Business and Credit Cycles in Emerging Economies: The Role of Financial Frictions

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First Version: NOV, 2017

This Version: MAY, 2018

Link to latest draft and online appendix

Abstract

What rationalizes the stylized facts of emerging market business and credit cycles? Business and credit cycles in emerging countries display very volatile consumption, highly volatile and countercyclical net exports, strongly countercyclical real interest rates, and procyclical flows of credit to the household sector and to the business sector. The standard small-open-economy (SOE) model cannot generate this cyclical pattern of the interest rate and the change in credit market liabilities of households. In order to correct this irregularity and account for the data pattern, this paper augments the SOE model to include collateral constraints for the household sector and limited enforcement constraints for the banking sector. The model generates business and credit cycles consistent with Korean data and gives a rationale for highly volatile consumption, countercyclical country interest rates, and procyclical credit flows. In the quantitative counterfactual experiments, we find that the output volatility in Korea is reduced by 11% and welfare gains amount to 0.17% increase in one quarter's steady-state consumption when the default risk in the financial sector is completely eliminated.

Keywords: Emerging market business cycles; credit cycles; financial frictions; collateral constraints; incentive constraints; financial intermediation; sudden stops

JEL codes: E43; F32; F34; F41; F44; G01.

[*]I am very grateful to Charles Engel for his guidance and advice. I thank Ken West, Dean Corbae, Enghin Atalay and Javier Bianchi for their encouragement and guidance. I would like to thank Juan Carlos Hatchondo for his valuable comments. I also thank Seung-Gyu (Andrew) Sim, JungJae Park, Pavel Brendler, Chenxin Liu, Akio Ino, as well as seminar participants at the University of Wisconsin-Madison for their discussions and helpful comments.

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1 Introduction

Financial factors have been known to play an important role over the business cycle, not just during deep economic recessions but also during normal times (Mendoza and Terrones (2012), Jermann and Quadrini (2012), Bahadir and Gumus (2016), Davis and Zlate (2016)). The literature has found that credit expansions are associated with the upswing period of the economic booms in a greater or less degree across advanced and emerging economies. On the other hand, it is well established that different from developed countries, emerging markets tend to display a larger volatility of consumption than output, countercyclical net exports, and countercyclical external borrowing costs (Neumeyer and Perri (2005), Aguiar and Gopinath (2007), Fernández and Gulan (2015)). These features of the data pose a challenge to the standard model of small-open economy in explaining business cycles of emerging markets.

This paper aims at assessing the impact that financial frictions in credit markets have on the balance sheets of households and domestic banks in explaining empirical facts on emerging market business and credit cycles. Can financial frictions in both the household credit market and the business credit market rationalize macroeconomic fluctuations of emerging economies? If financial frictions play an important role in explaining business cycles in emerging markets, what are the welfare gains when financial frictions are mitigated (or completely eliminated)? This paper attempts to address these questions by investigating the consequences of (the removal of) financial constraints in emerging economies.

Business cycles in emerging economies are characterized by strongly countercyclical real interest rates and net exports and by highly volatile consumption. These facts are in sharp contrast with procyclical real interest rates, acyclical net exports, and well stabilized consumption fluctuations in developed countries. In this paper, we reexamine the mechanism behind excessively volatile consumption, countercyclical net exports, and countercyclical interest rates by introducing collateral constraints to the household sector and incentive constraints to the banking sector.

In doing so, we note the fact that countercyclical net exports should be related to procyclical credit flows to private sectors. We document empirical statistics of credit flows to the household and nonfinancial business sectors and compare their properties in emerging and developed economies. We find that the volatility of each type of credit flows is comparable and both types of credit flows are procyclical in the two markets. However, household credit flows are significantly more procyclical in emerging markets.

What rationalizes procyclical household credit flows? The standard SOE-RBC model predicts that credit flows to households are countercyclical for consumption smoothing. One way that the previous literature has addressed this issue is to assume that productivity in emerging markets is highly persistent or frequently disturbed by trend shocks. That is, when the economy enters a boom, its current income is relatively low compared to permanent income due to positive innovations in productivity growth and thus the economy accumulates more debts to increase the current consumption. While this insight in Aguiar and Gopinath (2007) has proven quite influential, other strand of the literature such as Neumeyer and Perri (2005), García-Cicco, Pancrazi, and Uribe (2010), Chang and Fernández (2013), and Cao, LHuillier, and Yoo (2016) asserts that financial frictions are more important factors to explain emerging market business cycles. Especially, García-Cicco, Pancrazi, and Uribe (2010) and Chang and Fernández (2013) show that their estimation results assign a dominant role to financial frictions in accounting for aggregate fluctuations, whereas trend shocks play a minor role.

In accordance with this finding, we introduce dual financial frictions to an otherwise standard SOE-RBC model. We postulate the hypothesis that financial frictions in the banking sector of emerging markets hinder aggregate investment, leading to lower output and lower market value of households' collateral. In turn, credit flows to households are constrained by the value of their collateral and so linked to procyclical credit limits. In response to negative income shocks, collateral constraints raise the marginal cost of one additional debt through the increase in the shadow value of the collateral. Hence, households reduce their debts. On the other hand, positive shocks expand the credit limit. When the size of the positive income shock is small, then households are still constrained by the credit limit and they increase their borrowing. However, when the magnitude of the positive shock is large, households value current consumption less and decumulate their debts. In sum, household credit flows are procyclical for the negative income shock and for the small positive shock but become countercyclical when the size of positive shocks gets larger. The comovement of household credit flows with output depends on the relative importance of these two channels.

In order to investigate the mechanism of the countercyclical interest rate, we make use of the banking model á la Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). To rationalize the countercyclical country risk premium, we postulate that there is friction between international lenders and domestic bankers. Bankers must accumulate retained earnings to finance their loans from the international credit market. Due to the limited enforcement contract, international lenders do not supply funds unless the franchise value of the intermediary exceeds the value of the liquidated loan, which is the outside option to the bankers. In response to positive output shocks, asset prices get higher, the aggregate capital increases, and thus total loans to the investment sector rise. Bankers get more proceeds from their loans and accumulate more retained earnings. The larger rise in bankers' net worth relative to the increase in their external borrowing brings about a fall in the shadow value of the net worth and in turn the liquidity premium of the banking sector declines. Therefore, this mechanism accounts for the countercyclical borrowing costs of the private sector in emerging markets.

This paper studies the role of financial market frictions as amplifiers or stabilizers of business and credit cycles in emerging economies. In particular, we analyze the qualitative and quantitative implication of the interaction of two financial constraints: collateral constraints in the household sector and incentive constraints in the banking sector under the general equilibrium. To this end, our approach is to use the exact global nonlinear solution to capture the precautionary savings motive. To the best of our knowledge, none of the existing literature on emerging market business cycles analyzes the consequences of two financial constraints on both the household side and the business side by using the global nonlinear solution. The key contribution of this paper is to fill this gap and discuss the welfare implication of the removal of either of two constraints or both.

We take our model to Korean data, calibrate the parameters governing the banking sector as well as the productivity and capital quality process, and describe the model mechanism explaining data patterns. Then we conduct counterfactual experiments by shutting down the effects of incentive constraints and by replacing collateral constraints with the standard debt-elastic interest rates. The main findings of counterfactuals can be summarized as follows. Removing the financial friction in the banking sector has significant effects. Output volatility declines by 11% and the unconditional welfare gains amount to 0.17% increase in one quarter's steady-state consumption. It turns out that the consumption volatility relative to output increases when there is no financial friction in the banking sector. The consumption volatility itself declines when there is no default risk in the banking sector, but the decrease in output volatility outweighs the drop in consumption volatility.

On the other hand, replacing collateral constraints with the debt-elastic interest rates does not affect the equilibrium allocations of the business sector. This is so because aggregate consumption and household debts do not affect the production sector under the assumption of the *GHH* preference and the risk neural bankers. The features of household credit flows exhibit sharp contrast with the benchmark one. In response to negative income shocks, the marginal utility of current consumption rises, pushing the marginal cost of one additional borrowing downward in the absence of collateral constraints. Therefore, households borrow more. For the positive shocks, households always borrow less since the household's stochastic discount factor increases, which implies that the marginal cost of one additional borrowing rises. Therefore, there is no asymmetry in the responses of household credit flows and consumption responds less to the shock than output.

Contribution to the Literature There are two strands of literature which explain the "excess volatility of consumption puzzle."[1] The first is represented by Aguiar and Gopinath (2007). They claim that shocks to trend output drive emerging market business cycles. A positive shock to trend output leads to a period of high growth. Since a boost to current output implies an even larger increase in future output, the marginal benefit of future consumption declines and agents decrease savings. Hence, consumption responds more than

[1] Note that highly volatile consumption is closely related to countercyclical net exports. Holding net income from abroad constant, countercyclical net exports imply countercyclical current accounts. This indicates that a nation's net savings (i.e. savings minus investment) is countercyclical. Therefore, households in emerging economies save(borrow) more(less) when they earn less income, which hampers consumption smoothing. As a result, consumption becomes highly volatile. Why do agents in emerging economies save(borrow) more(less) when they earn less income? In answering this question, we follow the literature which explains countercyclical net exports by financial frictions (See Neumeyer and Perri (2005) and Chang and Fernández (2013)).

income. The second strand argues that financial frictions are essential to rationalize the empirical regularities of emerging economies (Neumeyer and Perri (2005) , García-Cicco, Pancrazi, and Uribe (2010) , Chang and Fernández (2013), Cao, LHuillier, and Yoo (2016)). Under the only possibility of issuing one-period, non-state-contingent bond in international financial markets, an upward movement in the country interest rate triggers a slowdown in economic activity and a drop in aggregate consumption. When the effect of the upward movement in the interest rate is amplified by the working capital constraint (Neumeyer and Perri (2005)) or the debt-elastic risk premium (García-Cicco, Pancrazi, and Uribe (2010), Chang and Fernández (2013)), consumption falls more than income. Compared to our paper, none of these papers reveals the mechanism of the countercyclical country interest rate in emerging markets. In addition, their SOE-RBC models with debt-elastic interest rates exhibit countercyclical credit flows to households, which is at odds with the data that we documented.

In modeling the countercyclical interest rates, there are at least three approaches considered in the literature. Uribe and Yue (2006) and Akıncı (2013) take structural VAR model to examine how the world interest rate shocks form aggregate fluctuations of emerging economies. Neumeyer and Perri (2005) and Chang and Fernández (2013) build up a structural DSGE model of a small open economy and postulate that the dynamics of the country spread is affected by expected future productivity. They claim that the model with the risk premium linked to economic fundamentals can explain the business cycle fluctuations of emerging economies. A full structural approach for the country spread is taken by Fernández and Gulan (2015). They focus on the mechanism of a financial accelerator and explain the countercyclicality of nonfinancial corporate sector leverages and country spreads. We extend this strand of literature by endogenizing the countercyclical interest rate through the banking sector and by matching credit cycles of the business sector. We find that the model with *Bernanke-Gertler-Gilchrist* financial frictions, which was the approach taken by Fernández and Gulan (2015), cannot generate volatile credit flows to the business sector.

Modeling the countercyclical real interest rates is also related to the sovereign default literature. Arellano (2008) endogenizes strategic defaults of emerging market governments and explains countercyclical sovereign interest rates. However, her model features endowment economy, which is different from our model with production. Mendoza and Yue (2012) extends the model in Arellano (2008) by incorporating the production sector. They explain why severe economic recession follows sovereign defaults. Relative to this paper, our model does not have endogenous default of the sovereign government and our focus is on explaining the countercyclical private-sector interest rates by modeling the defaulting incentive of the financial sector under the limited enforcement contract.

Incorporating the financial sector into the standard RBC model is mostly inspired by Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). Motivated by disruptions in financial intermediation during the global financial crisis of 2008, Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) devise the macroeconomic model which puts a prominent role to the financial sector and evaluate the effects of unconventional monetary policies practiced by central banks. Dedola, Karadi, and Lombardo (2013) extends their work to the open economy and examines international spillovers of unconventional policies. Gertler, Kiyotaki, and Queralto (2012) allows the intermediaries to issue outside equity as well as short term debt. By focusing on the bank's ex-ante incentive to take a risky balance sheet, they study the effects of macroprudential policies. Our contribution relative to this literature is twofold. One is that we introduce the financial sector to the SOE-RBC model to explain the countercyclical real interest rates of emerging markets. The models of Gertler and Kiyotaki (2010), Gertler and Karadi (2011) and Gertler, Kiyotaki, and Queralto (2012) are based on closed economy and Dedola, Karadi, and Lombardo (2013) uses two country model. The other difference is that our solution method is the global nonlinear method to capture precautionary savings motive under the two occasionally binding constraints. All of these papers use first(second)-order perturbation methods.

In regard to this second aspect, our paper is more relevant to Bocola (2016) and Akinci and Queralto (2017). In contrast with our paper, Bocola (2016) shows how the news of a future sovereign default have adverse effects on the production sector through the financial intermediation which requires higher returns as a compensation for holding the higher risk. Akinci and Queralto (2017) also features the SOE-RBC model with the banking sector characterized by the global nonlinear method. However, their model does not have collateral constraints on the household side and they focus on studying the effects of the macroprudential policy in developed countries.

Finally, our article is related to the SOE-RBC literature which study the quantitative implications of financial constraints for emerging market business cycles (see Mendoza and Smith (2006), Mendoza (2010), Bianchi (2011), and Benigno, Chen, Otrok, Rebucci, and Young (2013)). These papers propose the model which features endogenous Sudden Stops through the Fisherian debt deflation mechanism derived from the price-dependent collateral constraint. They interpret the periods of nonbinding financial constraints as normal times and those of binding financial constraints as crisis times to capture Sudden Stop dynamics. Novel features of our setup relative to this literature is to incorporate dual financial constraints into the household sector and the banking sector. In contrast with this literature, our paper does not distinguish normal times from crisis periods and studies the welfare implication of dual financial frictions over the cycle.

The remainder of the paper is organized as follows. Section 2 reports updated empirical evidence on the stylized facts about business and credit cycles in emerging countries and developed countries. Section 3 develops the model. Section 4 explains our calibration strategy. Section 5 presents key results and discusses the mechanism. Section 6 performs counterfactual experiments. Section 7 reports the results from the sensitivity analysis and concluding remarks are given in Section 8.

2 Empirical Facts

This section presents features of business and credit cycles of emerging countries. In particular, we chose eight small open emerging market economies − Argentina, Brazil, Chile, Colombia, Korea, Mexico, Thailand, and Turkey. To compare the characteristics of emerging economies with developed countries, we also consider a group of developed economies − Australia, Austria, Belgium, Canada, Denmark, Finland, Netherland, Portugal, Spain, Sweden, and Switzerland. Data availability limits the choice of countries and time periods. Output(Y), consumption(C), investment(I), and real interest rates(R) are in logs. Net exports(NX), change in total credit to households(ΔCH), and change in total credit to private nonfinancial corporate firms(ΔCF) are divided by output. We report the moments related to the quarterly change in credit since the relationship between macroeconomic fluctuations and credits is better captured by a measure for the newly created credit rather than the stock of credit. All series are deseasonalized[2] if necessary, and then HP filtered with a parameter of $1,600$. Table 1 summarizes the empirical fact on business and credit cycles in emerging and developed countries. It reproduces stylized facts of business cycles in both markets. We extend Aguiar and Gopinath (2007) with updated series from national accounts, sovereign interest rates as well as credit flows. All series have been updated through 2016:Q2. We can draw on the table to extract six points.

1. Emerging economies display higher output volatility relative to developed economies.
2. The volatility of consumption relative to output is on average greater than one and higher than in the developed economies.
3. Emerging economies exhibit much more volatile and more strongly countercyclical trade balances than developed countries.
4. The real interest rates are more than three times as volatile in the emerging markets as in the developed ones. The interest rates in emerging economies are countercyclical, but in contrast, the interest rates in developed economies are procyclical.
5. Credit flows to households are more strongly procyclical in emerging markets than in developed markets.
6. For both groups of countries, business credit flows are more than twice as volatile as household credit flows.

The first four empirical regularities are in line with earlier studies on emerging market business cycles. The last two regularities are new. Note that household credit is related to an increase in consumption and demand for goods and services whereas business credit is associated with investment and labor demand. We take the fact that credit flows to

[2] We removed seasonal components in data by using the U.S. Census Bureau's X13-ARIMA software.

