BANCO CENTRAL DE RESERVA DEL PERÚ

Mortgage Credit: Lending and Borrowing Constraints in a DSGE Framework

Elmer Sánchez León[1]

[1] Banco Central de Reserva del Perú

DT. N° 2016-009
Serie de Documentos de Trabajo
Working Paper series
Octubre 2016

Mortgage Credit: Lending and Borrowing Constraints in a DSGE Framework

Elmer Sánchez León*

June, 2016

Abstract

This paper develops a Dynamic Stochastic General Equilibrium (DSGE) framework to evaluate the relative importance of the easing of lending and borrowing constraints in mortgage credit markets for business cycle fluctuations in small open emerging economies. Credit markets are characterized by partial dollarization and are subject to demand shocks, innovations to stochastic loan-to-value ratios (borrowing constraints) imposed on borrowers, and supply shocks, innovations to stochastic bank capital-to-asset ratios (lending constraints) imposed on financial intermediaries. In addition, the model features a set of real and nominal domestic shocks to demand, productivity, and fiscal and monetary policy, as well as foreign shocks. The model is calibrated and estimated using data on the Peruvian economy. A historical decomposition conducted on household leverage ratios reveals that these variables' cyclical dynamics were mainly driven by borrowing constraint shocks or credit demand shifts, while lending constraint shocks played a residual role. Counterfactual simulations also provide evidence in favor of this channel: turning off the borrowing constraint shocks significantly attenuates the fluctuations of leverage ratios from their steady-state levels. The importance of the demand channel in Peru is consistent with mortgage demand-boosting public programs enacted in the 2000s. While applied in the Peruvian context here, the framework is easily adaptable to the historical evolution of credit markets in a large variety of emerging market economies.

JEL classification: E37, E44, E52.
Keywords: financial frictions, DSGE with banking sector.

*I would like to thank my advisor Professor Rahul Mukherjee for his invaluable guidance, as well as seminar participants at The Graduate Institute in Geneva for their useful comments. The author is also grateful to the BCC program and SECO for their support. The usual disclaimer applies.

*Senior Economist in Macroeconomic Modeling, Macroeconomic Models Department at Banco Central de Reserva del Perú (Central Reserve Bank of Peru). E-mail: elmer.sanchez@bcrp.gob.pe

1 Introduction

Housing and mortgage markets played an important role in the financial crisis that affected most developed economies. Prior to the Great Recession, many of those countries experienced increasing housing prices and current account deficits along with massive capital flows and credit booms. The consequences were grim: in the US, for example, the financial crisis precipitated the worst recession since the Great Depression. Countries in other regions, such as Latin America, have been experiencing most of those patterns for more than a decade, leading to valid concerns about the potential formation of financial instability.

It is known that the fast growth of mortgage loans may create financial instability and governments should improve their knowledge about this phenomenon. In this context, it is important to study the determinants of mortgage credit growth. The traditional literature associates sharp credit expansions with relaxed borrowing constraints as in the seminal paper of Kiyotaki and Moore (1997). Iacoviello (2005), Iacoviello and Neri (2010), and Gerali et al. (2010) assume that a collateral constraint limits households' ability to borrow against real estate; under this view, credit grows fast when these constraints are relaxed, for example when households have access to mortgages with higher initial loan-to-value ratios.

Justiniano, Primiceri, and Tambalotti (2015) introduce a novel approach by first drawing a distinction between supply and demand for credit as drivers of credit growth. These authors interpret the easing of borrowing constraints as a credit demand driver, and of lending constraints as a credit supply shifter. Under their view, the borrowing constraints are modeled as usual while the lending constraints, which capture a combination of technological and institutional factors that restrain the flow of funds from savers to mortgage borrowers, are modeled as a leverage restriction on financial institutions or lenders. These constraints may be relaxed as the flow of funds to mortgage loans expands due to a financial intermediation innovation, such as the diffusion and more intensive use of securitization and market-based financial intermediation that occurred in the US in the 2000s. Inflows of foreign funds into mortgage products are isomorphic to an easing of the domestic lending constraint, resulting in a shift in the overall amount of funds available to (mortgage) borrowers.

I follow this approach and build a Dynamic Stochastic General Equilibrium (DSGE) model that allows determination of the relative importance of the relaxation of lending and borrowing constraints as drivers of mortgage credit business cycle fluctuations. In particular, I develop a large-scale DSGE model for a small open economy with partially dollarized credit markets, characteristic of a typical emerging market. In this sense, this paper provides a comprehensive and rigorous tool that allows for the disentanglement and assessment of the role of shifts in credit supply and demand on credit and macroeconomic fluctuations. This is a key issue for monetary policy and macroprudential regulation, since different drivers require the implementation of supply- or demand-side policies to efficiently moderate the effects of credit boom-bust cycles on the economy.

The model is built in the spirit of Gerali et al. (2010) and Brzoza-Brzezina and Makarski (2011). It is an extended small open economy new Keynesian model (it includes monopolistically competitive markets and nominal rigidities in goods and labor markets) with a financial sector and heterogeneous agents (savers and borrowers), where some of them take debt denominated in foreign currency. The banking sector serves as an intermediary between lenders and borrowers. The production sector is standard. There are entrepreneurs that combine capital and labor to produce wholesale homogenous goods; next, intermediary producers differentiate those goods and sell them in monopolistically competitive markets. Then, domestic and foreign intermediate goods are combined into final goods in a two-step aggregation.

In application, I use the DSGE model to determine whether the easing of borrowing or lending constraints has been the main driver of the Peruvian mortgage credit business cycle dynamics since the early 2000s. I study Peru because of data availability issues, and because its mortgage and housing markets exhibit similar patterns as those in the rest of Latin America. Conducting a historical shock decomposition on Peruvian household leverage ratios (mortgage credit-to-collateral value ratios), allows me to decompose their business cycle dynamics in terms of the structural shocks. Furthermore, to analyze the relative strength of the lending and borrowing constraint shocks affecting those leverage ratios, I run counterfactual simulations by turning off those shocks.

The historical shock decomposition on household leverage ratios reveals that these variables' business cycle fluctuations were mainly driven by borrowing constraints shocks, while the lending constraint shocks have a secondary role. The counterfactual simulation exercises provide strong evidence in favor of this argument: while turning off the borrowing constraints shocks, the counterfactual household leverage ratio fluctuations tend to attenuate. These results differ from conclusions of Justiniano, Primiceri, and Tambalotti (2015) who report that the credit boom that preceded the international financial crisis in the US economy was driven by a loan supply expansion, following an easing of lending constraints. In this case, the findings reveal that the Peruvian mortgage credit fluctuations were driven mainly by credit demand shifts, supported by an encouraging macroeconomic stability and mortgage credit demand-boosting public programs. The secondary role of credit supply shocks is aligned with the fact that Peruvian financial intermediaries did not experience an important innovation as had occurred in US.

This paper relates to the literature which studies the determinants of credit booms and housing prices. Most of that literature has concentrated on the relation between credit and borrowing limits, following the approach introduced in Kiyotaki and Moore (1997). For instance, Iacoviello (2005) develops and estimates a DSGE model with heterogeneous households and collateral constraints tied to housing value. Using his model, he finds that monetary policy shock effects on the economy are amplified and propagated over time because of the endogenous relaxation of the borrowing constraint (due to the increase in housing prices).

An important distinction between this paper and Justiniano, Primiceri, and Tambalotti (2015) and other literature that focuses on borrowing constraints is that these authors interpret a financial liberalization and an inflow of foreign funds into credit markets as alternative drivers of credit growth. These economists follow this new approach because in models with collateral constraints, as in Kiyotaki and Moore (1997), looser borrowing requirements lead to an outward shift in the demand for credit and a subsequent increase heterogeneous in the interest rate, which is not compatible with credit growth accompanied by decreasing mortgage rates. As Gambacorta and Signoretti (2014) state, those "traditional" models consider financial frictions only on the borrower's side of credit markets while credit supply effects derived from financial intermediaries' behavior are completely neglected. Based on this, Justiniano, Primiceri, and Tambalotti (2015) use a stylized model and identify some key variables whose patterns help determine whether a credit boom is driven by an easing of lending or borrowing constraints.

The reference to looser collateral requirements as a credit demand shock might sound surprising, since credit contract terms are set by financial intermediaries, and hence they are usually taken to reflect credit supply conditions. However, I impose these restrictions directly on the borrowers or final users of credit, affecting the credit demand. The lending constraints are imposed on the other side of the credit market and affect just its supply.

The DSGE model considers borrowing constraint shocks—restrictions imposed on borrowers—as stochastic loan-to-value ratios. A positive innovation to these stochastic processes captures a borrowing constraint relaxation, meaning a greater ability of households to take debt, which in turn leads to an exogenous credit expansion driven by a demand movement upward. This reaction incrementally increases housing demand and real housing prices, which in turn eases the collateral requirements even more, increasing other types of credit. This endogenous easing represents an amplification mechanism closely related to the one introduced in Kiyotaki and Moore (1997) and Iacoviello (2005).

The model also considers the main driver of an easing of lending constraints mentioned by Justiniano, Primiceri, and Tambalotti (2015): financial intermediation innovations. This mechanism is modeled by introducing stochastic leverage restrictions given by bank capital-to-asset ratios (restrictions imposed on lenders). In this case, a negative innovation to these ratios generates looser lending constraints, i.e., increases banks' ability to grant loans, which leads to an exogenous loan expansion driven by a supply shift. Specifically, these innovations reduce the cost of granting loans relative to a given level of bank capital. Different from the previous type of shock, this one boosts only a particular type of credit.

The paper is also related to the literature that introduces financial constraints in DSGE models with heterogeneous agents. In the model, there are households who are net savers and others who are net borrowers (among them, there are agents who hold debt denominated in foreign currency). Gerali et al. (2010) study the role of credit factors in the Eurozone in a DSGE framework considering an imperfectly competitive banking sector and stochastic borrowing constraints. I follow their way of modeling the stochastic collateral constraints. However, I extend their framework by considering explicit shocks to credit supply and by allowing banks to obtain funds from international financial markets.

Brzoza-Brzezina and Makarski (2011) develop an open economy DSGE model with a banking sector and borrowing constrained agents to analyze the impact of a credit crunch in Poland. My model is different because it introduces stochastic bank leverage restrictions modeled as capital-to-asset ratios, which are interpreted as exogenous loan supply expansion drivers; additionally, it considers borrowers who hold foreign currency denominated debt and face exchange-rate risk. In this way, this paper is also linked to the literature that models partially dollarized economies in a DSGE environment as in Castillo, Montoro, and Tuesta (2013), who estimate a model of this type for the Peruvian economy.

The rest of the paper is organized as follows. Section 2 shows some motivating evidence about Peruvian markets, the application case country. Section 3 describes the DSGE model in detail. Section 4 presents the calibration and estimation of the model. Section 5 studies some dynamic properties of the model. Sections 6 and 7 present the historical shock decomposition and the counterfactual simulations results, respectively, which allow for a determination of the role of the structural shocks on the business cycle dynamics of mortgage credit in Peru. Finally, Section 8 offers some final remarks.

2 Motivating Evidence

Latin American countries have been experiencing some of the patterns in housing and credit markets that developed economies exhibited before the outbreak of the international financial crisis: for example, total credit has increased at fairly high rates—sometimes at historical rates—during some periods since the early 2000s. Within the credit increase in Latin America there has been a notable expansion in mortgage loans, as the International Monetary Fund (IMF) pointed out in its Western Hemisphere Regional Economic Outlook of April 2012. In these countries, mortgage loans have expanded at higher average rates than other types of credits. However, in terms of GDP, these economies' banking systems and mortgage markets are still small compared to developed-economy standards. It is also worth mentioning those countries' mortgage credit is partially dollarized and their final users (borrowers) usually face exchange-rate risks.

Given this background, I use the developed DSGE model to study the mortgage credit business cycle fluctuations of a Latin American economy. I choose Peru as a country of study because of data availability concerns and because it exhibits the common trends and features listed in the previous paragraph (suggesting that one may generalize this paper's findings). Thus, in this section I present some motivating evidence of the evolution of mortgage credit in that country.

In Peru, the mortgage credit markets were strongly affected by the hyperinflation of the 1980s but started recovering in the early 2000s. According to the view of Justiniano, Primiceri, and Tambalotti (2015), this development and subsequent mortgage credit growth might be caused by supply and/or demand determinants.

On the supply side, Peruvian financial intermediaries benefited from lower interest rates due to a decreasing country risk premium and access to international financial markets; the credit supply may also have expanded because of growing competition in the banking industry. The appearance of mortgage bonds, management companies, and securitization firms during the 2000s also represents innovations in the financial intermediation functions in credit markets, however none of them have had the impact of the boom in mortgage-backed securities in US. This is understandable since overall, the Peruvian financial markets are not as developed and sophisticated as the American market. Nevertheless, the increasing competition in the bank industry and the access of intermediaries to international financial markets might also shift loan supply.

On the demand side, macroeconomic stability, increasing GDP per capita, and increasing employment rates incremented the ability of Peruvian households to borrow; these factors, jointly with the national housing shortage, boosted credit demand. Public funds and programs such as *Fondo MiVivienda*, *Crédito MiHogar*, and *Techo Propio* have played an important role in the mortgage credit market's recovery by allowing low- and middle-class households to access mortgage credit markets for the first time and/or with more favorable contract terms than the existing traditional mortgage credit.[1] These looser conditions included new credit lines with higher loan-to-value ratios, longer maturities, and conditional direct subsidies to reduce payments. Thus, in the Peruvian case, an easing of borrowing constraints resulted from this easing of credit terms.

Regarding long-term trends, from 2003 to 2015, the total credit granted by the Peruvian banking system increased at an average annual rate of 13 percent.[2] Total credit represented 20 percent of GDP in 2003, and 40 percent in 2015. Of all types of credit, mortgages were the most dynamic, expanding at an average annual rate of 19 percent, and commercial credit grew at an average rate of 12 percent. The graph on the left-hand side of Figure 1 depicts the evolution of total and mortgage credit, both expressed in index 2003Q1=100. In this form, the differences in the cumulative expansion rates of these two financial variables are noticeable.

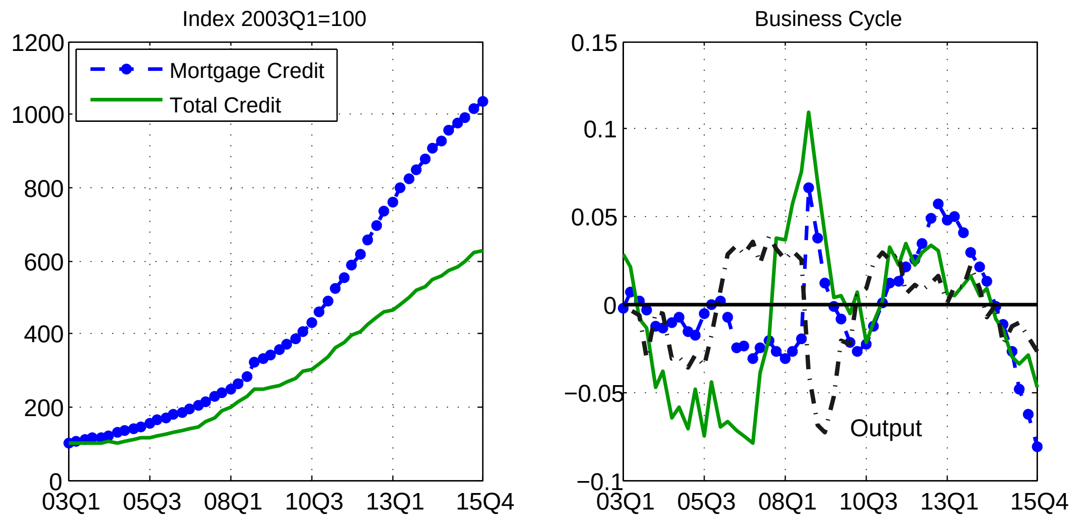
To be consistent with the DSGE analysis conducted in the next sections, which express variables as percent deviations from steady-state, I show the business cycle dynamics[3] of total and mortgage credit in the right-hand side of Figure 1. Despite the fact that mortgage credit expanded at greater rates, total credit's business cycle exhibits a volatility twice as large as mortgage credit's volatility. This last plot also shows the output gap. Note that mortgage credit did not fall during the domestic recession associated with the international financial crisis, but it did fall a few quarters after that, showing a strong resilience.

[1] Among them, *Fondo MiVivienda* has had the largest impact on credit markets. The fund started operating in 1998, but its credits grew exponentially in the 2000s. In 2006 for example, the fund's credits accounted for the 25 percent of total mortgage credit.

[2] In Peru, the bank entities grant more the 95 percent of the mortgage credit.

[3] The business cycle fluctuations are obtained using a two-sided Hodrick-Prescott Filter, as is usual in the DSGE literature.

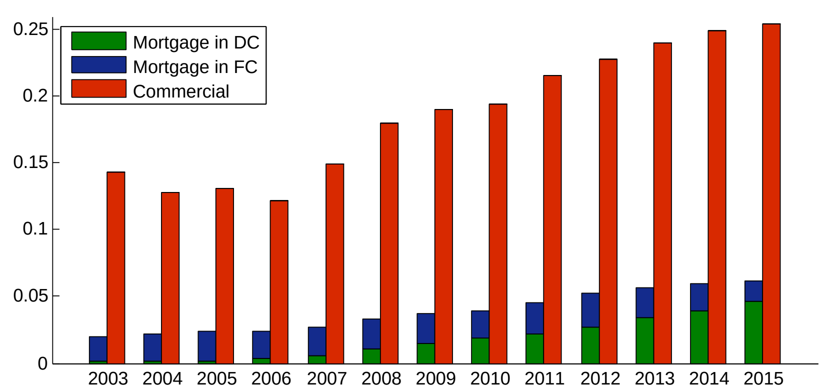
Figure 1: Mortgage and Total Credit



As in other Latin American countries, Peruvian credit markets are partially dollarized. As Castillo, Montoro, and Tuesta (2013) indicate, this is a particular feature of economies with a history of high inflation. According to the Central Reserve Bank of Peru's (BCRP) database, the banking system's credit had a dollarization ratio of 30 percent at the end of 2015; in the case of mortgage markets, the dollarized credit still represented 24 percent. Note that the DSGE model accounts for this particular feature by considering the kind of households that hold debt denominated in foreign currency. This is an important distinction from the models of Gerali et al. (2010) and Brzoza-Brzezina and Makarski (2011).

Figure 2 depicts the evolution of the shares of GDP of mortgage credit denominated in domestic (PEN) and foreign (USD) currency and commercial credit,[4] the three types of credit considered in the DSGE model. The graph shows not only the accelerating trend of mortgage credit growth, but also the change in its composition by currency of denomination, and specially the expansion of mortgage credit denominated in domestic currency.

Figure 2: Credit by Types: Share of GDP

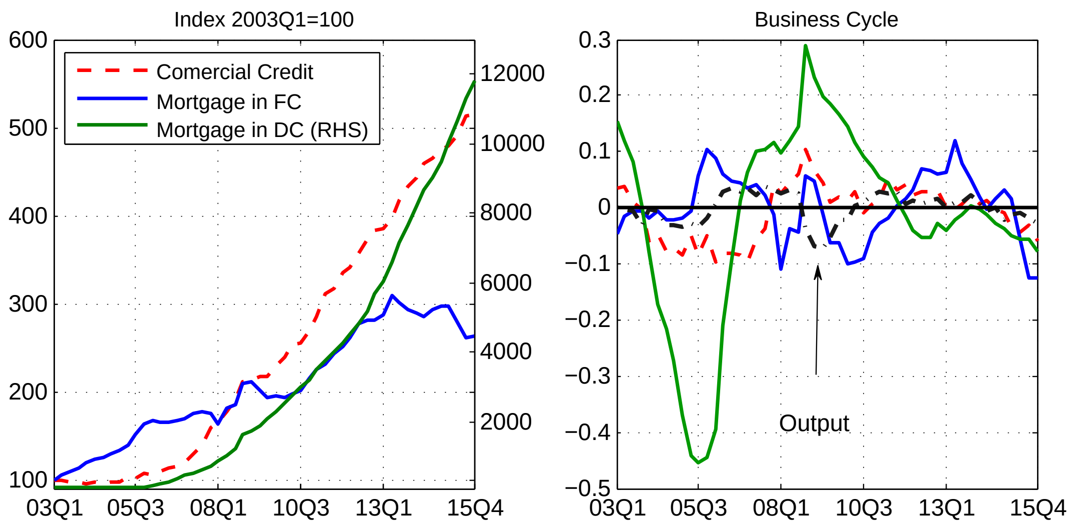


[4]For simplicity, I assume that all commercial credit is denominated in domestic currency.

Figure 3 presents both the 2003Q1=100 indexes and the business cycle fluctuations of the three types of credit. Given the high accumulated growth rate of domestic currency denominated mortgage credit (11,823 percent), its index is presented on a secondary vertical axis. The plot on Figure 3's right-hand side shows that mortgage credit in domestic currency has the most volatile and persistent business cycle among the three types of credit.

In addition, the second graph of Figure 3 allows identification of credit boom-bust cycles. The mortgage denominated in domestic currency's bust of the first half of the 2000s and its boom of the second half are the largest deviations from steady-state levels.

Figure 3: Credit By Types



Furthermore, it is relevant to notice that the two types of mortgages have a negative correlation, as shown in Table 1, which means that they respond to different determinants. Independently from these determinants—the negative correlation may be induced by households' portfolio choices or public policies and banking regulations that discourage taking debt in foreign currency—this empirical fact necessitates having the two types of mortgage credit in the DSGE model and not just one, as is common in the literature.

Table 1: Credit By Types: Contemporaneous Correlations

Sample Period: 2003 - 2015, Cyclical components

Type of Credit	**Correlation**			
Mortgage in domestic currency	1.00			
Mortgage in foreign currency	-0.31	1.00		
Commercial	0.71	-0.12	1.00	
GDP	0.10	0.15	-0.02	1.00

3 The Model

This is a small open economy model with financial frictions and heterogeneous agents. For the most part, it closely follows the frameworks developed in two papers. The modeling of heterogeneous agents and the real sector is based on the model of Brzoza-Brzezina and Makarski (2011), nevertheless I also consider households that hold debt denominated in foreign currency. Additionally, the explicitly modeled banking sector is based on the wholesale banking units introduced in Gerali et al. (2010), although I extend their setup by allowing banks to collect funds from abroad.

The economy is populated by patient households, impatient households, and entrepreneurs. The heterogeneous patience degree is modeled by different discount factors. Patient households, who have the highest discount factor, consume, accumulate housing stock, save, and work. Impatient households consume, accumulate housing stock, borrow, and work. There are two types of impatient households: those who take debt denominated in domestic currency and those who hold foreign currency denominated debt and face exchange-rate risk. Entrepreneurs, who are impatient agents, produce homogeneous intermediate goods using capital purchased from capital good producers and labor supplied by households. There are also capital good and housing producers, who use final consumption goods to produce capital or housing with a technology that is subjected to an investment adjustment cost. The adjustment cost allows for the price of capital and housing to differ from the price of consumption goods.

Both patient and impatient households supply their differentiated labor services through labor unions that set their wages to maximize members' utility, facing wage stickiness. Labor is sold to a competitive intermediary who supplies undifferentiated or aggregate labor services to entrepreneurs.

There are three stages of production. First, entrepreneurs produce homogeneous intermediate goods that are sold in perfectly competitive markets to retailers. Next, retailers, who face sticky prices, brand them at no cost and sell differentiated intermediate goods in monopolistically competitive markets to aggregators. Final good producers aggregate domestic intermediate differentiated goods and foreign imported differentiated goods into one final domestic good.

Two types of one-period financial instruments, supplied by the banking system, are available to agents: saving assets (deposits) and loans. Following Kiyotaki and Moore (1997) and Iacoviello (2005) when taking on a bank loan, agents face a borrowing constraint tied to the value of next period collateral holdings: households can borrow against their stock of housing while entrepreneurs' borrowing capacity is tied to the value of their physical capital stock. This constraint's restrictiveness is stochastically disturbed in the form of a shock to the required loan-to-value (LTV) ratio. In this sense, a positive innovation to this stochastic process would imply an exogenous borrowing constraint relaxation and generate a subsequent credit expansion driven by a credit demand shift.

The banking sector is composed of a bank that finances its loans to impatient households and entrepreneurs with deposits from patient agents, reinvested profits (bank equity), and funds obtained in the international financial market at an interest rate subject to a risk premium. There is a cost to banking activity related to the capital or leverage position. Specifically, the bank pays a quadratic cost whenever its leverage ratios, given by capital-to-asset ratios, move away from "optimal" values. There are different desired capital-to-asset ratio levels (one for each type of loan), which are stochastically disturbed. Following Justiniano, Primiceri, and Tambalotti (2015), exogenous reductions in these ratios would imply an easing of lending constraints and create a credit expansion driven by an exogenous loan supply shift.

There is also a central bank that conducts monetary policy by setting the interbank interest rate according to a standard Taylor rule. The government uses lump sum taxes to finance public expenditure. Following Pedersen and Ravn (2013), the foreign sector has a semi-structural New Keynesian modeling given that there exists a foreign interest rate that evolves according to a Taylor Rule, but I assume a simplification by considering that foreign demand and foreign inflation follow first-order autoregressive processes.

3.1 Households and Entrepreneurs

The economy is populated by impatient households and entrepreneurs who take debt in domestic currency, impatient households who assume debt in foreign currency, and patient households who are savers. The measures of these agents are γ^{IDC}, γ^{E}, γ^{IFC}, and γ^{P}, respectively (the measure of all agents in the economy is one, so $\gamma^{IDC} + \gamma^{E} + \gamma^{IFC} + \gamma^{P} = 1$). The important difference between agents is the value of their discount factors: the discount factor of patient households β_P is higher than the discount factors of impatient households and entrepreneurs (β_{IDC}, β_{IFC} and β_E).

3.1.1 Patient Households

The representative patient household ι chooses consumption c_t^P, the stock of housing h_t^P and deposits d_t^P. The decision on the labor supply n_t^P is not made by the household but by a labor union, whose problem is detailed later. The expected lifetime utility of a representative household is:

$$U_P = E_0 \sum_{t=o}^{\infty} \beta_P^t \left[\frac{\left(c_t^P(\iota) - \zeta c_{t-1}^P(\iota)\right)^{1-\sigma_c}}{1-\sigma_c} + \varepsilon_{h,t} \frac{h_t^P(\iota)^{1-\sigma_h}}{1-\sigma_h} - \frac{n_t^P(\iota)^{1-\sigma_n}}{1-\sigma_n} \right] \tag{1}$$

where the preferences exhibit internal habit formation with parameter ζ, and $\varepsilon_{h,t}$ are housing preference shocks that randomly disturb the marginal utility of housing and thus the housing demand. According to Iacoviello (2005) these shocks are a parsimonious way to assess the macro effects of an exogenous disturbance on housing prices. This process has an AR(1) representation with i.i.d. normal innovations:

$$\varepsilon_{h,t} = \varepsilon_{h,t-1}^{\rho_h} \exp^{\varpi_{h,t}}, \quad \varpi_{h,t} \sim N(0, \sigma_h) \tag{2}$$

The flow of expenses includes current consumption, accumulation of housing services, and deposits to be made this period d_t^P. Resources are composed of labor income $W_t n_t^P$, dividends from real and financial sector firms Π_t^P (all the firms are owned by the patient households), and deposits from the previous period d_{t-1}^P multiplied by the gross interest rate on household deposits R_{t-1}^d and lump sump taxes T_t. The representative patient household's budget constraint is expressed in nominal terms:

$$P_t c_t^P + P_t^h \left(h_t^P - (1-\delta_h) h_{t-1}^P\right) + d_t^P \leq W_t n_t^P + R_{t-1}^d d_{t-1}^P - T_t + \Pi_t^P \tag{3}$$

where P_t and P_t^h denote the nominal price of final consumption goods and the nominal price of housing, δ_h is the depreciation rate of the housing stock, and W_t is the nominal wage. The first-order conditions of these and the other agents are presented in the Appendix A.

