$\epsilon_{\phi_e,\bar{\omega}} = \frac{\frac{\mu}{\phi_e}\frac{\Gamma''(\bar{\omega})G'(\bar{\omega}) - G''(\bar{\omega})\Gamma'(\bar{\omega})}{\left[\Gamma'(\bar{\omega}) - \mu G'(\bar{\omega})\right]^2}}{\left\{\left[1 - \Gamma\left(\bar{\omega}\right)\right] + \frac{\Gamma'(\bar{\omega})}{\Gamma'(\bar{\omega}) - \mu G'(\bar{\omega})}\left[\Gamma(\bar{\omega}) - \mu G(\bar{\omega})\right]\right\}\frac{R_k}{R}}\bar{\omega}$$

(D.98)
$$\epsilon_{\phi_e,\sigma_e} = \frac{\left[\frac{1 - \mu\frac{G_{\sigma_e}(\bar{\omega})}{\Gamma_{\sigma_e}(\bar{\omega})}}{1 - \mu\frac{G'(\bar{\omega})}{\Gamma'(\bar{\omega})}}\right]\Gamma_{\sigma_e}(\bar{\omega})\frac{R_k}{R} + \frac{\mu}{\phi_e}\frac{G'(\bar{\omega})\Gamma'_{\sigma_e}(\bar{\omega}) - \Gamma'(\bar{\omega})G'_{\sigma_e}(\bar{\omega})}{\left[\Gamma'(\bar{\omega}) - \mu G'(\bar{\omega})\right]^2}}{\left[1 - \Gamma\left(\bar{\omega}\right)\right]\frac{R_k}{R} + \frac{\Gamma'(\bar{\omega})}{\Gamma'(\bar{\omega}) - \mu G'(\bar{\omega})}\left(1 - \frac{1}{\phi_e}\right)}\sigma_e$$

(D.99)
$$\epsilon_{z,\bar{\omega}} = \frac{\Gamma'(\bar{\omega}) - \mu G'(\bar{\omega})}{\Gamma(\bar{\omega}) - \mu G(\bar{\omega})}\bar{\omega}$$

(D.100)
$$\epsilon_{z,\sigma_e} = \frac{\Gamma_{\sigma_e}(\bar{\omega}) - \mu G_{\sigma_e}(\bar{\omega})}{\Gamma(\bar{\omega}) - \mu G(\bar{\omega})}\sigma_e$$

where

$$G''(\bar{\omega}) = -\frac{z_{\bar{\omega}}}{\bar{\omega}\sigma_e^2}F(\bar{\omega})$$

$$\Gamma''(\bar{\omega}) = -\frac{1}{\bar{\omega}\sigma_e}F(\bar{\omega})$$

$$G_{\sigma_e}(\bar{\omega}) = -\frac{z_{\bar{\omega}}}{\sigma_e} Npdf(z_{\bar{\omega}} - \sigma_e)$$
$$G'_{\sigma_e}(\bar{\omega}) = -\frac{F(\bar{\omega})}{\sigma_e^2}[1 - z_{\bar{\omega}}(z_{\bar{\omega}} - \sigma_e)]$$
$$\Gamma_{\sigma_e}(\bar{\omega}) = -Npdf(z_{\bar{\omega}} - \sigma_e)$$
$$\Gamma'_{\sigma_e}(\bar{\omega}) = \left(\frac{z_{\bar{\omega}}}{\sigma_e} - 1\right) F(\bar{\omega})$$

Next, the elasticity of external finance premium with respect to entrepreneurial leverage multiple and risk shock are respectively given by:

(D.101) $$\epsilon_{spr_e,\phi_e} = -\frac{\frac{\epsilon_{\phi_e,\bar{\omega}}}{\epsilon_{z,\bar{\omega}}}}{1 - \frac{\epsilon_{\phi_e,\bar{\omega}}}{\epsilon_{z,\bar{\omega}}}} \frac{1}{\phi_e - 1}$$

(D.102) $$\epsilon_{spr_e,\sigma_e} = -\frac{\frac{\epsilon_{\phi_e,\bar{\omega}}}{\epsilon_{z,\bar{\omega}}}\epsilon_{z,\sigma_e} - \epsilon_{\phi_e,\sigma_e}}{1 - \frac{\epsilon_{\phi_e,\bar{\omega}}}{\epsilon_{z,\bar{\omega}}}}$$

(D.1-6) in Chapter 2

Next,

(D.103) $$spr_e = 1 + \frac{\text{basis point}}{4 \times 10000}$$

(D.104) $$R^b = R \times spr_e, \qquad \text{thus} \qquad r_b = \frac{R_b}{\Pi}$$

(D.10-11) in Chapter 2

Next,

(D.105) $$R_k = \frac{R^b(\phi_e - 1)}{\phi_e \bar{\omega}}, \qquad \text{thus} \qquad r_k = \frac{R_k}{\Pi}$$

(D.12) in Chapter 2

(D.78-81) of the Pure model

(D.17-30) in Chapter 2

Now total consumption at the steady state:

(D.106) $$\frac{c_p}{h} = \frac{\left(1 - \frac{g}{y}\right)\frac{y}{h} - \left[(1-\omega_i)(p_i)^{\eta_i} + \omega_i (p_{i,im})^{\eta_i}\right]\frac{i}{h} - \mu r_k q \frac{k}{h}\int_0^{\bar{\omega}} \bar{\omega}\ dF(\bar{\omega})}{(1-\omega_c)(p_c)^{\eta_c} + \omega_c (p_{c,cm})^{\eta_c}}$$

which consists of household consumption c and entrepreneurial shareholder consumption c_e.

I have entrepreneurial net worth at the steady state from the equation (C.59)

$$n_e = \frac{\theta_e}{1-\chi_e} v_e \tag{D.107}$$

and the steady-state entrepreneurial profit from the equation (C.57)

$$v_e = \frac{1}{g_z}[1-\Gamma(\bar{\omega})] r_k q k \tag{D.108}$$

Rearranging (D.107) after substituting out for v_e using (D.108), I obtain the steady-state entrepreneurial leverage multiple:

$$\phi_e = \frac{g_z(1-\chi_e)}{\theta_e[1-\Gamma(\bar{\omega})] r_k} \tag{D.109}$$

I set χ_e such that ϕ_e is equal to my target.

(D.37-38) in Chapter 2, with

$$\frac{x}{h} = \frac{\tilde{m}}{h} = \frac{\tilde{c}_m}{h} + \frac{i_m}{h} \qquad \text{from (D.85)} \tag{D.110}$$

$$\frac{\tilde{c}_m}{h} = \omega_c \left(p_{c,cm}\right)^{\eta_c} \frac{c_p}{h} \qquad \text{from (C.30)} \tag{D.111}$$

(D.43-44) in Chapter 2

From (D.108),

$$\frac{v_e}{h} = \frac{1}{g_z}[1-\Gamma(\bar{\omega})] r_k q \frac{k}{h} \tag{D.112}$$

The shareholder consumption (C.58) in steady state gives:

$$\frac{c_e}{h} = (1-\theta_e)\frac{v_e}{h}\frac{1}{p_c} \quad , \quad \frac{c_e^*}{h^*} = (1-\theta_e^*)\frac{v_e^*}{h^*} \tag{D.113}$$

and thus

$$\frac{c}{h} = \frac{c_p}{h} - \frac{c_e}{h} \tag{D.114}$$

(D.48-50) and (D.53) in Chapter 2

Next

$$c_e = \frac{c_e}{h} h \tag{D.115}$$

$$\tilde{c}_d = (1-\omega_c)(p_c)^{\eta_c} c_p \tag{D.116}$$

$$\tilde{c}_m = \omega_c (p_{c,cm})^{\eta_c} c_p \tag{D.117}$$

(D.60) in Chapter 2

(D.118) $$\tilde{m} = \frac{\tilde{m}}{h} h$$

(D.62) in Chapter 2

(D.119) $$gdp = \frac{1}{1 - \frac{g}{y}} (\tilde{c}_d + \tilde{c}_m + i_d + i_m + x - \tilde{m}) \qquad \text{from (C.60) in steady state}$$

(D.65-66) in Chapter 2

Next,

(D.120) $$v_e = \frac{v_e}{h} h$$

(D.68-72) in Chapter 2

D.2.3 ICC version

(D.1-30) in Chapter 2

Next, I reduce the equilibrium condition of the real net foreign asset (C.84) to

$$v_X (R_x - 1) = v_M (R_m^* - 1)$$

and thus

(D.121) $$v_X = v_M \frac{(R_m^* - 1)}{(R_x - 1)}$$

Now total consumption at the steady state:

(D.122) $$\frac{c_p}{h} = \frac{\left(1 - \frac{g}{y}\right) \frac{y}{h} - \left[(1 - \omega_i)(p_i)^{\eta_i} + \omega_i (p_{i,im})^{\eta_i}\right] \frac{i}{h}}{(1 - \omega_c)(p_c)^{\eta_c} + \omega_c (p_{c,cm})^{\eta_c}}$$

which consists of household consumption c and banking shareholder consumption c_e.