Table 1: Summary of Business and Credit Cycle Statistics

Moment	Emerging Markets		Developed Markets	
$\sigma(Y)$	3.10	(0.18)	2.02	(0.05)
$\sigma(C)/\sigma(Y)$	1.14	(0.06)	0.66	(0.04)
$\sigma(I)/\sigma(Y)$	2.56	(0.11)	2.19	(0.08)
$\sigma(\frac{NX}{Y})$	2.50	(0.18)	1.36	(0.07)
$\sigma(R)$	0.94	(0.14)	0.26	(0.01)
$\sigma(\frac{\Delta CH}{Y})$	1.55	(0.14)	1.48	(0.10)
$\sigma(\frac{\Delta CF}{Y})$	4.23	(0.27)	4.81	(0.28)
$\rho(Y, C)$	0.81	(0.03)	0.61	(0.03)
$\rho(Y, I)$	0.83	(0.03)	0.75	(0.02)
$\rho(Y, \frac{NX}{Y})$	-0.44	(0.06)	0.00	(0.05)
$\rho(Y, R)$	-0.38	(0.08)	0.26	(0.05)
$\rho(Y, \frac{\Delta CH}{Y})$	0.42	(0.03)	0.15	(0.04)
$\rho(Y, \frac{\Delta CF}{Y})$	0.34	(0.03)	0.36	(0.05)

Note – Real GDP net of government spending(Y), private consumption(C), investment(I), quarterly gross real interest rate(R) were logged. NX, ΔCH, and ΔCF denote net exports, change in credit to households, and change in credit to nonfinancial private firms. All series were seasonally adjusted and HP filtered with a parameter of 1,600. Figures show the GMM estimated moments based on unbalanced panels. The standard deviations(σ) are in percentages and ρ denotes correlation coefficients. Standard errors are reported in brackets. All statistics are based on quarterly data. Emerging Markets : {ARG, BRA, CHL, COL, KOR, MEX, THA, TUR}, Developed Markets : {AUS, AUT, BEL, CAN, DNK, FIN, NLD, PRT, ESP, SWE, CHE}.

Source – Datastream, IFS, OECD, BIS, and author's calculations. See data appendix for details.

households are more procyclical in emerging markets as the evidence that households in developing countries are more credit constrained. Households would want to borrow more when their income declined during recession or save more when the economy was in boom. This indicates that credit flows would be countercyclical without any friction. However, if households face collateral constraints, the amount of credit is proportional to the value of their collateral when the constraint binds. Households could borrow more as their collateral increased in value during the economic boom. On the positive side, our main focus is to build up a model to match consumption volatility, and the volatilities and cyclical patterns of the credit flows and the real interest rates in emerging economies.

These six empirical regularities are documented in Table 2. Panel A of Table 2 reports the volatility of filtered output, consumption, investment, the ratio of net exports to output, real interest rates, and the ratio of credit flows to output. In emerging economies, the output volatility ranges from 1.49% in Colombia to 4.84% in Argentina whereas that of developed markets ranges from 1.36% in Switzerland to 2.68% in Finland. The relative volatility of consumption to output is more than the level of 0.80 in all emerging economies, but the relative volatility of consumption compared with output in all developed countries except Denmark, Portugal, and Spain is less than 0.65. Net exports are twice as volatile as those of developed counterparts on average and real interest rates are also more volatile in emerging markets. The relative volatility of investment and the volatility of credit flows are similar in the two markets.

Panel B of Table 2 documents the correlation of consumption, investment, net exports, interest rates, and credit flows with output at business cycle frequencies. Autocorrelation of output is roughly comparable in the two economies, but correlations of consumption and investment with output are smaller in developed markets. A distinctive feature is the large negative correlation of net exports and interest rates with output in emerging markets. In addition, the correlation of household credit with output is three times more procyclical in developing countries than in developed countries. While net exports in Chile and Colombia show exceptions to the average, the data indicate that emerging markets experience relatively more countercyclical net exports. Lastly, all emerging market countries exhibit strongly countercyclical interest rates but developed countries except Belgium and Sweden display strongly procyclical interest rates.

Table 2: Business and Credit Cycle Statistics

A. Volatility of {Y, C, I, $\frac{NX}{Y}$, R, $\frac{\Delta CH}{Y}$, and $\frac{\Delta CF}{Y}$}

EM	$\sigma(Y)$	$\frac{\sigma(C)}{\sigma(Y)}$	$\frac{\sigma(I)}{\sigma(Y)}$	$\sigma(NX/Y)$	$\sigma(R)$	$\sigma\left(\frac{\Delta CH}{Y}\right)$	$\sigma\left(\frac{\Delta CF}{Y}\right)$
ARG	4.84 (.32)	1.25 (.10)	2.40 (.19)	2.77 (.48)	2.01 (.30)	0.77 (.06)	2.07 (.15)
BRA	2.40 (.18)	0.81 (.08)	1.97 (.21)	1.09 (.12)	0.63 (.10)	0.96 (.11)	3.74 (.45)
CHL	2.18 (.14)	1.34 (.14)	3.13 (.37)	3.66 (.47)	0.44 (.04)	0.87 (.05)	5.85 (.57)
COL	1.49 (.28)	0.91 (.13)	2.91 (.29)	1.32 (.13)	0.49 (.11)	0.71 (.12)	1.75 (.18)
KOR	2.59 (.12)	1.31 (.10)	2.17 (.12)	2.84 (.18)	0.36 (.02)	2.84 (.24)	4.83 (.42)
MEX	2.15 (.23)	1.05 (.09)	2.37 (.16)	0.77 (.12)	0.47 (.07)	0.48 (.04)	1.53 (.15)
THA	3.35 (.20)	1.06 (.04)	3.58 (.22)	4.82 (.61)	0.31 (.03)	2.75 (.23)	9.05 (.48)
TUR	4.12 (.33)	0.94 (.03)	2.70 (.12)	2.21 (.22)	0.53 (.05)	1.27 (.10)	4.40 (.29)
All	3.10 (.18)	1.14 (.06)	2.56 (.11)	2.50 (.18)	0.94 (.14)	1.55 (.14)	4.23 (.27)

DM	$\sigma(Y)$	$\frac{\sigma(C)}{\sigma(Y)}$	$\frac{\sigma(I)}{\sigma(Y)}$	$\sigma(NX/Y)$	$\sigma(R)$	$\sigma\left(\frac{\Delta CH}{Y}\right)$	$\sigma\left(\frac{\Delta CF}{Y}\right)$
AUS	1.95 (.28)	0.65 (.08)	2.30 (.21)	1.19 (.07)	0.32 (.03)	0.12 (.02)	0.24 (.03)
AUT	1.77 (.36)	0.52 (.09)	1.57 (.18)	0.81 (.08)	0.19 (.03)	1.07 (.10)	3.67 (.35)
BEL	1.69 (.22)	0.62 (.08)	2.39 (.38)	1.52 (.14)	0.23 (.02)	0.80 (.09)	7.74 (1.08)
CAN	2.08 (.19)	0.52 (.06)	2.03 (.19)	1.15 (.09)	0.34 (.03)	1.12 (.14)	4.12 (.48)
DNK	2.54 (.32)	0.92 (.15)	2.16 (.24)	1.39 (.20)	0.20 (.03)	2.99 (.33)	6.45 (.79)
FIN	2.68 (.59)	0.47 (.05)	1.63 (.13)	1.49 (.16)	0.17 (.02)	0.80 (.12)	5.31 (.70)
NLD	1.80 (.29)	0.62 (.06)	2.38 (.31)	0.88 (.09)	0.20 (.03)	1.87 (.35)	4.49 (.54)
PRT	1.57 (.17)	1.06 (.07)	3.31 (.43)	1.57 (.14)	0.21 (.02)	1.34 (.14)	5.39 (.67)
ESP	1.64 (.25)	0.95 (.07)	3.07 (.10)	1.17 (.12)	0.30 (.03)	1.84 (.32)	4.54 (.71)
SWE	2.30 (.41)	0.55 (.06)	2.04 (.20)	1.07 (.13)	0.30 (.07)	1.44 (.26)	6.02 (.54)
CHE	1.36 (.24)	0.34 (.05)	1.89 (.18)	2.66 (.46)	0.17 (.02)	1.60 (.20)	2.62 (.28)
All	2.02 (.10)	0.66 (.04)	2.19 (.08)	1.36 (.07)	0.26 (.01)	1.48 (.10)	4.81 (.28)

B. Correlation with Output Y

EM	$\rho(Y_{-1})$	$\rho(C)$	$\rho(I)$	$\rho(\frac{NX}{Y})$	$\rho(R)$	$\rho\left(\frac{\Delta CH}{Y}\right)$	$\rho\left(\frac{\Delta CF}{Y}\right)$
ARG	0.83 (.06)	0.91 (.02)	0.94 (.02)	-.68 (.05)	-.50 (.12)	0.80 (.02)	0.53 (.04)
BRA	0.45 (.11)	0.68 (.05)	0.72 (.07)	-.14 (.15)	-.34 (.09)	0.12 (.02)	0.27 (.04)
CHL	0.83 (.05)	0.20 (.16)	0.28 (.13)	0.12 (.13)	-.12 (.17)	0.66 (.04)	0.38 (.03)
COL	0.77 (.09)	0.43 (.17)	0.73 (.10)	0.15 (.10)	-.14 (.11)	0.10 (.22)	0.10 (.11)
KOR	0.76 (.06)	0.77 (.04)	0.76 (.04)	-.51 (.07)	-.74 (.03)	0.56 (.05)	0.34 (.03)
MEX	0.88 (.06)	0.75 (.08)	0.75 (.04)	-.32 (.13)	-.08 (.14)	0.11 (.01)	0.20 (.04)
THA	0.79 (.12)	0.90 (.02)	0.85 (.02)	-.60 (.07)	-.44 (.11)	0.64 (.06)	0.63 (.05)
TUR	0.86 (.07)	0.93 (.02)	0.96 (.01)	-.75 (.08)	-.37 (.17)	0.49 (.15)	0.39 (.06)
All	0.78 (.04)	0.81 (.03)	0.83 (.03)	-.44 (.06)	-.38 (.08)	0.42 (.03)	0.34 (.03)

DM	$\rho(Y_{-1})$	$\rho(C)$	$\rho(I)$	$\rho(\frac{NX}{Y})$	$\rho(R)$	$\rho\left(\frac{\Delta CH}{Y}\right)$	$\rho\left(\frac{\Delta CF}{Y}\right)$
AUS	0.85 (.05)	0.49 (.13)	0.71 (.09)	-.04 (.14)	0.34 (.11)	0.21 (.17)	0.20 (.14)
AUT	0.75 (.08)	0.60 (.09)	0.71 (.06)	0.30 (.16)	0.73 (.05)	0.06 (.17)	0.32 (.14)
BEL	0.74 (.07)	0.54 (.13)	0.49 (.13)	-.10 (.12)	-.05 (.22)	0.43 (.11)	0.31 (.07)
CAN	0.90 (.04)	0.40 (.13)	0.76 (.05)	0.13 (.18)	0.36 (.07)	0.36 (.10)	0.64 (.07)
DNK	0.81 (.08)	0.73 (.07)	0.78 (.05)	-.22 (.15)	0.49 (.13)	0.14 (.10)	0.26 (.12)
FIN	0.84 (.06)	0.77 (.08)	0.83 (.05)	0.23 (.15)	0.18 (.16)	0.13 (.14)	0.32 (.15)
NLD	0.87 (.04)	0.81 (.05)	0.76 (.06)	0.08 (.15)	0.72 (.12)	0.14 (.10)	0.35 (.06)
PRT	0.85 (.04)	0.88 (.04)	0.74 (.08)	-.39 (.13)	0.09 (.21)	0.42 (.12)	0.34 (.11)
ESP	0.89 (.05)	0.86 (.04)	0.93 (.03)	-.66 (.09)	0.19 (.12)	0.29 (.15)	0.52 (.10)
SWE	0.78 (.05)	0.52 (.11)	0.78 (.03)	0.07 (.09)	-.14 (.14)	0.12 (.10)	0.44 (.11)
CHE	0.92 (.04)	0.59 (.14)	0.87 (.05)	0.25 (.11)	0.49 (.15)	-.46 (.13)	0.22 (.18)
All	0.82 (.02)	0.61 (.03)	0.75 (.02)	0.00 (.05)	0.26 (.05)	0.15 (.04)	0.36 (.05)

Note − Real GDP net of government spending(Y), private consumption(C), investment(I), quarterly gross real interest rate(R) were logged. NX, ΔCH, and ΔCF denote net exports, change in credit to households, and change in credit to nonfinancial private firms. All series were seasonally adjusted and HP filtered with a parameter of 1,600. Figures show the GMM estimated moments. The standard deviations(σ) are in percentages and ρ denotes correlation coefficients. Standard errors are reported in brackets. All statistics are based on quarterly data.

Source − Datastream, IFS, OECD, BIS, and author's calculations. See data appendix for details.

3 A Model of Small Open Economy with Financial Frictions

We consider a standard small-open economy (SOE, henceforth) model enriched with collateral constraints on households and a financial sector along the lines of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). The economy is inhabited by households, final goods producers, capital goods producers, entrepreneurs, bankers, and international lenders. Figure 1 describes the structure of the model.

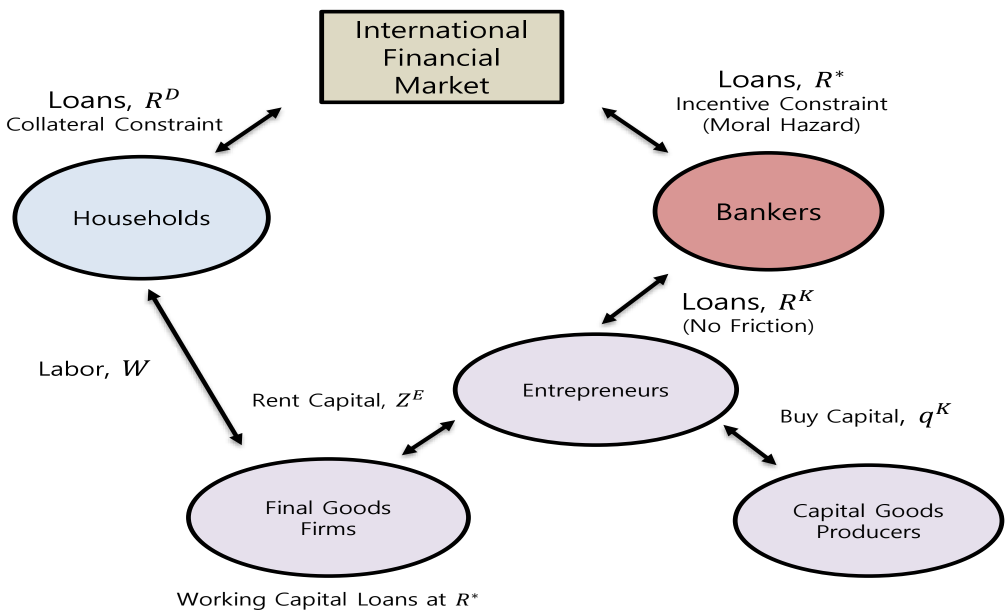


Figure 1: Model Structure

3.1 Households

A continuum of households maximizes the discounted value of their lifetime utility

$$\max_{\{C_t, H_t, D_t\}} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\left[C_t - \chi \cdot \frac{H_t^{1+\gamma}}{1+\gamma}\right]^{1-\sigma}}{1-\sigma}, \tag{1}$$

subject to a budget constraint and a collateral constraint

$$
\begin{aligned}
&C_t + R^D_{t-1} \cdot D_{t-1} = W_t H_t + D_t + \Pi^F_t + \Pi^B_t, \\
&R^D_t \cdot D_t \leq m_H \cdot \mathbb{E}_t \left[W_{t+1} H_{t+1} \right], \\
&R^D_t = R^*_t.
\end{aligned}
$$

The household values consumption, C_t and derives disutility from supplying labor, H_t according to the *Greenwood-Hercowitz-Huffman* (GHH, henceforth) periodic utility and discounts the future at the rate, β. We adopt GHH preferences between consumption and labor, which is sufficient to guarantee that both variables move in the same direction in response to exogenous shocks. Households supply labor to final goods firms and earn income, $W_t H_t$. Π^F_t and Π^B_t represents the net profits that the household receives from firms and banks in the business sector, respectively. Households can borrow or lend in the competitive banking sector and the amount of their debts is denoted by D_t. The bankers require collateral due to the limited enforcement of debt contracts. The total value of debts cannot exceed a fraction of households' expected labor income in the next period. The bankers require the interest payment at a rate of R^D_t and the interest rate is equalized to the world interest rate, R^*_t since the competitive banking sector finances its funds from the international financial market at a rate of R^*_t. Households' efficiency conditions are given by

$$
\begin{aligned}
R^D_t &= R^*_t, \\
\Lambda_{t,t+1} &\equiv \beta \frac{\left\{ C_{t+1} - \chi \cdot \frac{H_{t+1}^{1+\gamma}}{1+\gamma} \right\}^{-\sigma}}{\left\{ C_t - \chi \cdot \frac{H_t^{1+\gamma}}{1+\gamma} \right\}^{-\sigma}}, \\
W_t &= \chi \cdot H_t^{\gamma}, \\
1 &= R^D_t \cdot \mathbb{E}_t \Lambda_{t,t+1} + R^D_t \cdot \mu^H_t, \\
0 &= \mu^H_t \cdot \left\{ m_H \cdot \mathbb{E}_t \left[W_{t+1} H_{t+1} \right] - R^D_t \cdot D_t \right\},
\end{aligned}
$$

where $\mu^H_t \geq 0$ and $m_H \cdot \mathbb{E}_t \left[W_{t+1} H_{t+1} \right] \geq R^D_t \cdot D_t$ must hold every period by the complementary slackness.