3.1.2 Impatient Households who Hold Domestic Currency Denominated Debt

In contrast to patient households, the households are borrowers, not lenders, in the neighborhood of the steady-state. A representative impatient household of this class ι chooses consumption c_t^{IDC}, the stock of housing h_t^{IDC} and loans b_t^{IDC}. As for patient households, labor supply decisions are made by a labor union. Impatient households maximize the following expected utility:

$$U_{IDC} = E_0 \sum_{t=o}^{\infty} \beta_{IDC}^t \left[\frac{\left(c_t^{IDC}(\iota) - \zeta c_{t-1}^{IDC}(\iota)\right)^{1-\sigma_c}}{1-\sigma_c} + \varepsilon_{h,t} \frac{h_t^{IDC}(\iota)^{1-\sigma_h}}{1-\sigma_h} - \frac{n_t^{IDC}(\iota)^{1-\sigma_n}}{1-\sigma_n} \right] \tag{4}$$

where $\varepsilon_{h,t}$ is the same preference shock that affects the utility of patient households and ζ is the same parameter that governs the internal habit formation in consumption. Impatient household decisions have to match the following budget constraint, expressed in nominal terms:

$$P_t c_t^{IDC} + P_t^h \left(h_t^{IDC} - (1-\delta_h)\, h_{t-1}^{IDC}\right) + R_{t-1}^{bIDC} b_{t-1}^{IDC} \leq W_t n_t^{IDC} + b_t^{IDC} - T_t \tag{5}$$

in which resources spent for consumption, accumulation of housing services and reimbursement of past borrowing $R_{t-1}^{bIDC} b_{t-1}^{IDC}$ have to be financed with wage income and new borrowing.

Furthermore, impatient households face a borrowing constraint: the expected value of their housing stock at period t must be sufficient to guarantee debt repayment. This collateral constraint is consistent with standard lending criteria used in the mortgage market. The constraint is:

$$R_t^{bIDC} b_t^{IDC} \leq m_t^{IDC} E_t \left[P_{t+1}^h (1-\delta_h) h_t^{IDC}\right] \tag{6}$$

As in Gerali et al. (2010), m_t^{IDC} is the loan-to-value ratio which follows an AR(1) process with i.i.d. normal innovations:

$$m_t^{IDC} = (1-\rho_m^{IDC})\bar{m}^{IDC} + \rho_m^{IDC} m_{t-1}^{IDC} + \varpi_{m^{IDC},t}, \quad \varpi_{m^{IDC},t} \sim N\left(0, \sigma_{m^{IDC}}\right) \tag{7}$$

where $\bar{m}^{IDC}$ is the calibrated steady-state loan-to-value ratio of this type of credit. A positive innovation to this process implies an exogenous relaxation of borrowing restrictions, and a greater ability of households to obtain credit. The effect is a credit expansion driven by a demand shift that creates, as usual, an increase in the relevant price, in this case, the mortgage interest rate.

3.1.3 Impatient Households who Hold Foreign Currency Denominated Debt

These kind of impatient households are also net borrowers in the neighborhood of the steady-state. A representative impatient household of this type ι chooses consumption c_t^{IFC}, the stock of housing h_t^{IFC} and loans b_t^{IFC} which are denominated in foreign currency. Thus, these agents face exchange-rate risk. This modeling tries to capture partially dollarized credit markets, such as the Peruvian mortgage markets. Castillo, Montoro, and Tuesta (2013) develop a DSGE model that considers this phenomenon. The labor supply decision is made by a labor union. These impatient households maximize the following expected utility:

$$U_{IFC} = E_0 \sum_{t=o}^{\infty} \beta_{IFC}^t \left[\frac{\left(c_t^{IFC}(\iota) - \zeta c_{t-1}^{IFC}(\iota)\right)^{1-\sigma_c}}{1-\sigma_c} + \varepsilon_{h,t} \frac{h_t^{IFC}(\iota)^{1-\sigma_h}}{1-\sigma_h} - \frac{n_t^{IFC}(\iota)^{1-\sigma_n}}{1-\sigma_n} \right] \tag{8}$$

Impatient households decisions have to match the following budget constraint, expressed in nominal terms:

$$P_t c_t^{IFC} + P_t^h \left(h_t^{IFC} - (1-\delta_h)\, h_{t-1}^{IFC}\right) + R_{t-1}^{bIFC} S_t b_{t-1}^{IFC} \leq W_t n_t^{IFC} + S_t b_t^{IFC} - T_t \tag{9}$$

As in the previous case, resources spent for consumption, accumulation of housing, and reimbursement of past borrowing must be financed with wage income and new borrowing. However, in this case, borrowing and debt service are affected by the nominal exchange rate S_t.

These impatient households also face a borrowing constraint: the expected value of their housing stock at period t must be sufficient to guarantee debt repayment, which is now denominated in foreign currency. The constraint is:

$$R_t^{bIFC} S_t b_t^{IFC} \leq m_t^{IFC} E_t \left[P_{t+1}^h (1-\delta_h) h_t^{IFC}\right] \tag{10}$$

where m_t^{IFC} is the IFC households loan-to-value ratio, which follows an AR(1) process with i.i.d. normal innovations:

$$m_t^{IFC} = (1-\rho_m^{IFC})\bar{m}^{IFC} + \rho_m^{IFC} m_{t-1}^{IFC} + \varpi_{m^{IFC},t}, \quad \varpi_{m^{IFC},t} \sim N\left(0, \sigma_{m^{IFC}}\right) \tag{11}$$

This problem is similar to the one in the previous section, however the presence of the exchange-rate implies that these agents face exchange rate risk. In particular, an unexpected nominal depreciation increases the amount of debt they have to serve in the next period, tightening their borrowing restriction.

3.1.4 Entrepreneurs

Entrepreneurs draw utility only from their consumption c_t^E:

$$U_E = E_0 \sum_{t=o}^{\infty} (\beta_E)^t \left(\frac{\left(c_t^E(\iota) - c_{t-1}^E(\iota)\right)^{1-\sigma_c}}{1-\sigma_c} \right) \tag{12}$$

In order to finance consumption they run firms to produce homogeneous intermediate goods $y_{W,t}$ using capital and labor supplied by the households. They use the following technology:

$$y_{W,t}(\iota) = A_t \left[u_t(\iota) k_{t-1}(\iota)\right]^{\alpha} n_t(\iota)^{1-\alpha} \tag{13}$$

where $u_t \in [0, \infty)$ is the capital utilization rate and k_t is the capital stock and n_t is the labor input. A_t, the total factor productivity, follows an exogenous AR(1) process:

$$A_t = A_{t-1}^{\rho_A} \exp\left(\varpi_{A,t}\right), \quad \varpi_{A,t} \sim N\left(0, \sigma_A\right) \tag{14}$$

The capital utilization rate can be changed but only at a cost $\psi(u_t) k_{t-1}$, which is expressed in terms of consumption units. The function $\psi(u)$ satisfies $\psi(1) = 0$, $\psi'(1) > 0$ and $\psi''(1) > 0$ (there is no capital utilization adjustment cost in the deterministic steady-state). It is convenient to define $\Psi = \frac{\psi'(1)}{\psi''(1)}$. Such parameterization is standard in the literature, see for example Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003).

In order to finance their expenditures on consumption, labor services, capital accumulation, capital utilization rate adjustment costs and repayment of debt $R_{t-1}^E b_{t-1}^E$, entrepreneurs use the revenue from their output sales (the intermediate good product is sold in a competitive market at wholesale price P_t^W) and new loans b_t^E. Entrepreneurs' flow budget constraint is the following (expressed in nominal terms):

$$P_t c_t^E + W_t n_t + P_t^k \left(k_t - (1-\delta_k) k_{t-1}\right) + P_t \psi(u_t) k_{t-1} + R_{t-1}^{bE} b_{t-1}^E = P_t^W y_{W,t} + b_t^E \tag{15}$$

where P_t^k is the nominal capital price and δ_k is the depreciation rate of physical capital. For simplicity, I assume that entrepreneurs have access only to loan contracts denominated in domestic currency, which can be interpreted as commercial credit.

As with the impatient household case, I assume that the amount of resources that the bank is willing to lend to entrepreneurs is constrained by the value of their collateral, which is given by their holdings of physical capital. This assumption is taken from Gerali et al. (2010) and differs from Iacoviello (2005) where entrepreneurs borrow against housing (interpretable as commercial real estate credits). The borrowing constraint is thus:

$$R_t^{bE} b_t^E \leq m_t^E E_t \left[P_{t+1}^k (1-\delta_k) k_t^E\right] \tag{16}$$

where m_t^E is the firm's loan-to-value ratio, which follows an AR(1) process with i.i.d. normal innovations.

$$m_t^E = (1-\rho_m^E)\bar{m}^E + \rho_m^E m_{t-1}^E + \varpi_{m^E,t}, \quad \varpi_{m^E,t} \sim N(0, \sigma_{m^E}) \tag{17}$$

Again, a positive innovation $\varpi_{m^E,t}$ would imply a greater ability of entrepreneurs to take on or ask for debt and an exogenous easing of entrepreneurs' borrowing constraints.

3.1.5 Labor Supply

Following Brzoza-Brzezina and Makarski (2011) and to motivate labor market frictions, it is assumed that each household has a continuum of labor types of measure one, $h \in [0, 1]$. Moreover, for each type h there is a labor union that sets the wage for its labor type $W_t(h)$. Each household belongs to all labor unions, i.e., each union includes γ^P patient and $\gamma^{IDC} + \gamma^{IFC}$ impatient households. Labor services are sold to perfectly competitive aggregators who pool all the labor types into one undifferentiated labor service with the following function:

$$n_t = \left[\left(\gamma^P + \gamma^{IDC} + \gamma^{IFC}\right)\int_0^1 n_t(h)^{\frac{1}{1+\mu_w}}\, dh\right]^{1+\mu_w} \tag{18}$$

The problem of the aggregator gives the following demand for labor of type h:

$$n_t(h) = \frac{1}{\gamma^P + \gamma^{IDC} + \gamma^{IFC}}\left[\frac{W_t(h)}{W_t}\right]^{\frac{-(1+\mu_w)}{\mu_w}} n_t \tag{19}$$

where:

$$W_t = \left(\int_0^1 W_t(h)^{\frac{-1}{\mu_w}}\, dh\right)^{-\mu_w} \tag{20}$$

is the aggregate or average wage in the economy. The union's discount factor is the weighted average of those of its members:

$$\bar{\beta} = \frac{\gamma^P}{\gamma^P + \gamma^{IDC} + \gamma^{IFC}}\beta_P + \frac{\gamma^{IDC}}{\gamma^P + \gamma^{IDC} + \gamma^{IFC}}\beta_{IDC} + \frac{\gamma^{IFC}}{\gamma^P + \gamma^{IDC} + \gamma^{IFC}}\beta_{IDC} \tag{21}$$

Each union sets the wage according to a standard Calvo scheme, i.e., with probability $1-\theta_w$ it receives a signal to re-optimize and then sets its wage to maximize the utility of its average member subject to the demand for labor services, and with probability θ_w does not receive the signal and indexes its wage according to the following rule:

$$W_{t+1}(h) = \left((1-\zeta_w)\bar{\pi} + \zeta_w \pi_{t-1}\right) W_t(h) \tag{22}$$

where $\bar{\pi}$ is the steady-state inflation rate and $\zeta_w \in [0, 1]$.

3.2 Producers

This section closely follows a similar chapter of Brzoza-Brzezina and Makarski (2011). There are three sectors in the economy: capital goods, housing and consumption goods. The capital goods producers and housing producers operate in perfectly competitive markets. In the consumption goods sector there are entrepreneurs, who sell their undifferentiated goods to retailers who then brand or differentiate those goods and sell them to aggregators at home and abroad. Aggregators combine differentiated domestic intermediate goods and differentiated foreign intermediate goods into a single final good.

3.2.1 Capital Goods Producers

As Gerali et al. (2010) indicate, considering capital goods producers is a modeling device to derive a market price for capital, which is necessary to determine the value of entrepreneurs' collateral. Capital goods producers operate in a perfectly competitive market and use final consumption goods to produce capital goods. Each period a capital goods producer buys $i_{k,t}$ of final consumption goods and $(1-\delta_k)k_{t-1}$ old undepreciated capital from entrepreneurs. Next, she transforms the old undepreciated capital one-to-one into new capital, while the transformation of the final goods is subject to adjustment cost $S_k(i_{k,t}/i_{k,t-1})$. I adopt the specification of Christiano, Eichenbaum, and Evans (2005) and assume that in the deterministic steady-state there are no capital adjustment costs ($S_k(1) = S'_k(1) = 0$), and the function is concave in the neighborhood of that deterministic steady-state ($S''_k(1) = 1/\kappa_k > 0$). Thus the technology to produce new capital is given by:

$$k_t = (1-\delta_k)\, k_{t-1} + \left(1 - S_k\left(\frac{i_{k,t}}{i_{k,t-1}}\right)\right) i_{k,t}$$

After new capital is sold to entrepreneurs it can be used in the next period's production process. The real price of capital is denoted as $q_t^k = P_t^k/P_t$.

3.2.2 Housing Producers

Here, housing producers act in a similar fashion as capital good producers. This approach differs from the housing market modeling of Iacoviello (2005) and Gerali et al. (2010) who consider an exogenously fixed housing supply stock in the economy. Thus, a housing producer sector allows incorporation of housing's business cycle fluctuations. The stock of new housing evolves according to:

$$h_t = (1-\delta_h)\, h_{t-1} + \left(1 - S_h\left(\frac{i_{h,t}}{i_{h,t-1}}\right)\right) i_{h,t} \tag{23}$$

where the function describing adjustment cost $S_h(i_{h,t}/i_{h,t-1})$ satisfies $S_h(1) = S'_h(1) = 0$ and $S''_h(1) = 1/\kappa_h > 0$. The real price of housing is denoted as $q_t^h = P_t^h/P_t$.

3.3 Final Good Producers

Final good producers play the role of aggregators. They buy differentiated goods from domestic retailers $y_{H,t}(j_H)$ and importing retailers $y_{F,t}(j_F)$ and aggregate them into a single final good, which they sell in a perfectly competitive market. The final good is produced according to the following technology:

$$y_t = \left[\eta^{\frac{\mu}{1+\mu}} y_{H,t}^{\frac{1}{1+\mu}} + (1-\eta)^{\frac{\mu}{1+\mu}}\, y_{F,t}^{\frac{1}{1+\mu}}\right]^{1+\mu} \tag{24}$$

where:

$$y_{H,t} = \left[\int_0^1 y_{H,t}\left(j_H\right)^{\frac{1}{1+\mu_H}}\, dj_H\right]^{1+\mu_H} \quad \text{and} \quad y_{F,t} = \left[\int_0^1 y_{F,t}\left(j_F\right)^{\frac{1}{1+\mu_F}}\, dj_F\right]^{1+\mu_F} \tag{25}$$

μ governs the elasticity of substitution between domestic and foreign goods. η is the home bias parameter.

The problem of the aggregator entails the following demands for differentiated goods:

$$y_{H,t}\left(j_H\right) = \left(\frac{P_{H,t}\left(j_H\right)}{P_{H,t}}\right)^{-\frac{(1+\mu_H)}{\mu_H}} y_{H,t} \text{ and } \quad y_{F,t}\left(j_F\right) = \left(\frac{P_{F,t}\left(j_F\right)}{P_{F,t}}\right)^{-\frac{(1+\mu_F)}{\mu_F}} y_{F,t} \tag{26}$$

where:

$$y_{H,t} = \eta\left(\frac{P_{H,t}}{P_t}\right)^{-\frac{(1+\mu)}{\mu}} y_t \text{ and } \quad y_{F,t} = (1-\eta)\left(\frac{P_{F,t}}{P_t}\right)^{-\frac{(1+\mu)}{\mu}} y_t \tag{27}$$

and the aggregated price indexes are:

$$P_{H,t} = \left[\int P_{H,t}\left(j_H\right)^{\frac{-1}{\mu_H}} dj_H\right]^{-\mu_H} \text{ and } \quad P_{F,t} = \left[\int P_{F,t}\left(j_F\right)^{\frac{-1}{\mu_F}} dj_F\right]^{-\mu_F} \tag{28}$$

These two indexes, jointly with the technology represented in Equation 24, define the inflation rate as:

$$1+\pi_t = \left[\eta\Big(\pi_{H,t}\Big)^{-\frac{1}{\mu}}\left(\frac{P_{H,t-1}}{P_{t-1}}\right)^{-\frac{1}{\mu}} + (1-\eta)\Big(\pi_{F,t}\Big)^{-\frac{1}{\mu}}\left(\frac{P_{F,t-1}}{P_{t-1}}\right)^{-\frac{1}{\mu}}\right]^{-\mu} \tag{29}$$

3.3.1 Domestic Retailers

There is a continuum of domestic retailers of measure one identified by j_H. They purchase undifferentiated intermediate goods from entrepreneurs, brand them—thus transforming them into differentiated goods—and sell them to aggregators. They operate in a monopolistically competitive environment and set their prices according to a standard Calvo scheme.

In each period each domestic retailer receives with probability $1-\theta_H$ a signal to re-optimize and then sets her price to maximize the expected profits. When she does not receive the signal, she indexes her price according to the following rule:

$$P_{H,t+1}\left(j_H\right) = P_{H,t}\left(j_H\right)\left(\left(1-\zeta_H\right)\bar{\pi} + \zeta_H \pi_{t-1}\right) \tag{30}$$

where $\zeta_H \in [0,1]$.

3.3.2 Importing Retailers

There is a continuum of importing retailers of measure one denoted by j_F . Like domestic retailers, they purchase undifferentiated goods (from foreign markets), transform them into differentiated goods, and sell them to aggregators. They operate in a monopolistically competitive environment and set their prices according to the standard Calvo scheme. Prices are re-optimized with probability $(1-\theta_F)$ and with probability θ_F prices are indexed according to the following rule:

$$P_{F,t+1}\left(j_F\right) = P_{F,t}\left(j_F\right)\left(\left(1-\zeta_F\right)\bar{\pi} + \zeta_F \pi_{t-1}\right) \tag{31}$$

where $\zeta_F \in [0,1]$. I assume that prices are sticky in domestic currency, which is consistent with an incomplete pass through of exchange rate changes in import prices.

3.3.3 Exporting Retailers

There is also a continuum of exporting retailers of measure one denoted by j_H^*. Retailers purchase domestic undifferentiated goods, brand them and sell them abroad at a price $P_H^*(j_H^*)$, which is expressed in terms of foreign currency. Prices are sticky in foreign currency. The demand for exported goods is given by:

$$y_{H,t}^*(j_H^*) = \left(\frac{P_{H,t}^*(j_H^*)}{P_{H,t}^*}\right)^{-\frac{(1+\mu_{H^*})}{\mu_{H^*}}} y_{H,t}^* \tag{32}$$

where $y_{H,t}^*(j_H^*)$ denotes the output of the retailer j_H^*, $y_{H,t}^*$ is defined as:

$$y_{H,t}^* = \left[\int_0^1 y_{H,t}^*(j_H^*)^{\frac{1}{1+\mu_{H^*}}} dj_H^*\right]^{1+\mu_{H^*}} \tag{33}$$

and $P_{H,t}^*$ as:

$$P_{H,t}^* = \left[\int P_{H,t}^*(j_H^*)^{\frac{-1}{\mu_{H^*}}} dj_H^*\right]^{-\mu_{H^*}} \tag{34}$$

Moreover, the demand abroad is given by:

$$y_{H,t}^* = (1-\eta^*)\left(\frac{P_{H,t}^*}{P_t^*}\right)^{\frac{-(1+\mu_{H^*})}{\mu_{H^*}}} y_t^* \tag{35}$$

Exporting retailers re-optimize their prices with probability $1-\theta_H^*$ or index them according to the following formula:

$$P_{H,t+1}^*(j_H^*) = P_{H,t}^*(j_H^*)\left((1-\zeta_H^*)\bar{\pi}^* + \zeta_H^*\pi_{t-1}^*\right) \tag{36}$$

with probability θ_H^* where $\zeta_H^* \in [0,1]$.

Foreign variables modeling (foreign demand, interest rate, and inflation) is described later.

3.4 Banking Sector

The banking sector plays a central role in the model since it intermediates all financial transactions between agents in the model: the only saving instrument available to patient households is bank deposits, and the only way for impatient households and entrepreneurs to borrow is by applying for a bank loan.

Here, in contrast to Gerali et al. (2010), the banking system is composed by only one bank owned by all patient households. This entity can finance its domestic currency denominated loans to IDC households B_t^{IDC} and entrepreneurs B_t^E, as well as the loans denominated in foreign currency to IFC households L_t^{IFC} using deposits collected from patient agents D_t, funds obtained in the international market B_t^*, or bank equity K_t^b. These relations are summarized in the bank balance sheet identity:

$$B_t^{IDC} + S_t B_t^{IFC} + B_t^E = D_t + S_t B_t^* + K_t^b \tag{37}$$

where $B_t^{IDC} = \gamma^{IDC} b_t^{IDC}$, $B_t^{IFC} = \gamma^{IFC} b_t^{IFC}$ and $B_t^E = \gamma^E b_t^E$ are the total loans granted to impatient households and entrepreneurs. Similarly, $D_t = \gamma^P d_t^P$ are the aggregate deposits collected from patient households.

The financing sources are perfect substitutes from the point of view of the balance sheet, that is why it is necessary to introduce some non-linearity to pin down the choices of the bank. In order to do that, I assume that there exist three (exogenously given) “optimal” capital-to-asset (i.e., leverage) ratios for the bank, one for each type of loan, such that the bank pays a quadratic cost whenever these ratios move away from their desired levels. Moreover, these “optimal” ratios follow stochastic processes. Negative innovations to these processes generate loose lending constraints since they reduce the costs of raising credits relative to a given amount of bank capital and create a supply-driven credit expansion. Following the interpretation of Justiniano, Primiceri, and Tambalotti (2015), this easing of lending constraints also represents a credit expansion driver.

Bank capital $K_t^{b,n}$ (in nominal terms) is accumulated each period out of retained earnings according to:

$$K_t^{b,n} = (1-\delta_b)K_{t-1}^{b,n} + \omega_b J_{t-1}^{b,n} \tag{38}$$

where $J_{t-1}^{b,n}$ are the profits made by the bank expressed in nominal terms, $(1-\omega_b)$ summarizes the dividend policy of the bank, and δ_b measures the resources used in managing bank capital and conducting banking intermediation. The dividend policy is assumed to be exogenously fixed, so that bank capital is not a choice variable for the bank. The problem of the bank is to choose the amount of the three types of loans B_t^{IDC}, B_t^{IFC} and B_t^E, deposits D_t and foreign funding B_t^* so as to maximize profits, subject to a balance sheet constraint:

$$\max_{B_t^{IDC}, B_t^{IFC}, B_t^E, B_t^*, D_t} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \Bigg[R_t^{bIDC} B_t^{IDC} + R_t^{bIFC} S_t B_t^{IFC} + R_t^{bE} B_t^E \\ - R_t^d D_t - R_t^{b*} S_{t+1} B_t^* - K_t^b - CK_t^{IDC} - CK_t^{IFC} - CK_t^E \Bigg] \tag{39}$$

subject to:

$$B_t^{IDC} + S_t B_t^{IFC} + B_t^E = D_t + S_t B_t^* + K_t^b \tag{40}$$

where:

$$CK_t^{IDC} = \frac{\kappa_{K^{bIDC}}}{2} \left(\frac{K_t^b}{B_t^{IDC}} - v_{IDC,t} \right)^2 K_t^b \tag{41}$$

$$CK_t^{IFC} = \frac{\kappa_{K^{bIFC}}}{2} \left(\frac{K_t^b}{S_t B_t^{IFC}} - v_{IFC,t} \right)^2 K_t^b \tag{42}$$

$$CK_t^E = \frac{\kappa_{K^E}}{2} \left(\frac{K_t^b}{B_t^E} - v_{E,t} \right)^2 K_t^b \tag{43}$$

are the quadratic cost functions and $v_{IDC,t}$, $v_{IFC,t}$ and $v_{E,t}$ are the stochastic capital-to-asset ratios that follow these AR(1) processes:

$$v_{IDC,t} = (1-\rho_{v_{IDC}})\bar{v}_{IDC} + \rho_{v_{IDC}} v_{IDC,t-1} + \varpi_{v_{IDC},t}, \quad \varpi_{v_{IDC},t} \sim N(0, \sigma_{v_{IDC}}) \tag{44}$$

$$v_{IFC,t} = (1-\rho_{v_{IFC}})\bar{v}_{IFC} + \rho_{v_{IFC}} v_{IFC,t-1} + \varpi_{v_{IFC},t}, \quad \varpi_{v_{IFC},t} \sim N(0, \sigma_{v_{IFC}}) \tag{45}$$

$$v_{E,t} = (1-\rho_{v_E})\bar{v}_E + \rho_{v_E} v_{E,t-1} + \varpi_{v_E,t}, \quad \varpi_{v_E,t} \sim N(0, \sigma_{v_E}) \tag{46}$$

where $\bar{v}_{IDC}$, $\bar{v}_{IFC}$ and $\bar{v}_E$ are the desired or optimal capital-to-asset ratios that are calibrated such that:

$$\bar{v}_{IDC} = \frac{\bar{K}^b}{\bar{B}^{IDC}},\ \bar{v}_{IFC} = \frac{\bar{K}^b}{\bar{S}\bar{B}^{IDC}} \text{ and } \bar{v}_E = \frac{\bar{K}^b}{\bar{B}^E} \tag{47}$$

The first-order conditions of the bank's problem deliver equations linking the spreads between loan and deposit interest rates to leverage ratios $B_t^s/K_t^b, s \in \{IDC, IFC, E\}$ of the bank. Additionally, in order to close the model it is assumed that banks can invest any excess funds they have in a deposit facility at the central bank, remunerated at rate R_t, so that $R_t^d = R_t$, which is the monetary policy interest rate. The equations that arise from the first-order conditions are:

$$R_t^{bIDC} = R_t - \kappa_{K^{bIDC}} \left(\frac{K_t^b}{B_t^{IDC}} - v_{IDC,t} \right) \left(\frac{K_t^b}{B_t^{IDC}} \right)^2 \tag{48}$$

$$R_t^{bIFC} = R_t - \kappa_{K^{bIFC}} \left(\frac{K_t^b}{S_t B_t^{IFC}} - v_{IFC,t} \right) \left(\frac{K_t^b}{S_t B_t^{IFC}} \right)^2 \tag{49}$$

$$R_t^{bE} = R_t - \kappa_{K^{bE}} \left(\frac{K_t^b}{B_t^{E}} - v_{E,t} \right) \left(\frac{K_t^b}{B_t^{E}} \right)^2 \tag{50}$$

These equations highlight the role of bank capital in determining loan supply conditions. In particular, they can be rearranged to highlight the inverse relationship of the spreads between loan and deposit rates and bank leverage ratios. Additionally, note that negative innovations to the v_t processes, which lower the cost of granting credit for a given amount of bank capital and cause loose lending constraints, generating spread reductions. Those negative shocks can be interpreted as financial intermediation development shocks, while narrower interest spreads can be thought of as indicators of greater financial sector efficiency.