(D.34-38) in Chapter 2

(D.110-111) of the EFP version

(D.43-50), (D.53) and (D.56) in Chapter 2

(D.116-119) of the EFP version

(D.65-76) in Chapter 2

D.3 Chapter 4 – Baseline model

(D.88-102) of the EFP version in Chapter 3 and replacing R_e to R wherever it appears

(D.1-6) in Chapter 2

(D.103-104) of the EFP version in Chapter 3

(D.10-11) in Chapter 2

(D.105) of the EFP version in Chapter 3

(D.12) in Chapter 2

Combining the fact $\tau_f = \tau_x = \tau_e = \tau$, $r_f = r_x = r_e$ with the steady-state value of $\frac{R_k}{R_e}$ yields

(D.123)
$$R_f \equiv R_x \equiv R_e = R_k : \frac{R_k}{R_e}, \qquad \text{thus} \qquad r_f \equiv r_x \equiv r_e = \frac{R_e}{\Pi}$$

(D.9) and (D.13-32) in Chapter 2

Now, the steady-state ratio of total consumption to hours worked:

(D.124)
$$\frac{c_p}{h} = \frac{\left(1 - \frac{g}{y}\right)\frac{y}{h} - \left[(1-\omega_i)(p_i)^{\eta_i} + Expr \times \omega_i (p_{i,im})^{\eta_i}\right]\frac{i}{h} - \mu r_k q \frac{k}{h}\int_0^{\bar{\omega}} \bar{\omega}\ dF(\bar{\omega})}{(1-\omega_c)(p_c)^{\eta_c} + Expr \times \omega_c (p_{c,cm})^{\eta_c}}$$

which consists of household consumption c, entrepreneurial shareholder consumption c_e and banking shareholder consumption c_b.

(D.107-109) and (D.112-113) of the EFP version in Chapter 3

(D.34-46) in Chapter 2

As a result,

(D.125)
$$\frac{c}{h} = \frac{c_p}{h} - \frac{c_e}{h} - \frac{c_b}{h}$$

(D.48-55) in Chapter 2

(D.115) of the EFP version in Chapter 3

(D.56-66) in Chapter 2

(D.120) of the EFP version in Chapter 3

(D.67-76) in Chapter 2

Finally,

$$spr_b = \frac{R_f l_f + R_x l_x + R_b l_e}{Rl} \tag{D.126}$$

I choose the prior value for $f(\bar{\omega})$, which in turn yielded $R_f = R_x = R_e$ in (D.123), such that spr_b is equal to my target.

Appendix E

Log-linearized equilibriums

Log-linear deviations from steady state are defined as follows

$$\hat{x}_t \equiv \log x_t - \log x,$$

except for $\hat{g}_{z,t} \equiv g_{z,t} - g_z$ and $\hat{g}^*_{z,t} \equiv g^*_{z,t} - g^*_z$.

In the following subsections, I report the system of linear rational expectations equations in my models.

E.1 Chapter 2 - Baseline model

Home economy

Production function

$$\hat{y}_t = \frac{y+\Phi}{y}\left[\alpha \hat{k}_t + (1-\alpha)\hat{h}_t + \hat{\epsilon}_t\right] \tag{E.1}$$

Aggregate working capital loan

$$\hat{l}_{f,t} = \frac{v_H wh}{l_f}\left(\hat{w}_t + \hat{h}_t\right) + \frac{v_K z_k k}{l_f}\left(\hat{z}_{k,t} + \hat{k}_t\right) \tag{E.2}$$

Cost minimization

$$\hat{z}_{k,t} = -(\hat{k}_t - \hat{h}_t) + \hat{w}_t + (v_H - v_K)\hat{R}_{f,t} \tag{E.3}$$

Marginal cost - intermediate goods producer

$$\widehat{mc}_{d,t} = \alpha \hat{z}_{k,t} + (1-\alpha)\hat{w}_t + \left[(1-\alpha)v_H + \alpha v_K\right]\hat{R}_{f,t} - \hat{\epsilon}_t \tag{E.4}$$

Domestic goods inflation

$$\begin{aligned}\hat{\pi}_t - \hat{\bar{\pi}}_t = {} & \frac{\beta}{1+\beta(1-\iota_d)}(\hat{\pi}_{t+1} - \rho_{\bar{\pi}}\hat{\bar{\pi}}_t) + \frac{1-\iota_d}{1+\beta(1-\iota_d)}(\hat{\pi}_{t-1} - \hat{\bar{\pi}}_t) \\ & - \frac{\beta(1-\iota_d)}{1+\beta(1-\iota_d)}(1-\rho_{\bar{\pi}})\hat{\bar{\pi}}_t + \frac{(1-\xi_d)(1-\beta\xi_d)}{\left[1+\beta(1-\iota_d)\right]\xi_d}\left(\widehat{mc}_{d,t} + \hat{\lambda}_{d,t}\right)\end{aligned} \tag{E.5}$$

Total export

$$\hat{x}_t = (1-\omega_x)\hat{x}_{non,t} + \omega_x \hat{x}_{com,t} \tag{E.6}$$

Non-commodity export

$$\hat{x}_{non,t} = \hat{y}^*_t - \eta^* \hat{p}^*_{x,t} + \hat{\bar{z}}^*_t \tag{E.7}$$

Commodity export

$$\hat{x}_{com,t} = \hat{\varepsilon}_{com,t} + \hat{y}^*_t + \hat{\bar{z}}^*_t \tag{E.8}$$

Aggregate export credit

$$\hat{l}_{x,t} = \hat{x}_t \tag{E.9}$$

Marginal cost - exporters

$$\widehat{mc}_{x,t} = -\widehat{rer}_t - \hat{p}_{c,t} - \hat{p}^*_{x,t} + v_X \hat{R}_{x,t} \tag{E.10}$$

Export goods inflation

$$\begin{aligned}\hat{\pi}_{x,t} - \hat{\bar{\pi}}^*_t = {} & \frac{\beta}{1+\beta(1-\iota_x)}(\hat{\pi}_{x,t+1} - \rho^*_{\bar{\pi}}\hat{\bar{\pi}}^*_t) + \frac{1-\iota_x}{1+\beta(1-\iota_x)}(\hat{\pi}_{x,t-1} - \hat{\bar{\pi}}^*_t) \\ & - \frac{\beta(1-\iota_x)}{1+\beta(1-\iota_x)}(1-\rho^*_{\bar{\pi}})\hat{\bar{\pi}}^*_t + \frac{(1-\xi_x)(1-\beta\xi_x)}{[1+\beta(1-\iota_x)]\xi_x}(\widehat{mc}_{x,t} + \hat{\lambda}_{x,t})\end{aligned} \tag{E.11}$$

Total import

$$\hat{m}_t = \frac{c_m}{m}\hat{c}_{m,t} + \frac{i_m}{m}\hat{i}_{m,t} \tag{E.12}$$

Aggregate import credit

$$\hat{l}_{m,t} = \hat{m}_t - \hat{\bar{z}}^*_t \tag{E.13}$$

Nominal interest rate on foreign import loans

$$\hat{R}^*_{m,t} = \hat{R}^*_t + \widehat{spr}^*_t \tag{E.14}$$

Marginal cost - consumption goods importers

$$\widehat{mc}_{cm,t} = \widehat{rer}_t + \hat{p}_{c,t} - \hat{p}_{cm,t} + v_M \hat{R}^*_{m,t} \tag{E.15}$$

Marginal cost - investment goods importers

$$\widehat{mc}_{im,t} = \widehat{rer}_t + \hat{p}_{c,t} - \hat{p}_{im,t} + v_M \hat{R}^*_{m,t} \tag{E.16}$$

Import consumption goods inflation

$$\begin{aligned}\hat{\pi}_{cm,t} - \hat{\bar{\pi}}_t = {} & \frac{\beta}{1+\beta(1-\iota_{cm})}(\hat{\pi}_{cm,t+1} - \rho_{\bar{\pi}}\hat{\bar{\pi}}_t) + \frac{1-\iota_{cm}}{1+\beta(1-\iota_{cm})}(\hat{\pi}_{cm,t-1} - \hat{\bar{\pi}}_t) \\ & - \frac{\beta(1-\iota_{cm})}{1+\beta(1-\iota_{cm})}(1-\rho_{\bar{\pi}})\hat{\bar{\pi}}_t + \frac{(1-\xi_{cm})(1-\beta\xi_{cm})}{[1+\beta(1-\iota_{cm})]\,\xi_{cm}}\left(\widehat{mc}_{cm,t} + \hat{\lambda}_{cm,t}\right)\end{aligned} \tag{E.17}$$

Import investment goods inflation

$$\text{(E.18)}\quad \hat{\pi}_{im,t} - \hat{\bar{\pi}}_t = \frac{\beta}{1+\beta(1-\iota_{im})}(\hat{\pi}_{im,t+1} - \rho_{\bar{\pi}}\hat{\bar{\pi}}_t) + \frac{1-\iota_{im}}{1+\beta(1-\iota_{im})}(\hat{\pi}_{im,t-1} - \hat{\bar{\pi}}_t)$$
$$- \frac{\beta(1-\iota_{im})}{1+\beta(1-\iota_{im})}(1-\rho_{\bar{\pi}})\hat{\bar{\pi}}_t + \frac{(1-\xi_{im})(1-\beta\xi_{im})}{[1+\beta(1-\iota_{im})]\,\xi_{im}}(\widehat{mc}_{im,t} + \hat{\lambda}_{im,t})$$

Domestic consumption goods

$$\text{(E.19)}\quad \hat{c}_{d,t} = \frac{c}{c_p}(\hat{c}_t + \eta_c\hat{p}_{c,t}) + \frac{c_b}{c_p}(\hat{c}_{b,t} + \eta_c\hat{p}_{c,t})$$

Import consumption goods

$$\text{(E.20)}\quad \hat{c}_{m,t} = \frac{c}{c_p}[\hat{c}_t - \eta_c(1-\omega_c)(p_c)^{\eta_c-1}\hat{p}_{cm,t}] + \frac{c_b}{c_p}[\hat{c}_{b,t} - \eta_c(1-\omega_c)(p_c)^{\eta_c-1}\hat{p}_{cm,t}]$$

Domestic investment goods

$$\text{(E.21)}\quad \hat{i}_{d,t} = \hat{i}_t + \eta_i\hat{p}_{i,t} + (1-\omega_i)(p_i)^{\eta_i}\frac{z_k k}{i_d p_i}\hat{u}$$

Import investment goods

$$\text{(E.22)}\quad \hat{i}_{m,t} = \hat{i}_t - \eta_i(1-\omega_i)(p_i)^{\eta_i-1}\hat{p}_{im,t} + \omega_i(p_{i,im})^{\eta_i}\frac{z_k k}{i_m p_i}\hat{u}_t$$