3.2 Banks

Bankers are risk neutral and intermediate funds between international lenders and domestic corporate firms. At time t, each banker can be identified by the level of his accumulated net worth, n. If we denote the time-t distribution of the continuum of bankers by $F_t(n)$, the economy-wide net worth, N_t in the hands of all bankers is given by

$$N_t = \int_0^\infty n \, dF_t(n).$$

A bank pays the net worth as a dividend to his household when it exits with the probability, $(1-\phi)$. The bank discounts the future profit by the world interest rate, R_t^* and maximizes expected terminal net worth. The bank's problem is given by

$$v_t(n_t) = \max_{\{l_t, b_t^*, n_{t+1}\}} \mathbb{E}_t \sum_{\tau=t+1}^{\infty} \left(\frac{1}{\Pi_{h=t}^{\tau-1} R_h^*} \right) (1-\phi)\phi^{\tau-(t+1)} \cdot n_\tau \tag{2}$$

$$s.t. \quad \begin{cases} l_t = n_t + b_t^* \\ n_{t+1} = R_{t+1}^K \cdot l_t - R_t^* \cdot b_t^* \\ v_t(n_t) \geq m_B \cdot l_t \end{cases}$$

Each small-letter variable stands for the decision or the state variable for each heterogeneous individual banker. Capital-letter variables are general equilibrium objects or variables aggregated by the same manner as in the aggregate net-worth, $N_t = \int_0^\infty n \, dF_t(n)$.[3] Each banker raises external funds by foreign deposits, b_t^* at the world interest rate, R_t^*. The loan, l_t to entrepreneurs is financed with retained earnings, n_t and external funds, b_t^*. Hence, the intermediary balance sheet is given by

$$l_t = n_t + b_t^*.$$

[3] For example, the economy-wide bank loans to nonfinancial firms is derived as $L_t = \int_0^\infty l_t(n) \, dF_t(n)$ and the economy-wide external credits to banks is represented by $B_t^* = \int_0^\infty b_t^*(n) \, dF_t(n)$ since n is the state variable for each individual banker.

Accordingly, the total net worth available for surviving banks in $t+1$ can be described by the payoff to loans net of payments on liabilities

$$\begin{aligned} n_{t+1} &= R^K_{t+1} \cdot l_t - R^*_t \cdot b^*_t \\ &= (R^K_{t+1} - R^*_t) \cdot b^*_t + R^K_{t+1} \cdot n_t \\ &= (R^K_{t+1} - R^*_t) \cdot l_t + R^*_t \cdot n_t, \end{aligned}$$

where R^K_{t+1} is the state-contingent gross rate of return on a unit of loans to entrepreneurs from t to $t+1$. Following Gertler and Kiyotaki (2010) and Gertler and Karadi (2011), the model introduces an agency problem between bankers and their foreign creditors. The incentive compatibility constraint takes the form:

$$v_t(n_t) \geq m_B \cdot l_t.$$

The inequality constraint indicates that external creditors are willing to supply funds to the banker only when the continuation value of the bank, v_t is at least as high as the private benefit that the banker can enjoy in diverting the fraction, m_B of his assets, l_t. Note that we can exploit the linearity of the banking model in aggregating all individual variables. If we denote the lagrange multiplier on the incentive constraint by μ^B_t, then the efficiency conditions can be derived as

$$\begin{aligned} \mu^B_t \cdot m_B &= \mathbb{E}_t\left[\Omega_{t+1} \cdot \left\{R^K_{t+1} - R^*_t\right\}\right], \\ \overline{\omega}_t &= \frac{\nu^{b^*}_t}{1-\mu^B_t}, \\ \mu^B_t \cdot \overline{\omega}_t \cdot N_t &= \mu^B_t \cdot m_B \cdot L_t, \\ V_t &\equiv \overline{\omega}_t \cdot N_t, \\ \nu^l_t &\equiv \mathbb{E}_t\left[\Omega_{t+1} \cdot \left\{R^K_{t+1} - R^*_t\right\}\right], \\ \nu^{b^*}_t &\equiv \mathbb{E}_t\left[\Omega_{t+1} \cdot \{R^*_t\}\right], \\ \Omega_{t+1} &\equiv \frac{1}{R^*_t}(1-\phi+\phi \cdot \overline{\omega}_{t+1}), \end{aligned}$$

where $\mu^B_t \geq 0$ and $\overline{\omega}_t \cdot N_t \geq m_B \cdot L_t$ must hold by the complementary slackness. $L_t = N_t + B^*_t$ and $L_t = q^K_t \cdot K_{t+1}$ hold from the bank's balance sheet and entrepreneurs' debt decision. The marginal value of one additional net-worth of the bankers is denoted by $\overline{\omega}_t$. ν^l_t stands for the net marginal benefit of one additional loan to entrepreneurs when it is financed by one unit of the external debt and ν_t^{b*} represents the marginal cost of one additional borrowing from the international financial market. Note that the banker values one unit of next-period net-worth by

$$\mathbb{E}_t\left[\Omega_{t+1}\right] = \mathbb{E}_t\left[\frac{1}{R_t^*}\cdot(1-\phi+\phi\cdot\overline{\omega}_{t+1})\cdot 1\right]$$

in terms of current consumption. To be more specific, we can represent the banker's problem in a recursive form by exploiting the linearity of the efficiency conditions.

$$\begin{aligned} V_t &= \overline{\omega}_t\cdot N_t \\ &= \mathbb{E}_t\left[\frac{1}{R_t^*}\left\{(1-\phi)\cdot N_{t+1}+\phi\cdot V_{t+1}\right\}\right] \\ &= \mathbb{E}_t\left[\frac{1}{R_t^*}(1-\phi+\phi\cdot\overline{\omega}_{t+1})\cdot N_{t+1}\right]. \end{aligned}$$

When a banker is hit by the exit shock with the probability, $1-\phi$, he transfers all net-worth to households and it has no more additional value than one unit of consumption. On the other hand, when the banker keeps operating next period with the probability, ϕ, he can extend loans to entrepreneurs with the accumulated net-worth and the forward value of this equity capital from time $t+1$ on is captured by $\overline{\omega}_{t+1}$, which exceeds one unit of consumption.

The condition, $\mu_t^B\cdot m_B=\mathbb{E}_t\left[\frac{1}{R_t^*}(1-\phi+\phi\cdot\overline{\omega}_{t+1})\cdot\left\{R_{t+1}^K-R_t^*\right\}\right]$ shows the marginal cost and the net marginal benefit of one additional unit of loan are equalized in the equilibrium. If the bank is to extend one additional unit of the loan, then it should borrow from the international creditors as much. This tightens the incentive constraint by a fraction of divertible assets, m_B and hence the marginal cost of one additional loan corresponds to the shadow cost of tightening the constraint, μ_t^B multiplied by a portion, m_B. On the other hand, one additional loan enables the bank to accumulate next-period net-worth as much as the spread between the loan rate, R_{t+1}^K and the world interest rate, R_t^*. The condition, $\mu_t^B\cdot\overline{\omega}_t\cdot N_t=\mu_t^B\cdot m_B\cdot L_t$ represents the complementary slackness of the incentive constraint.

What determines the marginal value of one additional net worth, $\overline{\omega}_t$? To see this, we can rewrite the bankers' operation value as

$$
\begin{aligned}
V_t &= \overline{\omega}_t \cdot N_t \qquad (3) \\
&= \nu_t^l \cdot L_t + \nu_t^{b*} \cdot N_t \\
&= \mu_t^B \cdot m_B \cdot L_t + \nu_t^{b^*} \cdot N_t \\
&= \left(\mu_t^B \cdot \overline{\omega}_t + \nu_t^{b^*}\right) \cdot N_t.
\end{aligned}
$$

The second line in the equation (3) comes from the definition of the bankers' problem. It shows that the value of operation is determined by total expected net revenue from the loans, $\nu_t^l \cdot L_t$ plus the accumulated net worth, N_t multiplied by the marginal cost of one additional external debt, ν_t^{b*}. The additional term, $\nu_t^{b*} \cdot N_t$ compensates the missing value in the term $\nu_t^l \cdot L_t$ because N_t units of the loan, $L_t = N_t + B_t^*$ are self-financed but ν_t^l is the *net* marginal benefit of the loan financed by external borrowing. The third line of the equation (3) holds from the efficiency condition. The banker extends their loan until its net marginal benefit is equalized to the shadow cost of tightening the incentive constraint adjusted by the weight, m_B. The fourth line is derived by using the complementary slackness condition. In sum, the marginal value of the banker's net worth, $\overline{\omega}_t$ is proportional to the marginal cost of the bankers' external debt, $\nu_t^{b^*}$ since one additional net worth reduces external financing as much. In addition, $\overline{\omega}_t$ is positively associated with the shadow cost of tightening the incentive constraint, μ_t^B since this term multiplied by the fraction of divertible assets, m_B is equalized to the net marginal benefit of one additional loan, ν_t^l in the equilibrium. Therefore, $\overline{\omega}_t$ is pinned down by the equation, $\overline{\omega}_t = \frac{\nu_t^{b^*}}{1-\mu_t^B}$.

The economy-wide net worth of the banking sector evolves according to the dynamic process described in

$$
\begin{aligned}
N_t &= \phi \cdot \left\{R_t^K \cdot L_{t-1} - R_{t-1}^* \cdot B_{t-1}^*\right\} + \xi \cdot R_t^K L_{t-1} \\
&= \phi \cdot \left\{(R_t^K - R_{t-1}^*) \cdot L_{t-1} + R_{t-1}^* \cdot N_{t-1}\right\} + \xi \cdot R_t^K L_{t-1}.
\end{aligned}
$$

The period-t aggregate net worth, N_t is determined by two parts. One is the aggregate retained earnings of bankers who survived from the previous period with the probability ϕ. The other part is the transfer that households give for new entrants in the financial sector. Since bankers cannot operate without any resources, each new banker is provided with start-up funds from the household. Households provide new bankers with $\frac{\xi}{1-\phi}$ portion of the proceeds from the assets of exiting banks, $(1-\phi)\cdot R_t^K L_{t-1}$. Note that the net worth of exiting banks is transferred to households and thus net profits in the banking sector are given by

$$\Pi_t^B \;=\; (1-\phi)\cdot\left\{(R_t^K - R_{t-1}^*)\cdot L_{t-1} + R_{t-1}^*\cdot N_{t-1}\right\} - \xi\cdot R_t^K L_{t-1}.$$

Π_t^B stands for funds transferred from exiting bankers to households minus the funds transferred to new bankers.

3.3 Nonfinancial Firms

There are three types of nonfinancial firms: entrepreneurs, final goods firms, and capital goods producers.

Entrepreneurs Entrepreneurs must obtain funds from banks to purchase capital goods and commit to pay all the future gross profits to the creditor bank. Entrepreneurs are modeled along the lines of Bernanke, Gertler, and Gilchrist (1999), but we assume that they have no private information and do not accumulate net worth. An entrepreneur purchases raw capital using external funds and converts raw capital, K_t into effective capital services, $\psi_t K_t$. We interpret the shock ψ_t as a capital quality shock as in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). We assume the capital quality shock ψ_t follows $i.i.d$ log-normal process: $\log(\psi_t) = \epsilon_t^\psi$ where $\epsilon_t^\psi \sim i.i.d.\ N\left(0, \sigma^\psi\right)$. The representative entrepreneur solves:

$$\begin{aligned} \max_{\{K_t, L_{t-1}\}} \quad & Z_t^E\cdot\psi_t K_t + q_t^K\cdot(1-\delta)\cdot\psi_t K_t - R_t^K L_{t-1} \\ s.t. \quad & L_{t-1} = q_{t-1}^K\cdot K_t \end{aligned} \tag{4}$$

The timing of events of the representative entrepreneur is as follows. In period $t-1$, the entrepreneur issues L_{t-1} securities to banks and promises to pay a state-contingent rate of return, R_t^K after the aggregate uncertainty at time t is fulfilled. With the fund financed, he can buy K_t units of physical capital at a price, q_{t-1}^K and take one period to convert them into effective capital services. In period t, the realization of the capital quality shock, ψ_t determines the effective units of physical capital, $\psi_t K_t$. The entrepreneur rents the effective capital service, $\psi_t K_t$ to final goods firms at a rate, Z_t^E and then sells the undepreciated amount of capital, $(1-\delta)\cdot\psi_t K_t$ to capital goods producers at a price, q_t^K. By zero profit condition, the efficiency condition is given by

$$R_t^K \quad = \quad \frac{\psi_t \cdot \left[Z_t^E + q_t^K \cdot (1-\delta)\right]}{q_{t-1}^K}. \tag{5}$$

Final goods firms Final goods firms hire labor and rent capital to produce output according to the CRTS Cobb−Douglas technology. They face working capital constraints. Firms must pay a fraction, m_W of their wage bill before their revenues are realized in time t. The working capital loan is intratemporal and we assume that this intratemporal loan is not subject to the banking friction and hence the firm can borrow at the world interest rate, R_t^*. The firm solves:

$$\max_{\{H_t,K_t\}} \quad Y_t - \left[1 + m_W \cdot (R_{t-1}^* - 1)\right] \cdot W_t H_t - Z_t^E \cdot \psi_t K_t \tag{6}$$

$$s.t. \quad \begin{cases} Y_t = z_t \cdot \{\psi_t K_t\}^{\theta_K} \cdot H_t^{\theta_H} \\ \log(z_t) = \rho_z \cdot \log(z_{t-1}) + \epsilon_t^z \\ \theta_K + \theta_H = 1 \end{cases}$$

Firms' labor demand and capital demand are determined by

$$W_t \cdot \left[1 + m_W \cdot (R_{t-1}^* - 1)\right] \quad = \quad \theta_H \cdot \frac{Y_t}{H_t}, \tag{7}$$

$$Z_t^E \cdot \psi_t \quad = \quad \theta_K \cdot \frac{Y_t}{K_t}. \tag{8}$$

Note that the productivity z_t is the another source of business cycle fluctuations in the model economy and it is modeled as the standard autoregressive process.

Capital goods producers Capital producers conduct investment, I_t, supply new capital, K_{t+1} to entrepreneurs at a price, q_t^K and buy undepreciated capital, $(1-\delta)\psi_t K_t$. Capital goods producers build new capital goods using the technology, $\Phi\left(\frac{I_t}{\psi_t K_t}\right)\psi_t K_t$, where $\psi_t K_t$ is the aggregate effective capital stock and I_t is the input used in production. The representative capital goods producer solves:

$$\max_{\{I_t,K_{t+1}\}} \quad q_t^K \cdot K_{t+1} - q_t^K \cdot (1-\delta) \cdot \psi_t K_t - I_t \tag{9}$$

$$s.t. \quad K_{t+1} = (1-\delta)\cdot\psi_t K_t + \Phi\left(\frac{I_t}{\psi_t K_t}\right)\psi_t K_t$$

where the technology is described by three parameters ϕ_{K1}, ϕ_{K2}, and Φ_{KK} such that $\Phi\left(\frac{I_t}{\psi_t K_t}\right) \equiv \phi_{K1} \cdot \left(\frac{I_t}{\psi_t K_t}\right)^{1-\Phi_{KK}} + \phi_{K2}$ is defined. Hence, the efficiency condition characterizes the equilibrium Tobin's Q as

$$q_t^K = \frac{1}{\phi_{K1} \cdot (1 - \Phi_{KK})} \cdot \left[\frac{I_t}{\psi_t K_t}\right]^{\Phi_{KK}}.$$

In the calibration, we will set parameters ϕ_{K1} and ϕ_{K2} to obtain the deterministic steady-state of Tobin's Q equal to one and match the average investment-to-output ratio in emerging markets. The parameter, Φ_{KK} adjusts the elasticity of Tobin's Q with respect to the investment-capital ratio, $\Phi_{KK} = \frac{\partial \log\left(q_t^K\right)}{\partial \log\left(\frac{I_t}{\psi_t K_t}\right)}$. The net profits transferred to households is given by

$$\Pi_t^F = q_t^K \cdot K_{t+1} - q_t^K \cdot (1 - \delta) \cdot \psi_t K_t - I_t.$$

3.4 Aggregation

By putting all budget identities of households, firms, and banks together, we can derive the national income identity as follows:

$$Y_t = C_t + I_t + NX_t, \tag{10}$$

$$NX_t = R_{t-1}^D \cdot D_{t-1} - D_t + R_{t-1}^* B_{t-1}^* - B_t^* + (R_{t-1}^* - 1) \cdot B_t^{W*}. \tag{11}$$

where NX_t stands for net exports, and B_t^{W*} is the total working capital loan to final goods firms given by $B_t^{W*} = m_W \cdot W_t H_t$. Note that the model variables corresponding to interest rates and credit flows are defined in Table 3.