Furthermore, a UIP condition can be derived from these conditions. In this sense, the exchange rate is determined endogenously in the model. The bank has access to the foreign interbank market and obtains funds at a rate R_t^{b*}, which is modeled as the international risk-free interest rate RF_t^* multiplied by an interest rate premium ρ_t. The description of these last two variables is examined in the following section. The UIP equation is the following:

$$\frac{R_t}{R_t^{b*}} = E_t \left[\frac{S_{t+1}}{S_t} \right] \tag{51}$$

Further, using the real exchange rate definition $q_t = \frac{S_t P_t^*}{P_t}$, the UIP condition can be expressed as:

$$\frac{R_t}{R_t^{b*}} = E_t \left[\frac{q_{t+1}}{q_t} \frac{\pi_{t+1}}{\pi_{t+1}^*} \right] \tag{52}$$

The bank's profits are given by:

$$\begin{aligned} J_t^b = (R_t^{bIDC} - 1)B_t^{IDC} + (R_t^{bIFC} - 1)S_t B_t^{IFC} + (R_t^{bE} - 1)B_t^E - (R_t - 1)D_t \\ - (R_t^{b*} - 1)S_t B_t^* - CK_t^{IDC} - CK_t^{IFC} - CK_t^E \end{aligned} \tag{53}$$

3.5 Foreign Sector

I assume that foreign demand and inflation follow AR(1) processes. However, the international risk-free interest rate RF_t^{b*} is determined by a foreign monetary policy authority whose behavior is described by this

Taylor Rule:

$$\frac{RF_t^*}{\bar{RF}^*} = \left(\frac{RF_{t-1}^*}{\bar{RF}^*}\right)^{\zeta_{rf^*,1}} \left(\left(\frac{\pi_t^*}{\bar{\pi}^*}\right)^{\zeta_{rf^*,2}} \left(\frac{y_t^*}{\bar{y}^*}\right)^{\zeta_{rf^*,3}}\right)^{1-\zeta_{rf^*,1}} \varpi_{rf^*,t} \tag{54}$$

$\zeta_{rf^*,2}$ and $\zeta_{rf^*,3}$ are the weights of inflation and output stabilization, respectively. $\varepsilon_{rf^*,t}$ are i.i.d. normal monetary policy innovations with standard deviation σ_{rf^*}.

The foreign sector provides financial resources to the domestic economy through the banking system. In the model, the bank collects funds from the foreign markets at a rate R_t^{b*}, which is defined as the international risk-free rate multiplied by an interest rate premium, which is a function of the foreign debt-to-GDP ratio. As Schmitt-Grohe and Uribe (2003) indicate, this specification induces the stationarity of the small open economy model:

$$R_t^{b*} = \rho_t RF_t^* \tag{55}$$

The interest premium ρ_t is defined as:

$$\rho_t = exp\left(\varrho \frac{S_t B_t^*}{P_t \tilde{y}_t}\right) \varepsilon_{\rho,t} \tag{56}$$

where $\varepsilon_{\rho,t}$ has an AR(1) representation with $\varpi_{\varepsilon_\rho,t}$ i.i.d. innovations with standard deviation $\sigma_{\varepsilon_\rho}$. $\tilde{y}_t$ denotes real GDP.

3.6 The Government

The government uses lump sum taxes to finance government expenditure. Public budget constraint is given by:

$$g_t = \left(\gamma^P + \gamma^{IDC} + \gamma^{IFC}\right) T_t \tag{57}$$

where g_t denotes government expenditure. For simplicity, I assume that the government budget is balanced and that government expenditures are driven by a simple autoregressive process:

$$g_t = (1 - \rho_g)\bar{g} + \rho_g g_{t-1} + \varpi_{g,t} \tag{58}$$

with $\varpi_{g,t}$ are i.i.d. normal innovations with standard deviation of σ_g.

3.7 The Central Bank

Monetary policy is conducted according to a Taylor rule that targets deviations from the deterministic steady-state inflation and GDP, allowing for interest rate smoothing:

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\phi_R} \left(\left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi_\pi} \left(\frac{\tilde{y}_t}{\bar{\tilde{y}}}\right)^{\phi_y}\right)^{1-\phi_R} \varpi_{R,t} \tag{59}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$, and $\varpi_{R,t}$ are i.i.d. normal monetary policy innovations with standard deviation σ_R. ϕ_R is a persistence parameter. ϕ_π and ϕ_y are the weights of inflation and output stabilization, respectively. $\bar{R}$ is the steady-state policy interest rate.

3.8 Market Clearing, Balance of Payments, and GDP

In order to close the model, it is needed market-clearing conditions for the final and intermediate goods markets and the housing market, as well as the balance of payments and the GDP definitions.

In the final goods market, the market-clearing condition is:

$$c_t + i_{k,t} + i_{h,t} + g_t + \psi(u_t)k_{t-1} = y_t \tag{60}$$

where $c_t = \gamma^P c_t^P + \gamma^{IDC} c_t^{IDC} + \gamma^{IFC} c_t^{IFC} + \gamma^E c_t^E$

The market clearing condition in the intermediate homogenous goods market is:

$$\int_0^1 y_{H,t}(j)dj + \int_0^1 y_{H,t}^*(j)dj = y_{W,t} \tag{61}$$

The market clearing condition in the housing market is given by:

$$\gamma^P h_t^P + \gamma^{IDC} h_t^{IDC} \gamma^{IFC} h_t^{IFC} = h_{t-1} \tag{62}$$

The balance of payments, expressed in domestic currency, has the following form:

$$\int_0^1 P_{F,t}(j_F) y_{F,t}(j_F) dj_F + R_{t-1}^{b*} S_t B_{t-1}^* = S_t \int_0^1 P_{H,t}^*(j_H^*) y_{H,t}^*(j_H^*) dj_H^* + S_t B_t^* \tag{63}$$

Finally, the nominal GDP $P_t \tilde{y}_t$ is defined as follows:

$$P_t \tilde{y}_t = P_t y_t + S_t \int_0^1 P_{H,t}^*\left(j_H^*\right) y_{H,t}^*\left(j_H^*\right) dj_H^* - \int_0^1 P_{F,t}\left(j_F\right) y_{F,t}\left(j_F\right) dj_F \tag{64}$$

4 Calibration and Estimation

Following the DSGE literature, I partly calibrate and partly estimate the model's parameters. The calibrated parameters are mainly steady-state ratios (average ratios of the period 2003-2015) that can be found from Peruvian data and parameters established and broadly used in the literature. I also calibrate some parameters to match some steady-state ratios. The estimated coefficients are structural parameters that affect the dynamics of the model and parameters that govern the shock processes (autocorrelation parameters and standard deviations of shocks).

4.1 Calibration

The model is calibrated to match characteristics of the country of study. The entire set of calibrated parameters and steady-state ratios are shown in Appendix C in Tables 2 and 3, respectively.

Following Brzoza-Brzezina and Makarski (2011), I assume different measures for patient and impatient agents. In this line, the proportion of patient households is set to $\gamma^P = 0.5$, and the measures of the other agents are $\gamma^{IDC} = 0.15$, $\gamma^{IFC} = 0.10$, and $\gamma^E = 0.25$.

I set the patient household's discount factor $\beta_P = 0.998$ to match a steady-state annual real monetary policy rate of 1 percent, in line with the 2003-2015 average of the interbank market interest rate (my proxy for the monetary policy interest rate) of $\bar{R} = 3.8$ percent and a long-term average inflation rate of $\bar{\pi} = 2.9$ percent. The subjective discount factors of both types of impatient households β_{IDC} and β_{IFC} are set to 0.975. Following Iacoviello (2005), the entrepreneur's discount factor β_E is larger than the impatient households' and equal to 0.98. The discount factor of the impatient agents is in the range suggested by Iacoviello (2005) and Iacoviello and Neri (2010), ensuring that the borrowing constraints are binding in the steady-state.

The depreciation rate of physical capital is set to $\delta_k = 0.025$, as is generally used in the literature. The housing depreciation rate δ_h is calibrated at 0.0125 (which implies a annual depreciation rate of 5 percent). I set this value to match the real estate depreciation rate used by the Peruvian tax regulator. The elasticity of output with respect to capital is set to $\alpha = 0.3$, a value broadly used in the DSGE literature. The parameter μ_w of the labor aggregator is set to 0.1 implying a steady-state markup over wages of 10 percent. Regarding the real sector, the parameter μ is set to 1 so that the Armington elasticity of substitution between domestic and foreign goods equals to $\frac{1+\mu}{\mu} = 2$, as is consistent with Ruhl (2008). The home bias parameter is set to $\eta = 0.77$, according to the Peruvian average imports-to-absorption ratio for the period 2003-2015.

The steady-state loan-to-value ratios are calibrated using the maximum values required by the Peruvian banking regulator to domestic currency denominated mortgage credit ($\bar{m}^{IDC} = 0.80$) and foreign currency denominated mortgages ($\bar{m}^{IDC} = 0.70$). The calibration of entrepreneurs' loan-to-value $\bar{m}^E$ is problematic, as commercial loans are typically not collateralised credits. However, I set a value of $\bar{m}^E = 0.60$ following Ribeiro (2015), who calibrates this coefficient for the Peruvian economy. The entrepreneur loan-to-value ratios found in the literature—Brzoza-Brzezina and Makarski (2011) and Gerali et al. (2010) calibrate it and Christensen et al. (2007) estimate it—are mostly smaller than the mortgage loan-to-value ratios.

For the remaining parameters of the banking system, I set $\theta_b = 0.025$, which measures the resources used in managing bank capital. I take this value from Ribeiro (2015) and it is aligned with the operating margin of the banking entities of Peru. The three different capital-to-asset ratios are calibrated considering a long-term aggregate capital-to-asset ratio of 0.13 and their shares in the total amount of credit. The calibrated values are $\bar{v}_{IDC} = 1.69$, $\bar{v}_{IFC} = 1.38$ and $\bar{v}_E = 0.16$. The parameters that control the adjustment cost of the bank's capital-to-asset ratios, the κ_K parameters, are estimated given that these directly affect the credit rates dynamics and there are no consensual estimates available in the literature.

The steady-state foreign inflation $\bar{\pi}^*$ is set to 2.0 percent annually, in line with the long-term average inflation of the 20 main trade partners of Peru. The foreign inflation rate $\bar{RF}^*$ is calibrated to 2.1 percent annually, which is consistent with the 2003-2015 average of the 12-month Libor. The coefficients of the foreign Taylor Rule, as well as the parameters of the foreign inflation and foreign demand processes (autocorrelation and shocks' standard deviation parameters) come from the MPT Model (Quarterly Projection Model) of the BCRP, described in Winkelried (2013).

The steady-state export-, import-, consumption-, investment-, government expenditure-, and foreign debt-to-GDP ratios as well as mortgage and commercial credit-to-GDP ratios are calibrated to be consistent with long-term averages observed in the Peruvian data. The remaining calibrated ratios are derived from steady-state relationships.

4.2 Estimation

The model is estimated using Bayesian techniques. This methodology is a full information approach used to jointly estimate parameters of a model. The estimation is based on the likelihood function obtained from the solution of the log-linearised version of the model obtained and the Kalman Filter algorithm. Prior distributions are used to incorporate additional information into the estimation of the posterior distributions of the parameters of interest which are finally obtained by using a Metropolis-Hastings algorithm. This algorithm constructs a Gaussian approximation around the posterior mode (previously calculated) and uses a scaled version of the asymptotic covariance matrix as the covariance matrix for the proposal distribution.

In order to conduct the estimation, I fit the model using 14 Peruvian variables (given the number of stochastic processes, this is the maximum number of observable variables I can use to avoid a stochastic singularity problem): four macro variables, four interest rate series (monetary policy and credit rates), four financial variables (credit and deposit series), and two foreign series (inflation and interest rate). These series cover the period 2003Q1-2015Q4 giving T=52 quarterly observations. The series have been taken in log and de-trended using a two-sided Hodrick-Prescott filter. All data come from the BCRP's database. For a detailed description of the data see Appendix D.

4.2.1 Prior Distributions

Prior distributions reflect beliefs about the parameters' values. In this case, I choose existing values and distribution shapes used in the literature. Regarding the structural parameters, I choose Beta distributions for the internal habit persistence parameter ζ, for the adjustment cost parameters of physical capital and housing producers (κ_k and κ_h), and for all the Calvo probability and indexation degree parameters of the producing sector. According to a Beta distribution, the parameters belong to the interval $(0, 1)$.

For the case of the habit formation parameter, I set a prior mean of 0.75, which is a common value used in the literature. All the indexation degree coefficients have a prior mean 0.60, following Brzoza-Brzezina and Makarski (2011). In regard to the Calvo price rigidity probabilities, I assume a higher level of nominal stickiness for wages (θ_w) and imported prices (θ_F) than for domestic prices (θ_H) and export prices (θ_H^*). For instance, a value of $\theta_w = 0.90$ means that wages are adjusted every 3 years. The larger value for θ_F attempts to capture the low pass through of imported prices to domestic inflation observed in Peru. The prior means of $\kappa_k = 0.20$ and $\kappa_k = 0.02$ are taken from Brzoza-Brzezina and Makarski (2011), as well. These values mean that adjusting housing stock is much costly than adjusting physical capital. In some cases the prior distributions had to be tightened, since the posterior estimated diverged from previous knowledge.

I use Normal prior distributions for the intertemporal substitution parameters. I assume that the intertemporal substitution for housing σ_h is higher than for consumption σ_c (as one may expect), setting values of 4 and 2, respectively. The prior mean of the inverse of the Frisch labor supply elasticity σ_n is set to 4.

The banking ratios' adjustment costs have a prior mean of 1.0, a prior standard deviation of 0.5 and a prior Gamma distribution, which allows these parameters to be inside of $(0, \infty)$ range. Given that there is no consensus about these parameters' prior mean, I conducted the estimation starting with different means (2.5, 5.0, 7.5, and 10.0). These different values do not affect the main results and conclusions regarding the application case.

For the coefficients of the monetary policy rule, I set their prior means to those values used by the MPT model. Hence, ϕ_R, ϕ_π and ϕ_y have a prior means of 0.70, 1.50, and 0.50, respectively; all of them with standard deviations of 0.10. The left-hand side of Table 6 (see Appendix D) shows the priors distributions used in the estimation of the structural parameters.

Regarding the parameters of the shocks processes, I follow Gerali et al. (2010) and choose Beta distributions for the autocorrelation parameters and Inverse Gamma distributions for the innovations' standard deviation parameters. The Inverse Gamma distribution forces the standard deviation parameters to lie inside the interval $(0, \infty)$.

The prior means of the autocorrelation parameters are set to 0.7. Regarding the standard deviations, the prior means are set to 0.05 for financial shock processes and 0.1 for the other processes (monetary policy, government expenditure, technology and housing demand shocks). This calibration is based partly on Brzoza-Brzezina and Makarski (2011). The left hand side of Table 7 (see also Appendix D) shows the priors distributions used in the estimation of the shock processes' parameters.

4.2.2 Posterior Estimates

The estimation is conducted using Dynare and it is performed as follows. First, the posterior distributions' modes are found using a Monte-Carlo optimization routine. Next Dynare applies the Metropolis-Hastings algorithm; I use ten blocks each of 200,000 replications to approximate the complete posterior distributions. Since the average acceptance rates amounted to 25-30 percent and the multivariate diagnostic tests introduced by Brooks and Gelman (1998) confirmed convergence of the Markov chains, I use the second half of the draws to calculate posterior distributions. See Appendix D for further technical details about the estimation procedure. The right-hand side of Tables 6 and 7 (both in Appendix D) show some posterior distributions' moments achieved by the estimation.

The posterior estimated for Calvo rigidity parameters confirms that import prices are stickier than domestic and export prices; this finding together with the high indexation parameter support the low pass-through of imported prices to domestic CPI inflation. The estimated coefficients of the Taylor Rule indicate a higher degree of persistence of the monetary policy rate.

As in Gerali et al. (2010) and Brzoza-Brzezina and Makarski (2011), I find shocks' autocorrelation coefficients ranging from 0.60 to 0.75. The autocorrelation parameter of the productivity shock is estimated among the largest at 0.768, however it is not above 0.90 as in Real Business Cycles DSGE models. In those models, the productivity shock is the main source of persistence, but here the DSGE has alternative sources of persistence (financial shocks).

Regarding the shocks' size, the shock to housing demand is the largest; this is also found in Brzoza-Brzezina and Makarski (2011), whose estimation reports that the preference shocks are among the largest ones. Finally, regarding the two macroeconomic policy shocks, the model and data generate much longer fiscal policy shocks, as is clearly identified in Peruvian data.

5 Impulse Response Functions Analysis

To understand how the borrowing and lending constraint relaxation shocks affect the economy, and given space restrictions, I present the impulse response functions (IRF's) of a selected set of 16 variables to two types of exogenous fluctuations: a borrowing constraint relaxation shock modeled as a positive innovation to the stochastic loan-to-value ratio faced by the impatient households who take debt in domestic currency (IDC households), and a lending constraint relaxation shock modeled as a negative innovation to the stochastic bank capital-to-asset ratio related to IDC household debt (named IDC bank capital-to-asset ratio).

The responses are expressed in percent deviations from the steady-state and correspond to the reactions to an one-time 1 percent innovation. The impulse responses to other financial shocks as well as to the standard ones, e.g., monetary policy, fiscal policy, productivity, and foreign demand shocks, are presented in Appendix E. In the next two sets of graphs, the vertical axes represent percent deviations (basis points in the case of rates) from steady-state levels and the horizontal axes correspond to quarters after the initial shock.

5.1 Borrowing Constraint Relaxation Shock: An Exogenous Increase in the LTV Ratio of IDC Households

Figure 4 presents the responses that take place after a positive shock of 1 percent to the LTV ratio faced by IDC households, which represents a loosening of borrowing constraints. Note that in the steady-state, the borrowing constraints are binding, meaning that indebted impatient households are willing to borrow more. Furthermore, when the LTV ratio increases, it expands households' ability to borrow. In the case of Peru, this positive innovation would capture, for example, the access of households to mortgage credits with looser contract terms (higher loan-to-value ratios, longer maturities, subsidies to reduce payments) like the ones promoted by public programs such *Fondo MiVivienda*, *Crédito MiHogar* and *Techo Propio*.

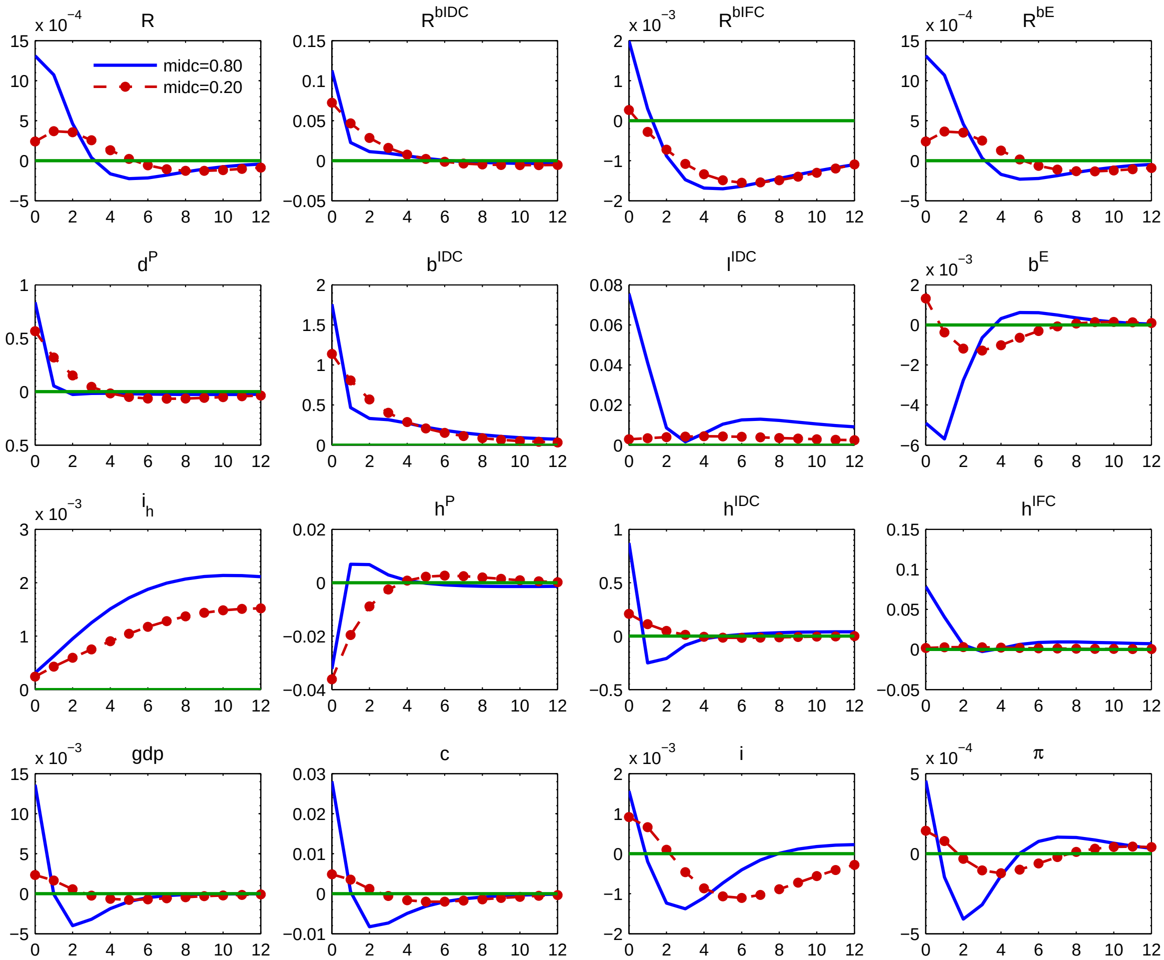
The final effect of this shock is a credit expansion driven by a credit demand shift. Thus, after the positive shock, the IDC households raise their mortgage debt ($\mathtt{b}^{\mathtt{IDC}}$) above its steady-state level, which allows them to increase their housing holdings ($\mathtt{h}^{\mathtt{IDC}}$). The larger housing demand fosters the housing investment ($\mathtt{i}_{\mathtt{h}}$), however real housing prices increase (not shown) since marginal real estate demand exceeds new housing supply.

The housing price hike endogenously relaxes IDC household borrowing constraints, since the value of collateral assets increases. Justiniano, Primiceri, and Tambalotti (2015) and Iacoviello (2005) point out this endogenous effect, closely related to the amplification mechanism introduced in Kiyotaki and Moore (1997). The housing price reaction also relaxes the borrowing constraints faced by the other type of households (IFC households) that also increase borrowing ($\mathtt{l}^{\mathtt{IFC}}$). That effect generates successive but smaller increments in IFC credit rates ($\mathtt{R}^{\mathtt{bIFC}}$) and housing holdings ($\mathtt{h}^{\mathtt{IFC}}$).

The initial shock also raises the impatient household consumption and thus the aggregate consumption. This leads to a quantitatively unimportant effect on $\mathtt{gdp}$ that is followed by similar increases in monetary policy ($\mathtt{R}$) and inflation rates. These small effects are explained by the limited share of IDC mortgage and housing investment in GDP (calibrated to 2 and 1 percent in steady-steady, respectively). It also suggests that, given the small share of this type of credit relative to GDP and relative to total credit, the central bank should not react, that is, should not adjust its monetary policy rate, after a mortgage credit increase of this type. These findings are not a property of the model itself but of its calibration; setting the IDC mortgage-to-GDP and housing investment-to-GDP ratios to 70 and 5 percent (long-term average ratios the US economy), respectively, the same shock generates a positive deviation in GDP of 0.1 percent in one quarter.

Nevertheless, the mortgage credit, consumption, GDP and inflation increases result in a monetary policy tightening which increases the savings of patient households ($\mathtt{d}^{\mathtt{P}}$), who decide to sell some of their housing stock because of a substitution effect. The central bank's reaction is also followed by higher commercial loan rates. This in turn, leads to a decrease in commercial credit. However, all these effects are also quantitatively unimportant.

Figure 4: Impulse Response Functions to an IDC Household LTV Ratio Positive Shock



To illustrate the amplification effects of the borrowing constraints, Figure 4 also shows the responses considering lower loan-to-value ratios, which correspond to the case of tighter borrowing or collateral restrictions. In this simulation, the three loan-to-value ratios are set to a quarter of their original values. The IRFs depicted by dash lines indicate that the same slackening borrowing constraint shock generates a lower response in IDC mortgage debt, as well as in the other selected endogenous variables.

The short-term effect on IDC borrowing reduces by half, since that mortgage credit is less collateralized now, which diminishes the first-round effects as the expansionary effect of an loan-to-value ratio increase is smaller, and second-round effects as there is also a lower endogenous loosening induced by more limited housing price incremental changes. Given that the loan-to-value ratio faced by the households who take debt in foreign currency is also reduced, the endogenous (and smaller) housing price incremental change generates a lower increase in housing stock value, which leads, in turn, to a minor expansion in borrowing: under this case, the IFC borrowing and IFC housing holdings display quantitatively unimportant responses. Similarly, the new lower initial effect on IDC borrowing generates minor effects on aggregate consumption, GDP, inflation, and monetary policy interest rates.

5.2 Lending Constraint Relaxation Shock: An Exogenous Reduction in the IDC Bank Capital-to-Asset Ratio

Figure 5 presents the economy's adjustments generated by an 1 percent negative shock to the IDC bank capital-to-asset (debt held by IDC households) ratio. This innovation represents a slackening of the lending constraints faced by the bank.

As in the previous case, the economy starts from a steady-state where the lending constraints are binding, which means that the bank would want to grant more loans if any capital-to-asset ratio decreases. A decrease in the level of these "optimal" ratios reduces the cost of granting credit relative to a fixed level of bank capital. Thus, a negative shock to the IDC bank capital-to-asset ratio is also followed by an increase in the corresponding credit ($\mathtt{b}^{\mathtt{IDC}}$), but now driven by a supply shift. In the case of Peru, this supply expansion might be caused by increasing competition in the banking industry, intermediaries' access to international financial markets, and new mortgage firms.