Trade balance

$$\text{(E.23)}\quad \widehat{nx}_t = \hat{x}_t - \hat{m}_t$$

CPI inflation

$$\text{(E.24)}\quad \hat{\pi}_{c,t} = (1-\omega_{cm})(p_c)^{\eta_c-1}\hat{\pi}_t + \omega_{cm}(p_{cm})^{1-\eta_c}\hat{\pi}_{cm,t} + \hat{\varepsilon}_{\pi_{c,t}}$$

Relative prices

$$\text{(E.25)}\quad \hat{p}_{c,t} = \omega_c(p_{cmc})^{1-\eta_c}\hat{p}_{cm,t}$$

$$\text{(E.26)}\quad \hat{p}_{i,t} = \omega_i(p_{imi})^{1-\eta_i}\hat{p}_{im,t}$$

$$\text{(E.27)}\quad \hat{p}_{cm,t} = \hat{p}_{cm,t-1} + \hat{\pi}_{cm,t} - \hat{\pi}_t$$

$$\text{(E.28)}\quad \hat{p}_{im,t} = \hat{p}_{im,t-1} + \hat{\pi}_{im,t} - \hat{\pi}_t$$

$$\text{(E.29)}\quad \hat{p}^*_{x,t} = \hat{p}^*_{x,t-1} + \hat{\pi}_{x,t} - \hat{\pi}^*_t$$

Uncovered interest parity condition

$$\text{(E.30)}\quad \hat{R}_t - \hat{R}^*_t = \widehat{rer}_{t+1} - \widehat{rer}_t + \widehat{\pi}_{c,t+1} - \widehat{\pi}^*_{t+1} + \hat{\Psi}_t$$

Risk country premium

$$\widehat{\Psi}_t = -\phi_s \widehat{rer}_{t+1} + \phi_s \widehat{rer}_{t-1} - \phi_a \hat{a}_t + \hat{\psi}_t \tag{E.31}$$

Consumption

$$\hat{c}_t = \frac{bg_z}{g_z^2 + b^2\beta}(\hat{c}_{t-1} + \beta \hat{c}_{t+1}) - \frac{bg_z}{g_z^2 + b^2\beta}(\hat{g}_{z,t} - \beta \hat{g}_{z,t+1}) - \frac{(g_z - b\beta)(g_z - b)}{g_z^2 + b^2\beta}\widehat{\lambda}_t - \frac{(g_z - b\beta)(g_z - b)}{g_z^2 + b^2\beta}\hat{p}_{c,t} + \frac{g_z - b}{g_z^2 + b^2\beta}(g_z \hat{b}_t - b\beta \hat{b}_{t+1}) \tag{E.32}$$

Euler equation

$$\widehat{\lambda}_t = \hat{R}_t + E_t\{\hat{\lambda}_{t+1} - \hat{g}_{z,t+1} - \hat{\pi}_{t+1}\} \tag{E.33}$$

Wage inflation

$$\hat{w}_t = \frac{\beta}{1+\beta}\hat{w}_{t+1} + \frac{1}{1+\beta}\hat{w}_{t-1} + \frac{1-\iota_w}{1+\beta}(\hat{\pi}_{c,t-1} - \hat{\bar{\pi}}_t) - \frac{1}{1+\beta}(\hat{\pi}_t - \hat{\bar{\pi}}_t) - \frac{\beta(1-\iota_w)}{1+\beta}(\hat{\pi}_{c,t} - \rho_{\bar{\pi}}\hat{\bar{\pi}}_t) + \frac{\beta}{1+\beta}(\hat{\pi}_{t+1} - \rho_{\bar{\pi}}\hat{\bar{\pi}}_t) - \frac{(1-\xi_w)(1-\beta\xi_w)}{(1+\beta)\xi_w\left(1 + \sigma_H \frac{\lambda_w}{\lambda_w - 1}\right)}(\hat{\mu}_{w,t} + \hat{\lambda}_{w,t}) \tag{E.34}$$

Wage markup

$$\hat{\mu}_{w,t} = \hat{w}_t - (\sigma_H \hat{h}_t + \hat{b}_t - \widehat{\lambda}_t) \tag{E.35}$$

Investment equation

$$\hat{i}_t = \frac{1}{1+\beta}(\hat{i}_{t-1} - \hat{g}_{z,t}) + \frac{\beta}{1+\beta}E_t(\hat{i}_{t+1} + \hat{g}_{z,t+1}) + \frac{1}{F'' g_z^2(1+\beta)}(\hat{q}_t - \hat{p}_{i,t} + \hat{\mu}_t) \tag{E.36}$$

Capital accumulation

$$\hat{\bar{k}}_t = \frac{1-\delta}{g_z}(\hat{\bar{k}}_{t-1} - \hat{g}_{z,t}) + \left(1 - \frac{1-\delta}{g_z}\right)(\hat{i}_t + \hat{\mu}_t) \tag{E.37}$$

Aggregate entrepreneurial loan

$$\hat{l}_{e,t} = \frac{\phi_e}{\phi_e - 1}(\hat{q}_t + \hat{k}_{t+1}) - \frac{1}{\phi_e - 1}\hat{n}_{e,t} \tag{E.38}$$

Capital service

$$\hat{k}_t = \hat{\bar{k}}_{t-1} - \hat{g}_{z,t} + \hat{u}_t \tag{E.39}$$

Optimal capital utilization

$$\hat{u}_t = \frac{(1-\zeta)}{\zeta}(\hat{z}_{k,t} - \hat{p}_{i,t}) \tag{E.40}$$

Price of capital

$$\hat{q}_{t-1} = \frac{\omega_K - \delta}{\omega_K r_k}\hat{q}_t + \frac{z_k}{\omega_K q r_k}\hat{z}_{k,t} - \hat{r}_{k,t} \tag{E.41}$$

Total loan

$$\widehat{l}_t = \frac{l_e}{l}\hat{l}_{e,t} + \frac{l_f}{l}\widehat{l}_{f,t} + \frac{l_x}{l}\widehat{l}_{x,t} \tag{E.42}$$

Real return of loans

$$\hat{r}_{f,t} = \hat{R}_{f,t} - \hat{\pi}_{t+1} \tag{E.43}$$

$$\hat{r}_{x,t} = \hat{R}_{x,t} - \hat{\pi}_{t+1} \tag{E.44}$$

$$\hat{r}_{k,t+1} = \hat{R}_{k,t} - \hat{\pi}_{t+1} \tag{E.45}$$

Real interest rate

$$\hat{r}_t = \hat{R}_t - \hat{\pi}_{t+1} \tag{E.46}$$

Marginal gain from expanding capital working loan

$$\begin{aligned} \hat{\tau}_t = {} & \frac{(1-\theta)\beta}{\tau g_z}(r_f - r)\left(\widehat{\lambda}_{t+1} - \widehat{\lambda}_t - \hat{g}_{z,t+1}\right) + \frac{(1-\theta)\beta}{\tau g_z}(r_f\hat{r}_{f,t} - r\hat{r}_t) \\ & + \theta\beta\left(\widehat{\lambda}_{t+1} - \widehat{\lambda}_t + \hat{l}_{f,t+1} - \hat{l}_{f,t} + \hat{\tau}_{t+1}\right) + \frac{\theta\beta}{\tau g_z}\left[\tau g_z - (r_f - r)\right]\hat{\theta}_{t+1} \end{aligned} \tag{E.47}$$

Marginal gain from expanding export credit

$$\begin{aligned} \hat{\tau}_t = {} & \frac{(1-\theta)\beta}{\tau g_z}(r_x - r)\left(\widehat{\lambda}_{t+1} - \widehat{\lambda}_t - \hat{g}_{z,t+1}\right) + \frac{(1-\theta)\beta}{\tau g_z}(r_x\hat{r}_{x,t} - r\hat{r}_t) \\ & + \theta\beta\left(\widehat{\lambda}_{t+1} - \widehat{\lambda}_t + \hat{l}_{x,t+1} - \hat{l}_{x,t} + \hat{\tau}_{t+1}\right) + \frac{\theta\beta}{\tau g_z}\left[\tau g_z - (r_x - r)\right]\hat{\theta}_{t+1} \end{aligned} \tag{E.48}$$

Marginal gain from expanding entrepreneurial loan

$$\begin{aligned} \hat{\tau}_t = {} & \frac{(1-\theta)\beta}{\tau g_z}(r_k - r)\left(\widehat{\lambda}_{t+1} - \widehat{\lambda}_t - \hat{g}_{z,t+1}\right) + \frac{(1-\theta)\beta}{\tau g_z}(r_k\hat{r}_{k,t+1} - r\hat{r}_t) \\ & + \theta\beta\left(\widehat{\lambda}_{t+1} - \widehat{\lambda}_t + \hat{l}_{e,t+1} - \hat{l}_{e,t} + \hat{\tau}_{t+1}\right) + \frac{\theta\beta}{\tau g_z}\left[\tau g_z - (r_k - r)\right]\hat{\theta}_{t+1} \end{aligned} \tag{E.49}$$

Marginal value of expanding net worth

$$\begin{aligned} \hat{\gamma}_t = {} & \frac{(1-\theta)\beta r}{\gamma g_z}\left(\widehat{\lambda}_{t+1} - \widehat{\lambda}_t - \hat{g}_{z,t+1} + \hat{r}_t\right) \\ & + \theta\beta\left(\widehat{\lambda}_{t+1} - \widehat{\lambda}_t + \hat{n}_{b,t+1} - \hat{n}_{b,t} + \hat{\gamma}_{t+1}\right) + \frac{\theta\beta}{\gamma g_z}(\gamma g_z - r)\hat{\theta}_{t+1} \end{aligned} \tag{E.50}$$