Table 3: The model definition for interest rates and credit flows

Data Notation	The Model Counterpart
R_t	$\mathbb{E}_t R_{t+1}^K$
ΔCH_t	$D_t - D_{t-1}$
ΔCF_t	$L_t - L_{t-1}$

where ΔCH_t denotes the credit flow to the household sector and ΔCF_t represents the credit flow to the private nonfinancial corporate sector. Total stock of intertemporal loan to the nonfinancial corporate sector is given by $L_t = N_t + B_t^* = q_t^K \cdot K_{t+1}$.

4 Calibration

Table 4: Calibrated Parameters for the SOE model with financial frictions

Param.	Description	Value	Source
β	Households' discount rate	0.9800	Aguiar-Gopinath(2007)
σ	Relative risk aversion	2.0000	Aguiar-Gopinath(2007)
γ	Frisch labor elasticity parameter	0.6000	Neumeyer-Perri(2005)
χ	Labor disutility parameter	2.8485	1/3 steady-state labor
m_H	Household debt-to-income ratio	0.4271	29% steady-state household debt-to-output ratio
R^*	The world interest rate	1.0020	Long-run U.S. 3M T-Bill real rate (1960-2016)
θ_K	Capital share in production	0.3200	Aguiar-Gopinath(2007)
θ_H	Labor share in production	0.6800	CRTS Cobb-Douglas technology
m_W	Fraction of Working Capital	1.0000	Neumeyer-Perri(2005)
δ	Capital depreciation rate	0.0500	Aguiar-Gopinath(2007)
ϕ_{K1}	Tobin's Q parameter	0.8922	27% steady-state investment-to-output ratio
ϕ_{K2}	Tobin's Q parameter	-.0067	Steady-state Tobin's Q normalized to one, $q^K = 1$
Φ_{KK}	Tobin's Q parameter	0.0600	Matching Data Moments: $\frac{\sigma(I)}{\sigma(Y)}$
ϕ	Survival rate of the bankers	0.9200	Matching Data Moments: $\sigma(Y)$ & $\frac{\sigma(\Delta CF/Y)}{\sigma(Y)}$
m_B	Fraction of assets divertible	0.5777	4.7% annual EMBI interest rate
ξ	Income transfer to new bankers	0.0031	A bank's leverage ratio of $\frac{q^K K}{N} = 6.5$
ρ_z	Persistence of TFP shock	0.6632	Matching Data Moments: $\rho(Y, Y_{-1})$
σ^z	Size of TFP shock	0.0092	Matching Data Moments: $\sigma(Y)$ & $\frac{\sigma(\Delta CF/Y)}{\sigma(Y)}$
σ^ψ	Size of capital quality shock	0.0055	Matching Data Moments: $\sigma(Y)$ & $\frac{\sigma(\Delta CF/Y)}{\sigma(Y)}$

The objective of computational experiments performed in the following sections is to investigate whether the SOE model with financial frictions can match the overall pattern of business and credit cycles in emerging economies and discover the mechanism of highly volatile consumption relative to output, countercyclical country interest rates, and procyclical credit flows. Then we will conduct counterfactual experiments to examine the welfare gains from eliminating collateral constraints of the household sector and default risks of the financial sector. To be more specific, we take the model with collateral constraints of households and incentive constraints of bankers as a benchmark, and then eliminate those two constraints one by one in order to compare welfare gains. For this purpose, we fix all parameters to be constant across different regimes of financial frictions.

We calibrate the preference and production parameters using standard values from the literature. Table 4 summarizes parameter values that we use. We take one period in the model to represent a quarter. The quarterly discount rate, β is set to 0.98 and the parameter for risk aversion, σ is set to two as in Aguiar and Gopinath (2007). The wage elasticity of labor supply is set to 1.67 by fixing γ at 0.6 in accordance with Neumeyer and Perri (2005) and Mendoza and Smith (2006).[4] The portion of working capital loan, m_W is set to one as in Neumeyer and Perri (2005) and the parameter for the weight on disutility from supplying labor, χ is fixed at 2.8485, which implies that the deterministic steady-state share of time devoted to labor is one-third. We derived the world interest rate, R^* by averaging the time series of the U.S. 3 month Treasury Bill real interest rate in quarterly terms from 1960:Q3 to 2016:Q4. The capital exponent, θ_K in production is set at 0.32 and the depreciation rate at 0.05 following Aguiar and Gopinath (2007). We chose Φ_{KK} to be 0.0600 to match the relative volatility of investment to output in data. The other parameters for Tobin's Q, ϕ_{K1} and ϕ_{K2} are respectively set to 0.8922 and -0.0067, which implies the steady-state investment-to-output ratio is 27%[5] and the steady-state Tobin's Q is normalized to be one. Households' debt-to-income parameter, m_H is chosen to be 0.4271 to match the long-run ratio of household debt to output, 29% averaged over our sample of emerging market countries.

We then assign values to the three parameters relating to financial intermediaries. We calibrate ϕ to be 0.9200 to match the output volatility and the relative volatility of business credit flows, implying that bankers operate for 3.13 years on average. This number is lower than that used in Gertler and Kiyotaki (2010).[6] The fraction of assets that bankers can divert in defaulting, m_B is set at 0.5777 to fix the steady-state annual loan rate at 4.7%, which is the average annual three month EMBI real interest rate of emerging markets in our sample. We pick up a small number, 0.0031 for the transfer rate, ξ to set the steady-state leverage ratio of the banking sector to 6.5 following Akinci and Queralto (2017).

We calibrated parameters for the exogenous shock process $\left\{\rho_z, \sigma^z, \sigma^\psi\right\}$ to match empirical moments: the autocorrelation of output, $\rho(Y, Y_{-1})$, the volatility of output, $\sigma(Y)$, the relative volatility of investment, $\frac{\sigma(I)}{\sigma(Y)}$, and the relative volatility of credit flows to the business sector, $\frac{\sigma(\Delta CF/Y)}{\sigma(Y)}$. We set the persistence of the TFP process at 0.6632, the size

[4] The wage elasticity of labor supply is given by $\frac{1}{\gamma}$

[5] We derived the steady-state investment-to-output ratio, 27% by averaging long-run investment-to-output ratios in emerging markets: {ARG, BRA, CHL, COL, KOR, MEX, THA, TUR}.

[6] Gertler and Kiyotaki (2010) fixed ϕ at 0.975, which implies that the bankers survive for 10 years on average. We had to choose $\phi = 0.9200$ to obtain higher steady-state loan rate.

of the TFP shock at 0.0092, and the size of the capital quality shock at 0.0055. All in all, we jointly calibrate values for five parameters, $\left\{\Phi_{KK}, \phi, \rho_z, \sigma^z, \sigma^\psi\right\}$ to match four data moments, $\left\{\sigma(Y), \frac{\sigma(I)}{\sigma(Y)}, \frac{\sigma(\Delta CF/Y)}{\sigma(Y)}, \rho(Y, Y_{-1})\right\}$.

5 Results

5.1 Law of Motion of Aggregate Endogenous States

Figures 2, 3, and 4 present the effect of inequality constraints which bind occasionally on the simulation path as well as grid points that we used for global nonlinear solution. Figures also show the law of motion of aggregate endogenous states. Our focus on these pictures is to understand the effect of two occasionally binding constraints on the dynamics of the aggregate states in the global nonlinear solution. In appendices A and B, we characterize the recursive competitive equilibrium and describe our numerical solution method. We follow the notation used for the recursive competitive equilibrium in this section. Note that the state vector is denoted by $\mathbb{S} = [D, B^*, K, z, \psi]$ and $\mathbf{\Gamma}(\cdot)$ stands for the vector of the law of motion for the aggregate state variables. Figure 2 shows households' collateral constraints bind occasionally but bankers' incentive constraints always bind over the simulation. Collateral constraints bind during 46.4% of total simulation periods under the calibrated values of parameters. This high frequency of binding collateral constraints is associated with highly volatile consumption relative to output and procyclical credit flows to households. With the higher survival rate of bankers holding other parameters constant, the incentive constraint becomes binding more and this enables the model to get the degree of comovement of investment, net exports, interest rates, and credit flows with output closer to data. When the survival rate, ϕ declines, the incentive constraint becomes slack more frequently and simulated business cycles become more volatile and acyclical.

Figure 3 shows the law of motion of economy-wide external debt holdings of the banking sector, B^* and aggregate capital, K by setting the amount of households' debt, $\overline{D}$ to its ergodic mean. Gray points represent the state (B^*, K), blue points stand for optimal allocation of $\left(B^{*'}(\mathbb{S}), K'(\mathbb{S})\right)$, and black arrows track down their exact mapping. Profit-

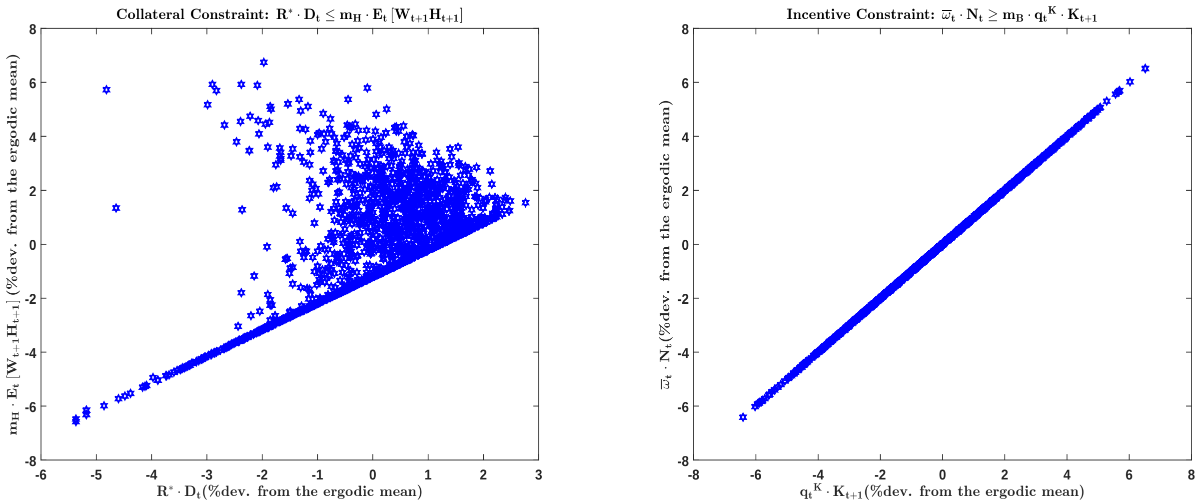


Figure 2: Collateral Constraint vs. Incentive Constraint

maximizing bankers who only care about total expected return want to extend their loan, $L(\mathbb{S}) = q^K(\mathbb{S})K'(\mathbb{S})$ to entrepreneurs as much as possible since the rate of return of the loan is not less than the borrowing cost in the equilibrium. However, the incentive constraint restricts the banker's loan not to rise beyond the value of their equity, $\overline{\omega}(\mathbb{S})N(\mathbb{S})$. Notice that aggregate capital, $K'(\mathbb{S})$ can be found by combining all efficiency conditions from the banking sector and capital goods producers since the marginal value of the net worth, $\overline{\omega}(\mathbb{S})$ and Tobin's Q, $q^K(\mathbb{S})$ must be determined simultaneously with the capital.[7] Due to this nonlinearity, the relation between $B^{*'}(\mathbb{S}) = \mathbf{\Gamma}_{B^*}(\mathbb{S})$ and $K'(\mathbb{S}) = \mathbf{\Gamma}_K(\mathbb{S})$ cannot be exactly characterized in a closed form, but we can observe from the figure 3 that they are positively proportional to each other through equations $B^{*'}(\mathbb{S}) = q^K(\mathbb{S})K'(\mathbb{S}) - N(\mathbb{S})$ and $\overline{\omega}(\mathbb{S}) \cdot N(\mathbb{S}) \geq m_B \cdot q^K(\mathbb{S})K'(\mathbb{S})$.[8] Given the state $\mathbb{S} = [D, B^*, K, z, \psi]$, bankers increase(or decrease) their loan to entrepreneurs by borrowing more(or less) from the international fi-

[7]Rearranging and combining the equilibrium conditions, we can see that the equilibrium labor and output are independent of determining the other endogenous variables through $H(\mathbb{S}) = \left(\frac{\theta_H \cdot z \cdot (\psi \cdot K)^{\theta_K}}{\chi[1+m_W \cdot (R^*-1)]}\right)^{\frac{1}{1+\gamma-\theta_H}}$ and $Y(\mathbb{S}) = z \cdot \{\psi \cdot K\}^{\theta_K} \cdot H(\mathbb{S})^{\theta_H}$. We can use these equations and efficiency conditions of bankers and capital producers to find the equilibrium capital $K'(\mathbb{S})$ by applying one-dimensional root-finding method. Then the capital pins down investment, $I(\mathbb{S})$, Tobin's Q, $q^K(\mathbb{S})$, the equity of the banking sector, $N(\mathbb{S})$, the shadow value of relaxing the incentive constraint, $\mu^B(\mathbb{S})$, and the marginal value of the equity, $\overline{\omega}(\mathbb{S})$ one after another.

[8]Combining these two equations, we obtain $(\overline{\omega}(\mathbb{S}) - m_B) \cdot q^K(\mathbb{S})K'(\mathbb{S}) \geq \overline{\omega}(\mathbb{S}) \cdot B^{*'}(\mathbb{S})$ and this inequality constraint always binds in the equilibrium with $\overline{\omega}(\mathbb{S}) > m_B$.

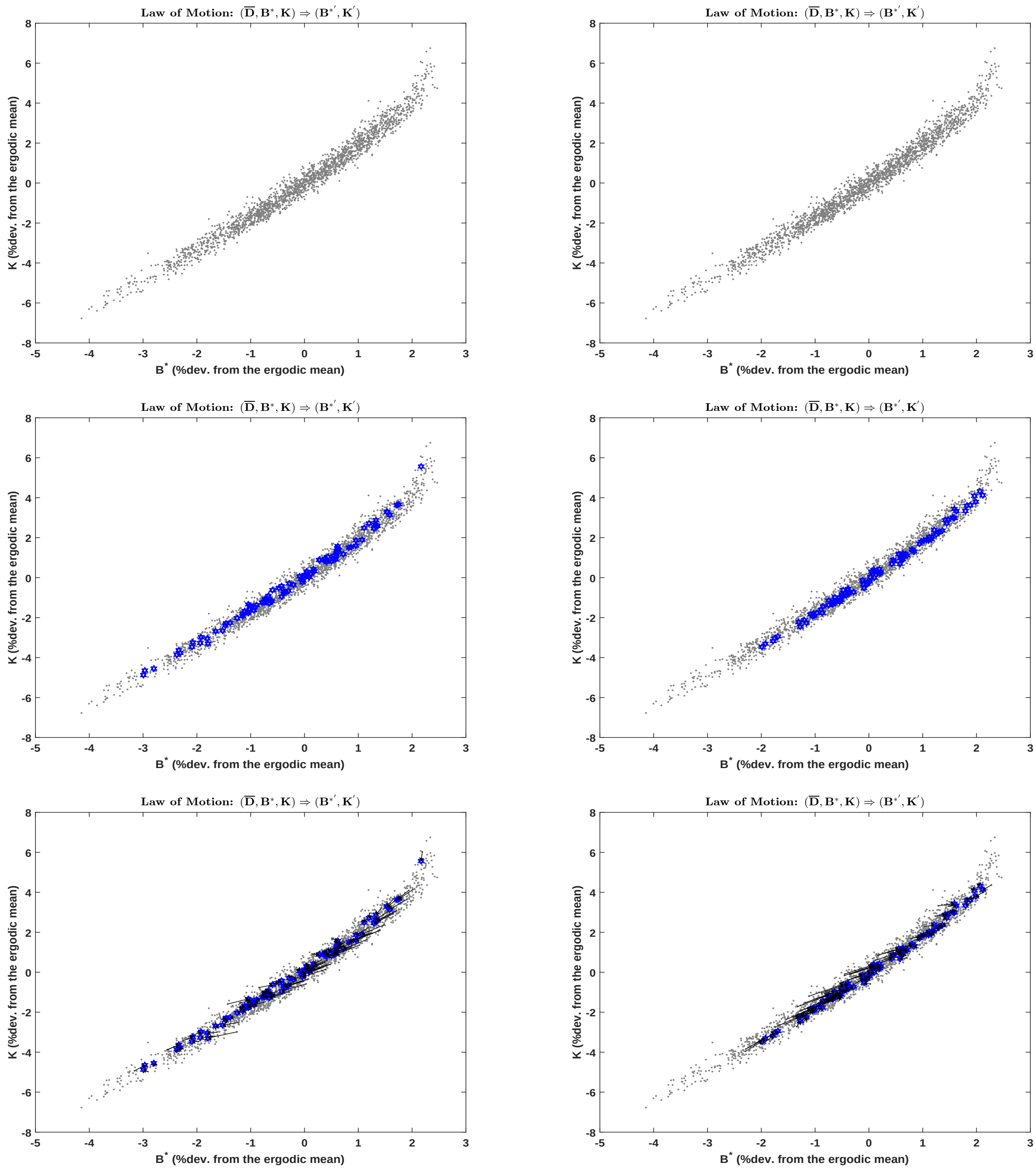
nancial market up to the point where the marginal benefit of the loan is equalized to the shadow cost of binding the incentive constraint multiplied by the fraction of divertible assets, m_B. Entrepreneurs demand the loan up to the point where total return of capital is equalized to the repayment to the bankers, and the equilibrium rate of return of the loan and Tobin's Q are determined through market clearing. Blue points and the black arrows in the figure 3 show the result of this mechanism in the general equilibrium. When the economy is hit by a negative shock, the rate of return of loan and capital declines and so do the aggregate capital and bankers' external borrowing. On the contrary, when there is a positive productivity shock, the rate of return of loan and capital rises and hence bankers extend the loan to entrepreneurs more by accumulating more debt from the international lenders. With more loan, entrepreneurs buy more capital and this raises the economy-wide level of capital. Why do bankers always borrow from the external capital market to make loans to entrepreneurs? This is because ongoing births and deaths of bankers preclude the possibility that the bankers will accumulate enough net worth to be fully self-financing.