Given the model's construction, this shock directly generates a fall in IDC credit interest rates ($\mathtt{R}^{\mathtt{bIDC}}$). The increase in IDC mortgages generates a positive deviation on IDC household housing stock ($\mathtt{h}^{\mathtt{idc}}$) and a subsequent endogenous loosening of IDC borrowing constraints. Although this second-round easing of borrowing constraints also benefits the IFC households, the shrinkage of mortgage credit denominated in foreign currency ($\mathtt{l}^{\mathtt{IFC}}$) persists because the bank, to maximize profit, prefers granting mortgages in domestic currency, creating a negative correlation between the two types of mortgage credits. The reduction in the latter type of mortgage leads to a bust in the IFC households' real estate stock ($\mathtt{h}^{\mathtt{IFC}}$).

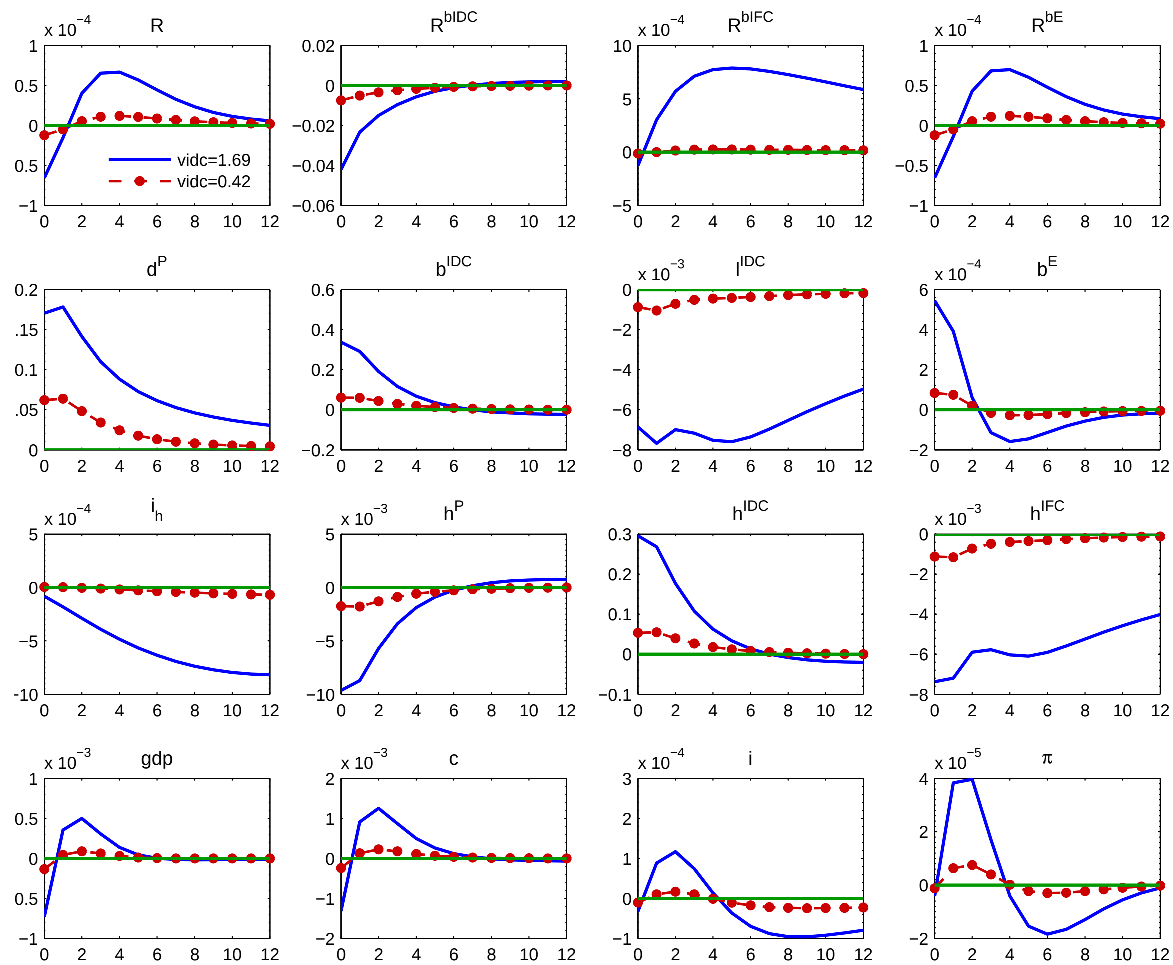
After the initial shock, the bank demands more deposits to grant larger amounts of IDC mortgages at lower interest rates. Thus, patient households increase their deposits ($\mathtt{d}^{\mathtt{P}}$), reducing their housing stock by a substitution effect. On the aggregate level, housing investment ($\mathtt{i}_{\mathtt{h}}$) shows a quantitatively unimportant negative response. Although the other agents' consumption rises, aggregate private consumption decreases, which, jointly with the negative effect on housing investment, reduce GDP. Meanwhile, inflation increases given an incremental increase in domestic inflation, which originates from a reduction in entrepreneurs' wholesale production. The central bank implements a countercyclical policy, reducing commercial loan rates.

A negative shock to the IDC capital-to-asset ratio creates a negative but quantitatively unimportant response in output, meaning that the initial credit expansion does not generate an economic boost. This is not the case for a negative shock to the capital-to-asset ratio associated with the entrepreneurs' debt (see Appendix E.4). Moreover, using the same exercise and and calibrating the model to replicate some US economy features, this lending constraint shock generates an expansion of 0.05 percent in one quarter.

Note an important difference between the responses shown in the last two figures. First, the DSGE model responses suggest that a borrowing constraint relaxation increases mortgage interest rates, while a lending constraint relaxation decreases them. These are the opposite effects generated by the two different credit shift drivers suggested by Justiniano, Primiceri, and Tambalotti (2015). This distinction allows the DSGE model to distinguish the drivers of credit business cycle fluctuations. Second, the credit expanding effects of the lending shocks appear to be market specific, meaning that a shock to a particular bank leverage ratio boosts just its credit type. Meanwhile, the borrowing constraint shocks expand different types of mortgage credit.

Figure 5 also shows the responses in the case where these constraint relaxations lead to smaller endogenous variable reactions. Unlike the borrowing constraint case, this happens when lending constraints are looser or less tight than under the original calibration. To illustrate this, the calibrated steady-state bank capital-to-

Figure 5: Impulse Response Functions to an IDC Bank Capital-to-asset Ratio Negative Shock



asset ratios are set to a quarter of their originally calibrated values. The same lending constraint relaxation shock entails a much lower effect on IDC mortgage debt: when the bank faces much looser lending constraints, a further reduction in those restrictions does not create a considerable credit expansion. In other words, the model's reactions imply that a relaxation of lending constraints creates larger credit expansions when those financial restrictions are tighter. Given that the shock creates an unimportant effect on the IDC mortgage market, it does not affect the other types of credit markets. Further simulations suggest that the effects of a lending constraint relaxation on the other types of credit depends on the relative degree of lending restrictions tightness.

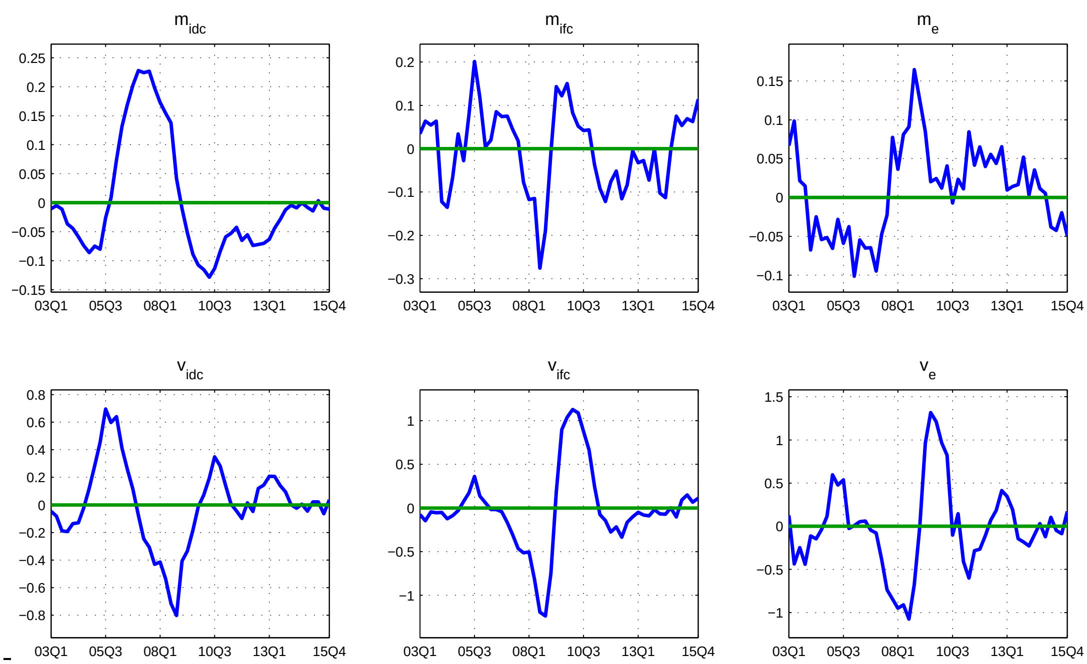
6 Historical Shock Decomposition

I conduct a historical shock decomposition exercise to determine the contributions of each shock to the business cycle dynamics of some key endogenous variables. This decomposition is obtained by using the Kalman Smoother algorithm, and expresses the observable variables as functions of smoothed initial conditions and smoothed structural shocks. See Appendix F for further details.

Given that this algorithm works backwards in time, the smoothed variables are the model's "best guess" for the endogenous variables given all data provided. Hence, this exercise allows the determination of the smoothed shocks' contributions to the deviations of the endogenous variables from their steady-state levels or business cycle fluctuations, taking into account all of the model's *structure*: the first and second order effects of the structural shocks on the endogenous variables, as well as their size and persistence. As Gerali et al. (2010) says, this exercise allows for learning from the model which shocks were mainly responsible for the past evolution of the endogenous variables. To conduct this exercise, I use the same set of observable variables as for the Bayesian estimation.

Before presenting the results, it is important to know how, according to the model and given all the data provided, the financial constraint variables (bank capital-to-asset and loan-to-value ratios) evolved in the sample period in Peru. This helps determine periods of loose lending and borrowing constraints. The first row of Figure 6 shows the smoothed loan-to-value ratios of the three types of credit. For example, looking at the IDC loan-to-value ratio's path, notice that there were two periods of (inferred) tight borrowing constraints for this type of credit: one in the first half of the 2000s and the second after the international financial crisis. In contrast, between those two periods, there were loose borrowing constraints.

Figure 6: Smoothed Financial Variables



Regarding lending conditions, there is a high and positive correlation between the business cycle fluctuations of smoothed capital-to-asset ratios of foreign currency denominated mortgage and commercial credit, while these two variables are negatively correlated with the IDC bank capital-to-asset ratio. There were tight lending constraints in the IDC mortgage credit market during the period 2004-2007, while the periods of tight lending constraints in the other credit markets occurred during some quarters right after the international financial crisis. This is consistent with the fact that during that period, the Peruvian banking system faced liquidity restrictions.

Before doing the historical decomposition exercise and to facilitate the visual analysis, I group the 14 shocks into four sets. In the model, there are three shocks that can be classified as borrowing constraint shocks, the exogenous processes related to the three loan-to-value ratios $\varpi_{m^{IDC},t}$, $\varpi_{m^{IFC},t}$ and $\varpi_{m^{E},t}$. In a similar fashion, there are three shocks which can be described as lending constraints shocks: the ones associated with the three stochastic bank capital-to-asset ratios $\varpi_{\kappa_{IDC},t}$, $\varpi_{\kappa_{IFC},t}$ and $\varpi_{\kappa_E,t}$. Additionally, I group the monetary policy, government expenditure, productivity, and housing demand shocks ($\varpi_{R,t}$, $\varpi_{g,t}$, $\varpi_{A,t}$ and $\varpi_{h,t}$, respectively) in a group called "aggregate shocks." Finally, I consider a foreign shocks set consisting of foreign demand, foreign inflation, and foreign monetary policy shocks ($\varpi_{y^*,t}$, $\varpi_{\pi^*,t}$ and $\varpi_{rf^*,t}$, respectively), as well as the shock to the international interest prime rate $\varpi_{\rho,t}$.

I conduct and present the decomposition exercise on the business cycle fluctuations of the leverage ratios of the two types of impatient households. I prefer doing the shock decomposition on these variables and not on mortgage credit, because the former control for the business cycle dynamics of the housing prices and housing holdings. The business cycle fluctuations of the IDC and IFC leverage ratios are defined as follows:

$$\hat{leve}_t^{IDC} = \hat{b}_t^{IDC} - (\hat{q}_t{}^h + \hat{h}_t^{IDC}) \tag{65}$$

$$\hat{leve}_t^{IFC} = \hat{l}_t^{IFC} - (\hat{q}_t{}^h + \hat{h}_t^{IFC}) \tag{66}$$

where hatted variables are log-linearised variables and denote percent deviations from steady-state levels. In the two following figures, the black lines depict the percent deviations from steady-state of the corresponding smoothed leverage ratios. The colored bars correspond to the contributions of the respective group of smoothed shocks to those fluctuations, meaning that the summation of colored bars is equal to the level indicated by the solid line. The "initial values" in the graphs refer to the part of the deviations not explained by the smoothed shocks, but rather by the unknown (and smoothed) initial value of the variables.

6.1 Leverage Ratio of IDC Households

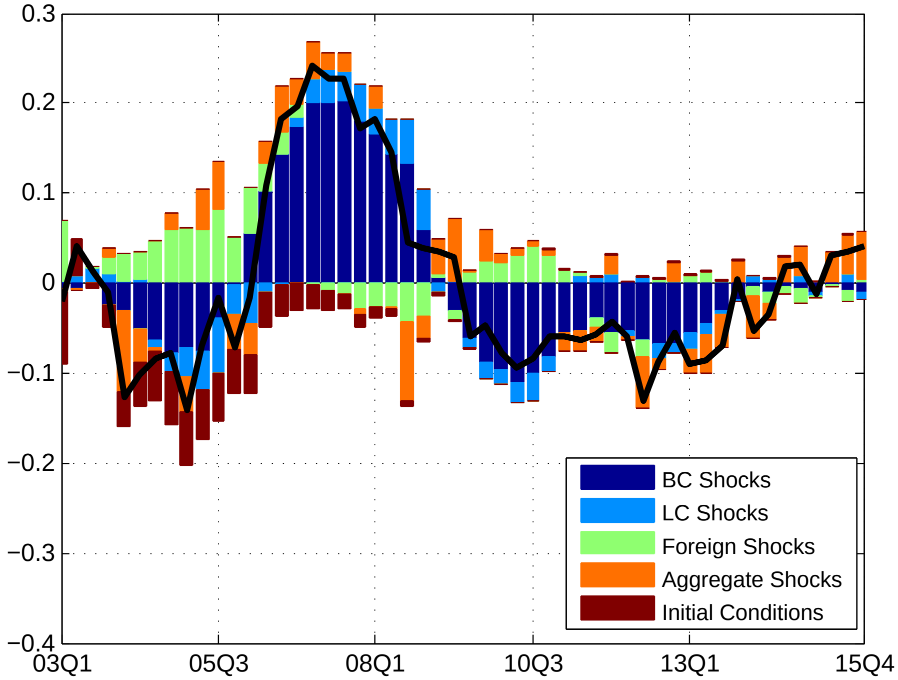
Figure 7 shows the outcomes of the shock decomposition exercise on the IDC household leverage ratio. This smoothed leverage ratio was below its steady-state in the first half of the 2000s. After that, it shows positive deviations. Moreover, it seems that the IDC household leverage has remained below steady-state levels since the international financial crisis.

The results suggest that the business cycle fluctuations of these household leverage ratios were driven mainly by borrowing constraint shocks, meaning credit demand shifts. Among the shocks that comprise this set, the shock to the IDC loan-to-value ratio is the most important one. The lending constraint shocks have a secondary role. The following important sets of shocks are the aggregate (mostly the monetary policy shocks) and foreign shocks but their contribution is residual.

The historical shock decomposition finds that the borrowing constraint shocks set explains both positive and negative deviations, despite the fact that the model and observable variables are able to reflect fluctuations in the IDC bank capital-to-asset ratio. Figure 6 reveals that for the case of the IDC mortgage credit market, in almost all periods when there were loose borrowing constraints, there were also loose lending constraints. However, the shock decomposition takes into account the shocks' size, as well as all the *structure* imposed by the DSGE model. This means that although there were changes of the lending constraints, the model shows the dynamics of observable variables and the implied relations among them and among the rest of the endogenous variables, and reveals that those lending constraint shocks were not the drivers of the leverage ratio fluctuations.

Possibly, given that a negative shock to the capital-to-asset ratio associated with a mortgage credit type reduces other types of credit, the lending constraint shocks' contributions compensate each other such that their aggregate contribution to the business fluctuations tends to disappear. This actually happens but just

Figure 7: Historical Shock Decomposition: IDC Household Leverage



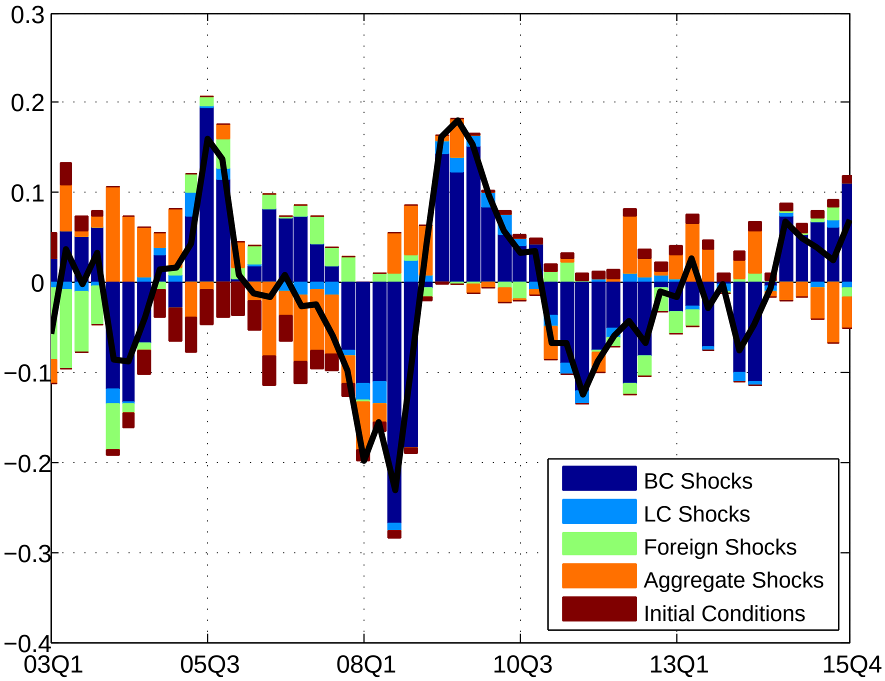
on a small scale. Analyzing the shock decomposition results without grouping the shocks leads to the same conclusions: the shocks to IDC bank capital-to-asset ratios have residual contributions.

6.2 Leverage Ratio of IFC Households

Figure 8 shows the results of the shock decomposition on the IFC leverage ratio. One can see that the smoothed IFC household leverage ratio shows a lower persistence than the smoothed IDC household leverage ratio. Its deviations from steady-state are also smaller. Despite these differences, the exercise yields similar results. The business cycle fluctuations of this ratio are also explained mainly by the borrowing constraint or credit demand shocks set. Among this set, in this case, the most important is the shock to the IFC loan-to-value ratio. The lending constraint shocks, jointly with the aggregate shocks, have a secondary role in explaining the dynamics of this leverage ratio.

The result of this second shock decomposition exercise constitutes further evidence for the argument that the main driver of the Peruvian mortgage credit's cyclical behavior was relaxed collateral constraints or shifts in credit demand, rather than loose lending constraints. According to postulates of Justiniano, Primiceri, and Tambalotti (2015), this argument is consistent with the fact that during that period, there were not any important financial intermediation innovations that would have expanded the loan supply. Instead, the mortgage credit demand shifts appear to have relevant contributions to the cyclical dynamics of household leverage. As noted, the expansion of credit demand might be encouraged by favorable macroeconomic stability, increasing GDP per capita and higher employment rates, as well as by public funds and programs that allowed households to access to mortgage markets.

Figure 8: Historical Shock Decomposition: IFC Household Leverage



7 Counterfactual Scenarios

To gain more insight into the effects of financial shocks on mortgage credit and validate the results obtained from the shock decomposition, I conduct counterfactual simulations as done in Brzoza-Brzezina and Makarski (2011). I run two counterfactual scenarios that involve substituting zero values for selected shocks. In the first, the three borrowing constraint shocks are turned off during the entire sample period, while in the second, the three lending constraint shocks are shut off. Figure 23 shown in Appendix G collects the smoothed shocks used in the simulation exercises.

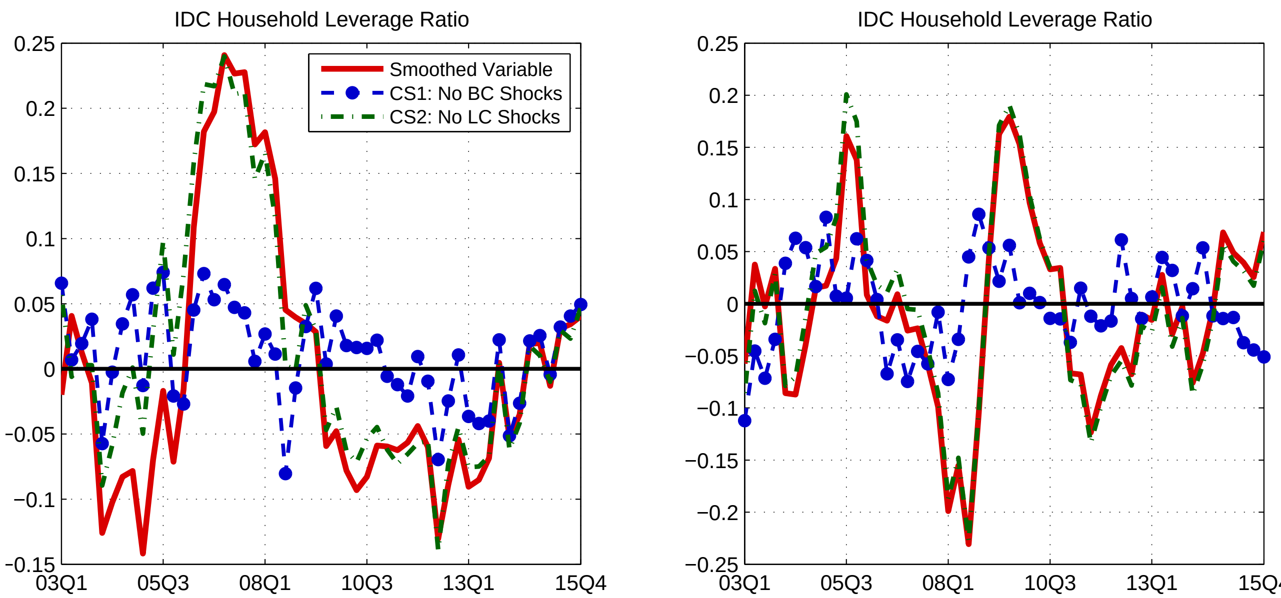
These shocks are closely related to the smoothed financial variables shown in Figure 6, since these variables are generated by the smoothed shocks. Examining the plots clarifies, for instance, why the IDC loan-to-value ratio assumed historical maxima before the international financial crisis and historical minima after this event. These patterns reflect the accumulation of positive or negative shocks, respectively.

The outcomes of the simulation are shown in the following graphs where the solid lines represent the model-based historical, smoothed, estimated leverage ratios (these are the same as the ones shown in the last two figures), while the dash lines depict the counterfactual series: `CS1` corresponds to the counterfactual simulation where the three borrowing constraints shocks are turned off during the sample period, and `CS2` is the simulation where the lending constraint shocks have zero values.

The graph on the left side of Figure 9 presents the counterfactual scenarios for the case of the IDC household leverage ratio. These results confirm the relevance of the borrowing constraint shocks set in explaining the business cycle dynamics of this ratio. When these credit demand-side shocks are turned off, the counterfactual leverage ratio does not display any cyclical movement, practically speaking. Meanwhile, when all the lending constraint shocks are shut down, the smoothed IDC leverage ratio exhibits almost the same path as in the original case. These findings help to determine that loose collateral constraints or credit demand shifts were the main driver behind IDC mortgage credit fluctuations.

In a similar way, the picture on the right-hand side of Figure 9 shows the results of the counterfactual simulations on the IFC household leverage ratio. This exercise also helps to verify that borrowing constraint shocks played a dominant role driving the business cycle of these agents' leverage ratios.

Figure 9: Counterfactual Simulations



The overall results differ from the findings of Justiniano, Primiceri, and Tambalotti (2015) who conclude that loose lending constraints were the drivers of the credit boom that preceded the international financial crisis in the US economy. This DSGE provides evidence that, since the early 2000s and in Peru, the easing of borrowing constraints that directly shifted mortgage credit demand were the main driver of the business cycle fluctuations for mortgage credit.

8 Concluding Remarks

Following Justiniano, Primiceri, and Tambalotti (2015), I draw a distinction between demand and supply for credit as potential drivers of a credit expansion, and interpret borrowing constraints as a credit demand driver and lending constraints as a loan supply shifter. This paper then develops a DSGE model that allows for a determination of the relative importance of the relaxation of lending and borrowing constraints as drivers of the business cycle fluctuations for mortgage credit. As an application, I study the case of Peruvian mortgage credit markets' business cycles since the early 2000s.

The DSGE model incorporates the ideas of Justiniano, Primiceri, and Tambalotti (2015) while attempting to disentangle the effects of credit demand and supply shifts. However, by using a DSGE model and conducting historical shock decompositions and counterfactual simulations, I am able to decompose the cyclical dynamics of mortgage credit in terms of the structural shocks and to determine the quantitative contributions of these shocks to mortgage loan business cycle fluctuations. The advantage is that these exercises consider all the quantitative first- and second-order effects of the structural shocks—including lending and borrowing constraint shocks—on the endogenous variables.

The model developed in this paper is a large-scale DSGE model for a small open economy based on Gerali et al. (2010) and Brzoza-Brzezina and Makarski (2011), in which I consider exogenous shocks to lending and borrowing constraints as well as monetary, fiscal, housing preferences, productivity and foreign shocks. The model considers impatient households who hold domestic currency denominated mortgage debt as well as households who take foreign currency denominated debt to match the partially dollarized mortgage credit markets. I model loose borrowing constraints as an increase in a stochastic loan-to-value ratio, and the relaxation of lending constraints as a decrease in a stochastic bank capital-to-asset ratio, related to the lender's leverage position. The former is directly applied to borrowers, being interpreted as a demand shifter; the latter restriction is imposed on the economy's lender, representing a loan supply expansion factor.