Banking leverage

$$\hat{\phi}_{b,t} = \frac{\tau}{\varpi - \tau}\hat{\tau}_t + \frac{\gamma}{(\varpi - \tau)\phi_b}\hat{\gamma}_t - \frac{\varpi}{\varpi - \tau}\hat{\varpi}_t \tag{E.51}$$

Balance sheet constraint

$$\hat{l}_t = \hat{\phi}_{b,t} + \hat{n}_{b,t} \tag{E.52}$$

Aggregate banking profit

$$\hat{v}_{b,t} = \frac{n_b}{g_z v_b} \Big\{ r\hat{r}_t + \phi_b (r_k - r)\hat{\phi}_{b,t-1} + \phi_b \Big[\frac{l_f}{l} \Big(r_f \hat{r}_{f,t} - r\hat{r}_t + (r_f - r)(\hat{l}_{f,t-1} - \hat{l}_{t-1}) \Big) + \frac{l_x}{l} \Big(r_x \hat{r}_{x,t} - r\hat{r}_t + (r_x - r)(\hat{l}_{x,t-1} - \hat{l}_{t-1}) \Big) + \frac{l_e}{l} \Big(r_k \hat{r}_{k,t} - r\hat{r}_t + (r_k - r)(\hat{l}_{e,t-1} - \hat{l}_{t-1}) \Big) \Big] \Big\} + \hat{n}_{b,t-1} - \hat{g}_{z,t} \tag{E.53}$$

Total net worth

$$\hat{n}_{b,t} = \frac{\theta v_b}{n_b} (\hat{\theta}_t + \hat{v}_{b,t}) \tag{E.54}$$

Shareholder consumption

$$\hat{c}_{b,t} = \hat{v}_{b,t} - \frac{\theta}{1-\theta}\hat{\theta}_t - \hat{p}_{c,t} \tag{E.55}$$

Spread

$$\widehat{spr}_t = \frac{1}{spr} \Big[\frac{r_f l_f}{rl}(\hat{r}_{f,t} - \hat{r}_t) + \frac{r_f l_f}{rl}(\hat{l}_{f,t} - \hat{l}_t) + \frac{r_x l_x}{rl}(\hat{r}_{x,t} - \hat{r}_t) + \frac{r_x l_x}{Rl}(\hat{l}_{x,t} - \hat{l}_t) + \frac{r_k l_e}{rl}(\hat{r}_{k,t+1} - \hat{r}_t) + \frac{r_k l_e}{rl}(\hat{l}_{e,t} - \hat{l}_t) \Big] \tag{E.56}$$

Taylor rule

$$\hat{R}_t = \rho_r \hat{R}_{t-1} + (1-\rho_r) \left[r_\pi (\hat{\pi}_{c,t+1} - \hat{\bar{\pi}}_t) + r_{\Delta y} \hat{g}_{gdp,t} \right] + \hat{\varepsilon}_t \tag{E.57}$$

Resource constraint

$$\hat{y}_t = \hat{g}_t + \frac{c_d}{y}\hat{c}_{d,t} + \frac{i_d}{y}\hat{i}_{d,t} + \frac{x}{y}\hat{x}_t \tag{E.58}$$

GDP

$$\widehat{gdp}_t = \hat{g}_t + \frac{\tilde{c}_d}{gdp}(\hat{c}_t + \eta_c \hat{p}_{c,t}) + \frac{\tilde{c}_m}{gdp}[\hat{c}_t + \eta_c (1-\omega_c)(p_c)^{\eta_c - 1}\hat{p}_{cm,t}] + \frac{i_d}{gdp}(\hat{i}_t + \eta_i \hat{p}_{i,t}) + \frac{i_m}{gdp}[\hat{i}_t + \eta_i (1-\omega_i)(p_i)^{\eta_i - 1}\hat{p}_{im,t}] + \frac{x}{gdp}\hat{x}_t - \frac{m}{gdp}\hat{m}_t \tag{E.59}$$

Net foreign assets

$$\hat{a}_t = \frac{R}{\pi g_z}\hat{a}_{t-1} + [1 + v_X (R_x - 1)]\, x \left[\widehat{rer}_t + \hat{p}_{c,t} + v_X \hat{R}_{x,t} + (1-\omega_x)\hat{p}^*_{x,t} + \omega_x \hat{p}^*_{com,t} + \hat{x}_t \right] - [1 + v_M (R^*_m - 1)]\, m(\widehat{rer}_t + \hat{p}_{c,t} + v_M \hat{R}^*_{m,t} + \hat{m}_t) \tag{E.60}$$

Foreign economy

Marginal cost - intermediate goods producer

$$\widehat{mc}_t^* = \alpha^* \hat{z}_{k,t}^* + (1-\alpha^*)\hat{w}_t^* + \left[(1-\alpha^*)v_H^* + \alpha^* v_K^*\right]\hat{R}_{f,t}^* - \hat{\epsilon}_t^* \tag{E.61}$$

Inflation

$$\begin{aligned}\hat{\pi}_t^* - \hat{\bar{\pi}}_t^* = {} & \frac{\beta^*}{1+\beta^*(1-\iota_p^*)}(\hat{\pi}_{t+1}^* - \rho_{\bar{\pi}}^*\hat{\bar{\pi}}_t^*) + \frac{1-\iota_p^*}{1+\beta^*(1-\iota_p^*)}(\hat{\pi}_{t-1}^* - \hat{\bar{\pi}}_t^*) \\ & - \frac{\beta^*(1-\iota_p^*)}{1+\beta^*(1-\iota_p^*)}(1-\rho_{\bar{\pi}}^*)\hat{\bar{\pi}}_t^* + \frac{(1-\xi_p^*)(1-\beta^*\xi_p^*)}{\left[1+\beta^*(1-\iota_p^*)\right]\xi_p^*}(\widehat{mc}_t^* + \hat{\lambda}_{p,t}^*)\end{aligned} \tag{E.62}$$

Consumption

$$\begin{aligned}\hat{c}_t^* = {} & \frac{b^* g_z^*}{g_z^{*2} + b^{*2}\beta^*}(\hat{c}_{t-1}^* + \beta^*\hat{c}_{t+1}^*) - \frac{b^* g_z^*}{g_z^{*2} + b^{*2}\beta^*}(\hat{g}_{z,t}^* - \beta^*\hat{g}_{z,t+1}^*) \\ & - \frac{(g_z^* - b^*\beta^*)(g_z^* - b^*)}{g_z^{*2} + b^{*2}\beta^*}\widehat{\lambda}_t^* + \frac{g_z^* - b^*}{g_z^{*2} + b^{*2}\beta^*}(g_z^*\hat{b}_t^* - b^*\beta^*\hat{b}_{t+1}^*)\end{aligned} \tag{E.63}$$

Wage inflation

$$\begin{aligned}\hat{w}_t^* = {} & \frac{\beta^*}{1+\beta^*}\hat{w}_{t+1^*} + \frac{1}{1+\beta^*}\hat{w}_{t-1} + \frac{1-\iota_w^*}{1+\beta^*}(\hat{\pi}_{t-1}^* - \hat{\bar{\pi}}_t^*) - \frac{1}{1+\beta^*}(\hat{\pi}_t^* - \hat{\bar{\pi}}_t^*) \\ & - \frac{\beta^*(1-\iota_w^*)}{1+\beta^*}(\hat{\pi}_t^* - \rho_{\bar{\pi}^*}\hat{\bar{\pi}}_t^*) + \frac{\beta^*}{1+\beta^*}(\hat{\pi}_{t+1}^* - \rho_{\bar{\pi}^*}\hat{\bar{\pi}}_t^*) - \frac{(1-\xi_w^*)(1-\beta^*\xi_w^*)}{(1+\beta^*)\xi_w^*\left(1+\sigma_H^*\frac{\lambda_w^*}{\lambda_w^*-1}\right)}(\hat{\mu}_{w,t}^* + \hat{\lambda}_{w,t}^*)\end{aligned} \tag{E.64}$$

Investment equation

$$\hat{i}_t^* = \frac{1}{1+\beta^*}(\hat{i}_{t-1}^* - \hat{g}_{z,t}^*) + \frac{\beta^*}{1+\beta^*}E_t(\hat{i}_{t+1}^* + \hat{g}_{z,t+1}^*) + \frac{1}{F''^* g_z^{*2}(1+\beta^*)}(\hat{q}_t^* + \hat{\mu}_t^*) \tag{E.65}$$

Optimal capital utilization

$$\hat{u}_t^* = \frac{(1-\zeta^*)}{\zeta^*}\hat{z}_{k,t}^* \tag{E.66}$$

Total loan

$$\widehat{l}_t^* = \frac{l_e^*}{l^*}\hat{l}_{e,t}^* + \frac{l_f^*}{l^*}\widehat{l}_{f,t}^* \tag{E.67}$$

Aggregate banking profit

$$\begin{aligned}\hat{v}_{b,t}^* = {} & \frac{n_b^*}{g_z^* v_b^*}\Big\{ r^*\hat{r}_t^* + \phi_b^*(r_k^* - r^*)\hat{\phi}_{b,t-1}^* \\ & + \phi_b^*\Big[\frac{l_f^*}{l^*}\left(r_f^*\hat{r}_{f,t}^* - r^*\hat{r}_t^* + (r_f^* - r^*)(\hat{l}_{f,t-1}^* - \hat{l}_{t-1}^*)\right) \\ & + \frac{l_e^*}{l^*}\left(r_k^*\hat{r}_{k,t}^* - r^*\hat{r}_t^* + (r_k^* - r^*)(\hat{l}_{e,t-1}^* - \hat{l}_{t-1}^*)\right)\Big]\Big\} + \hat{n}_{b,t-1}^* - \hat{g}_{z,t}^*\end{aligned} \tag{E.68}$$

Shareholder consumption

$$\hat{c}_{b,t}^* = \hat{v}_{b,t}^* - \frac{\theta^*}{1-\theta^*}\hat{\theta}_t^* \tag{E.69}$$