Figure 4 shows the mapping from households' debt, D and aggregate capital, K to their next-period counterparts in holding external debt in the banking sector, $\overline{B^*}$ its ergodic mean. Gray points represent the state (D, K), blue points stand for optimal allocation of $\left(D^{'}(\mathbb{S}), K^{'}(\mathbb{S})\right)$, and black arrows track down their exact mapping. Under the CRTS Cobb$-$Douglas production technology, the labor income, $W(\mathbb{S})H(\mathbb{S})$ is a fraction of output adjusted by the working capital constraint, $\frac{\theta_H Y(\mathbb{S})}{1+m_W\cdot(R^*-1)}$. Due to the absence of the wealth effect on the labor supply under the GHH preference, the equilibrium labor is positively proportional to the productivity, z by $H(\mathbb{S}) = \left(\frac{\theta_H\cdot z\cdot(\psi\cdot K)^{\theta_K}}{\chi[1+m_W\cdot(R^*-1)]}\right)^{\frac{1}{1+\gamma-\theta_H}}$ and the labor income increases with the capital, K as in $W(\mathbb{S})H(\mathbb{S}) = \left(\frac{\theta_H\cdot z}{1+m_W\cdot(R^*-1)}\right)^{\frac{1+\gamma}{1+\gamma-\theta_H}} \cdot \left(\frac{1}{\chi}\right)^{\frac{\theta_H}{1+\gamma-\theta_H}} \cdot (\psi\cdot K)^{\frac{\theta_K\cdot(1+\gamma)}{1+\gamma-\theta_H}}$. Consequently, when collateral constraints bind, households' next-period debt $D^{'}(\mathbb{S})$ and the optimal capital $K^{'}(\mathbb{S})$ are linked according to the equation:

$$\begin{aligned} & R^D \cdot D^{'}(\mathbb{S}) \qquad (12) \\ \leq\ & m_H \cdot \mathbb{E}_{\mathbb{S}}\left[W(\mathbb{S}^{'})H(\mathbb{S}^{'})\right] \\ =\ & m_H \cdot \left(K^{'}(\mathbb{S})\right)^{\frac{\theta_K\cdot(1+\gamma)}{1+\gamma-\theta_H}} \cdot \mathbb{E}_{\mathbb{S}}\left[\left(\frac{\theta_H\cdot z^{'}}{1+m_W\cdot(R^*-1)}\right)^{\frac{1+\gamma}{1+\gamma-\theta_H}} \cdot \left(\frac{1}{\chi}\right)^{\frac{\theta_H}{1+\gamma-\theta_H}} \cdot \left(\psi^{'}\right)^{\frac{\theta_K\cdot(1+\gamma)}{1+\gamma-\theta_H}}\right]. \end{aligned}$$

Those blue points aligned along the concave curve in Figure 4 describe this relation between $D^{'}(\mathbb{S})$ and $K^{'}(\mathbb{S})$. In the calibration, the representative household's time preference rate is larger than the world interest rate.[9] As a result, households would borrow to the credit limit were it not for the prudence against the borrowing limit and risks from productivity and capital quality. The magnitude of the risks and precautionary savings motive prevent them from always staying at the borrowing limit. Figure 4 shows households extend their debt, $D^{'}$ when there is a positive productivity shock and there is not sufficient amount of capital. When there is sufficient capital and households value current consumption less than future consumption, households reduce their borrowing in response to a positive shock. When a negative productivity shock tightens the credit limit, households tend to decumulate their debt holdings.

[9] Households are impatient in a sense that their time preference rate, $\frac{1}{\beta}$ exceeds the interest rate $R^D = R^*$, that is, $\frac{1}{\beta} > R^D$.

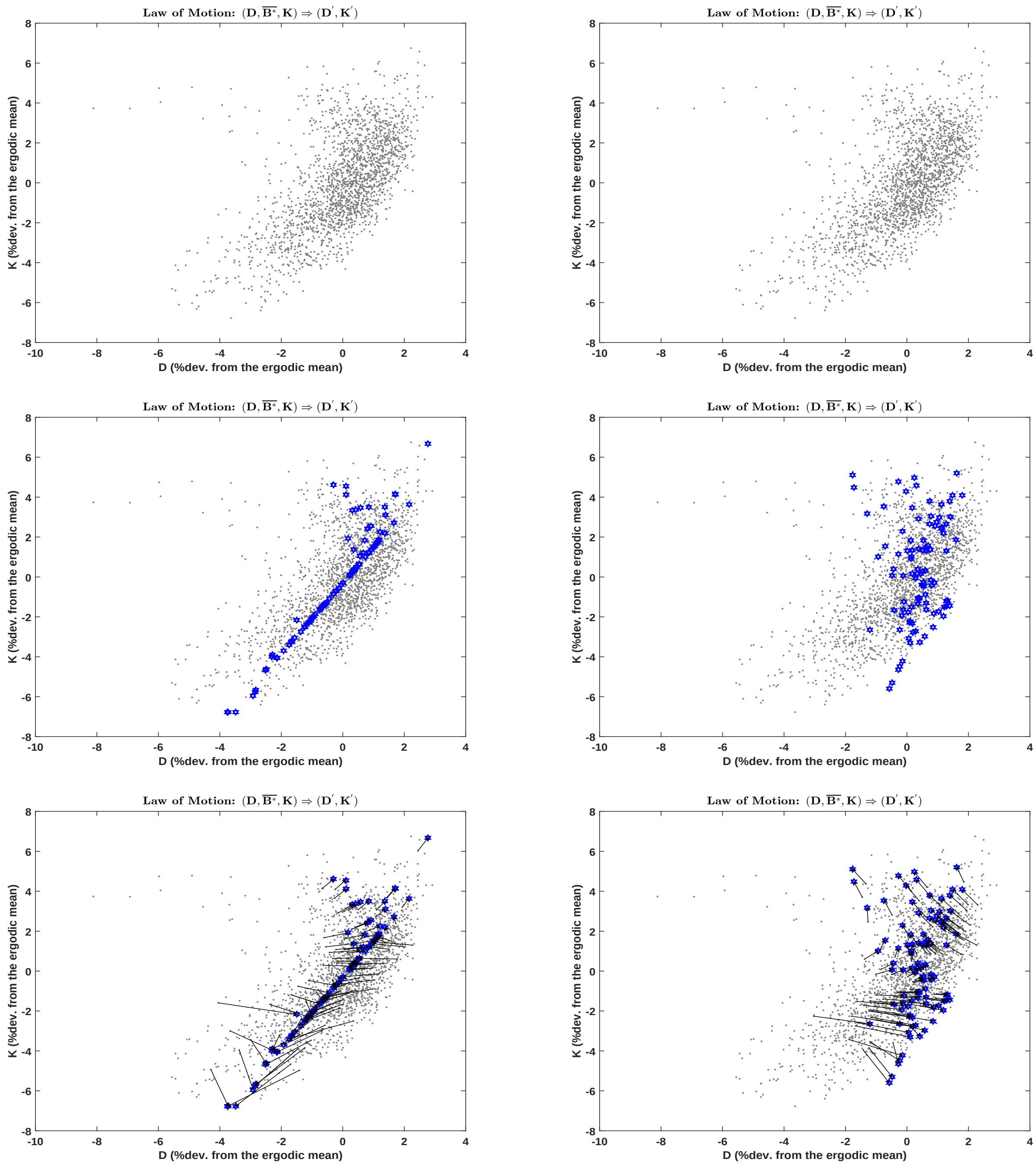


-1STD in TFP

+1STD in TFP

Figure 3: Law of Motion for $\left[\mathbf{\Gamma}_{B^*}(\overline{D}, B^*, K, z, \overline{\psi}), \mathbf{\Gamma}_K(\overline{D}, B^*, K, z, \overline{\psi})\right]$

Note $-$ Gray points in the top row of figure 3 represent grid points on (B^*, K) that we used for global nonlinear solution. Blue points indicate the position of optimal allocation, $\left(B^{*'}(\mathbb{S}), K^{'}(\mathbb{S})\right)$, and black arrows track down their exact mapping in fixing households' debt, $\overline{D}$ at its ergodic mean. The first column presents the law of motion when negative one standard deviation shock in productivity hits the economy and the second column shows the motion induced by positive one standard deviation shock in productivity.



-1STD in TFP   +1STD in TFP

Figure 4: Law of Motion for $\left[\mathbf{\Gamma}_D(D, \overline{B^*}, K, z, \overline{\psi}), \mathbf{\Gamma}_K(D, \overline{B^*}, K, z, \overline{\psi})\right]$

Note – Gray points in the top row of figure 4 represent grid points on (D, K) that we used for global nonlinear solution. Blue points indicate the position of optimal allocation, $\left(D'(\mathbb{S}), K'(\mathbb{S})\right)$, and black arrows track down their exact mapping in fixing bankers' debt, $\overline{B^*}$ at its ergodic mean. The first column presents the law of motion when negative one standard deviation shock in productivity hits the economy and the second column shows the motion induced by positive one standard deviation shock in productivity.

5.2 Business Cycle Statistics

Business and credit cycle moments In order to assess the performance of the model in matching the main characteristics of business and credit cycles observed in Korea[10], we examine the statistical properties of the model moments. The targeted moments are autocorrelation of output, $\rho(Y, Y_{-1})$ and volatilities of output, investment, and credit flows to nonfinancial private firms as a ratio to output, $\left\{\sigma(Y), \sigma(I), \sigma(\frac{\Delta CH}{Y})\right\}$. We adjust parameters of the survival probability of the bankers, ψ, Tobin's Q, Φ_{KK}, the persistence and the size of the TFP shock, $\{\rho_z, \sigma^z\}$, and the size of the capital quality shock, σ^ψ to produce the model moments which reside within one standard error from targeted moments of the Korean data. We simulate for the period of $10,000$ quarters and discard the first 500 observations to remove the effect of the initial state values. Output, consumption, investment, and interest rates, $\{Y, C, I, R\}$ are transformed into percent deviations from their ergodic mean. Net exports, household credit flows, and business credit flows as a ratio to output, $\left\{\frac{NX}{Y}, \frac{\Delta CH}{Y}, \frac{\Delta CF}{Y}\right\}$ are just demeaned.

In Table 5, we report models' performance along the empirical moments. We also report average moments across emerging economies for the comparison. The fourth column, $Model(z, \psi)$ in Table 5 shows the model successfully generates the overall pattern of business cycles, credit cycles and their comovements. The relative volatility of consumption to output is about 1.19, which is comparable to the data, 1.31. Consumption, investment, household credit flows and business credit flows are procyclical, which is consistent with the data. Importantly, the model succeeds in generating countercyclical net exports and interest rates. The correlation between consumption and output is stronger in the model than the data: 0.98 vs. 0.77. The comovement of investment, net exports, interest rates, and credit flows to both sectors with output tends to be weaker in the model.

In regard to non-targeted standard deviations, the model generates much weaker volatility of net exports, interest rates, and household credit flows. The standard deviation of net

[10] The interest rate data for Korea span from 1994:Q1 to 2004:Q3. It is restricted by the availability of J.P. Morgan EMBI sovereign spread data. The rest of the data for Korea covers the period from 1980:Q1 to 2004:Q3. We implicitly assume that Korea was considered as a small-open emerging market up to the period of 2004:Q3 since Korean data of J.P. Morgan Emerging Market Bond Index were available up to that period.

exports and interest rates are half of the size of the volatility in the data: 1.51 vs. 2.84 and 0.19 vs. 0.36, respectively. The model cannot match strong volatility of household credit flows: the relative standard deviation is only 0.09 but it is 1.10 in the data. Even if we take into account the fact that the volatility of household credit flows in Korea is much higher than the average across emerging markets: 1.10 vs. 0.50, we can see that still the model volatility of household credit flows is much smaller than its empirical counterpart in emerging markets. This suggests that the model miss some source of credit cycle fluctuations other than productivity and capital quality. Since fluctuations in productivity and capital quality are disturbances to the supply side, we can infer that the collateral constraint of the model does not propagate these shocks to the demand side enough to generate the realistic level of household credit volatility.

Assessing the effects of different shocks The fifth and sixth columns in the table 5 show the relative importance of productivity shocks and capital quality shocks in generating the model dynamics. The fifth column, $Model(z)$ presents the contribution of productivity shocks to aggregate fluctuations and the sixth column, $Model(\psi)$ reports the contribution of capital quality shocks to aggregate fluctuations. The agents in the model form their rational expectation according to the law of motion perturbed by both productivity and capital quality disturbances, but realizations of capital quality shocks are zero in the simulation for the fifth column, $Model(z)$, and realizations of productivity shocks are zero in the simulation for the sixth column, $Model(\psi)$.[11]

Note that the elasticity of output with respect to productivity is given by $\frac{1+\gamma}{1+\gamma-\theta_H} = 1.7391$ and capital quality affects output by the elasticity of $\frac{\theta_K \cdot [1+\gamma]}{1+\gamma-\theta_H} = 0.5565$ under our parametrization.[12] This clearly explains their relative importance in output volatility: productivity shocks generate 92% $\left(= \frac{2.40}{2.60}\right)$ of output volatility and capital quality shocks reproduce only 44% $\left(= \frac{1.15}{2.60}\right)$ of output volatility.

[11] Since the model was solved by the global method, total variance is not divided neatly among the two productivity and capital quality shocks as it would be in the linearized solution.

[12] Recall the production function is given by $Y_t = z_t \cdot \{\psi_t K_t\}^{\theta_K} \cdot H_t^{\theta_H} = z_t^{\frac{1+\gamma}{1+\gamma-\theta_H}} \cdot \psi_t^{\frac{\theta_K \cdot [1+\gamma]}{1+\gamma-\theta_H}} \cdot \left(\frac{\theta_H^{\theta_H} \cdot K_t^{\theta_K(1+\gamma)}}{\chi[1+m_W(R^*-1)]}\right)^{\frac{1}{1+\gamma-\theta_H}}$ since the equilibrium labor is pinned down as $H_t = \left(\frac{\theta_H \cdot z_t \cdot (\psi_t \cdot K_t)^{\theta_K}}{\chi[1+m_W \cdot (R^*-1)]}\right)^{\frac{1}{1+\gamma-\theta_H}}$ under the *GHH* preference. Hence, we get $\frac{\partial \log(Y_t)}{\partial \log(z_t)} = \frac{1+\gamma}{1+\gamma-\theta_H}$ and $\frac{\partial \log(Y_t)}{\partial \log(\psi_t)} = \frac{\theta_K \cdot [1+\gamma]}{1+\gamma-\theta_H}$.