It is relevant to study the cyclical fluctuations of financial variables in a DSGE framework since they amplify the economic cycles leading to excessive volatility. Furthermore, analyzing those cyclical deviations allows for disentangling the role of financial frictions on the mortgage and housing markets and revealing the sources of macroeconomic fluctuations. This is important because different drivers or determinants would require the implementation of demand- or supply-side oriented policies, such as macroprudential tools, to moderate the effects of credit boom-bust cycles on the economy. Indeed, there is a close relation between the financial shocks introduced in the model and some extensively used macroprudential instruments. In the DSGE, the loan-to-value ratios are modeled as exogenous AR(1) processes, however these ratios are asset-side macroprudential tools. Mendicino and Punzi (2014) and Rubio and Carrasco-Uribe (2014), for example, introduce them as Taylor rule-type LTV ratios so that they respond to credit growth. The bank capital-to-asset ratios, also modeled as AR(1) series, are capital-based macroprudential tools or capital requirements as considered by, for instance, Angelini, Neri, and Panetts (2012).

Despite of the applicability and usefulness of DSGE models, the decomposition and counterfactual exercises on the business cycle dynamics do not allow for the study of endogenous variable trends: for example, I cannot distinguish whether Peruvian credit trends correspond to a balanced growth path or to a convergence path toward a steady-state with larger credit markets. This interesting question may be part of a different research agenda.

Regarding the application to the Peruvian economy, the historical shock decomposition on the two types of impatient household leverage ratios reveals that their business cycle fluctuations were mainly driven by borrowing constraints shocks or credit demand shifts. The counterfactual simulation exercises provide evidence in favor of this argument: while turning off the borrowing constraints shocks, the counterfactual leverage ratios cyclical dynamics tends to attenuate.

These findings differ from the conclusions of Justiniano, Primiceri, and Tambalotti (2015) who report that loose lending constraints were the drivers of the credit boom that preceded the international financial crisis in the US economy. In this particular case, this difference may be explained by several factors: (i) banking intermediation in Peru is not as developed and sophisticated as in the US, which makes the Peruvian economy less prone to experience exogenous loan supply expansions; (ii) there has not been an important financial intermediation innovation in Peru such as the explosion of securitization that occurred in the US in the 2000s; and (iii) the Peruvian banking system is not as integrated into the international financial markets as the US banking system, which makes it less likely that inflows of foreign funds played a determinant role in increasing the supply of funds to mortgage borrowers.

Alternatively, the results reveal the relevance of credit demand as a credit expansion driver. This is consistent with a Peruvian mortgage credit demand expansion encouraged by a supportive macroeconomic environment and demand-boosting public programs that allowed low- and middle- class households to access to mortgage credit markets with loose contract terms.

References

Angelini, P., Neri, S. and F. Panetts(2012). Monetary and macroprudential policies. Working Paper Series 1449. European Central Bank.

Brooks, S. and A. Gelman (1998). General methods for monitoring convergence of iterative simulations. *Journal of Computational and Graphical Statictics*, 7(4), 434-455.

Brzoza-Brzezina, M. and K. Makarski (2011). Credit crunch in a small open economy. *Journal of International Money and Finance*, 30, 1406-1428.

Castillo, P., Montoro, C. and V. Tuesta (2013). An estimated stochastic general equilibrium model with partial dollarization: A Bayesian approach. *Open Economics Review*, 24, 217-265.

Christiano, L., Eichenbaum, M. and C. Evans (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, 113(1), 1–45.

Christensen, I., P. Corrigan, C. Mendicino, and S. Nishiyama (2007). An estimated open-economy general equilibrium model with housing investment and financial frictions. Bank of Norway, mimeo.

Gambacorta, L. and F. Signoretti (2014). Should monetary policy lean against the wind? An analysis based on a DSGE model with banking. *Journal of Economic Dynamics and Control*, 43, 146-174.

Gerali, A., Neri, S., Sessa, L. and F. Signoretti (2010). Credit and banking in a DSGE model of the Euro Area. *Journal of Money, Credit and Banking*, 42, 107-141.

Glocker, C. and P. Towbin (2012). Reserve requirements for price and financial stability: When are they effective? *International Journal of Central Banking*, 8(1), 65-113.

Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review*, 95(3), 739–764.

Iacoviello, M. and S. Neri (2010). Housing Market Spillovers Evidence from an Estimated DSGE Model. *American Economic Journal: Macroeconomics*, 2(2), 125-164.

International Monetary Fund (2012). Western Hemisphere Regional Economic Outlook. April 2012.

Juillard, M., C. Freedman, D. Korshunov, D. Laxton, O. Kamenik, I. Carabenciov, I. Ermolaev, and J. Laxton (2008). A Small Quarterly Multi-Country Projection Model with Financial-Real Linkages and Oil Prices. IMF Working Papers 08/280, International Monetary Fund.

Justiniano, A., Primiceri, G. and A. Tambalotti (2013). The effects of the saving and banking glut on the U.S. Economy. *Journal of International Economics Supplement* (NBER International Seminar on Macroeconomics), 92, S52-S67.

Justiniano, A., Primiceri, G. and A. Tambalotti (2015). Credit Supply and the housing boom. NBER Working Papers, 20874.

Kiyotaki, N. and J. Moore (1997). Credit cycles. *Journal of Political Economy*, 105(2), 211–48.

Mendicino, C. and M. Punzi (2014). House prices, capital inflows and macroprudential policy. *Journal of Banking and Finance*, 49, 337-355.

Pedersen, J. and S.H. Ravn (2013). What drives the business cycle in a small open economy? Evidence from an estimated DSGE model of the Danish economy. Working Papers, 88. Danmarks Nationalbank.

Ribeiro, J. (2015). Medidas macroprudenciales y manejo de política monetaria en una economía pequeña y abierta. Revista de Estudios Económicos, 29, 55-73. Banco Central de Reserva del Perú.

Rubio, M. and J. Carrasco-Gallego (2014). Macroprudential and monetary policies: implications for financial stability and welfare. *Journal of Banking and Finance*, 49, 326-336.

Ruhl, K. (2008). The international elasticity puzzle. NYU Stern School of Business Working Paper 2008-30.

Schmitt-Grohe, S. and M. Uribe (2003). Closing small open economy models. *Journal of International Economics*, 61, 163–185.

Smets, F. and R. Wouters (2003). An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European Economic Association*, 1(5), 1123–1175.

Winkelried, D. (2013). Modelo de proyección trimestral del BCRP: Actualización y novedades. Revista de Estudios Económicos, 26, 9-60. Banco Central de Reserva del Perú.

Appendix

A First-Order Conditions

The first-order conditions (FOC) of the four types of agent are the following:

A.1 Patient Households

1. Marginal utility of consumption:
$$U_{c,t}^{P} = \beta_P^t (c_t^P - \zeta c_{t-1}^P)^{-\sigma_c}$$

2. FOC with respect to consumption:
$$\frac{\partial}{\partial c_t^P} = \beta_P^t U_{c,t}^P - P_t \lambda_t^P = 0$$

3. FOC with respect to housing demand:
$$\frac{\partial}{\partial h_t^P} = \beta_P^t \varepsilon_{h,t} h_t^{P^{-\sigma_h}} - \lambda_t^P P_t^h + \lambda_{t+1}^P (1-\delta_h) P_{t+1}^h = 0$$

4. FOC with respect to labor:
$$\frac{\partial}{\partial n_t^P} = -\beta_P^t n_t^{P^{-\sigma_n}} + \lambda_t^P W_t = 0$$

5. FOC with respect to deposits:
$$\frac{\partial}{\partial d_t^P} = -\lambda_t^P + \lambda_{t+1}^P R_t^d = 0$$

where λ_t^P is the Lagrangian multiplier of the representative patient household budget constraint. Combining the second and the last equations leads to a standard Euler equation.

A.2 Impatient Households who Hold Domestic Currency Denominated Debt

1. Marginal utility of consumption:
$$U_{c,t}^{IDC} = \beta_{IDC}^t (c_t^{IDC} - \zeta c_{t-1}^{IDC})^{-\sigma_c}$$

2. FOC with respect to consumption:
$$\frac{\partial}{\partial c_t^{IDC}} = \beta_{IDC}^t U_{c,t}^{IDC} - P_t \lambda_t^{IDC} = 0$$

3. FOC with respect to housing demand:
$$\frac{\partial}{\partial h_t^{IDC}} = \beta_{IDC}^t \varepsilon_{h,t} h_t^{IDC^{-\sigma_h}} - \lambda_t^P P_t^h + \mu_t^{IDC} \frac{m_t^{IDC} P_{t+1}^h (1-\delta_h)}{R_t^{bIDC}} + \lambda_{t+1}^{IDC} (1-\delta_h) P_{t+1}^h = 0$$

4. FOC with respect to labor:
$$\frac{\partial}{\partial n_t^{IDC}} = -\beta_{IDC}^t n_t^{IDC^{-\sigma_n}} + \lambda_t^{IDC} W_t = 0$$

5. FOC with respect to debt:

$$\frac{\partial}{\partial b_t^{IDC}} = \lambda_t^{IDC} - \mu_t^{IDC} - \lambda_{t+1}^{IDC} R_t^{bIDC} = 0$$

where λ_t^{IDC} is the Lagrangian multiplier of the representative IDC household budget constraint, meanwhile μ_t^{IDC} is the Lagrangian multiplier of these agents' borrowing constraint. This last term makes the Euler and housing demand equations differ from standard formulations.

A.3 Impatient Households who Hold Foreign Currency Denominated Debt

1. Marginal utility of consumption:

$$U_{c,t}^{IFC} = \beta_{IFC}^t (c_t^{IFC} - \zeta c_{t-1}^{IFC})^{-\sigma_c}$$

2. FOC with respect to consumption:

$$\frac{\partial}{\partial c_t^{IFC}} = \beta_{IFC}^t U_{c,t}^{IFC} - P_t \lambda_t^{IFC} = 0$$

3. FOC with respect to housing demand:

$$\frac{\partial}{\partial h_t^{IFC}} = \beta_{IFC}^t \varepsilon_{h,t} h_t^{IFC^{-\sigma_h}} - \lambda_t^P P_t^h + \mu_t^{IFC} \frac{m_t^{IFC} P_{t+1}^h (1-\delta_h)}{R_t^{bIFC}} + \lambda_{t+1}^{IFC} (1-\delta_h) P_{t+1}^h = 0$$

4. FOC with respect to labor:

$$\frac{\partial}{\partial n_t^{IFC}} = -\beta_{IFC}^t n_t^{IFC^{-\sigma_n}} + \lambda_t^{IFC} W_t = 0$$

5. FOC with respect to debt:

$$\frac{\partial}{\partial b_t^{IFC}} = \lambda_t^{IFC} S_t - \mu_t^{IFC} S_t - \lambda_{t+1}^{IFC} R_t^{bIFC} S_{t+1} = 0$$

where λ_t^{IFC} is the Lagrangian multiplier of the representative IFC household budget constraint, meanwhile μ_t^{IFC} is the Lagrangian multiplier of these agents' borrowing constraint. This term and the nominal exchange rate S_t make the Euler and housing demand equations differ from standard formulations.

A.4 Entrepreneurs

1. Marginal utility of consumption:

$$U_{c,t}^E = \beta_E^t (c_t^E - \zeta c_{t-1}^E)^{-\sigma_c}$$

2. FOC with respect to consumption:

$$\frac{\partial}{\partial c_t^E} = \beta_E^t U_{c,t}^E - P_t \lambda_t^E = 0$$

3. FOC with respect to capital:

$$\frac{\partial}{\partial k_t} = -\lambda_t^E P_t^k + \lambda_{t+1}^E \Big[\alpha P_{t+1}^W \frac{y_{W,t+1}}{k_t} + P_{t+1}^k (1-\delta_k) - P_{t+1} \psi(u_{t+1})\Big] - \mu_t^E m_t^E \frac{P_{t+1}^k (1-\delta_k) k_t}{R_t^{bE}} = 0$$

4. FOC with respect to labor:

$$\frac{\partial}{\partial n_t} = \lambda_t^E \left[(1-\alpha) P_t^W \frac{y_{W,t}}{n_t} - W_t \right] = 0$$

5. FOC with respect to debt:

$$\frac{\partial}{\partial b_t^E} = \lambda_t^E - \lambda_{t+1}^E R_t^{bE} + \mu_t^E = 0$$

6. FOC with respect to capital utilisation rate:

$$\frac{\partial}{\partial u_t} = \lambda_t^E \left[\alpha P_t^W \frac{y_{W,t}}{u_t} - P_t \psi\prime(u_t) k_{t-1} \right] = 0$$

where λ_t^E is the Lagrangian multiplier of the representative entrepreneur budget constraint, meanwhile μ_t^E is the Lagrangian multiplier of these agents' borrowing constraint.

B Log-Linearized Version of the Model

In order to solve the model, it must be reduced to a linearized system of equations. To do that, I log-linearize it. After this process, all the variables are expressed in terms of percent deviations from their steady-state level. The next equations describe the log-linearized version of the DSGE model. In general, $\hat{z}_t$ denotes percent deviations from deterministic steady-state and $\bar{z}$ (a variable without t subscript) denotes steady-state values.

B.1 Patient Households

1. Marginal utility:
$$\hat{u}^P_{c,t} = \frac{-\sigma_c}{1-\zeta}(\hat{c}^P_t - \zeta \hat{c}^P_{t-1})$$

2. Euler equation:
$$\hat{u}^P_{c,t} = E_t[\hat{u}^P_{c,t+1}] + \hat{R}^d_t - E_t[\hat{\pi}_{t+1}]$$

3. Housing demand:
$$\sigma_h \hat{h}^P_t = -\hat{u}^P_{c,t} - \hat{q}^h_t + \frac{\beta_P(1-\delta_h)}{1-\beta_P(1-\delta_h)}\Big(E_t[\hat{\pi}_{h,t+1}] - \hat{R}^d_t\Big) + \hat{\varepsilon}_{h,t}$$

   where:
$$\hat{\pi}_{h,t} = \hat{q}^h_t - \hat{q}^h_{t-1} + \hat{\pi}_t$$

   Since I use the flow of funds equations of the impatient households and entrepreneurs, I do not need a fourth one (patient households' flow of funds), given that this one is satisfied by Walras Law.

B.2 Impatient Households who Hold Domestic Currency Denominated Debt

1. Marginal utility:
$$\hat{u}^{IDC}_{c,t} = \frac{-\sigma_c}{1-\zeta}(\hat{c}^{IDC}_t - \zeta \hat{c}^{IDC}_{t-1})$$

2. Housing demand:
$$\begin{aligned}\left(1-\beta_{IDC}(1-\delta_h) + (1-\delta_h)\bar{m}^{IDC}\left(\beta_{IDC} - \frac{\bar{\pi}}{\bar{R}^{bIDC}}\right)\right)(\hat{\varepsilon}_{h,t} - \sigma_h \hat{h}^{IDC}_t) &= \hat{u}^{IDC}_{c,t} + \hat{q}^h_t \\ + (1-\delta_h)\bar{m}^{IDC}\beta_{IDC}E_t[\hat{u}^{IDC}_{c,t+1}] + (1-\delta_h)\left(\beta_{IDC} - \frac{\bar{\pi}}{\bar{R}^{bIDC}}\right)&\bar{m}^{IDC}\Big(E_t[\hat{q}^h_{t+1}] + \hat{m}^{IDC}_t\Big) \\ - (1-\delta_h)\bar{m}^{IDC}\frac{\bar{\pi}}{\bar{R}^{bIDC}}\Big(E_t[\hat{\pi}_{t+1}] + \hat{u}^{IDC}_{c,t} - \hat{R}^{bIDC}_t\Big) &- (1-\delta_h)\beta_{IDC}\Big(E_t[\hat{u}^{IDC}_{c,t+1} + \hat{q}^h_{t+1}]\Big)\end{aligned}$$

   In this case, I use the Euler equation to solve for the Lagrangian multiplier of the borrowing restriction and replace it with the housing demand's FOC.

3. Labor supply:
$$\hat{w}_t = \hat{u}^{IDC}_{c,t} - \sigma_n \hat{n}^{IDC}_t$$

4. Borrowing constraint:

$$\hat{R}_t^{bIDC} + \hat{b}_t^{IDC} = \hat{m}_t^{IDC} + E_t[\hat{q}_{t+1}^h + \hat{\pi}_{t+1}] + \hat{h}_t^{IDC}$$

5. Flow of funds:

$$\gamma^{IDC}\frac{\bar{c}^{IDC}}{\bar{c}}\frac{\bar{c}}{\bar{\bar{y}}}\hat{c}_t^{IDC} + \gamma^{IDC}\frac{\bar{h}^{IDC}}{\bar{h}}\frac{\bar{i}_h}{\bar{\bar{y}}}\left(\hat{q}_t^h + \frac{1}{\delta_h}\hat{h}_t^{IDC} - \frac{1-\delta_h}{\delta_h}\hat{h}_{t-1}^{IDC}\right)$$
$$+\frac{\bar{R}^{bIDC}}{\bar{\pi}}\frac{\bar{b}^{IDC}}{\bar{\bar{y}}}\left(\hat{R}_{t-1}^{bIDC} + \hat{b}_{t-1}^{IDC} - \hat{\pi}_t\right) = \gamma^{IDC}\frac{\bar{w}\bar{n}}{\bar{\bar{y}}}\left(\hat{w}_t + \hat{n}_t^{IDC}\right) + \frac{\bar{b}^{IDC}}{\bar{\bar{y}}}\hat{b}_t^{IDC} - \gamma^{IDC}\frac{T}{\bar{\bar{y}}}\hat{T}_t$$

B.3 Impatient Households who Hold Foreign Currency Denominated Debt

1. Marginal utility:

$$\hat{u}_{c,t}^{IFC} = \frac{-\sigma_c}{1-\zeta}(\hat{c}_t^{IFC} - \zeta\hat{c}_{t-1}^{IFC})$$

2. Housing demand:

$$\left(1-\beta_{IFC}(1-\delta_h) + (1-\delta_h)\bar{m}^{IFC}\left(\frac{\beta_{IDC}}{\bar{\pi}^*} - \frac{1}{\bar{R}^{bIFC}}\right)\bar{\pi}\right)(\hat{\varepsilon}_{h,t} - \sigma_h\hat{h}_t^{IFC}) = \hat{u}_{c,t}^{IFC} + \hat{q}_t^h$$
$$+(1-\delta_h)\bar{m}^{IFC}\beta_{IFC}\frac{\bar{\pi}}{\bar{\pi}^*}E_t[\hat{u}_{c,t+1}^{IFC}\hat{q}_{t+1} - \hat{q}_t - \hat{\pi}_{t+1}^* + \hat{\pi}_{t+1}] + (1-\delta_h)\bar{\pi}\left(\frac{\beta_{IDC}}{\bar{\pi}^*} - \frac{1}{\bar{R}^{bIFC}}\right)\bar{m}^{IFC}\left(E_t[\hat{q}_{t+1}^h] + \hat{m}_t^{IFC}\right)$$
$$-(1-\delta_h)\bar{m}^{IFC}\frac{\bar{\pi}}{\bar{R}^{bIFC}}\left(E_t[\hat{\pi}_{t+1}] + \hat{u}_{c,t}^{IFC} - \hat{R}_t^{bIFC}\right) - (1-\delta_h)\beta_{IFC}\left(E_t[\hat{u}_{c,t+1}^{IFC} + \hat{q}_{t+1}^h]\right)$$

where $q_t = \frac{S_t P_t^*}{P_t}$ is the real exchange rate.

3. Labor supply:

$$\hat{w}_t = \hat{u}_{c,t}^{IFC} - \sigma_n\hat{n}_t^{IFC}$$

4. Borrowing constraint:

$$\hat{R}_t^{bIFC} + \hat{l}_t^{IFC} = \hat{m}_t^{IFC} + E_t[\hat{q}_{t+1}^h + \hat{\pi}_{t+1}] + \hat{h}_t^{IFC}$$

where $l_t^{IFC} = \frac{S_t b_t^{IFC}}{P_t}$.

5. Flow of funds:

$$\gamma^{IFC}\frac{\bar{c}^{IFC}}{\bar{c}}\frac{\bar{c}}{\bar{\bar{y}}}\hat{c}_t^{IFC} + \gamma^{IFC}\frac{\bar{h}^{IFC}}{\bar{h}}\frac{\bar{i}_h}{\bar{\bar{y}}}\left(\hat{q}_t^h + \frac{1}{\delta_h}\hat{h}_t^{IFC} - \frac{1-\delta_h}{\delta_h}\hat{h}_{t-1}^{IFC}\right)$$
$$+\frac{\bar{R}^{bIFC}}{\bar{\pi}^*}\frac{\bar{l}^{IFC}}{\bar{\bar{y}}}\left(\hat{R}_{t-1}^{bIFC} + \hat{l}_{t-1}^{IFC} + \hat{q}_t - \hat{q}_{t-1} - \hat{\pi}_t^*\right) = \gamma^{IFC}\frac{\bar{w}\bar{n}}{\bar{\bar{y}}}\left(\hat{w}_t + \hat{n}_t^{IFC}\right) + \frac{\bar{l}^{IFC}}{\bar{\bar{y}}}\hat{l}_t^{IFC} - \gamma^{IFC}\frac{T}{\bar{\bar{y}}}\hat{T}_t$$

B.4 Entrepreneurs

1. Marginal utility:

$$\hat{u}_{c,t}^{E} = \frac{-\sigma_c}{1-\zeta}(\hat{c}_t^{E} - \zeta\hat{c}_{t-1}^{E})$$

2. Labor demand:

$$\hat{w}_t = \hat{p}_t^W + \hat{A}_t + \alpha\hat{u}_t + \alpha(\hat{k}_{t-1} - \hat{n}_t)$$

where $\hat{p}_t^W$ comes from $p_t^W = \frac{P_t^W}{P_t}$.

3. Capital utilization:

$$\hat{u}_t = \Psi\Big[\hat{p}_t^W + \hat{A}_t + (1-\alpha)(\hat{n}_t - \hat{u}_t - \hat{k}_{t-1})\Big]$$

4. Euler equation:

$$\begin{aligned}\hat{q}_t^k = (1-\delta_k)\beta_E E_t[\hat{q}_{t+1}^k + (\hat{u}_{c,t+1}^E - \hat{u}_{c,t}^E)] + \beta_E\psi\prime(1)E_t[\hat{u}_{c,t+1}^E - \hat{u}_{c,t}^E + \Psi^{-1}\hat{u}_{t+1}] \\ + \bar{m}^E(1-\delta_k)\bar{\pi}\left[\left(\frac{1}{\bar{R}^{bE}} - \frac{\beta_E}{\bar{\pi}}\right)(\hat{m}_t^E + E_t[\hat{q}_{t+1}^k]) - \frac{1}{\bar{R}^{bE}}(\hat{R}_t^{bE} - E_t[\hat{\pi}_{t+1}]) - \frac{\beta_E}{\bar{\pi}}E_t[\hat{u}_{c,t+1}^E - \hat{u}_{c,t}^E]\right]\end{aligned}$$

5. Borrowing constraint:

$$\hat{R}_t^{bE} + \hat{b}_t^{bE} = \hat{m}_t^E + E_t[\hat{q}_{t+1}^k + \hat{\pi}_{t+1}] + \hat{k}_t$$

6. Production function:

$$\hat{y}_{W,t} = \hat{A}_t + \alpha(\hat{u}_t + \hat{k}_{t-1}) + (1-\alpha)\hat{n}_t$$

7. Flow of funds:

$$\begin{aligned}\gamma^E\frac{\bar{c}^E}{\bar{c}}\frac{\bar{c}}{\bar{\bar{y}}}\hat{c}_t^E = \frac{\bar{p}^W\bar{y}_w}{\bar{\bar{y}}}(\hat{p}_t^W + \hat{y}_{W,t}) + \frac{1-\delta_k}{\delta_k}\frac{\bar{i}_k}{\bar{\bar{y}}}(\hat{q}_t^k + \hat{k}_{t-1}) \\ + \frac{\bar{b}^E}{\bar{\bar{y}}}\hat{b}_t^E - \frac{\bar{w}\bar{n}}{\bar{\bar{y}}}(\hat{w}_t + \hat{n}_t) - \frac{1}{\delta_k}\frac{\bar{i}_k}{\bar{\bar{y}}}(\hat{q}_t^k + \hat{k}_t) \\ - \frac{\psi\prime(1)}{\delta_k}\frac{\bar{i}_k}{\bar{\bar{y}}}\hat{u}_t - \frac{\bar{R}^{bE}}{\bar{\pi}}\frac{\bar{b}^E}{\bar{\bar{y}}}(\hat{R}_{t-1}^{bE} + \hat{b}_{t-1}^E - \hat{\pi}_t) - \gamma^E\frac{\bar{T}}{\bar{\bar{y}}}\hat{T}_t\end{aligned}$$

B.5 Labor Market

1. Wages:

$$\begin{aligned}\frac{\theta_w}{1+\theta_w}(\hat{w}_t - \hat{w}_{t-1} + \hat{\pi}_t - \zeta_w\hat{\pi}_{t-1}) = \frac{1-\bar{\beta}\theta_w}{1+\sigma_n\frac{1+\mu_w}{\mu_w}}(\sigma_n\hat{n}_t - \hat{U}_{c,t} - \hat{w}_t) \\ + \frac{\bar{\beta}\theta_w}{1-\theta_w}E_t[\hat{w}_{t+1} - \hat{w}_t + \hat{\pi}_{t+1} - \zeta_w\hat{\pi}_t]\end{aligned}$$

where the average discount factor used by the union is defined as:

$$\bar{\beta} = \frac{\gamma^P}{\gamma^P + \gamma^{IDC} + \gamma^{IFC}}\beta_P + \frac{\gamma^{IDC}}{\gamma^P + \gamma^{IDC} + \gamma^{IFC}}\beta_{IDC} + \frac{\gamma^{IFC}}{\gamma^P + \gamma^{IDC} + \gamma^{IFC}}\beta_{IDC}$$

and the average marginal utility is $\hat{U}_{c,t}$:

$$\hat{U}_{c,t} = \frac{\gamma^P\left(\frac{\bar{c}^P}{\bar{c}}\right)^{-\sigma_c}}{\gamma^P\left(\frac{\bar{c}^P}{\bar{c}}\right)^{-\sigma_c} + \gamma^{IDC}\left(\frac{\bar{c}^{IDC}}{\bar{c}}\right)^{-\sigma_c} + \gamma^{IFC}\left(\frac{\bar{c}^{IFC}}{\bar{c}}\right)^{-\sigma_c}}\hat{u}^P_{c,t} + \frac{\gamma^{IDC}\left(\frac{\bar{c}^{IDC}}{\bar{c}}\right)^{-\sigma_c}}{\gamma^P\left(\frac{\bar{c}^P}{\bar{c}}\right)^{-\sigma_c} + \gamma^{IDC}\left(\frac{\bar{c}^{IDC}}{\bar{c}}\right)^{-\sigma_c} + \gamma^{IFC}\left(\frac{\bar{c}^{IFC}}{\bar{c}}\right)^{-\sigma_c}}\hat{u}^P_{c,t} + \frac{\gamma^{IFC}\left(\frac{\bar{c}^{IFC}}{\bar{c}}\right)^{-\sigma_c}}{\gamma^P\left(\frac{\bar{c}^P}{\bar{c}}\right)^{-\sigma_c} + \gamma^{IDC}\left(\frac{\bar{c}^{IDC}}{\bar{c}}\right)^{-\sigma_c} + \gamma^{IFC}\left(\frac{\bar{c}^{IFC}}{\bar{c}}\right)^{-\sigma_c}}\hat{u}^P_{c,t}$$

where $\gamma^H = \gamma^P + \gamma^{IDC} + \gamma^{IFC}$

B.6 Capital Good Producers

1. Price of capital (Tobin's q):
$$\hat{i}_{k,t} = \frac{\kappa_k}{1+\beta_P}\hat{q}^k_t + \frac{\beta_P}{1+\beta_P}E_t[\hat{i}_{k,t+1}] + \frac{1}{1+\beta_P}\hat{i}_{k,t-1}$$
2. Capital accumulation:
$$\hat{k}_t = (1-\delta_k)\hat{k}_{t-1} + \delta_k\hat{i}_{k,t}$$