Spread

$$\widehat{spr}^*_t = \frac{1}{spr^*}\left[\frac{r^*_f l^*_f}{r^* l^*}(\hat{r}^*_{f,t} - \hat{r}^*_t) + \frac{r^*_f l^*_f}{r^* l^*}(\hat{l}^*_{f,t} - \hat{l}^*_t) + \frac{r^*_k l^*_e}{r^* l^*}(\hat{r}^*_{k,t+1} - \hat{r}^*_t) + \frac{r^*_k l^*_e}{r^* l^*}(\hat{l}^*_{e,t} - \hat{l}^*_t)\right] \tag{E.70}$$

Taylor rule

$$\hat{R}^*_t = \rho^*_r \hat{R}^*_{t-1} + (1-\rho^*_r)\left[r^*_\pi(\hat{\pi}^*_{t+1} - \hat{\bar{\pi}}^*_t) + r^*_{\Delta y}\hat{g}^*_{gdp,t}\right] + \hat{\varepsilon}^*_t \tag{E.71}$$

Resource constraint

$$\hat{y}^*_t = \hat{g}^*_t + \frac{c^*}{y^*}\hat{c}^*_t + \frac{c^*_b}{y^*}\hat{c}^*_{b,t} + \frac{i^*}{y^*}\hat{i}^*_t + \frac{z^*_k k^*}{y^*}\hat{u}^*_t \tag{E.72}$$

GDP

$$\widehat{gdp}^*_t = \hat{g}^*_t + \frac{c^*}{gdp^*}\hat{c}^*_t + \frac{i^*}{gdp^*}\hat{i}^*_t \tag{E.73}$$

E.2 Chapter 3

E.2.1 Pure model

Home economy

(E.1) in Chapter 2

Cost minimization

$$\hat{z}_{k,t} = -(\hat{k}_t - \hat{h}_t) + \hat{w}_t + (v_H - v_K)\hat{R}_t \tag{E.74}$$

Marginal cost - intermediate goods producer

$$\widehat{mc}_{d,t} = \alpha\hat{z}_{k,t} + (1-\alpha)\hat{w}_t + \left[(1-\alpha)v_H + \alpha v_K\right]\hat{R}_t - \hat{\epsilon}_t \tag{E.75}$$

(E.5-8) in Chapter 2

Marginal cost - exporters

$$\widehat{mc}_{x,t} = -\widehat{rer}_t - \hat{p}_{c,t} - \hat{p}^*_{x,t} + v_X\hat{R}_t \tag{E.76}$$

(E.11-14) in Chapter 2

Nominal interest rate on foreign import loans

$$\hat{R}^*_{m,t} = \hat{R}^*_t \tag{E.77}$$

Marginal cost - consumption goods importers

$$\widehat{mc}_{cm,t} = \widehat{rer}_t + \hat{p}_{c,t} - \hat{p}_{cm,t} + \upsilon_M \hat{R}^*_t \tag{E.78}$$

Marginal cost - investment goods importers

$$\widehat{mc}_{im,t} = \widehat{rer}_t + \hat{p}_{c,t} - \hat{p}_{im,t} + \upsilon_M \hat{R}^*_t \tag{E.79}$$

(E.17-18) in Chapter 2

Domestic consumption goods

$$\hat{\hat{c}}_{d,t} = \hat{c}_t + \eta_c \hat{p}_{c,t} \tag{E.80}$$

Import consumption goods

$$\hat{\hat{c}}_{m,t} = \hat{c}_t - \eta_c(1-\omega_c)(p_c)^{\eta_c - 1}\hat{p}_{cm,t} \tag{E.81}$$

(E.21-40) in Chapter 2

Price of capital

$$\hat{q}_t = \frac{\beta(1-\delta)}{g_z}\hat{q}_{t+1} + \frac{\beta z_k}{q g_z}\hat{z}_{k,t+1} + \widehat{\lambda}_{t+1} - \widehat{\lambda}_t - \hat{g}_{z,t+1} \tag{E.82}$$

Taylor

$$R_t = \rho R_{t-1} + (1-\rho)\left[r_\pi\left(\pi_{c,t+1} - \bar{\pi}_t\right) + r_{\Delta_{gdp}}\frac{1}{4}g_{gdp,t}\right] + \varepsilon_t \tag{E.83}$$

Resource constraint

$$\hat{y}_t = \hat{g}_t + \frac{c_d}{y}\hat{c}_{d,t} + \frac{i_d}{y}\hat{i}_{d,t} + \frac{x}{y}\hat{x}_t \tag{E.84}$$

GDP

$$\begin{aligned} \widehat{gdp}_t = \hat{g}_t &+ \frac{c_d}{gdp}(\hat{c}_t + \eta_c\hat{p}_{c,t}) + \frac{c_m}{gdp}[\hat{c}_t - \eta_c(1-\omega_c)(p_c)^{\eta_c-1}\hat{p}_{cm,t}] \\ &+ \frac{i_d}{gdp}(\hat{i}_t + \eta_i\hat{p}_{i,t}) + \frac{i_m}{gdp}[\hat{i}_t - \eta_i(1-\omega_i)(p_i)^{\eta_i-1}\hat{p}_{im,t}] + \frac{x}{gdp}\hat{x}_t - \frac{m}{gdp}\hat{m}_t \end{aligned} \tag{E.85}$$

Net foreign assets

$$\begin{aligned} \hat{a}_t = &\frac{R}{\pi g_z}\hat{a}_{t-1} \\ &+ [1 + \upsilon_X(R-1)]\, x\left[\widehat{rer}_t + \hat{p}_{c,t} + \upsilon_X\hat{R}_t + (1-\omega_x)\hat{p}^*_{x,t} + \omega_x\hat{p}_{com,t} + \hat{x}_t\right] \\ &\qquad - [1 + \upsilon_M(R^*-1)]\, m(\widehat{rer}_t + \hat{p}_{c,t} + \upsilon_M\hat{R}^*_t + \hat{m}_t) \end{aligned} \tag{E.86}$$

Foreign economy

Price of capital

$$\hat{q}_t^* = \frac{\beta^*(1-\delta^*)}{g_z^*}\hat{q}_{t+1}^* + \frac{\beta^* z_k^*}{g_z^*}\hat{z}_{k,t+1}^* + \widehat{\lambda}_{t+1}^* - \widehat{\lambda}_t^* - \hat{g}_{z,t+1}^* \tag{E.87}$$

Resource constraint

$$\hat{y}_t^* = \hat{g}_t^* + \frac{c^*}{y^*}\hat{c}_t^* + \frac{i^*}{y^*}\hat{i}_t^* + \frac{z_k^* k^*}{y^*}\hat{u}_t^* \tag{E.88}$$

(E.74) in Chapter 2

E.2.2 EFP version

(E.1-2) in Chapter 2

(E.75-76) of the Pure model

(E.5-9) in Chapter 2

(E.77) of the Pure model

(E.11) and (E.13) in Chapter 2

(E.78-80) of the Pure model

(E.17-18) in Chapter 2

Domestic consumption goods

$$\hat{c}_{d,t} = \frac{c}{c_p}(\hat{c}_t + \eta_c \hat{p}_{c,t}) + \frac{c_e}{c_p}(\hat{c}_{e,t} + \eta_c \hat{p}_{c,t}) \tag{E.89}$$

Import consumption goods

$$\hat{c}_{m,t} = \frac{c}{c_p}[\hat{c}_t - \eta_c(1-\omega_c)(p_c)^{\eta_c - 1}\hat{p}_{cm,t}] + \frac{c_e}{c_p}[\hat{c}_{e,t} - \eta_c(1-\omega_c)(p_c)^{\eta_c - 1}\hat{p}_{cm,t}] \tag{E.90}$$

(E.21-22) and (E.24-37) in Chapter 2

Aggregate entrepreneurial loan

$$\hat{l}_{e,t} = \hat{n}_{e,t} + \frac{\phi_e}{\phi_e - 1}\hat{\phi}_{e,t} \tag{E.91}$$

Entrepreneurial leverage multiple

$$\hat{\phi}_{e,t} = \hat{q}_t + \hat{k}_{t+1} - \hat{n}_{e,t} \tag{E.92}$$

Capital service

$$\hat{k}_t = \hat{\bar{k}}_{t-1} - \hat{g}_{z,t} + \hat{u}_t + \hat{\omega}_{t-1} \tag{E.93}$$

(E.40) in Chapter 2

Price of capital

$$\hat{q}_{t-1} = \frac{\beta(1-\delta)}{g_z}\hat{q}_t + \frac{g_z - \beta(1-\delta)}{g_z}\hat{z}_{k,t} - \hat{r}_{k,t} \tag{E.94}$$

(E.42) in Chapter 2

Ex-ante lending rate on entrepreneurial loan

$$\hat{r}_{b,t} = \hat{r}_{k,t} + \epsilon_{z,\bar{\omega}}\hat{\bar{\omega}}_t + \epsilon_{z,\sigma_e}\hat{\sigma}_{e,t-1} - \frac{1}{\phi_e - 1}\hat{\phi}_{e,t-1} \tag{E.95}$$

Ex-post return on capital

$$E_t\hat{r}_{k,t+1} = \hat{r}_t + \epsilon_{spr_e,\phi_e}\hat{\phi}_{e,t} + \epsilon_{spr_e,\sigma_e}\hat{\sigma}_{e,t} \tag{E.96}$$

Cut-off value

$$\hat{\bar{\omega}}_t = \frac{1}{\epsilon_{z,\bar{\omega}}(\phi_e - 1)}\hat{\phi}_{e,t-1} - \frac{1}{\epsilon_{z,\bar{\omega}}}\left(\hat{r}_{k,t} - \hat{r}_{t-1}\right) - \frac{\epsilon_{z,\sigma_e}}{\epsilon_{z,\bar{\omega}}}\hat{\sigma}_{e,t-1} \tag{E.97}$$