One of our targeted moments is the relative volatility of business credit flows with respect to output, $\frac{\sigma\left(\frac{\Delta CF}{Y}\right)}{\sigma(Y)}$, which is closely linked to the non-targeted interest rate volatility, $\sigma(R)$. We can clearly see that the model cannot generate the realistic volatility of business credit flows solely by productivity shocks without capital quality shocks: $\sigma\left(\frac{\Delta CF}{Y}\right) = 2.23$ vs. 4.50, unless the output volatility of the model becomes substantially larger than the realistic one. This observation motivated us to take capital quality shocks as another source of aggregate fluctuations. Why are shocks in the capital quality relatively more important to explain fluctuations of business credit flows, $\sigma\left(\frac{\Delta CF}{Y}\right)$ and real interest rates, $\sigma(R)$?[13] This is because shocks in the capital quality raise the ex-post rate of return of capital, R_t^K more than productivity shocks do through the entrepreneur's efficiency condition:

$$\begin{aligned} R_t^K &= \frac{\psi_t \cdot \left[Z_t^E + q_t^K \cdot (1-\delta)\right]}{q_{t-1}^K} \qquad (13) \\ &= \frac{\theta_K \cdot \frac{Y_t}{K_t} + \psi_t \cdot q_t^K \cdot (1-\delta)}{q_{t-1}^K} \\ &= \frac{1}{q_{t-1}^K} \cdot \left[\theta_K \cdot z_t^{\frac{1+\gamma}{1+\gamma-\theta_H}} \cdot \psi_t^{\frac{\theta_K \cdot [1+\gamma]}{1+\gamma-\theta_H}} \cdot \left(\frac{\theta_H^{\theta_H} \cdot K_t^{(\theta_K-1)(1+\gamma)+\theta_H}}{\chi\left[1+m_W\left(R_{t-1}^* - 1\right)\right]}\right)^{\frac{1}{1+\gamma-\theta_H}} + \psi_t \cdot q_t^K \cdot (1-\delta)\right]. \end{aligned}$$

Since the endogenous Tobin's Q, q_t^K shows up in the equation for R_t^K, we cannot explain the relative importance of the capital quality, ψ_t algebraically. Instead, we depend on generalized impulse responses. The net worth in the current period is positively associated with R_t^K through the law of motion for aggregate net worth, N_t:

$$N_t = (\phi + \xi) \cdot R_t^K \cdot q_{t-1}^K \cdot K_t - \phi \cdot R_{t-1}^* \cdot B_{t-1}^*. \qquad (14)$$

When the net worth rises, the marginal value of net worth falls since the net worth in the banking sector is abundant. However, the net effect on the franchise value of the banking sector, $V_t (= \overline{\omega} \cdot N_t)$ is positive and the increase in the ex-post rate of return of capital, R_t^K leads to more loan to entrepreneurs, L_t since the incentive constraint is always binding in the equilibrium under our calibration:

$$V_t \equiv \overline{\omega} \cdot N_t \geq m_B \cdot L_t. \qquad (15)$$

[13] Recall we define interest rates as the expected rate of return of the capital, $R_t = E_t\left[R_{t+1}^K\right]$, which exactly corresponds to the expected rate of return of the loan, $L_t\left(= q_t^K \cdot K_{t+1}\right)$ from the banking sector.

Figure 5 shows this mechanism. One standard deviation shocks in productivity and capital quality raise the ex-post rate of return of capital, R_t^K by 30bp and 69bp respectively. This leads to the increase in the net worth, N_t by 0.011 and 0.024 in unit of consumption. Even if the marginal value of net worth, $\overline{\omega}_t$ falls as shown in the third row of the figure 5, the net effect on the market value of the banking sector, $V_t(= \overline{\omega} \cdot N_t)$ turns out to be positive gains of 0.0091 and 0.0180 for each shock. Therefore, one standard deviation shocks in the productivity and capital quality expand the equilibrium loan, L_t by 0.0157 and 0.0302 severally.

Table 5: Business and Credit Cycle Statistics: The Performance of the Model

Moment	Data (**EM**)	Data (Korea)	Model (z,ψ)	Model (z)	Model (ψ)
A. [Targeted] Volatility of Output, Investment, Firm Credit Flows, and Autocorrelation of Output					
$\sigma(Y)$	3.10 (.18)	2.59 (.12)	2.60	2.40	1.15
$\frac{\sigma(I)}{\sigma(Y)}$	2.56 (.11)	2.17 (.12)	2.13	1.80	3.03
$\frac{\sigma(\Delta CF/Y)}{\sigma(Y)}$	1.36 (.13)	1.87 (.27)	1.93	0.93	3.90
$\sigma(I)$	7.94 (.34)	5.62 (.31)	5.53	4.32	3.50
$\sigma(\Delta CF/Y)$	4.23 (.27)	4.83 (.42)	5.01	2.23	4.50
$\rho(Y,Y_{-1})$	0.78 (.04)	0.76 (.06)	0.78	0.76	0.96
B. [Non-Targeted] Volatility of Consumption, Net Exports, Interest Rates, and Household Credit Flows					
$\frac{\sigma(C)}{\sigma(Y)}$	1.14 (.06)	1.31 (.10)	1.19	1.12	1.46
$\frac{\sigma(NX/Y)}{\sigma(Y)}$	0.81 (.07)	1.10 (.08)	0.58	0.37	1.10
$\frac{\sigma(R)}{\sigma(Y)}$	0.30 (.04)	0.14 (.01)	0.07	0.03	0.15
$\frac{\sigma(\Delta CH/Y)}{\sigma(Y)}$	0.50 (.06)	1.10 (.12)	0.09	0.09	0.08
$\sigma(C)$	3.54 (.19)	3.39 (.26)	3.09	2.70	1.69
$\sigma(NX/Y)$	2.50 (.18)	2.84 (.18)	1.51	0.89	1.27
$\sigma(R)$	0.94 (.14)	0.36 (.02)	0.19	0.08	0.17
$\sigma(\Delta CH/Y)$	1.55 (.14)	2.84 (.24)	0.22	0.21	0.09
C. [Non-Targeted] Correlation with Output					
$\rho(Y,C)$	0.81 (.03)	0.77 (.04)	0.98	0.99	0.97
$\rho(Y,I)$	0.83 (.03)	0.76 (.04)	0.67	0.88	0.19
$\rho(Y,\frac{NX}{Y})$	-.44 (.06)	-.51 (.07)	-.42	-.66	-.16
$\rho(Y,R)$	-.38 (.08)	-.74 (.03)	-.55	-.87	-.57
$\rho(Y,\frac{\Delta CH}{Y})$	0.42 (.03)	0.56 (.05)	0.15	0.16	0.12
$\rho(Y,\frac{\Delta CF}{Y})$	0.34 (.03)	0.34 (.03)	0.23	0.51	0.05

Note – Figures in data represent the GMM estimated moments. The column with **EM** reports the unbalanced panel data from emerging markets: {ARG, BRA, CHL, COL, KOR, MEX, THA, TUR}. The standard deviations(σ) are in percentages and ρ denotes correlation coefficients. Standard errors are reported in brackets. All statistics are based on quarterly data. Real GDP net of government spending(Y), private consumption(C), investment(I), quarterly gross real interest rate(R) were logged. NX, ΔCH, and ΔCF denote net exports, credit flows to households, and credit flows to nonfinancial private firms. In computing model moments, $\{Y,C,I,R\}$ are transformed into percent deviations from the ergodic mean, and $\left\{\frac{NX}{Y},\frac{\Delta CH}{Y},\frac{\Delta CF}{Y}\right\}$ are just demeaned. The column with Model(z) shows the results when the model dynamics are generated solely by productivity and the column with Model(ψ) presents the results from the dynamics generated only by capital quality.

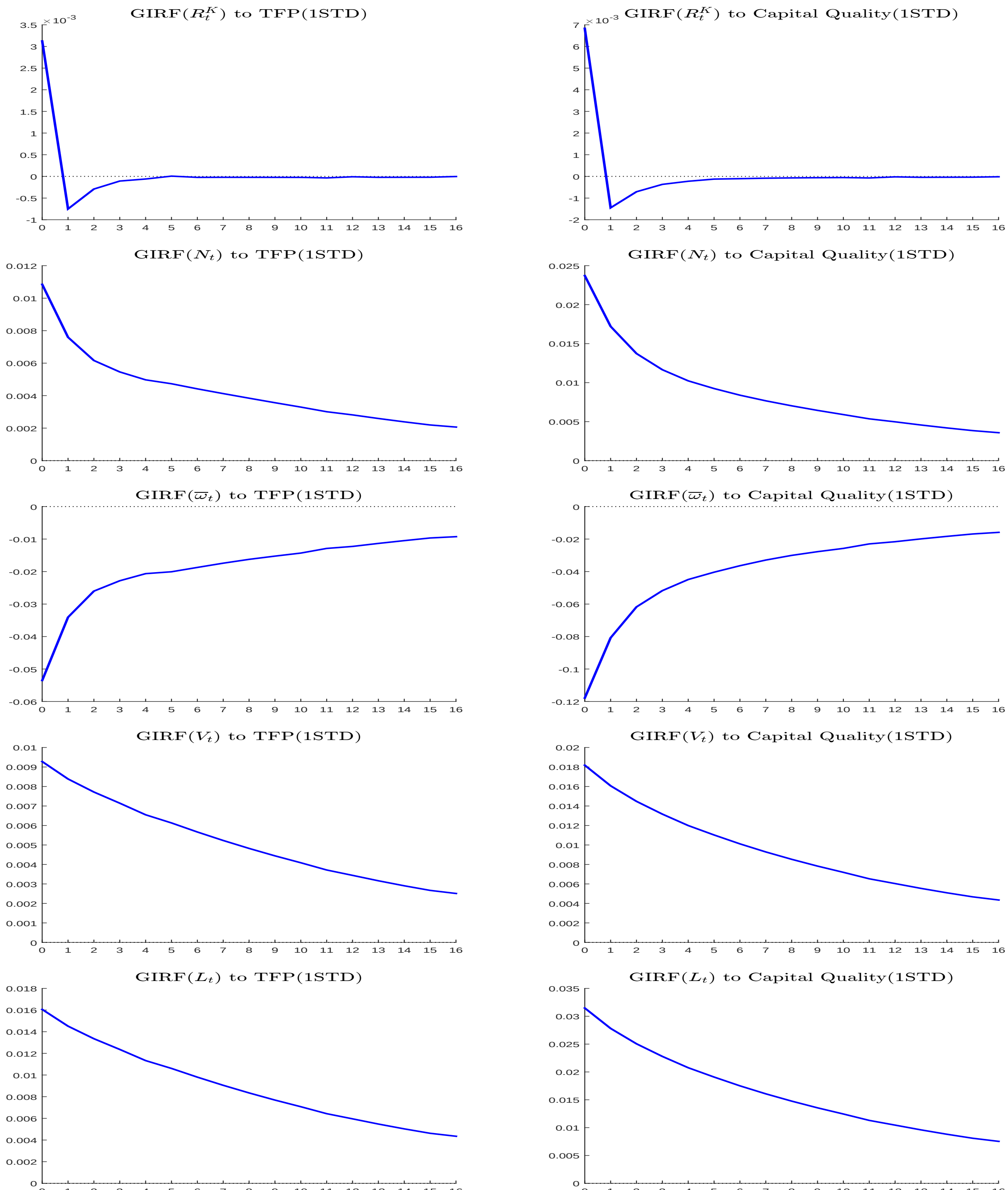


Figure 5: Generalized Impulse Responses to Shocks in Productivity and Capital Quality

Note – R^K denotes the ex-post rate of return of capital. N denotes the net worth of the banking sector. $\overline{\omega}$ stands for the marginal value of the net worth. V is the value of operating banks. L is the loan extended to entrepreneurs. Figures show impulse responses of these variables to one standard deviation shocks in productivity and capital quality. Numbers in Y-axis are interpreted as deviation from the ergodic mean. Numbers in X-axis denote the time elapsed in quarterly frequency. Impulse responses of $\{R^K, N, V, L\}$ are in terms of numéraire(consumption). The impulse response of $\overline{\omega}$ is unitless. Each impulse response was computed as the mean of 200 replications of simulation.

5.3 Mechanism

In this section, we inspect the mechanism of the model in reproducing countercyclical interest rates, procyclical credit flows, countercyclical net exports, and consumption volatility exceeding output volatility.

Countercyclical interest rates Figure 6 shows the impulse responses of the expected loan interest rates. We only show the responses to productivity since the responses to capital quality have exactly the same qualitative feature but different magnitude. From the leftmost sub-figure, we can clearly see that the loan interest rate is reduced by $7.46bp$ when positive one standard deviation shock to productivity hits the economy. Why is the loan interest rate countercyclical?

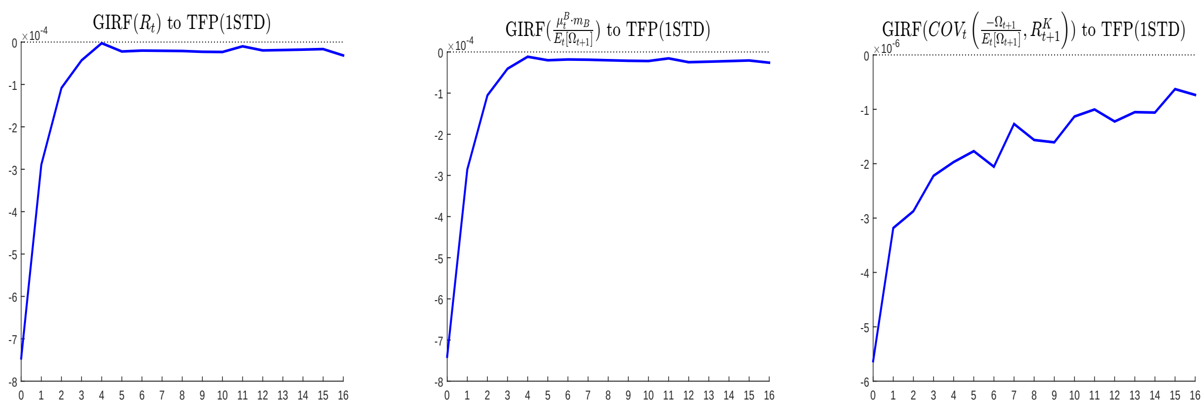


Figure 6: Generalized Impulse Responses to Shocks in Productivity

Note – $R_t = \mathbb{E}_t\left[R_{t+1}^K\right]$ denotes the loan interest rate. R_{t+1}^K stands for the one-period ahead ex-post rate of return of the loan. $\Omega_{t+1}\left(=\frac{1}{R^*}\left(1-\phi+\phi\cdot\overline{\omega}_{t+1}\right)\right)$ denotes the banker's risk-adjusted stochastic discount factor. μ_t^B stands for the shadow value of the banker's net worth. $\overline{\omega}_t$ stands for the marginal value of the banker's net worth. Figures show impulse responses to one standard deviation shocks in productivity. Numbers in Y-axis are interpreted as deviation from the ergodic mean. Numbers in X-axis denote the time elapsed in quarterly frequency. Impulse responses of $\left\{R_t, \frac{\mu_t^B \cdot m_B}{\mathbb{E}_t\left[\Omega_{t+1}\right]}, COV_t\left(\frac{-\Omega_{t+1}}{\mathbb{E}_t\left[\Omega_{t+1}\right]}, R_{t+1}^K\right)\right\}$ are unitless. Each impulse response was computed as the mean of 200 replications of simulation.

To see this, we reformulate the banker's euler equation as follows.

$$\mathbb{E}_t\left[R_{t+1}^K\right] = R_t^* + \underbrace{\frac{\mu_t^B \cdot m_B}{\mathbb{E}_t\left[\Omega_{t+1}\right]}}_{\text{Liquidity Premium}} + \underbrace{COV_t\left(\frac{-\Omega_{t+1}}{\mathbb{E}_t\left[\Omega_{t+1}\right]}, R_{t+1}^K\right)}_{\text{Risk Premium}}. \tag{16}$$

Following Bocola (2016), we interpret three components of the interest rate as the risk-free world interest rate, the liquidity premium, and the risk premium. We also plotted the two premiums in Figure 6. Note that both liquidity premium and risk premium are countercyclical. The risk premium is countercyclical because both the market price of risk, $\frac{\Omega_{t+1}}{\mathbb{E}_t[\Omega_{t+1}]}$ and the one-period ahead ex-post rate of return of the loan, R^K_{t+1} are countercyclical. Observe that the risk premium is quantitatively very small. It only responds to the shock by $0.06bp$. On the other hand, the liquidity premium responds by $7.40bp$ and hence we focus on the mechanism of the countercyclical liquidity premium.

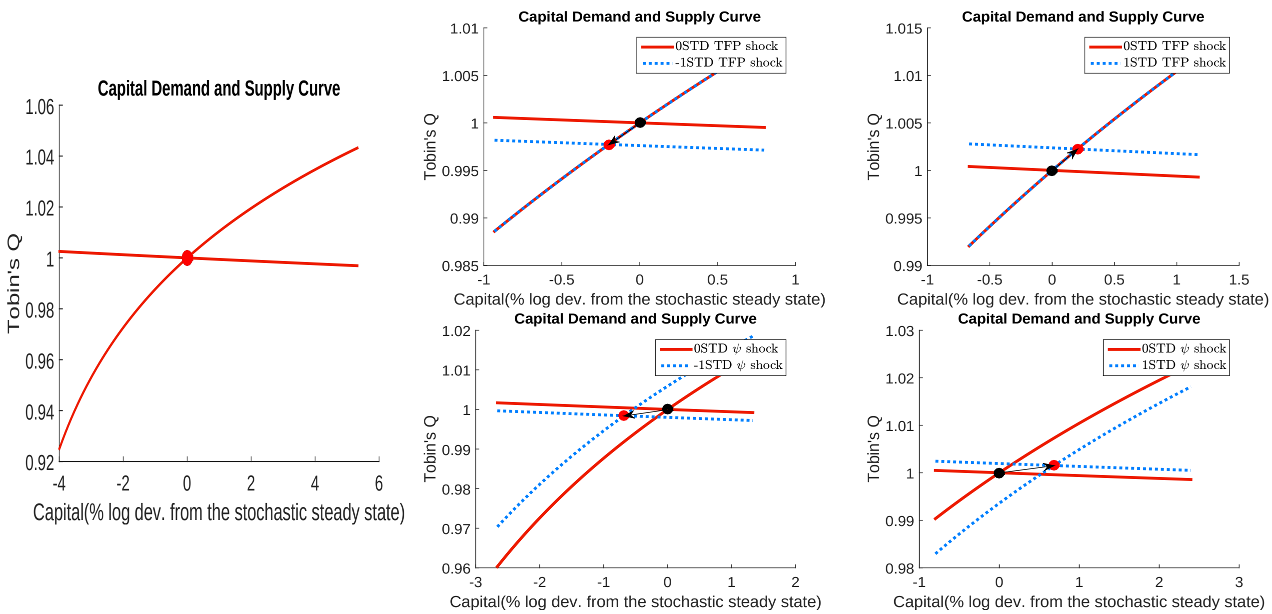


Figure 7: Capital Market Equilibrium

Note – TFP stands for the productivity and ψ denotes the capital quality. The black point denotes the state of the economy with the stochastic steady state and with no shock. The red point represents the transition induced by corresponding shocks. The black arrow tracks down the exact mapping.