B.7 Housing Producers

1. Price of housing:
$$\hat{i}_{h,t} = \frac{\kappa_h}{1+\beta_P}\hat{q}^h_t + \frac{\beta_P}{1+\beta_P}E_t[\hat{i}_{h,t+1}] + \frac{1}{1+\beta_P}\hat{i}_{h,t-1}$$
2. Housing accumulation:
$$\hat{h}_t = (1-\delta_h)\hat{h}_{t-1} + \delta_h\hat{i}_{h,t}$$

B.8 Final Good Producers

1. Production function:
$$\hat{y}_t = \eta^{\frac{\mu}{1+\mu}}\left(\frac{\bar{y}_H}{\bar{y}}\right)^{\frac{1}{1+\mu}}\hat{y}_{H,t} + (1-\eta)^{\frac{\mu}{1+\mu}}\left(\frac{\bar{y}_F}{\bar{y}}\right)^{\frac{1}{1+\mu}}\hat{y}_{F,t}$$
2. Demand for domestic and imported intermediate goods:
$$\hat{y}_{H,t} = -\frac{1+\mu}{\mu}\hat{p}_{H,t} + \hat{y}_t$$
$$\hat{y}_{F,t} = -\frac{1+\mu}{\mu}\hat{p}_{F,t} + \hat{y}_t$$
where $\hat{p}_{H,t}$ and $\hat{p}_{F,t}$ come from $p_{H,t} = \frac{P_{H,t}}{P_t}$ and $p_{F,t} = \frac{P_{F,t}}{P_t}$ respectively.
3. Inflation:
$$\hat{\pi}_t = (1-\eta)(\bar{p}_F)^{-\frac{1}{\mu}}(\hat{\pi}_{F,t} + \hat{p}_{F,t-1}) + \eta(\bar{p}_H)^{-\frac{1}{\mu}}(\hat{\pi}_{H,t} + \hat{p}_{H,t-1})$$

B.9 Domestic Retailers

1. Domestic goods inflation:
$$\hat{\pi}_{H,t} = \hat{\pi}_t + \hat{p}_{H,t} - \hat{p}_{H,t-1}$$
2. Domestic goods prices:
$$\frac{\theta_H}{1-\theta_H}(\hat{p}_{H,t} + \hat{\pi}_t - \hat{p}_{H,t-1} - \zeta_H \hat{\pi}_{t-1}) = (1-\beta_P\theta_H)(\hat{p}_t^W - \hat{p}_{H,t}) + \frac{\beta_P\theta_H}{1-\theta_H} E_t[\hat{p}_{H,t+1} - \hat{p}_{H,t} + \hat{\pi}_{t+1} - \zeta_H \hat{\pi}_t]$$

B.10 Importing Retailers

1. Imported goods inflation:
$$\hat{\pi}_{F,t} = \hat{\pi}_t + \hat{p}_{F,t} - \hat{p}_{F,t-1}$$
2. Domestic goods prices:
$$\frac{\theta_F}{1-\theta_F}(\hat{p}_{F,t} + \hat{\pi}_t - \hat{p}_{F,t-1} - \zeta_F \hat{\pi}_{t-1}) = (1-\beta_P\theta_F)(\hat{q}_t - \hat{p}_{F,t}) + \frac{\beta_P\theta_F}{1-\theta_F} E_t[\hat{p}_{F,t+1} - \hat{p}_{F,t} + \hat{\pi}_{t+1} - \zeta_F \hat{\pi}_t]$$

B.11 Exporting Retailers

In this case, $\hat{p}^*_{H,t}$ comes from $p^*_{H,t} = \frac{P^*_{H,t}}{P_t}$

1. Demand for exported intermediate goods:
$$\hat{y}^*_{H,t} = -\frac{1+\mu^*_H}{\mu^*_H}\hat{p}^*_{H,t} + \hat{y}^*_t$$
2. Exported goods inflation:
$$\hat{\pi}^*_{H,t} = \hat{\pi}^*_t + \hat{p}^*_{H,t} - \hat{p}^*_{H,t-1}$$
3. Exported goods prices:
$$\frac{\theta^*_H}{1-\theta^*_H}(\hat{p}^*_{H,t} + \hat{\pi}^*_t - \hat{p}^*_{H,t-1} - \zeta^*_H \hat{\pi}^*_{t-1}) = (1-\beta_P\theta^*_H)(\hat{p}_t^W - \hat{q}_t - \hat{p}^*_{H,t}) + \frac{\beta_P\theta^*_H}{1-\theta^*_H} E_t[\hat{p}^*_{H,t+1} - \hat{p}^*_{H,t} + \hat{\pi}^*_{t+1} - \zeta^*_H \hat{\pi}^*_t]$$

B.12 Banking Sector

1. From the bank's first-order conditions:
$$\hat{R}_t^{bIDC} = \hat{R}_t - \frac{\kappa_{k^{bIDC}}}{\bar{R}}\bar{v}^3_{IDC}(\hat{K}^b_t - \hat{b}^{IDC}_t) + \frac{\kappa_{k^{bIDC}}}{\bar{R}}\bar{v}^3_{IDC}\hat{v}_{IDC,t}$$
$$\hat{R}_t^{bIFC} = \hat{R}_t - \frac{\kappa_{k^{bIFC}}}{\bar{R}}\bar{v}^3_{IFC}(\hat{K}^b_t - \hat{l}^{IFC}_t) + \frac{\kappa_{k^{bIFC}}}{\bar{R}}\bar{v}^3_{IDC}\hat{v}_{IFC,t}$$
$$\hat{R}_t^{bE} = \hat{R}_t - \frac{\kappa_{k^{bE}}}{\bar{R}}\bar{v}^3_{E}(\hat{K}^b_t - \hat{b}^{E}_t) + \frac{\kappa_{k^{bE}}}{\bar{R}}\bar{v}^3_{IDC}\hat{v}_{E,t}$$

2. Bank balance sheet condition:

$$\hat{K}^b_t = \frac{1}{\bar{v}_{IDC}}\hat{b}^{IDC}_t + \frac{1}{\bar{v}_{IFC}}\hat{l}^{IFC}_t + \frac{1}{\bar{v}_E}\hat{b}^E_t - \frac{\bar{D}}{\bar{K}^b}\hat{d}^P_t - \frac{\bar{l}^*}{\bar{K}^b}\hat{l}^*_t$$

where $l^*_t = \frac{S_t B^*_t}{P_t}$.

3. Bank capital accumulation:

$$\bar{\pi}(\hat{K}^b_t + \hat{\pi}_t) = (1-\delta_b)\hat{K}^b_{t-1} + \Big[\bar{\pi} - (1-\delta_b)\Big]\hat{J}^b_{t-1}$$

4. Bank profits:

$$\Big(\frac{\bar{\pi} - (1-\delta_b)}{\omega_b}\Big)\hat{J}^b_t = \bar{R}\Big[\frac{1}{v_{IDC}}\hat{R}^{bIDC}_t + \frac{1}{v_{IFC}}\hat{R}^{bIFC}_t + \frac{1}{v_E}\hat{R}^{bE}_t - \frac{\bar{D}}{\bar{K}^b}\hat{R}_t\Big] - \bar{R}^{b*}\frac{\bar{l}^*}{\bar{K}^b}\hat{R}^{b*}_t$$
$$+ (\bar{R}-1)\Big[\frac{1}{v_{IDC}}\hat{b}^{IDC}_t + \frac{1}{v_{IFC}}\hat{l}^{IFC}_t + \frac{1}{v_E}\hat{b}^E_t - \frac{\bar{D}}{\bar{K}^b}\hat{d}^P_t\Big] - \Big(\bar{R}^{b*} - 1\Big)\frac{\bar{l}^*}{\bar{K}^b}\hat{l}^*_t$$

5. The UIP condition derived from bank's problem:

$$\hat{R}_t - \hat{R}^{b*}_t = E_t\Big[\hat{q}_{t+1} - \hat{q}_t + \hat{\pi}_{t+1} - \hat{\pi}^*_{t+1}\Big]$$

6. Deposit interest rate assumption:

$$\hat{R}^d_t = \hat{R}_t$$

B.13 Foreign Sector

1. Foreign demand:

$$\hat{y}^*_t = \zeta_{y^*}\hat{y}^*_{t-1} + \hat{\varpi}_{y^*,t}$$

2. Foreign inflation:

$$\hat{\pi}^*_t = \zeta_{\pi^*}\hat{\pi}^*_{t-1} + \hat{\varpi}_{\pi^*,t}$$

3. Foreign Taylor Rule:

$$\hat{RF}^b_t = \zeta_{rf^*,1}\hat{RF}^*_{t-1} + (1-\zeta_{rf^*,1})\Big(\zeta_{rf^*,2}\hat{\pi}^*_t + \zeta_{rf^*,3}\hat{y}^*_t\Big) + \hat{\varpi}_{rf^*,t}$$

4. International funding interest rate:

$$R^{b*}_t = RF^*_t + \rho_t$$

5. Interest rate premium's definition:

$$\hat{\rho}_t = \varrho\frac{\bar{l}^*}{\bar{\tilde{y}}}(\hat{l}^*_t - \hat{\tilde{y}}_t) + \hat{\varepsilon}_{\rho,t}$$

B.14 The Government

1. Government expenditures:

$$\hat{g}_t = \rho_g\hat{g}_{t-1} + \hat{\varpi}_{g,t}$$

2. Government's budget:

$$\hat{g}_t = \hat{T}_t$$

B.15 The Central Bank

1. Taylor Rule:

$$\hat{R}_t = \phi_R \hat{R}_{t-1} + (1-\phi_R)(\phi_\pi \hat{\pi}_t + \phi_y \hat{\tilde{y}}_t) + \hat{\varpi}_{R,t}$$

B.16 Market Clearing, Balance of Payments, and GDP

1. Final goods:

$$\frac{\bar{c}}{\bar{\tilde{y}}}\hat{c}_t + \frac{\bar{i}_k}{\bar{\tilde{y}}}\hat{i}_{k,t} + \frac{\bar{i}_h}{\bar{\tilde{y}}}\hat{i}_{h,t} + \frac{\bar{g}}{\bar{\tilde{y}}}\hat{g}_t + \frac{\psi\prime(1)}{\delta_k}\frac{\bar{i}_k}{\bar{\tilde{y}}}\hat{u}_t = \frac{\bar{y}}{\bar{\tilde{y}}}\hat{y}_t$$

$$\gamma^P \frac{\bar{c}^P}{\bar{c}}\hat{c}_t^P + \gamma^{IDC}\frac{\bar{c}^{IDC}}{\bar{c}}\hat{c}_t^{IDC} + \gamma^{IFC}\frac{\bar{c}^{IFC}}{\bar{c}}\hat{c}_t^{IFC} + \gamma^E \frac{\bar{c}^E}{\bar{c}}\hat{c}_t^E = \hat{c}_t$$

2. Intermediate homogenous goods:

$$\frac{\bar{y}_H}{\bar{y}_H + \bar{y}_H^*}\hat{y}_{H,t} + \frac{\bar{y}_H^*}{\bar{y}_H + \bar{y}_H^*}\hat{y}_{H,t}^* = \hat{y}_{W,t}$$

3. Housing:

$$\gamma^P \frac{\bar{h}^P}{\bar{h}}\hat{h}_t^P + \gamma^{IDC}\frac{\bar{h}^{IDC}}{\bar{h}}\hat{h}_t^{IDC} + \gamma^{IFC}\frac{\bar{h}^{IFC}}{\bar{h}}\hat{h}_t^{IFC} = \hat{h}_{t-1}$$

4. Balance of payments:

$$\frac{\bar{p}_F \bar{y}_F}{\bar{\tilde{y}}}(\hat{p}_{F,t} + \hat{y}_{F,t}) + \frac{\bar{l}^*}{\bar{\tilde{y}}}\frac{\bar{R}^{b*}}{\bar{\pi}^*}(\hat{q}_t - \hat{q}_{t-1} - \hat{\pi}_t^* + \hat{l}_{t-1}^* + \hat{R}_{t-1}^{b*}) + \frac{\bar{q}\bar{p}_H^* \bar{y}_H^*}{\bar{\tilde{y}}}(\hat{p}_{H,t}^* + \hat{y}_{H,t}^* + \hat{q}_t) + \frac{\bar{l}^*}{\bar{\tilde{y}}}\hat{l}_t^*$$

5. Real GDP definition:

$$\hat{\tilde{y}}_t = \frac{\bar{y}}{\bar{\tilde{y}}}\hat{y}_t + \frac{\bar{q}\bar{p}_H^* \bar{y}_H^*}{\bar{\tilde{y}}}(\hat{p}_{H,t}^* + \hat{y}_{H,t}^* + \hat{q}_t) - \frac{\bar{p}_F \bar{y}_F}{\bar{\tilde{y}}}(\hat{p}_{F,t} + \hat{y}_{F,t})$$

B.17 Exogenous Processes

1. Housing demand preferences shock:

$$\hat{\varepsilon}_{h,t} = \rho_h \hat{\varepsilon}_{h,t-1} + \hat{\varpi}_{h,t}$$

2. Stochastic LTV ratios of impatient agents:

$$\hat{m}_t^{IDC} = \rho_m^{IDC}\hat{m}_{t-1}^{IDC} + \hat{\varpi}_{m^{IDC},t}$$

$$\hat{m}_t^{IFC} = \rho_m^{IFC}\hat{m}_{t-1}^{IFC} + \hat{\varpi}_{m^{IFC},t}$$

$$\hat{m}_t^{E} = \rho_m^{E}\hat{m}_{t-1}^{E} + \hat{\varpi}_{m^{E},t}$$

3. Stochastic entrepreneurs' productivity:

$$\hat{A}_t = \rho_A \hat{A}_{t-1} + \hat{\varpi}_{A,t}$$

4. Stochastic capital-to-asset ratios:

$$\hat{v}_{IDC,t} = \rho_{v_{IDC}} \hat{v}_{IDC,t-1} + \hat{\varpi}_{v_{IDC},t}$$

$$\hat{v}_{IFC,t} = \rho_{v_{IFC}} \hat{v}_{IFC,t-1} + \hat{\varpi}_{v_{IFC},t}$$

$$\hat{v}_{E,t} = \rho_{v_E} \hat{v}_{E,t-1} + \hat{\varpi}_{v_E,t}$$

5. Stochastic process of interest rate premium:

$$\hat{\varepsilon}_{\rho,t} = \rho_{\varepsilon_\rho} \hat{\varepsilon}_{\rho,t-1} + \hat{\varpi}_{\varepsilon_\rho,t}$$

C Calibration

Table 2: Calibrated Parameters of the model

Parameter	Description	Value
Population Measures		
γ^P	Patient households' mass measure	0.50
γ^{IDC}	IDC households' mass measure	0.15
γ^{IFC}	IFC households' mass measure	0.10
γ^E	Entrepreneurs' mass measure	0.25
Preferences Parameters		
β_P	Patient households' discount factor	0.998
β_{IDC}	IDC households' discount factor	0.975
β_{IFC}	IFC households' discount factor	0.975
β_E	Entrepreneurs' discount factor	0.980
Labor Sector Parameters		
μ_w	Labor aggregator elasticity	0.1
Capital and Housing Producers		
δ_k	Physical capital depreciation rate	0.025
δ_h	Housing depreciation rate	0.0125
Producing sector		
α	Output-capital elasticity	0.3
μ	Domestic-foreign goods substitution elasticity parameter	1.0
η	Home bias coefficient	0.77
Banking sector		
δ_b	Bank operating margin parameter	0.025
$\bar{m}^{IDC}$	Steady-state LTV ratio for IDC households	0.80
$\bar{m}^{IFC}$	Steady-state LTV ratio for IFC households	0.70
$\bar{m}^E$	Steady-state LTV ratio for entrepreneurs	0.60
Aggregate Variables		
$\bar{\pi}$	Steady-state gross inflation rate	1.028
$\bar{R}$	Steady-state gross interest rate	1.038
Foreign Sector		
$\bar{\pi}^*$	Steady-state gross foreign inflation rate	1.020
$\bar{RF}^*$	Steady-state gross foreign interest rate	1.021
ρ_{π^*}	Foreign inflation persistence	0.74
ρ_{y^*}	Foreign demand persistence	0.95
σ_{rf^*}	Standard Deviation of foreign monetary policy shocks	0.600
σ_{y^*}	Standard Deviation of foreign demand shocks	0.608
σ_{π^*}	Standard Deviation of foreign inflation shocks	1.433

Gross inflation and interest rates are expressed in annual terms.

Table 3: Selected steady-state Ratios of the Model

Ratio	**Value**
National Accounting Ratios	
Absorption-to-GDP ratio	0.97
Consumption share in GDP	0.63
Investment share in GDP	0.22
Government expenditure share in GDP	0.11
Exports share in GDP	0.26
Imports share in GDP	0.23
External debt-to-GDP ratio	0.35
Banking Ratios	
IDC Households loans-to-GDP ratio	0.02
IFC Households loans-to-GDP ratio	0.02
Entrepreneurs loans-to-GDP ratio	0.19
Steady-state bank capital-to-IDC asset ratio $\bar{v}_{IDC}$	1.69
Steady-state bank capital-to-IFC asset ratio $\bar{v}_{IFC}$	1.38
Steady-state bank capital-to-EE asset ratio $\bar{v}_{E}$	0.16

D Bayesian Estimation

D.1 Data Used in Estimation

Table 4 reports the data used in the estimation and some brief descriptions.

Table 4: Data Used in the Bayesian Estimation

Notation	Variable	Comments
$\tilde{y}_t$	Real GDP	
π_t	CPI Inflation Gross Rate	
q_t	Real Effective Exchange Rate	
q_t^h	Real Housing Prices	
R_t	Interbank Market Gross Interest Rate	
R_t^{bIDC}	Domestic Currency Mortgage Credit Gross Interest Rate	Average interest rate of banking system
R_t^{bIFC}	Foreign Currency Mortgage Credit Gross Interest Rate	Average interest rate of banking system
R_t^{bE}	Commercial Credit Gross Interest Rate	Average interest rate of banking system
d_t^P	Deposits	Total deposits of banking system
b_t^{IDC}	Real Domestic Currency Mortgage Credits	Total mortgage credit of banking system
l_t^{IFC}	Real Foreign Currency Mortgage Credits expressed in domestic currency	Total mortgage credit of banking system
b_t^E	Real Commercial Credits	Total commercial credit of banking system
π_t^*	Foreign Inflation Gross Rate	Weighted average inflation rate of the Peruvian 20 main trade partners
RF_t^*	Foreign Gross Interest Rate	12-months Libor interest rate

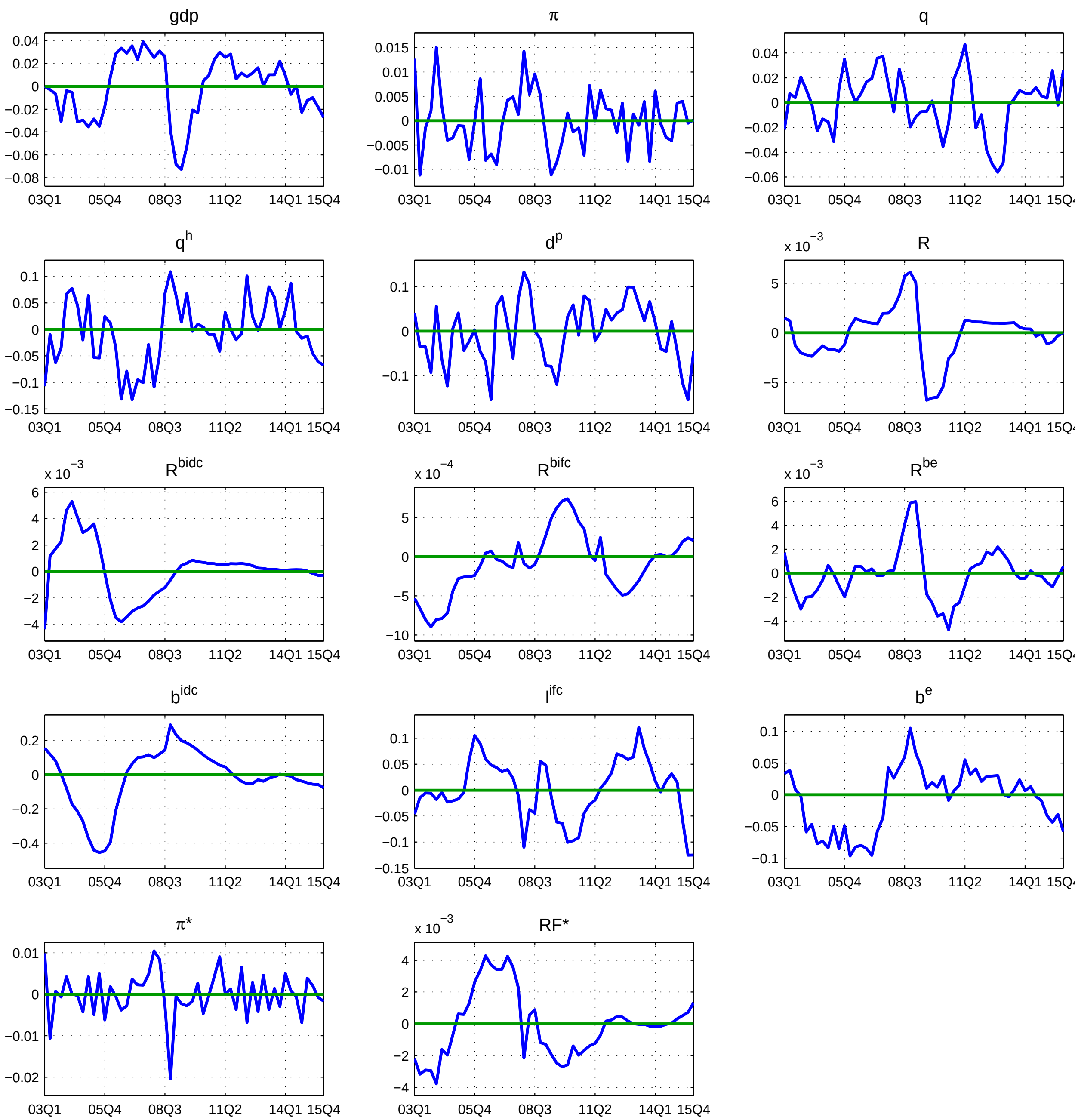
Source: BCRP's database.

Figure 10 depicts the business cycle fluctuations of the observable variables during the sample period. The filter can identify the business cycles of the Peruvian economy (see the plot for `gdp`), in particular the recession of the first half of the 2000's, the subsequent boom, and the bust associated to the international financial crisis.

All the interest rates show high persistence. Among the loan rates, the commercial credit interest rate ($\mathtt{R}^{\mathtt{be}}$) shows the highest correlation with the interbank market rate (`R`), the proxy of monetary policy rate. Figure 10 also shows the negative correlation between the business cycle fluctuations of the two types of mortgage credits ($\mathtt{b}^{\mathtt{idc}}$ and $\mathtt{l}^{\mathtt{ifc}}$) and the close connection between the monetary policy rate and the international interest rate ($\mathtt{RF}^*$).

Table 5 reports some relevant statistics of the series. In terms of volatility, mortgage and commercial credits are more volatile than output. A special case is the domestic currency denominated mortgage credit that exhibits the highest standard deviation, suggesting larger business cycle fluctuations. The real housing prices and the interbank market interest rate present also higher volatility. Domestic CPI inflation and the real effective exchange rate are less volatile than output, the same for the foreign variables.

Figure 10: Data Used in the Bayesian Estimation



Regarding the contemporaneous correlation with output, during the period 2003-2015, Peruvian data presents some distinct features. The inflation rate, real effective exchange rate, and credit are procyclical, whereas the real housing prices are countercyclical. The domestic currency denominated mortgage credit interest rate presents a positive contemporaneous correlation with output, while the foreign currency denominated mortgage rate is clearly countercyclical. The commercial credit rate and the deposit seems to have no correlation with output.

Table 5: Selected Moments of the Data

Sample Period: 2003 - 2015

Variables	**Relative Std.**	**First-Order Autocorr.**	**Cross-corr. with Output**
$\tilde{y}_t$	1.00	0.81	1.00
π_t	0.23	0.12	0.27
q_t	0.85	0.63	0.27
q_t^h	2.22	0.53	-0.36
R_t	2.55	0.47	0.46
R_t^{bIDC}	0.10	0.84	0.36
R_t^{bIFC}	0.08	0.87	-0.49
R_t^{bE}	0.01	0.93	-0.09
d_t^P	0.08	0.82	-0.09
b_t^{IDC}	6.41	0.95	0.10
b_t^{IFC}	2.17	0.80	0.15
b_t^E	1.82	0.86	-0.02
π_t^*	0.20	-0.11	0.31
RF_t^*	0.08	0.88	0.42

Relative Std. is the standard deviation relative to output's std.

D.2 Estimation Procedure Details

The system of log-linearized equations, presented in Appendix B, forms a linear rational expectation system can be written as follows:

$$\Gamma_0(\vartheta)z_t = \Gamma_1(\vartheta)z_{t-1} + \Gamma_2(\vartheta)\epsilon_t + \Gamma_3(\vartheta)\xi_t$$

where z_t is a vector that contains the model's variables expressed as log-deviation from their steady-state values. It includes the endogenous variables and the exogenous processes (the autoregressive processes of order one). Vector ϵ_t contains the white noise innovations to these exogenous processes, and ξ_t is a vector of rational expectation forecast errors. The matrices Γ_1, Γ_2 and Γ_3 are non linear functions of structural parameters contained in ϑ. The solution of this system is given by:

$$z_t = \Omega_z(\vartheta)z_{t-1} + \Omega_\epsilon(\vartheta)\epsilon_t \text{ and } y_t = Hz_t$$

These two last equations correspond to the state-space form representation of y_t, which is a vector of observable variables. Ω_z and Ω_ϵ are functions of the structural parameters and H is a matrix that selects elements from z_t. Under the assumption of normal distributed white noise innovations, the conditional likelihood function for the structural parameters $L(\vartheta|y^T)$ can be computed using the Kalman Filter, where $y^T = \{y_1, y_2, \ldots, y_T\}$. The object of interest is the joint posterior distribution of the parameters given the data,

$$p(\vartheta|y^T) = \frac{L(y^T|\vartheta)p(\vartheta)}{\int L(y^T|\vartheta)p(\vartheta)d\vartheta}$$

where $p(\vartheta)$ is the prior distribution of the structural parameters. The data y^T is used to update those priors through the likelihood function. An approximated solution for the posterior distribution is computed by using the Metropolis-Hastings procedure, a "rejection sampling" algorithm, that generates a sequence of samples known as a "Markov Chain" from a distribution that is unknown at the outset.