Aggregate entrepreneurial profit

$$\hat{v}_{e,t} = \hat{n}_{e,t-1} - g_{z,t} + \hat{r}_{k,t} + \hat{\phi}_{e,t-1} - \frac{\Gamma'\left(\bar{\omega}\right)\bar{\omega}}{1-\Gamma\left(\bar{\omega}\right)}\hat{\bar{\omega}}_t - \frac{\Gamma_{\sigma_e}\left(\bar{\omega}\right)\sigma_e}{1-\Gamma\left(\bar{\omega}\right)}\hat{\sigma}_{e,t-1} \tag{E.98}$$

Entrepreneurial networth

$$\hat{n}_{e,t} = \frac{\theta_e v_e}{n_e}(\hat{v}_{e,t} + \hat{\theta}_{e,t}) \tag{E.99}$$

Shareholder consumption

$$\hat{c}_{e,t} + \hat{p}_{c,t} = \hat{v}_{e,t} - \frac{\theta_e}{1-\theta_e}\hat{\theta}_{e,t} \tag{E.100}$$

Credit spread

$$\widehat{spr}_{e,t} = \hat{r}_{b,t} - \hat{r}_t \tag{E.101}$$

(E.83) in the Pure model

Resource constraint

$$\hat{y}_t = \hat{g}_t + \frac{\tilde{c}_d}{y}\hat{\tilde{c}}_{d,t} + \frac{i_d}{y}\hat{i}_{d,t} + \frac{x}{y}\hat{x}_t + \frac{r_k k}{y}\mu G(\bar{\omega})\left(\hat{r}_{k,t} + \hat{q}_{t-1} + \hat{k}_{t-1} + \frac{G'(\bar{\omega})}{G(\bar{\omega})}\bar{\omega}\bar{\omega}_t\right) \tag{E.102}$$

Domestic consumption goods

$$\hat{\tilde{c}}_{d,t} = \frac{c}{c_p}(\hat{c}_t + +\eta_c\hat{p}_{c,t}) + \frac{c_e}{c_p}(\hat{c}_{e,t} + \eta_c\hat{p}_{c,t}) \tag{E.103}$$

Import consumption goods

$$\hat{\tilde{c}}_{m,t} = \frac{c}{c_p}[\hat{c}_t - \eta_c(1-\omega_c)(p_c)^{\eta_c-1}\hat{p}_{cm,t}] + \frac{c_e}{c_p}[\hat{c}_{e,t} - \eta_c(1-\omega_c)(p_c)^{\eta_c-1}\hat{p}_{cm,t}] \tag{E.104}$$

Total import

$$\hat{\tilde{m}}_t = \frac{\tilde{c}_m}{\tilde{m}}\hat{\tilde{c}}_{m,t} + \frac{i_m}{\tilde{m}}\hat{i}_{m,t} \tag{E.105}$$

Trade balance

$$\widehat{nx}_t = \hat{x}_t - \hat{\tilde{m}}_t \tag{E.106}$$

GDP

$$\begin{aligned}\widehat{gdp}_t = \hat{g}_t + \frac{\tilde{c}_d}{gdp}(\hat{c}_t + \eta_c\hat{p}_{c,t}) + \frac{\tilde{c}_m}{gdp}[\hat{c}_t - \eta_c(1-\omega_c)(p_c)^{\eta_c-1}\hat{p}_{cm,t}] \\ + \frac{i_d}{gdp}(\hat{i}_t + \eta_i\hat{p}_{i,t}) + \frac{i_m}{gdp}[\hat{i}_t - \eta_i(1-\omega_i)(p_i)^{\eta_i-1}\hat{p}_{im,t}] + \frac{x}{gdp}\hat{x}_t - \frac{\tilde{m}}{gdp}\hat{\tilde{m}}_t\end{aligned} \tag{E.107}$$

(E.86) of the Pure model

Foreign economy

Shareholder consumption

$$\hat{c}^*_{e,t} = \hat{v}^*_{e,t} - \frac{\theta^*_e}{1-\theta^*_e}\hat{\theta}^*_{e,t} \tag{E.108}$$

Resource constraint

$$\begin{aligned}\hat{y}^*_t = \hat{g}^*_t + \frac{c^*}{y^*}\hat{c}^*_t + \frac{c^*_e}{y^*}\hat{c}^*_{e,t} + \frac{i^*}{y^*}\hat{i}^*_t + \frac{z^*_k k^*}{y^*}\hat{u}^*_t \\ + \frac{r^*_k k^*}{y^*}\mu^* G(\bar{\omega}^*)\left(\hat{r}^*_{k,t} + \hat{q}^*_{t-1} + \hat{k}^*_{t-1} + \frac{G'(\bar{\omega}^*)}{G(\bar{\omega}^*)}\bar{\omega}^*\bar{\omega}^*_t\right)\end{aligned} \tag{E.109}$$

E.2.3 ICC version

(E.1-11), (E.13-18), (E.21-22) and (E.24-57) in Chapter 2

Resource constraint

$$\hat{y}_t = \hat{g}_t + \frac{\tilde{c}_d}{y}\hat{\tilde{c}}_{d,t} + \frac{i_d}{y}\hat{i}_{d,t} + \frac{x}{y}\hat{x}_t \tag{E.110}$$

Domestic consumption goods

$$\hat{\tilde{c}}_{d,t} = \frac{c}{c_p}(\hat{c}_t + \eta_c \hat{p}_{c,t}) + \frac{c_b}{c_p}(\hat{c}_{b,t} + \eta_c \hat{p}_{c,t}) \tag{E.111}$$

Import consumption goods

$$\hat{\tilde{c}}_{m,t} = \frac{c}{c_p}[\hat{c}_t - \eta_c(1-\omega_c)(p_c)^{\eta_c - 1}\hat{p}_{cm,t}] + \frac{c_b}{c_p}[\hat{c}_{b,t} - \eta_c(1-\omega_c)(p_c)^{\eta_c - 1}\hat{p}_{cm,t}] \tag{E.112}$$

(E.105-106) of the EFP version

GDP

$$\widehat{gdp}_t = \hat{g}_t + \frac{\tilde{c}_d}{gdp}(\hat{c}_t + \eta_c \hat{p}_{c,t}) + \frac{\tilde{c}_m}{gdp}[\hat{c}_t - \eta_c(1-\omega_c)(p_c)^{\eta_c - 1}\hat{p}_{cm,t}]$$
$$+ \frac{i_d}{gdp}(\hat{i}_t + \eta_i \hat{p}_{i,t}) + \frac{i_m}{gdp}[\hat{i}_t - \eta_i(1-\omega_i)(p_i)^{\eta_i - 1}\hat{p}_{im,t}] + \frac{x}{gdp}\hat{x}_t - \frac{\tilde{m}}{gdp}\hat{\tilde{m}}_t \tag{E.113}$$

(E.60) in Chapter 2

E.3 Chapter 4 - Baseline model

(E.1-18) in Chapter 2

Domestic consumption goods

$$\hat{c}_{d,t} = \frac{c}{c_p}(\hat{c}_t + \eta_c \hat{p}_{c,t}) + \frac{c_e}{c_p}(\hat{c}_{e,t} + \eta_c \hat{p}_{c,t}) + \frac{c_b}{c_p}(\hat{c}_{b,t} + \eta_c \hat{p}_{c,t}) \tag{E.114}$$

Import consumption goods

$$\hat{c}_{m,t} = \frac{c}{c_p}[\hat{c}_t - \eta_c(1-\omega_c)(p_c)^{\eta_c - 1}\hat{p}_{cm,t}] + \frac{c_e}{c_p}[\hat{c}_{e,t} - \eta_c(1-\omega_c)(p_c)^{\eta_c - 1}\hat{p}_{cm,t}]$$
$$+ \frac{c_b}{c_p}[\hat{c}_{b,t} - \eta_c(1-\omega_c)(p_c)^{\eta_c - 1}\hat{p}_{cm,t}] \tag{E.115}$$

(E.21-37) in Chapter 2

(E.91-93) of the EFP version in Chapter 3

(E.40) in Chapter 2

(E.94-95) of the EFP version in Chapter 3

Ex-post return on capital

$$E_t \hat{r}_{k,t+1} = E_t \hat{r}_{e,t+1} + \epsilon_{spr_e,\phi_e}\hat{\phi}_{e,t} + \epsilon_{spr_e,\sigma_e}\hat{\sigma}_{e,t} \tag{E.116}$$

Cut-off value

$$\hat{\bar{\omega}}_t = \frac{1}{\epsilon_{z,\bar{\omega}}(\phi_e - 1)} \hat{\phi}_{e,t-1} - \frac{1}{\epsilon_{z,\bar{\omega}}} (\hat{r}_{k,t} - \hat{r}_{e,t}) - \frac{\epsilon_{z,\sigma_e}}{\epsilon_{z,\bar{\omega}}} \hat{\sigma}_{e,t-1} \tag{E.117}$$

(E.98-101) of the EFP version in Chapter 3

(E.42-48) in Chapter 2

Marginal gain from expanding entrepreneurial loan

$$\begin{aligned} \hat{\tau}_t = {} & \frac{(1-\theta_b)\beta}{\tau g_z} (r_e - r) \left(\widehat{\lambda}_{t+1} - \widehat{\lambda}_t - \hat{g}_{z,t+1} \right) + \frac{(1-\theta_b)\beta}{\tau g_z} (r_e \hat{r}_{e,t+1} - r \hat{r}_t) \\ & + \theta_b \beta \left(\widehat{\lambda}_{t+1} - \widehat{\lambda}_t + \hat{l}_{e,t+1} - \hat{l}_{e,t} + \hat{\tau}_{t+1} \right) + \frac{\theta_b \beta}{\tau g_z} [\tau g_z - (r_e - r)] \hat{\theta}_{b,t+1} \end{aligned} \tag{E.118}$$