In order to fully understand the mechanism, we start from the capital market equilibrium. Figure 7 shows the capital market equilibrium perturbed from the stochastic steady state by an one standard deviation shock in each of productivity and capital quality. We can derive the inverse demand and supply curves in the capital market from entrepreneurs' first-order conditions and capital goods producers' efficiency conditions, respectively.

$$\begin{aligned} \text{Inverse Demand:} \quad q_t^K &= \frac{\theta_K \mathbb{E}_t[Y_{t+1}]}{\mathbb{E}_t\left[R^K_{t+1}\right]} \cdot \frac{1}{K_{t+1}} + \frac{\mathbb{E}_t\left[\psi_{t+1} \cdot q^K_{t+1} \cdot (1-\delta)\right]}{\mathbb{E}_t\left[R^K_{t+1}\right]}, \\ \text{Inverse Supply:} \quad q_t^K &= \frac{\left[K_{t+1} \cdot (\psi_t K_t)^{-\Phi_{KK}} + (\delta - 1 - \phi_{K2}) \cdot (\psi_t K_t)^{1-\Phi_{KK}}\right]^{\frac{\Phi_{KK}}{1-\Phi_{KK}}}}{(1-\Phi_{KK}) \cdot (\phi_{K1})^{\frac{1}{1-\Phi_{KK}}} \cdot (\psi_t K_t)^{\Phi_{KK}}}. \end{aligned} \tag{17}$$

Observe that the productivity shock does not affect the supply curve, but the capital quality shock does. Positive productivity shocks shift only the demand to the right and positive capital quality shocks shift both the demand and the supply outwards. Since the inverse demand curve is very inelastic with respect to the change in capital,[14] the effect from the demand side is dominant and the asset price, q_t^K increases and the equilibrium capital, K_{t+1} rises. Therefore, the equilibrium loan, $L_t = q_t^K \cdot K_{t+1}$ goes up in response to positive productivity and capital quality shocks.

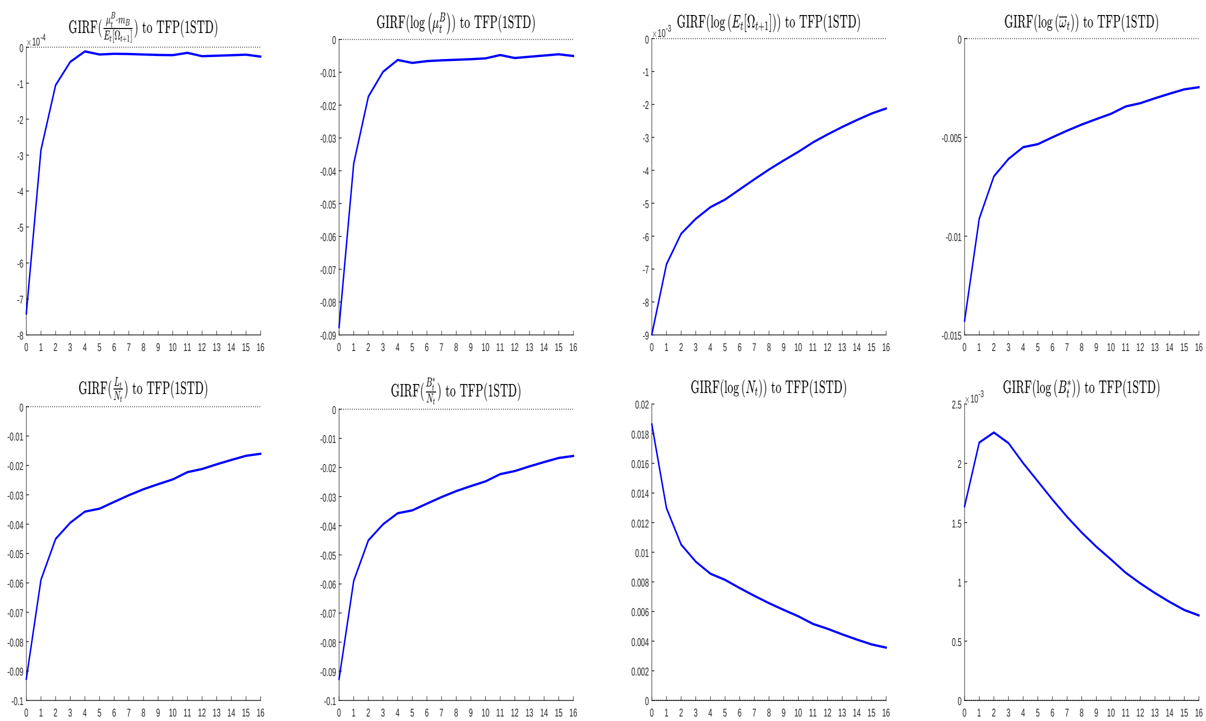


Figure 8: Generalized Impulse Responses to Shocks in Productivity

Note – $\Omega_{t+1} \left(= \frac{1}{R^*} \left(1 - \phi + \phi \cdot \overline{\omega}_{t+1}\right)\right)$ denotes the banker's risk-adjusted stochastic discount factor. μ_t^B stands for the shadow value of the banker's net worth. $\overline{\omega}_t$ stands for the marginal value of the banker's net worth. L_t denotes the amount of loans extended to entrepreneurs. N_t denotes the net worth of the banking sector. B_t^* stands for the amount of debt accumulated in the banking sector. Figures show impulse responses of these variables to one standard deviation shocks in productivity. Numbers in Y-axis are interpreted as deviation from the ergodic mean. Numbers in X-axis denote the time elapsed in quarterly frequency. Impulse responses of $\left\{ \frac{\mu_t^B \cdot m_B}{\mathbb{E}_t[\Omega_{t+1}]}, \log\left(\mu_t^B\right), \log\left(\mathbb{E}_t\left[\Omega_{t+1}\right]\right), \log\left(\overline{\omega}_t\right), \frac{L_t}{N_t}, \frac{B_t^*}{N_t}, \log\left(N_t\right), \log\left(B_t^*\right) \right\}$ are unitless. Each impulse response was computed as the mean of 200 replications of simulation.

Now the question is, why is the liquidity premium, $\frac{\mu_t^B \cdot m_B}{\mathbb{E}_t[\Omega_{t+1}]}$ countercyclical? To see this, we plotted impulse responses of all relevant variables in Figure 8.[15] Observe that both the shadow value of the net worth, μ_t^B and the expected stochastic discount factor of the

[14] That is, the demand curve is very elastic with respect to the change in Tobin's Q.

[15] We only show responses to the productivity shocks since the capital quality shocks affect the loan interest rate in the same direction with different magnitude.

bankers, $\mathbb{E}_t[\Omega_{t+1}]$ is countercyclical. The ratio, $\frac{\mu_t^B}{\mathbb{E}_t[\Omega_{t+1}]}$ falls because $\log(\mu_t^B)$ falls by 8.5% but $\log(\mathbb{E}_t[\Omega_{t+1}])$ declines by 0.9% and so the net effect on the ratio is negative.

Why does the shadow value of the net worth, μ_t^B decline in response to positive shocks? It is positively associated with the marginal value of the net worth through the banker's efficiency condition, $\mu_t^B = 1 - \frac{\nu_t^{b^*}}{\overline{\omega}_t}$. Observe that the impulse response of the log of the marginal cost of one additional debt in the banking sector, $\nu_t^{b^*}\ (= \mathbb{E}_t[\Omega_{t+1}] \cdot R_t^*)$ exactly corresponds to the impulse response of the log of the expected stochastic discount factor, $\mathbb{E}_t[\Omega_{t+1}]$. Since $\log\left(\nu_t^{b^*}\right)$ declines by 0.9%[16] and $\log(\overline{\omega}_t)$ falls by 1.4%, the ratio, $\frac{\nu_t^{b^*}}{\overline{\omega}_t}$ increases and their net effect on the shadow value, μ_t^B is negative.

Then what drives the decrease in the marginal value of the net worth, $\overline{\omega}_t$? Notice that the banker's incentive constraint is always binding in the equilibrium and the marginal value of the net worth, $\overline{\omega}_t$ is equalized to the leverage, $\frac{L_t}{N_t}$[17] weighted by the fraction of divertible assets, m_B as in

$$\overline{\omega}_t \;=\; m_B \cdot \frac{L_t}{N_t} = m_B \cdot \left(1 + \frac{B_t^*}{N_t}\right). \tag{18}$$

In the equilibrium, an one standard deviation productivity shock reduces the banker's leverage, $\frac{L_t}{N_t}$ by 9%. This is because bankers get more proceeds from the previous-period loan and so accumulate retained earnings more. Optimizing bankers depend on external financing less in order to be less constrained by incentive constraints. See from the bottom of Figure 8 that the log of the external debt, B_t^* positively responds by 0.16% but the log of the net worth increases by 1.83%.

Therefore, in response to positive one standard deviation shock in productivity, the leverage, $\frac{B_t^*}{N_t} = \frac{L_t}{N_t} - 1$ falls, the marginal value of the net worth, $\overline{\omega}_t$ falls, and this leads to the decrease in the shadow value of the net worth, μ_t^B through the equilibrium condition, $\mu_t^B = 1 - \frac{\nu_t^{b^*}}{\overline{\omega}_t}$. Even if the expected stochastic discount factor of the bankers, $\mathbb{E}_t[\Omega_{t+1}]$ also declines, its response is less elastic than the shadow value of the net worth and so the net effect on the liquidity premium, $\frac{\mu_t^B \cdot m_B}{\mathbb{E}_t[\Omega_{t+1}]}$ is negative. This exactly describes the mechanism of the countercyclical loan interest rate.

[16] See the impulse response of $\log(\mathbb{E}_t[\Omega_{t+1}])$ in the top row and the third column of Figure 8.

[17] The total loan, L_t is financed by retained earnings, N_t and external financing, B_t^*.

Procyclical credit flows and countercyclical net exports Our next analysis is on the mechanism of procyclical credit flows to households and entrepreneurs and the mechanism of countercyclical net exports. In the previous subsection, we have discussed the mechanism of procyclical credit to entrepreneurs, L_t and procyclical credit to the bankers, B_t^*. Hence, we focus on procyclical credit flows to households in this subsection. When the shadow value of the household's labor income, μ_t^H is positive, the debt holdings are characterized by the collateral constraint:

$$\begin{aligned} R_t^D \cdot D_t &= m_H \cdot \mathbb{E}_t\left[W_{t+1}H_{t+1}\right] \qquad (19) \\ &= m_H \cdot (K_{t+1})^{\frac{\theta_K\cdot(1+\gamma)}{1+\gamma-\theta_H}} \cdot \mathbb{E}_t\left[\left(\frac{\theta_H \cdot z_{t+1}}{1+m_W\cdot(R_t^*-1)}\right)^{\frac{1+\gamma}{1+\gamma-\theta_H}} \cdot \left(\frac{1}{\chi}\right)^{\frac{\theta_H}{1+\gamma-\theta_H}} \cdot (\psi_{t+1})^{\frac{\theta_K\cdot(1+\gamma)}{1+\gamma-\theta_H}}\right]. \end{aligned}$$

Since the equilibrium capital, K_{t+1} and the expectation term, $\mathbb{E}_t\left[(z_{t+1})^{\frac{1+\gamma}{1+\gamma-\theta_H}} \cdot (\psi_{t+1})^{\frac{\theta_K\cdot(1+\gamma)}{1+\gamma-\theta_H}}\right]$ are procyclical, this constraint clearly drives the household credit flows, $D_t - D_{t-1}$ procyclical when it is binding. To be more specific, Figure 9 shows the impulse responses of household credit flows to shocks in productivity and capital quality. Note that the household's euler equation is given by

$$\text{HH's Euler Equ:} \quad 1 = \beta \cdot R_t^D \cdot \frac{\mathbb{E}_t\left[\left\{C_{t+1}-\chi\cdot\frac{H_{t+1}{}^{1+\gamma}}{1+\gamma}\right\}^{-\sigma}\right]}{\left\{C_t-\chi\cdot\frac{H_t{}^{1+\gamma}}{1+\gamma}\right\}^{-\sigma}} + R_t^D \cdot \mu_t^H, \qquad (20)$$

where $R_t^D = R_t^*$ holds. The marginal benefit of one additional debt is just one unit of consumption and the marginal cost is given by the right-hand side of the euler equation (20). The first column in the figure 9 shows the responses with respect to different magnitude of productivity and capital quality shocks over the next four years and the second column presents the impulse responses on impact with respect to different size of shocks. All responses are in terms of deviations from the ergodic mean. Observe that The debt holdings respond to productivity shocks much larger than that to capital quality shocks.[18] This is because under our calibration, the credit limit is more elastic to the change in the productivity than the capital quality.[19]. Therefore, we focus on the response to productivity shocks.

[18] The response to shocks in productivity varies approximately from -2% to 0% in terms of log deviation from the ergodic mean. However, the response to shocks in capital quality only varies from -0.25% to 0%.

[19] The exponent on the productivity, $\frac{1+\gamma}{1+\gamma-\theta_H} = 1.7391$ is much bigger than the exponent on the capital quality, $\frac{\theta_K\cdot(1+\gamma)}{1+\gamma-\theta_H} = 0.5565$

Note that were it not for any uncertainty, the household would borrow to the credit limit since his time preference rate is larger than the interest rate, $\frac{1}{\beta} > R^D (= R^*)$. However, there are two components for the household's precautionary savings motive. One is the convexity of the household's marginal utility, that is, the household's fondness for one additional consumption diminishes exponentially. The other is the precautionary behavior against the possibility that the household's debt stock might hit the collateral constraint in the future. These two channels increase the marginal cost of one additional borrowing and shift the marginal cost curve upward. In response to positive one standard deviation shock, it turns out that households do not expand their debt holdings more than they would do with no shock.[20] We can observe that the negative shocks to productivity force households to reduce their debt stock due to the decrease in the expected labor income. On the other hand, the response of the household's debt is not symmetric about the shocks. For the positive shocks, the household does not expand his borrowing as much as the increase in the credit limit due to his precautionary savings motive and the decrease in the marginal utility of current consumption. As a result, the household credit flows are procyclical in response to negative shocks. For positive shocks, it becomes procyclical only for those small shocks of much less than one standard deviation and otherwise it becomes countercyclical. Under the calibration, the effect of negative shocks on households' debt is dominant and the household credit flows are positively associated with the output on average. If the magnitude of the positive shock gets larger, then precautionary savings motive gets stronger and the magnitude of the decrease in the marginal utility of current consumption becomes larger, which implies that the credit flows can be acyclical or even countercyclical on average.

For the final remark, note that the cyclical behavior of net exports, $NX_t (= R^D_{t-1} \cdot D_{t-1} - D_t + R^*_{t-1} B^*_{t-1} - B^*_t + (R^*_{t-1} - 1) \cdot B^{W*}_t)$[21] is in the opposite direction to those two credit flows: the procyclical household credit flows, $D_t - D_{t-1}$ and the procyclical banking-sector credit flows, $B^*_t - B^*_{t-1}$. Therefore, the discussion so far also reveals the mechanism of the countercyclical net exports in the model.

[20] See the sub-figures in the second column of Figure 9.

[21] The intratemporal working capital loan, $B^{W*}_t (= m_W \cdot W_t H_t)$ is procyclical, but its effect is muted by larger size of the procyclical intertemporal external debt in the banking sector, B^*_t.