D.3 Prior Distributions and Posterior Estimates

Table 6: Prior and posterior distributions: Structural Parameters

Parameter	**Prior distribution**			**Posterior distribution**		
	Shape	**Mean**	**Std. Dev.**	**Mode**	**Mean**	**Std. Dev.**
Preferences Parameters						
ζ	Beta	0.75	0.10	0.45	0.44	0.048
σ_c	Normal	2.00	0.10	1.76	1.75	0.050
σ_h	Normal	4.00	0.10	3.98	3.98	0.029
σ_n	Normal	4.00	0.10	4.00	4.00	0.053
Labor Sector Parameters						
θ_w	Beta	0.90	0.05	0.98	0.97	0.019
ζ_w	Beta	0.60	0.10	0.45	0.45	0.034
Capital and Housing Producers						
κ_k	Beta	0.20	0.05	0.21	0.21	0.015
κ_h	Beta	0.02	0.005	0.02	0.02	0.002
Producing Sector						
θ_H	Beta	0.75	0.05	0.63	0.63	0.017
ζ_H	Beta	0.60	0.10	0.39	0.40	0.034
θ_F	Beta	0.90	0.05	0.93	0.93	0.017
ζ_F	Beta	0.60	0.10	0.61	0.61	0.029
θ_H^*	Beta	0.60	0.10	0.61	0.62	0.070
ζ_H^*	Beta	0.60	0.10	0.50	0.51	0.076
Banking Sector						
$\kappa_{K^{bIDC}}$	Gamma	1.00	0.50	1.17	1.15	0.259
$\kappa_{K^{bIFC}}$	Gamma	1.00	0.50	0.003	0.003	0.258
$\kappa_{K^{bE}}$	Gamma	1.00	0.50	1.07	1.00	0.216
Monetary Policy Rule						
ϕ_R	Beta	0.70	0.10	0.86	0.85	0.031
ϕ_π	Normal	1.50	0.10	1.49	1.49	0.048
ϕ_y	Normal	0.50	0.10	0.57	0.58	0.059

Table 7: Prior and posterior distributions: Shocks Processes

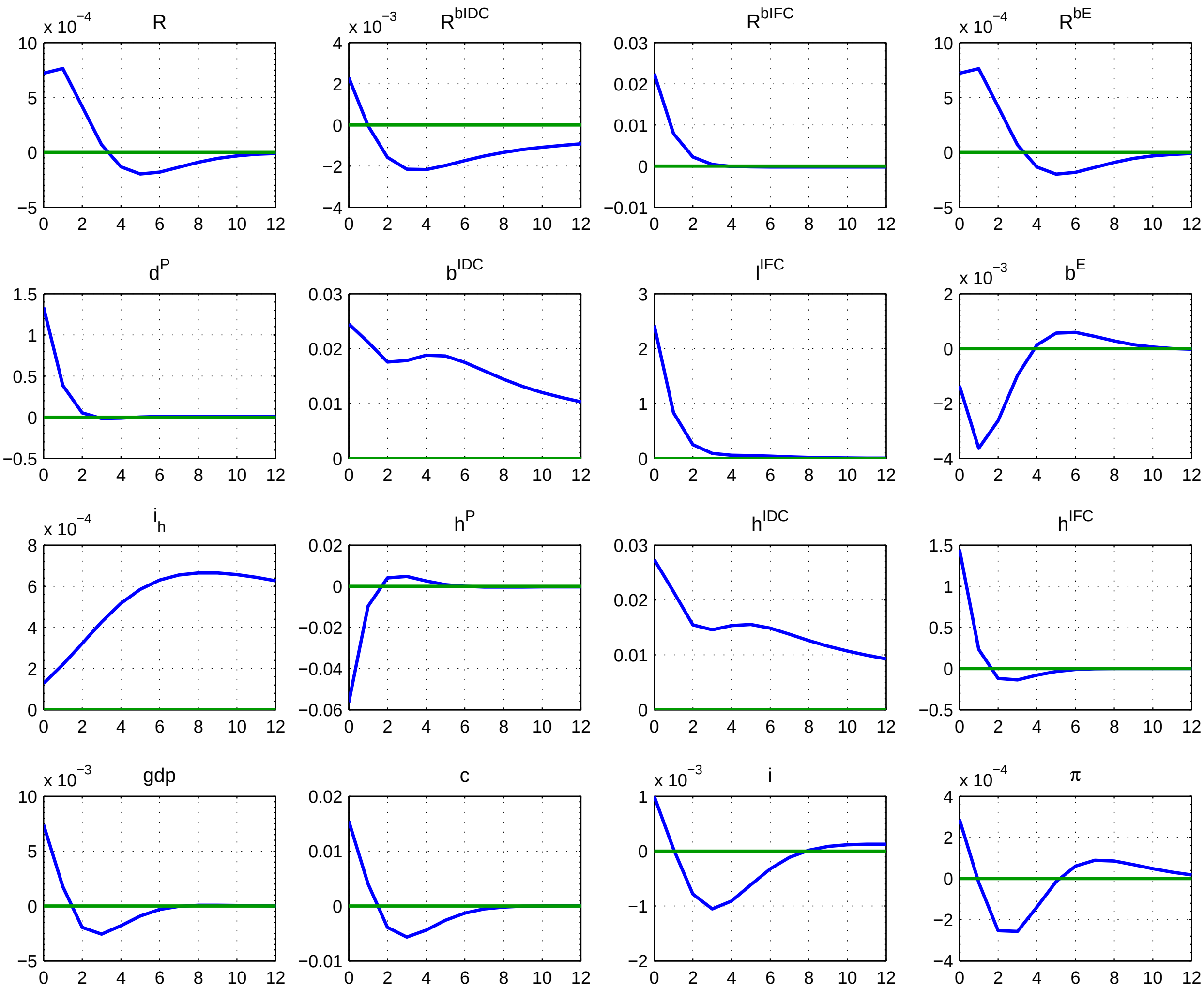
Parameter	**Prior distribution**			**Posterior distribution**		
	Shape	**Mean**	**Std. Dev.**	**Mode**	**Mean**	**Std. Dev.**
Autocorrelation Parameters						
ρ_m^{IDC}	Beta	0.70	0.05	0.74	0.74	0.018
ρ_m^{IFC}	Beta	0.70	0.05	0.60	0.61	0.032
ρ_m^{E}	Beta	0.70	0.05	0.70	0.70	0.021
$\rho_{v_{IDC}}$	Beta	0.70	0.05	0.71	0.70	0.029
$\rho_{v_{IFC}}$	Beta	0.70	0.05	0.73	0.73	0.019
ρ_{v_E}	Beta	0.70	0.05	0.68	0.68	0.021
ρ_{ε_ρ}	Beta	0.70	0.10	0.69	0.70	0.052
ρ_A	Beta	0.70	0.10	0.71	0.73	0.040
ρ_h	Beta	0.70	0.10	0.71	0.72	0.047
ρ_g	Beta	0.70	0.10	0.63	0.63	0.046
Standard Deviation Parameters						
$\sigma_{m^{IDC}}$	Invg	0.10	Inf	0.03	0.03	0.003
$\sigma_{m^{IFC}}$	Invg	0.10	Inf	0.07	0.07	0.008
σ_{m^E}	Invg	0.10	Inf	0.04	0.04	0.005
$\sigma_{v_{IDC}}$	Invg	0.10	Inf	0.04	0.04	0.011
$\sigma_{v_{IFC}}$	Invg	0.10	Inf	0.16	0.17	0.015
σ_{v_E}	Invg	0.10	Inf	0.25	0.29	0.138
$\sigma_{\varepsilon_\rho}$	Invg	0.05	Inf	0.01	0.01	0.001
σ_A	Invg	0.05	Inf	0.03	0.03	0.004
σ_h	Invg	0.05	Inf	1.03	1.03	0.174
σ_g	Invg	0.05	Inf	0.16	0.17	0.019
σ_R	Invg	0.05	Inf	0.01	0.01	0.0004

E Impulse Response Functions

In this section, I present the impulse response functions of the selected variables to the other shocks considered in the model. For the cases of shocks to monetary policy, foreign and inflation rates, I show the responses to a 25 basis points positive innovation. For the other cases, the responses correspond to 1 percent innovations.

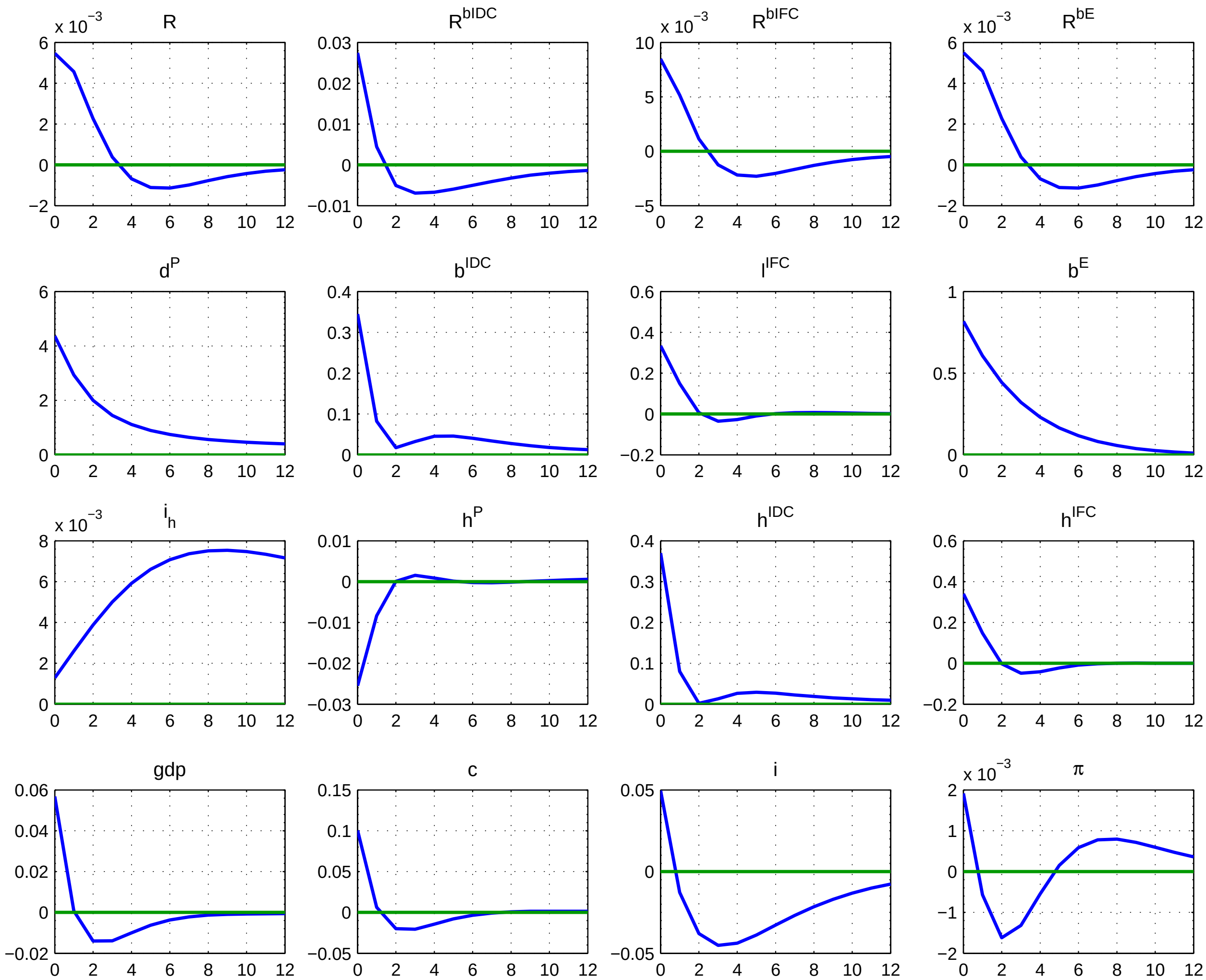
E.1 Borrowing Constraint Relaxation Shock I: An Exogenous Increase in the LTV Ratio of IFC Households

Figure 11: Impulse Response Functions to an IFC Household LTV Ratio Positive Shock



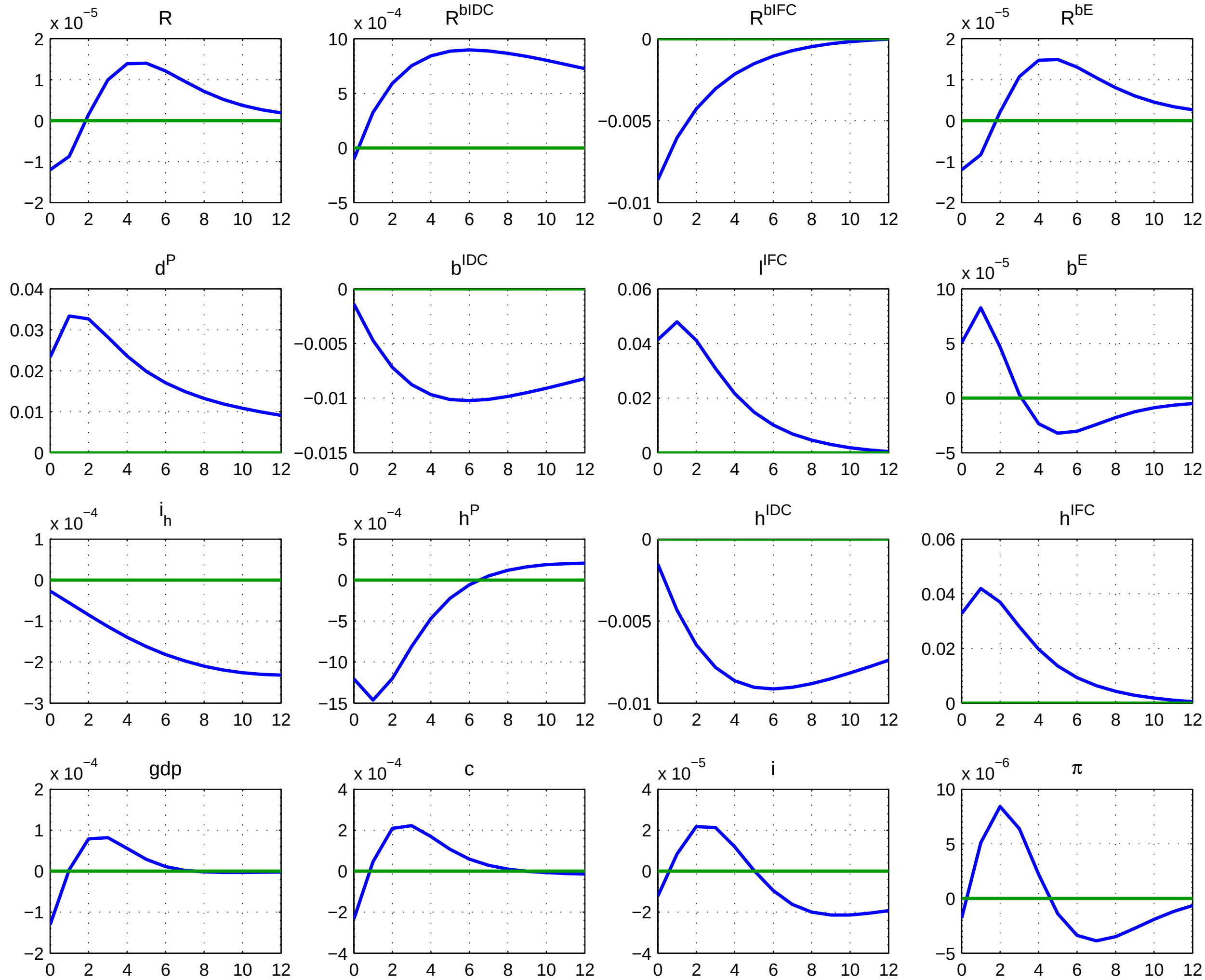
E.2 Borrowing Constraint Relaxation Shock I: An Exogenous Increase in the LTV Ratio of Entrepreneurs

Figure 12: Impulse Response Functions to an Entrepreneur LTV Ratio Positive Shock



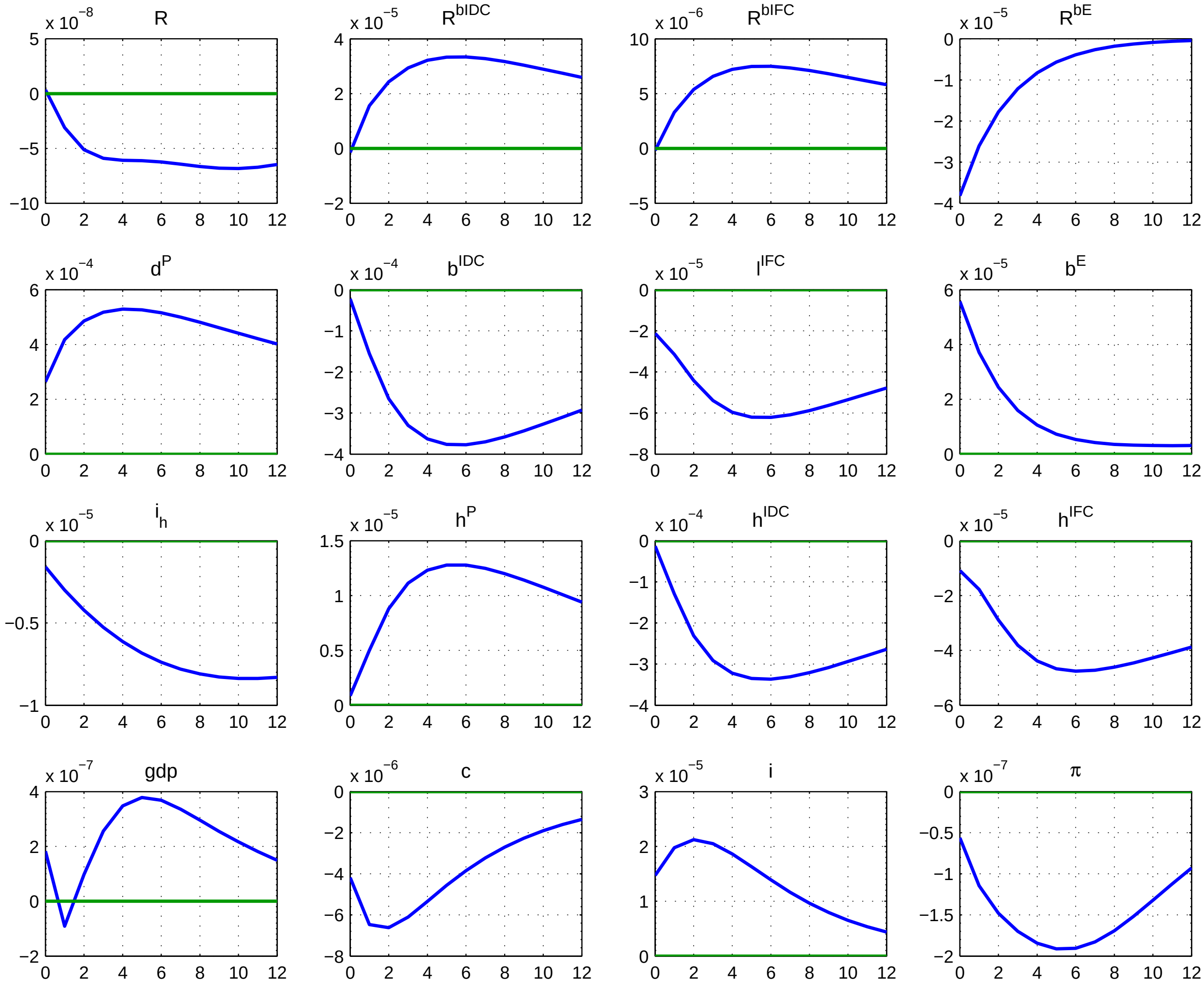
E.3 Lending Constraint Relaxation Shock II: An Exogenous Reduction in the IFC Bank capital-to-asset Ratio

Figure 13: Impulse Response Functions to an IFC Bank Capital-to-asset Ratio Negative Shock



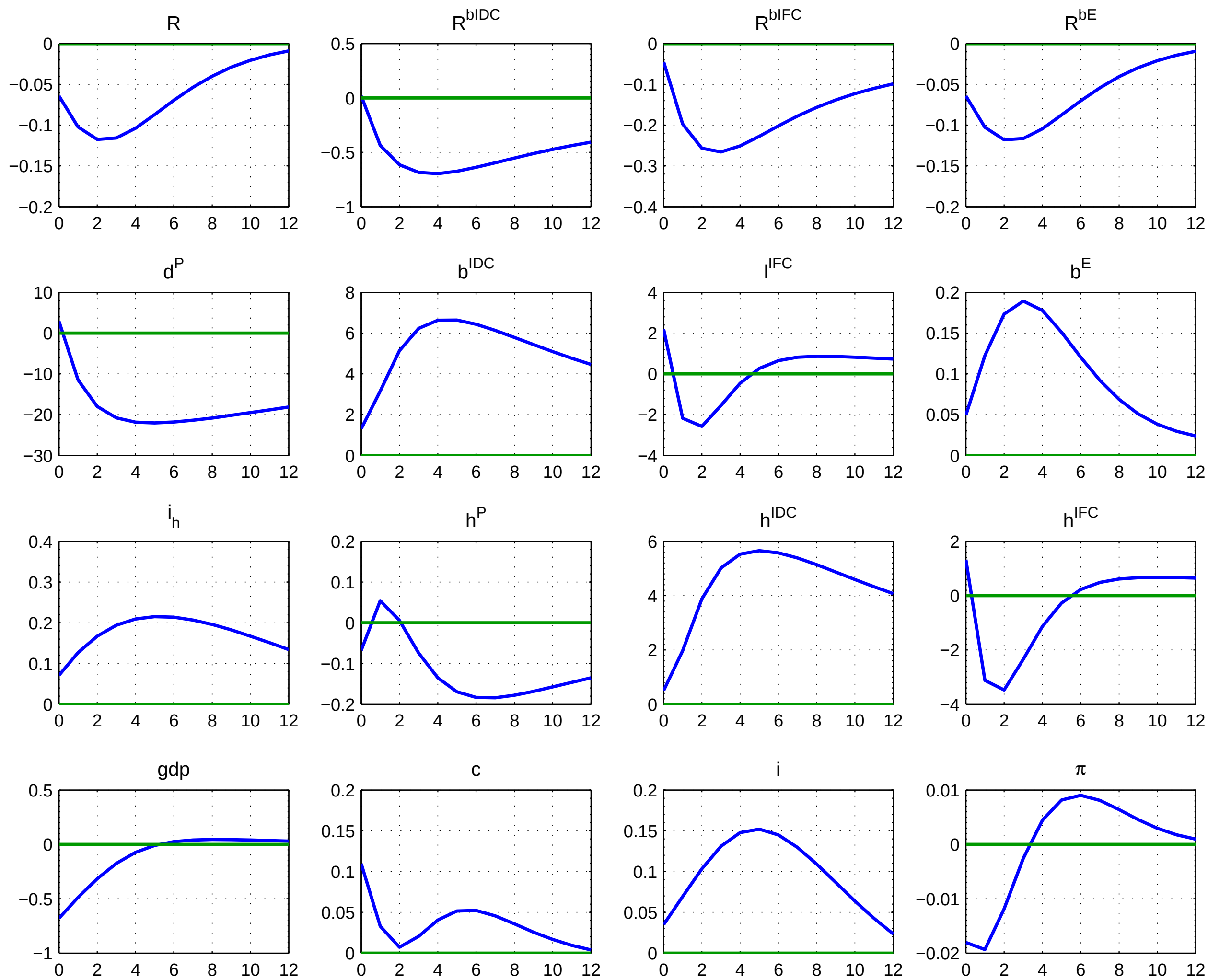
E.4 Lending Constraint Relaxation Shock III: An Exogenous Reduction in the Bank Capital-to-Commercial Loan Ratio

Figure 14: Impulse Response Functions to a Bank Capital-to-commercial loan Ratio Negative Shock



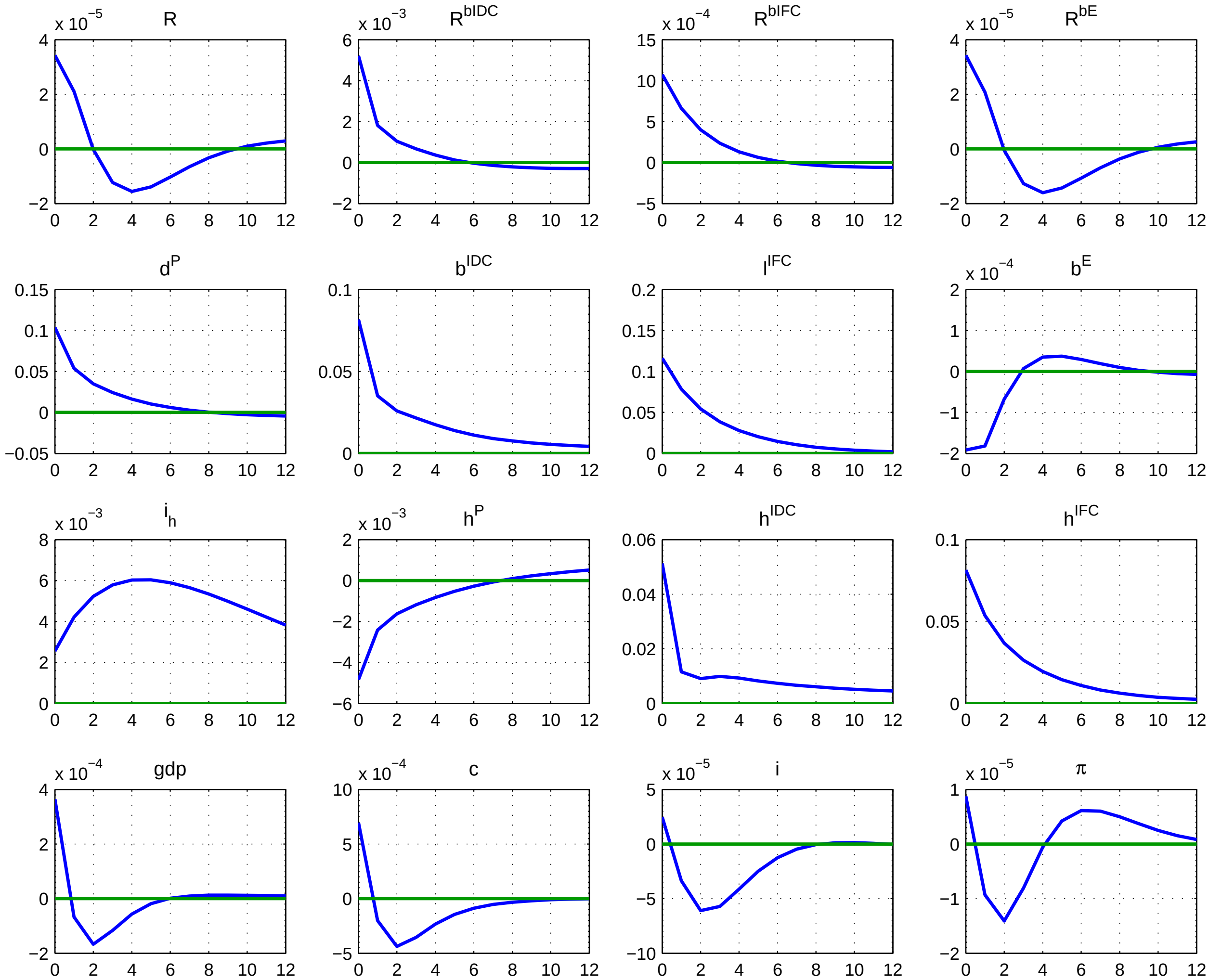
E.5 Lending Constraint Relaxation Shock IV: An Exogenous Reduction in the Interest Rate Premium