(E.50-55) in Chapter 2

Credit spread

$$\begin{aligned} \widehat{spr}_{b,t} = \frac{1}{spr_b} \Bigg[& \frac{r_f l_f}{rl} (\hat{r}_{f,t} - \hat{r}_t) + \frac{r_f l_f}{rl} (\hat{l}_{f,t} - \hat{l}_t) + \frac{r_x l_x}{rl} (\hat{r}_{x,t} - \hat{r}_t) \\ & + \frac{r_x l_x}{rl} (\hat{l}_{x,t} - \hat{l}_t) + \frac{r_b l_e}{rl} (\hat{r}_{b,t} - \hat{r}_t) + \frac{r_b l_e}{rl} (\hat{l}_{e,t} - \hat{l}_t) \Bigg] \end{aligned} \tag{E.119}$$

(E.57) in Chapter 2

Resource constraint

$$\hat{y}_t = \hat{g}_t + \frac{c_d}{y} \hat{c}_{d,t} + \frac{i_d}{y} \hat{i}_{d,t} + \frac{x}{y} \hat{x}_t + \frac{r_k k}{y} \mu G(\bar{\omega}) \left(\hat{r}_{k,t} + \hat{q}_{t-1} + \hat{k}_{t-1} + \frac{G'(\bar{\omega})}{G(\bar{\omega})} \bar{\omega} \bar{\omega}_t \right) \tag{E.120}$$

(E.59-60) in Chapter 2

Foreign economy

Spread

$$\begin{aligned} \widehat{spr}^*_t = \frac{1}{spr^*} \Bigg[& \frac{r^*_f l^*_f}{r^* l^*} (\hat{r}^*_{f,t} - \hat{r}^*_t) + \frac{r^*_f l^*_f}{r^* l^*} (\hat{l}^*_{f,t} - \hat{l}^*_t) \\ & + \frac{r^*_b l^*_e}{r^* l^*} (\hat{r}^*_{b,t} - \hat{r}^*_t) + \frac{r^*_b l^*_e}{r^* l^*} (\hat{l}^*_{e,t} - \hat{l}^*_t) \end{aligned} \tag{E.121}$$

Resource constraint

$$\begin{aligned} \hat{y}^*_t = {} & \hat{g}^*_t + \frac{c^*}{y^*} \hat{c}^*_t + \frac{c^*_e}{y^*} \hat{c}^*_{e,t} + \frac{c^*_b}{y^*} \hat{c}^*_{b,t} + \frac{i^*}{y^*} \hat{i}^*_t + \frac{z^*_k k^*}{y^*} \hat{u}^*_t \\ & + \frac{r^*_k k^*}{y^*} \mu^* G(\bar{\omega}^*) \left(\hat{r}^*_{k,t} + \hat{q}^*_{t-1} + \hat{k}^*_{t-1} + \frac{G'(\bar{\omega}^*)}{G(\bar{\omega}^*)} \bar{\omega}^* \bar{\omega}^*_t \right) \end{aligned} \tag{E.122}$$

Appendix F

Normalization of the shocks

The parameter expression of some exogenous shocks is normalized to enter with a unit coefficient in the estimation equation as in Smets and Wouters (2007). In particular, I normalize the parameter expression of the shock to intertemporal preference, investment, and markups as follows:

$$
\begin{aligned}
\frac{g_z(g_z - b)}{g_z^2 + b^2\beta}\hat{b}_t &= 1 \times \hat{b}_t \\
\frac{1}{F'' g_z^2(1+\beta)}\hat{\mu}_t &= 1 \times \hat{\mu}_t \\
\frac{(1-\xi_w)(1-\beta\xi_w)}{(1+\beta)\xi_w\left(1+\sigma_H \frac{\lambda_w}{\lambda_w - 1}\right)}\hat{\lambda}_{w,t} &= 1 \times \hat{\lambda}_{w,t} \\
\frac{(1-\xi_d)(1-\beta\xi_d)}{\left[1+\beta(1-\iota_d)\right]\xi_d}\hat{\lambda}_{d,t} &= 1 \times \hat{\lambda}_{d,t} \\
\frac{(1-\xi_x)(1-\beta\xi_x)}{[1+\beta(1-\iota_x)]\xi_x}\hat{\lambda}_{x,t} &= 1 \times \hat{\lambda}_{x,t} \\
\frac{(1-\xi_{cm})(1-\beta\xi_{cm})}{\left[1+\beta(1-\iota_{cm})\right]\xi_{cm}}\hat{\lambda}_{cm,t} &= 1 \times \hat{\lambda}_{cm,t} \\
\frac{(1-\xi_{im})(1-\beta\xi_{im})}{\left[1+\beta(1-\iota_{im})\right]\xi_{im}}\hat{\lambda}_{im,t} &= 1 \times \hat{\lambda}_{im,t}
\end{aligned}
$$

The normalization of shocks bring about some benefit for the estimation exercise (Justiniano, Primiceri, and Tambalotti (2010)). First, it is easier to choose a reasonable prior for the standard deviation of the innovation to shocks. Second, the normalization often improves the convergence properties of the Markov Chain Monte Carlo algorithm.

Appendix G

Data definitions and data sources

G.1 Australia

GDP, GDP_t: Gross Domestic Product, in millions of AU dollars, current prices, quarterly, seasonally adjusted, deflated by the GDP Price Deflator. Source: Australia Bureau of Statistics, Cat No. 5206.0, Table 3. Expenditure on Gross Domestic Product.

Consumption, C_t: Household Final Consumption Expenditure on Non-durables and Services (Total Consumption minus Durables), in millions of AU dollars, current prices, quarterly, seasonally adjusted, deflated by the GDP Price Deflator. Source: Australia Bureau of Statistics, Cat No. 5206.0, Table 8. Household Final Consumption Expenditure.

Investment, I_t: Gross Private Fixed Capital Formation plus Durable Consumption, in millions of AU dollars, current prices, quarterly, seasonally adjusted, deflated by the GDP Price Deflator. Source: Australia Bureau of Statistics, Cat No. 5206.0, Table 3. Expenditure on Gross Domestic Product and Table 8. Household Final Consumption Expenditure.

Hours worked, H_t: Non-farm Hours Worked, Quarterly Hours Worked in All Jobs, market excluding agriculture (rest of market plus education and training), quarterly, seasonally adjusted. Source: Australia Bureau of Statistics, Cat No. 6202.0, Table 21. Quarterly hours worked in all jobs by Market and Non-market sectorX.

Wage, W_t: Wage Per Hour, Total Non-farm Compensation of Employee, in millions of AU dollars, current prices, quarterly, seasonally adjusted, divided by Non-farm Hours Worked and by the GDP Price Deflator. Source: Australia Bureau of Statistics, Cat No. 5206.0, Table 24. Selected Analytical.

Interest rates, R_t: Cash Rate Target, percent, quarter-average, original. Source: Reserve Bank of Australia, Statistical Table F1.1. Interest Rates and Yields - Money Market.

Consumption Price Inflation, $\Pi_{c,t}$: Consumer Price Index, excluding interest payments and tax changes, trimmed mean, percent change, quarterly, seasonally adjusted. Source: Reserve Bank of Australia, Statistical Table G1. Consumer Price Inflation.

Domestic inflation, Π_t: Logarithmic first difference of the GDP Price Deflator, percent change, quarterly, seasonally adjusted. Source: Australia Bureau of Statistics, Cat No. 5206.0, Table 5. Expenditure on Gross Domestic Product, Implicit price deflators.

Relative price of investment, $\Pi_{i,t}$: Logarithmic first difference of the Investment Price Deflator divided by the GDP Price Deflator, percent change, quarterly, seasonally adjusted. Source: Australia Bureau of Statistics, Cat No. 5206.0, Table 5. Expenditure on Gross Domestic Product, Implicit price deflators.

Relative price of commodities, $\Pi^*_{com,t}$: Logarithmic first difference of the Index of USD Commodity Prices divided by the US GDP Price Deflator, percent change, quarter-average. Source: Reserve Bank of Australia, Statistical Table I2. Commodity Prices.

Real exchange rate, RER_t: Real Trade-weighted Index, index numbers, quarterly, original. Source: Reserve Bank of Australia, Table F15. Real Exchange Rate Measures.

Non-commodity export, $X_{non,t}$: Exports of Goods and Services minus General Merchandise, in millions of AU dollars, current prices, quarterly, seasonally adjusted, deflated by the GDP Price Deflator. Source: Australia Bureau of Statistics, Cat No. 5206.0 and Cat No. 5302.0, Table 3. Expenditure on Gross Domestic Product and Table 6. Goods Credits.

Commodity export, $X_{com,t}$: General Merchandise, in millions of AU dollars, current prices, quarterly, seasonally adjusted, deflated by the GDP Price Deflator. Source: Australia Bureau of Statistics, Cat No. 5302.0, Table 6. Goods Credits.

Import, M_t: Imports of Goods and Services, in millions of AU dollars, current prices, quarterly, seasonally adjusted, deflated by the GDP Price Deflator. Source: Australia Bureau of Statistics, Cat No. 5206.0, Table 3. Expenditure on Gross Domestic Product.

Entrepreneurial net worth, $N_{e,t}$: All Ordinaries Close Index, quarter-average, deflated by the GDP Price Deflator. Source: Australia Stock Exchange.

External finance premium, Efp_t: Weighted-average of Spread on Corporate 10-year BBB-rated Bonds and Spread on Large Business Loans. Alternative measure: Weighted-average of Spread on Corporate 10-year A-rated Bonds and Spread on Large Business Loans. Prior 2005Q2, backcasted using Spread on Large business loans.

Spread on Corporate 10-year BBB-rated bonds: Corporate BBB-rated Bond Spread to Australian Commonwealth Government Securities, 10 year target tenor, basis points, quarter-average, original. Source: RBA Statistical Table F5. Aggregate Measures of Australian Corporate Bond Spreads and Yields (Non-financial Corporate Bonds).