Figure 15: Impulse Response Functions to an Interest Rate Premium Negative Shock



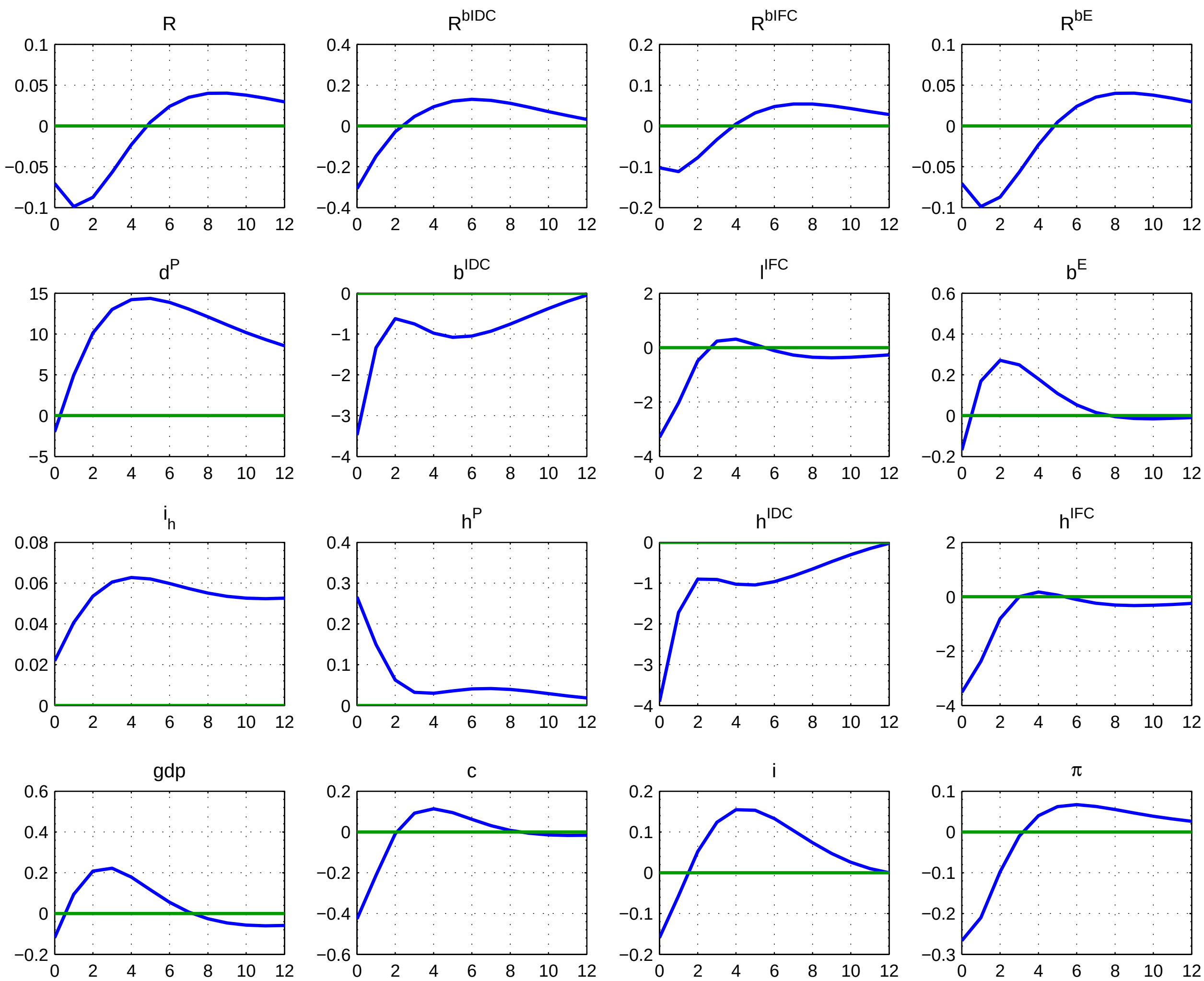
E.6 Housing Demand Shock

Figure 16: Impulse Response Functions to a Positive Housing Demand Shock



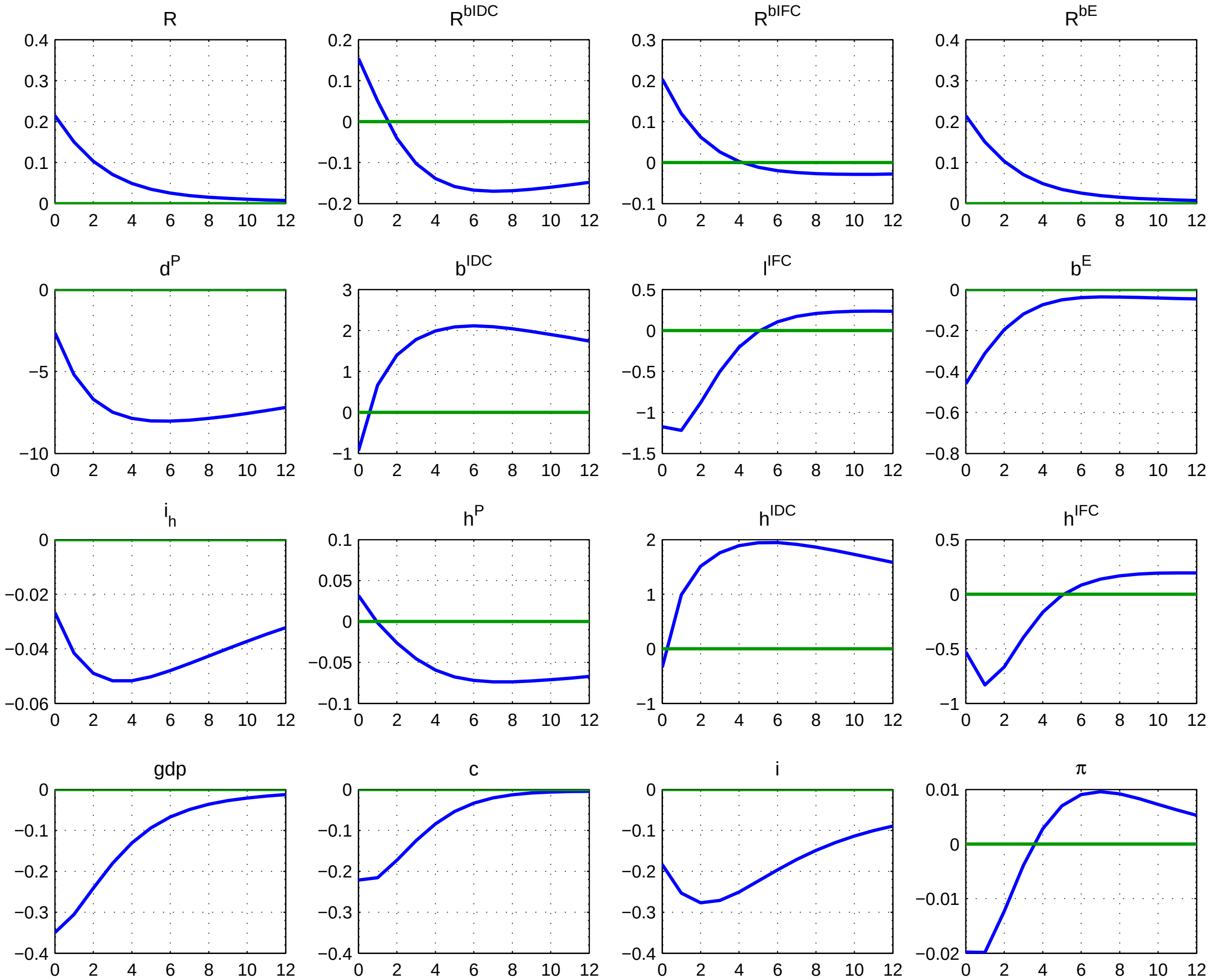
E.7 Productivity Shock

Figure 17: Impulse Response Functions to a Positive Productivity Shock



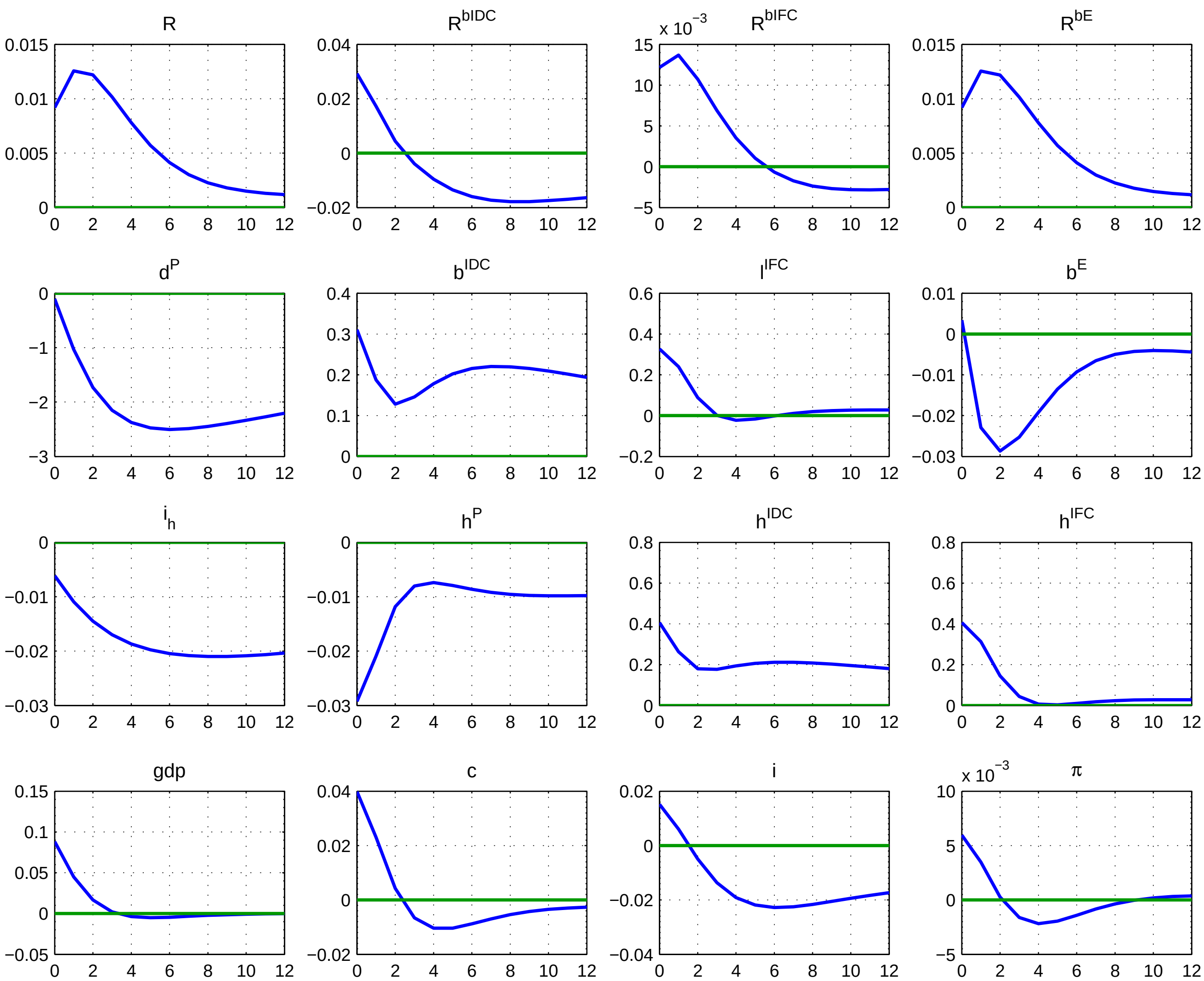
E.8 Monetary Policy Shock

Figure 18: Impulse Response Functions to a Positive Monetary Policy Shock



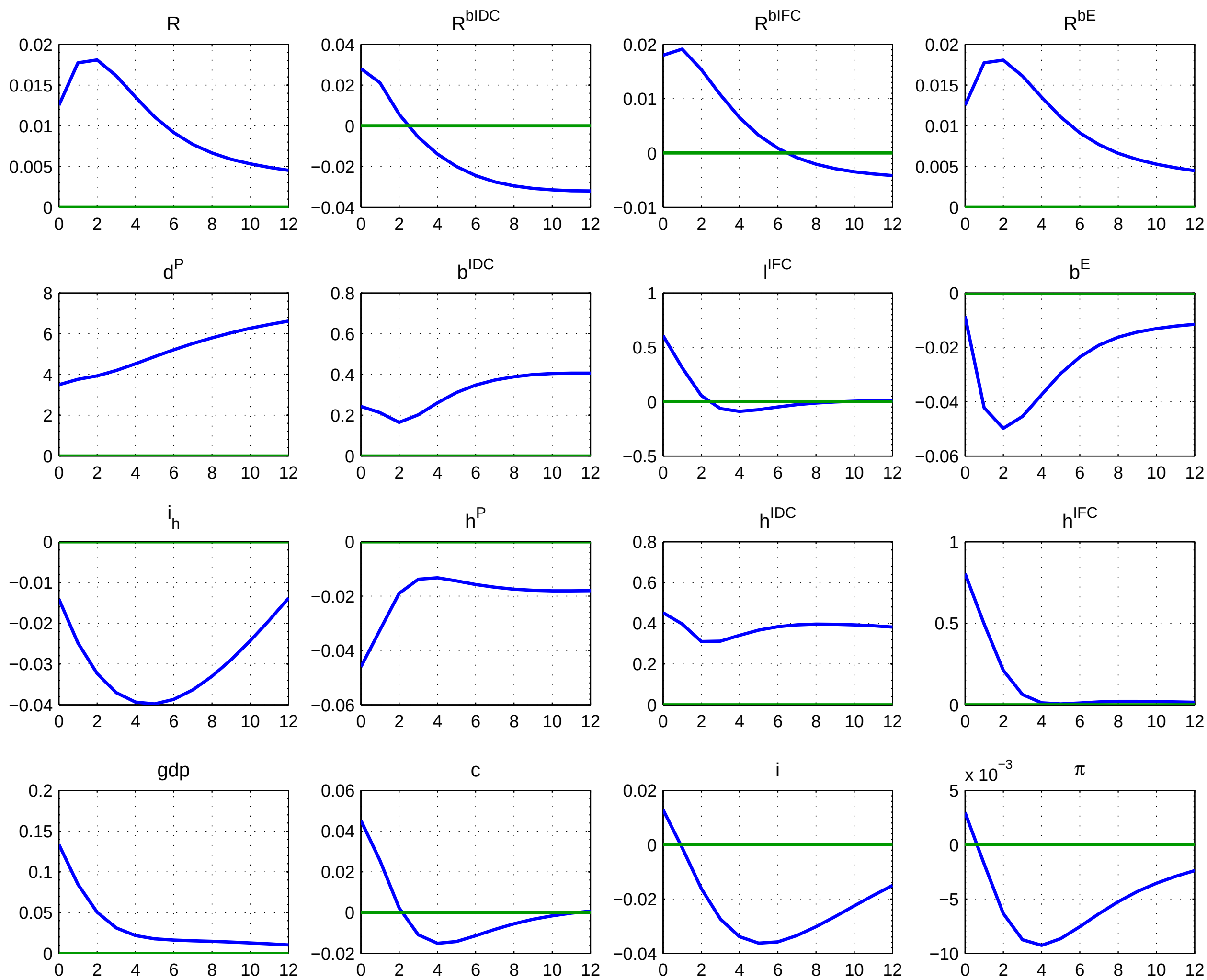
E.9 Fiscal Policy Shock

Figure 19: Impulse Response Functions to a Positive Fiscal Policy Shock



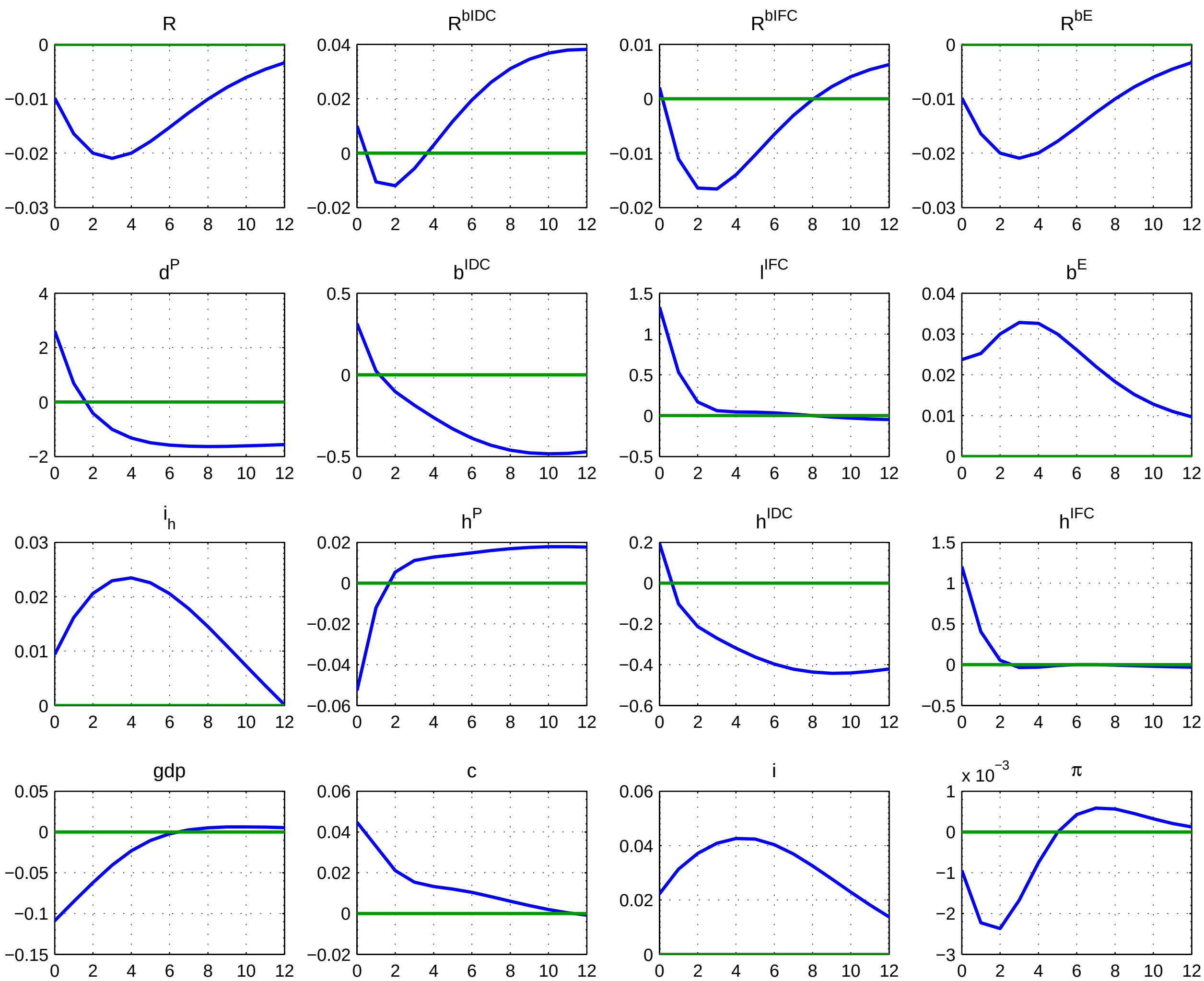
E.10 Foreign Demand Shock

Figure 20: Impulse Response Functions to a Positive Foreign Demand Shock



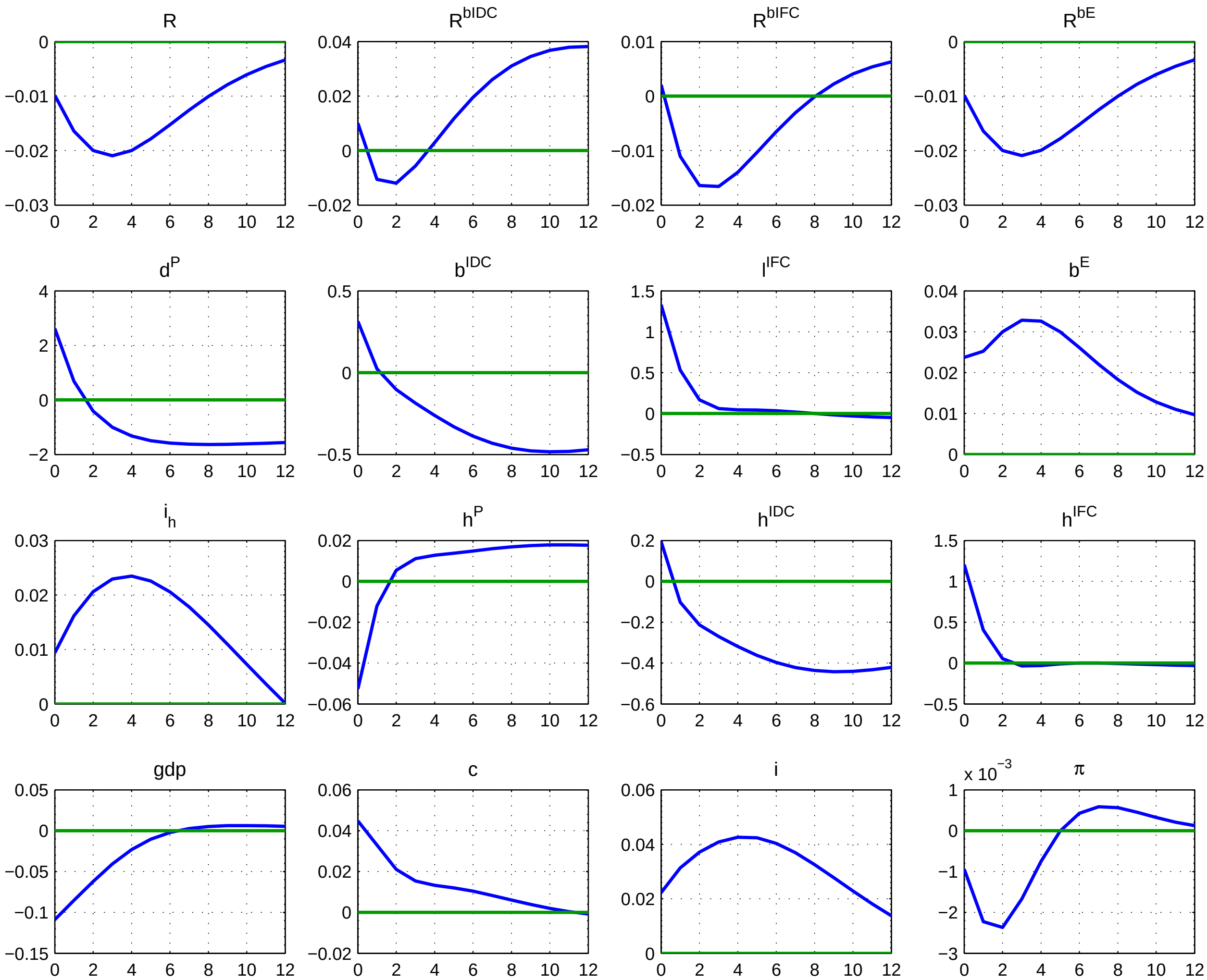
E.11 Foreign Inflation Shock

Figure 21: Impulse Response Functions to a Positive Foreign Inflation Shock



E.12 Foreign Interest Rate Shock

Figure 22: Impulse Response Functions to a Positive Foreign Interest Rate Shock



F Historical Shock Decomposition

The solution of the log-linearised DSGE model is a set of policy functions that can be written as follows:

$$z_t = \Omega_z(\vartheta) z_{t-1} + \Omega_\epsilon(\vartheta)\epsilon_t \tag{A}$$

where z_t is a vector that contains the endogenous variables and exogenous processes. ϵ_t contains the white noise innovations to these exogenous processes. Ω_z and Ω_ϵ are functions of the model's parameters.

As Christiano, Eichenbaum, and Evans (2005) say, DSGE models can be expressed as linear state-space models. Following this line, the last equation corresponds to a state equation of the state-space representation of the DSGE model, which is the based of the historical shock decomposition. After solving it recursively and given an initial condition z_0, the state equation can be expressed as:

$$z_t = \Omega_z(\vartheta)^t z_0 + \Big[\sum_{j=0}^{t-1} \Omega_\epsilon(\vartheta)^j \Omega_z(\vartheta)\epsilon_{t-j}\Big]$$

which means that at every period t, any endogenous variable x_t in z_t can be decomposed as a summation of contributions of a initial condition z_0 and a sequence of structural shocks ϵ_t. However, to do this type of decomposition, it is needed to specify the variables that are observed. These variables are determined in the observation or measurement equation:

$$Y_t = W z_t \tag{B}$$

where W is a matrix that selects the observable variables from the vector z_t.

Equations (A) and (B) characterize the state-space form of the DSGE, which together with the Kalman Smoother algorithm allow to compute the historical shock decomposition of the observed endogenous variables, considering the first and second order effects of shocks on the endogenous variables (contemplated in the policy functions), as well as their size and persistence. The Kalman Smoother helps to infer or estimate the initial conditions and the sequence of structural shocks using all the data one can provide. After applying this algorithm, the shock decomposition is given by:

$$z_{t|T} = \Omega_z(\vartheta)^t z_{0|T} + \Big[\sum_{j=0}^{t-1} \Omega_\epsilon(\vartheta)^j \Omega_z(\vartheta)\epsilon_{t-j|T}\Big]$$

$$Y_{t|T} = W z_{t|T}$$

where $x_{t|T}$ is a smoothed estimate or the inferred value of x_t based on the full set of data collected. This estimate is provided by the Kalman algorithm.

G Counterfactual Scenarios

Figure 23: Smoothed Shocks