Spread on Large Business Loans: Large Business Weighted-average Variable Interest Rate on Credit Outstanding minus Cash Rate Target, percent, quarter-average, original. Source: Reserve Bank of Australia, Table F5. Indicator Lending Rates.

Weights on bonds: Sum of Private Non-financial Business Equities and Bond Liabilities, in billions of AU dollars, current prices, quarterly, original; divided by Sum of Private Non-financial Business Loans, Equities and Bond Liabilities. Source: RBA Statistical Table E1. Household and Business Balance Sheets.

Weights on loans: Private Non-financial Business Loans, in billions of AU dollars, current prices, quarterly, original; divided by Sum of Private Non-financial Business Loans, Equities and Bond Liabilities. Source: RBA Statistical Table E1. Household and Business Balance Sheets.

Credit, L_t: Credit Market Instruments Liabilities of Nonfinancial Corporations, in millions of AU dollars, quarterly, original, deflated by the GDP Price Deflator. Credit Market Instruments consists of four debt instruments: one name paper, bonds, short term loans and placements, and long term loans and placements. Source: Australia Bureau of Statistics, Cat No. 5232.0, Table 6. Financial Assets and Liabilities of Non-Financial Corporations.

Spread, Spr_t: Corporate 10-year BBB-rated Bonds Yield minus Cash Rate Target, and Large Business Weighted-average Variable Interest Rate on Credit Outstanding minus Cash Rate Target, percent, quarter-average, original. Alternative measure: Corporate 10-year A-rated Bonds Yield minus Cash Rate Target, and Large Business Weighted-average Variable Interest Rate on Credit Outstanding minus Cash Rate Target. Source: RBA Statistical Table F5.

G.2 United States

GDP, GDP_t^*: Gross Domestic Product, in billions of US dollars, current prices, quarterly, seasonally adjusted annual rate, deflated by the GDP Price Deflator. Source:

Bureau of Economic Analysis.

Consumption, C_t^*: Personal Consumption Expenditures, in billions of US dollars, current prices, quarterly, seasonally adjusted annual rate, deflated by the GDP Price Deflator. Source: Bureau of Economic Analysis.

Investment, I_t^*: Gross Private Domestic Investment plus Personal Consumption Expenditures on Durables, in billions of US dollars, current prices, quarterly, seasonally adjusted annual rate, deflated by the GDP Price Deflator. Source: Bureau of Economic Analysis.

Real wage, W_t^*: Real Non-farm Business Sector Hourly Compensation, index, quarterly, seasonally adjusted, divided by the GDP Price Deflator. Source: Bureau of Labour Statistics.

Labor, H_t^*: Non-farm Business Sector Hours Worked, index, quarterly, seasonally adjusted. Source: Bureau of Labour Statistics.

Interest rates, R_t^*: Effective Federal Funds Rate, percent, quarterly, not seasonally adjusted. Source: FRED.

Inflation, Π_t^*: Logarithmic first difference of the GDP Price Deflator, percent change, quarterly, seasonally adjusted. Source: FRED.

Entrepreneurial net worth, $N_{e,t}^*$: Wilshire 5000 Total Market Index, quarter-average, not seasonally adjusted, deflated by the GDP Price Deflator. Source: FRED.

External finance premium, Efp_t^*: Moody's Seasoned Baa Corporate Bond Yield Relative to Yield on 10-Year Treasury Constant Maturity, quarterly, not seasonally adjusted. Alternative measure: Moody's Seasoned Aaa Corporate Bond Yield Relative to Yield on 10-Year Treasury Constant Maturity. Source: FRED.

Credit, L_t^*: Credit Market Instruments Liabilities of Nonfinancial Corporate Business plus Credit Market Instruments Liabilities of Nonfinancial Noncorporate Business, in billions of US dollars, quarterly, seasonally adjusted, deflated by the GDP Price Deflator. Credit Market Instruments consists of four debt instruments: commercial paper, municipal securities and loans, corporate bonds, bank loans not elsewhere classified, other loans and advances, and mortgages. Source: Federal Reserve Board, Flow of Funds Accounts, Table D.3 and Table B.103 (or Table L.1).

Spread, Spr_t^*: Moody's Seasoned Baa Corporate Bond Yield minus Effective Federal Funds Rate, percent, quarterly, not seasonally adjusted. Alternative measure: Moody's Seasoned Aaa Corporate Bond Yield minus Effective Federal Funds Rate. Source: FRED.

Appendix H

Measurement equations

I need to identify the trend growth component when mapping the endogenous real variables of our theoretical model to the observable variables in the dataset. This is because some data series have a trend growth while all scaled real variables in the theoretical model are stationary by scaling. Recall that in the theoretical model, variations in the real variables originate partly from the permanent technology shock. I therefore express the model's scaled real variables in first difference form in order to include a stationary trend growth rate shock into their measurement equations. The following set of measurement equations describes the mapping from the endogenous variables of the theoretical model to the observables in the dataset.

$$\Delta GDP_t = \widehat{gdp}_t - \widehat{gdp}_{t-1} + \hat{g}_{z,t}$$

$$\Delta \tilde{C}_t = \hat{c}_t - \hat{c}_{t-1} + \left(\frac{\eta_c}{\tilde{c}_d + \tilde{c}_m}\right)\left[\tilde{c}_d \omega_c \left(\frac{p_c}{p_{cm}}\right)^{\eta_c - 1} - \tilde{c}_m (1-\omega_c)\,(p_c)^{\eta_c - 1}\right](\hat{\pi}_{cm,t} - \hat{\pi}_t) + \hat{g}_{z,t}$$

$$\Delta \tilde{I}_t = \hat{i}_t - \hat{i}_{t-1} + \left(\frac{\eta_i}{i_d + i_m}\right)\left[i_d \omega_i \left(\frac{p_i}{p_{im}}\right)^{\eta_i - 1} - i_m (1-\omega_i)\,(p_i)^{\eta_i - 1}\right](\hat{\pi}_{im,t} - \hat{\pi}_t) + \hat{g}_{z,t}$$

$$\Delta X_{non,t} = -\eta^*(\hat{\pi}_{x,t} - \hat{\pi}_t^*) + \widehat{gdp}_t^* - \widehat{gdp}_{t-1}^* + \hat{\tilde{z}}_t^* - \hat{\tilde{z}}_{t-1}^* + \hat{g}_{z,t}$$

$$\Delta X_{com,t} = \hat{\varepsilon}_{com,t} - \hat{\varepsilon}_{com,t-1} + \widehat{gdp}_t^* - \widehat{gdp}_{t-1}^* + \hat{\tilde{z}}_t^* - \hat{\tilde{z}}_{t-1}^* + \hat{g}_{z,t}$$

$$\Delta \tilde{M}_t = \frac{\tilde{c}_m}{\tilde{c}_m + i_m}\left[\hat{c}_t - \hat{c}_{t-1} + \eta_c(1-\omega_c)(p_c)^{\eta_c - 1}(\hat{\pi}_t - \hat{\pi}_{cm,t})\right] + \frac{i_m}{\tilde{c}_m + i_m}\left[\hat{i}_t - \hat{i}_{t-1} + \eta_i(1-\omega_{im})(p_i)^{\eta_i - 1}(\hat{\pi}_t - \hat{\pi}_{im,t})\right] + \hat{g}_{z,t}$$

$$\Delta W_t = \widehat{w}_t - \widehat{w}_{t-1} + \hat{g}_{z,t}$$

$$H_t = \hat{h}_t$$

$$R_t = \hat{R}_t$$

$$\Pi_{c,t} = \hat{\pi}_{c,t}$$

$$\Pi_t = \hat{\pi}_t$$

$$\Pi_{i,t} = \hat{p}_{i,t} - \hat{p}_{i,t-1}$$

$$\Pi^*_{com,t} = \hat{p}^*_{com,t} - \hat{p}^*_{com,t-1}$$

$$\Delta RER_t = \widehat{rer}_t - \widehat{rer}_{t-1}$$

$$\Delta L_t = \hat{l}_t - \hat{l}_{t-1} + \hat{g}_{z,t}$$

$$\Delta N_{e,t} = \hat{n}_{e,t} - \hat{n}_{e,t-1} + \hat{g}_{z,t}$$

$$Spr_{e,t} = \widehat{spr}_{e,t}$$

$$Spr_{b,t} = \widehat{spr}_{b,t}$$

$$\Delta GDP^*_t = \widehat{gdp}^*_t - \widehat{gdp}^*_{t-1} + \hat{g}^*_{z,t}$$

$$\Delta C_t = \hat{c}^*_t - \hat{c}^*_{t-1} + \hat{g}^*_{z,t}$$

$$\Delta I_t = \hat{i}^*_t - \hat{i}^*_{t-1} + \hat{g}^*_{z,t}$$

$$\Delta W^*_t = \widehat{w}^*_t - \widehat{w}^*_{t-1} + \hat{g}^*_{z,t}$$

$$H^*_t = \hat{h}^*_t$$

$$R^*_t = \hat{R}^*_t$$

$$\Pi^*_t = \hat{\pi}^*_t$$

$$\Delta N^*_{e,t} = \hat{n}^*_{e,t} - \hat{n}^*_{e,t-1} + \hat{g}^*_{z,t}$$

$$\Delta L^*_t = \hat{l}^*_t - \hat{l}^*_{t-1} + \hat{g}^*_{z,t}$$

$$Spr^*_{e,t} = \widehat{spr}^*_{e,t}$$

$$Spr^*_{b,t} = \widehat{spr}^*_{b,t}$$

Note: For the Pure model, $\tilde{c}_d$ and $\tilde{c}_m$ in the measurement equations of $\Delta\tilde{C}_t$ and $\Delta\tilde{I}_t$ are replaced by c_d and c_m, respectively.