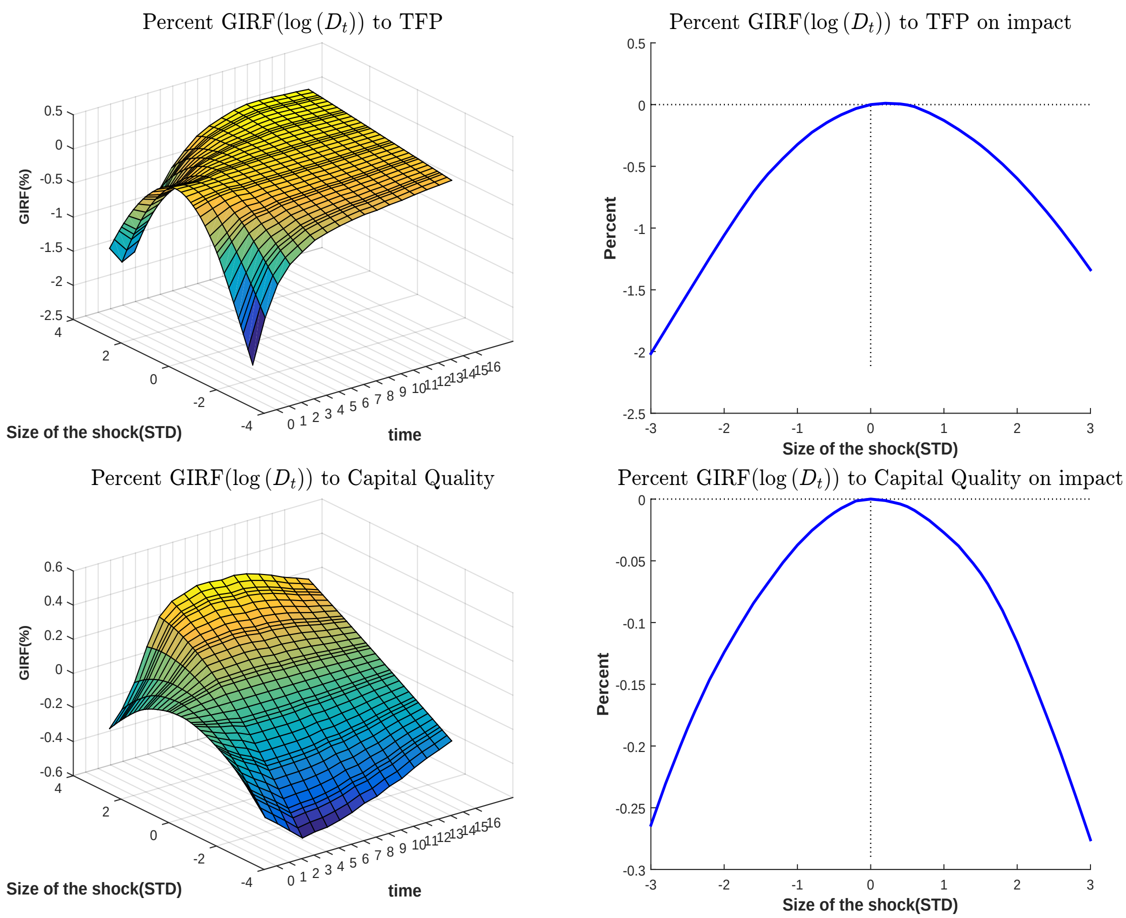


Figure 9: Generalized Impulse Responses of Household Credit Flows to Shocks

Note – TFP stands for the productivity and ψ denotes the capital quality. The first row reports the impulse response of household credit flows to productivity shocks. The second row presents the impulse response of household credit flows to capital quality shocks.

Procyclical credit flow-to-output ratio and consumption volatility Even if we comprehensively show what drives procyclical household credit flows, $D_t - D_{t-1}$ and procyclical business credit flows, $L_t - L_{t-1}$, the cyclical property of its ratio to output, $\frac{\Delta CH_t}{Y_t} = \frac{D_t - D_{t-1}}{Y_t}$ and $\frac{\Delta CF_t}{Y_t} = \frac{L_t - L_{t-1}}{Y_t}$ needs further discussion. Figure 10 reports the impulse responses of the ratio of household credit flows to output in the first two columns. The last two columns present the impulse responses of the ratio of business credit flows to output.

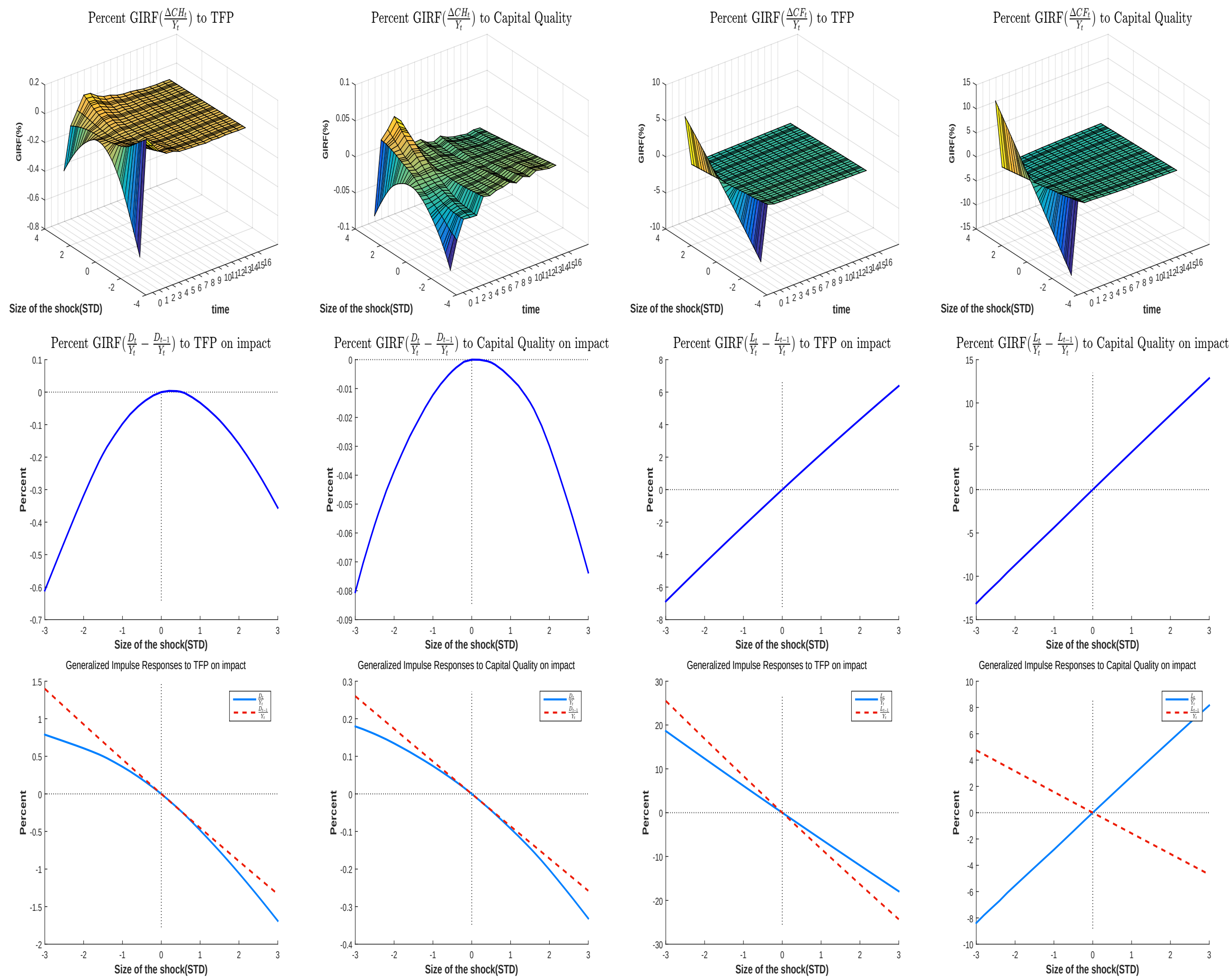


Figure 10: Generalized Impulse Responses to Shocks in Productivity and Capital Quality

Note – TFP stands for the productivity and ψ denotes the capital quality. The first and second column report the impulse response of household credit flow-to-output ratio to TFP and capital quality, respectively. The third and fourth column report the impulse response of business credit flow-to-output ratio to TFP and capital quality, severally.

The sub-figures in the top row reveal that household credit flow-to-output ratio responds to the shocks persistently but business credit flow-to-output ratio responds on impact and get back to the ergodic mean rapidly. The second and third rows show distinct responses of household and business credit flow-to-output ratio to different shocks on impact. Firstly, for the size of shocks ranged from negative three standard deviation to positive three standard deviation, the ratio of household credit flows to output responds only by the range of $[-0.61\%, +0.01\%]$ for productivity shocks and by the range of $[-0.08\%, +0.00\%]$ for capital quality shocks. On the other hand, the magnitude of the response of the ratio of business credit flows to output is much larger. Its range is given by $[-6.88\%, +6.38\%]$ for productivity shocks and by $[-13.13\%, +12.86\%]$ for capital quality shocks. Secondly, observe that the ratio of household credit flows to output positively comoves with the output only for negative shocks and small positive shocks in productivity as we discussed thoroughly before. The ratio of business credit flows to output responds symmetrically to both shocks and always procyclical no matter what size of shocks perturb the economy. From the last row of the figure, we can see that credit stock-to-output ratios, $\frac{D_t}{Y_t}$ and $\frac{L_t}{Y_t}$ respond to shocks in the opposite direction to the output, except the response of the loan-to-output ratio, $\frac{L_t}{Y_t}$ to capital quality shocks. Therefore, the procyclical cycles in the ratio of household credit flows and business credit flows to output come from the net effect adjusted by the ratio of previous-period credit stock to output, $\frac{D_{t-1}}{Y_t}$ and $\frac{L_{t-1}}{Y_t}$.

Our last discussion is on the volatility of consumption exceeding the output volatility. How does the model generate higher volatility of consumption relative to output? To see this, we rewrite the household's euler equation for the consumption:

$$\begin{aligned} C_t &= \chi \cdot \frac{{H_t}^{1+\gamma}}{1+\gamma} + \left\{ \frac{\beta \cdot R_t^D}{1 - R_t^D \cdot \mu_t^H} \mathbb{E}_t \left[\left\{ C_{t+1} - \chi \cdot \frac{{H_{t+1}}^{1+\gamma}}{1+\gamma} \right\}^{-\sigma} \right] \right\}^{\frac{-1}{\sigma}} \qquad (21) \\ &= Y_t \cdot \left(\frac{\theta_H}{(1+\gamma)(1 + m_W \cdot (R_{t-1}^* - 1))} + \frac{1}{Y_t} \cdot \left\{ \frac{\beta \cdot R_t^D \cdot \mathbb{E}_t \left[\left\{ C_{t+1} - \chi \cdot \frac{{H_{t+1}}^{1+\gamma}}{1+\gamma} \right\}^{-\sigma} \right]}{1 - R_t^D \cdot \mu_t^H} \right\}^{\frac{-1}{\sigma}} \right) \\ &\equiv Y_t \cdot M_t^{YC}, \end{aligned}$$

where $R_t^D = R_t^*$ holds. Observe that the multiplier, M_t^{YC} depends on the shadow value of the household's labor income, μ_t^H, which would have been absent in the euler equation under the frictionless environment. Its effect on the multiplier, M_t^{YC} cannot be evaluated from the equation algebraically and so we examine the impulse responses. Figure 11 reports the result. The first column of the figure presents the impulse responses of the log of the consumption-to-output ratio with respect to different shocks and different size of each shock over the next four years. The second column reports the responses on impact with respect to different shocks and their different magnitudes. The third column shows the elasticity of consumption and output with respect to those shocks. From the third column, we can clearly see that the response of consumption to those two shocks is more elastic than that of output. The response of consumption to productivity is asymmetric: consumption gets more volatile with respect to negative productivity shocks than to positive productivity shocks. We can infer that this is due to the presence of collateral constraints, which amplifies the effect of negative productivity shocks. On the other hand, we have seen the capital quality shocks do not affect the credit limit of households as much[22] and thus its impact on consumption itself is smaller and more symmetric. However, the relative elasticity of consumption compared to output is larger in response to capital quality shocks than to productivity shocks and hence the capital quality drives the relative volatility of consumption to output more than the productivity, especially for the case of positive shocks.

[22] Recall $R_t^D \cdot D_t \leq m_H \cdot \mathbb{E}_t\left[W_{t+1}H_{t+1}\right]$ and $m_H \cdot \mathbb{E}_t\left[W_{t+1}H_{t+1}\right] = m_H \cdot (K_{t+1})^{\frac{\theta_K\cdot(1+\gamma)}{1+\gamma-\theta_H}} \cdot \mathbb{E}_t\left[\left(\frac{\theta_H\cdot z_{t+1}}{1+m_W\cdot(R_t^*-1)}\right)^{\frac{1+\gamma}{1+\gamma-\theta_H}} \cdot \left(\frac{1}{\chi}\right)^{\frac{\theta_H}{1+\gamma-\theta_H}} \cdot (\psi_{t+1})^{\frac{\theta_K\cdot(1+\gamma)}{1+\gamma-\theta_H}}\right]$. Check exponents of productivity and capital quality in this equation.

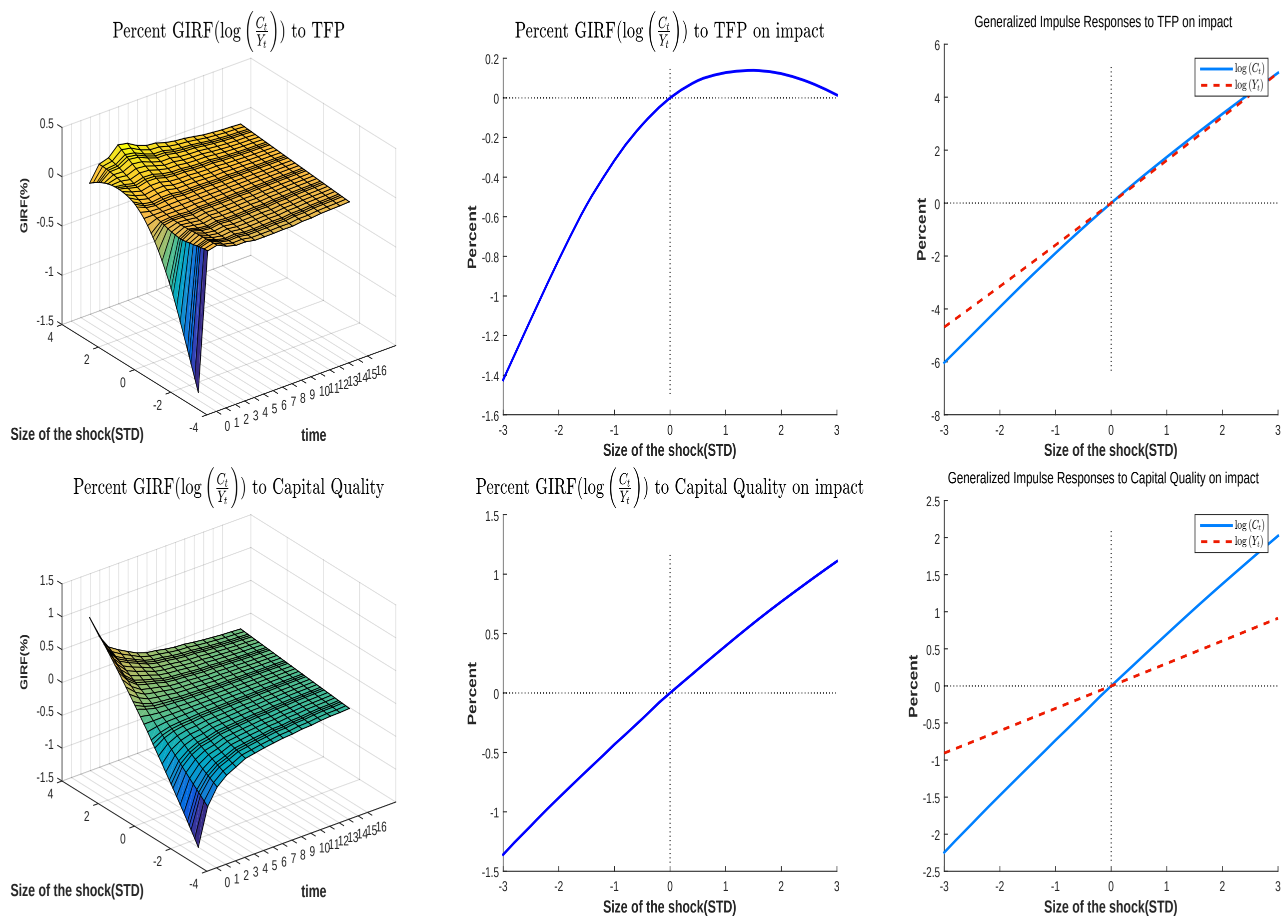


Figure 11: Generalized Impulse Responses to Shocks in Productivity and Capital Quality

Note – TFP stands for the productivity and ψ denotes the capital quality. The first row reports the impulse response of the consumption-to-output ratio to productivity shocks. The second row presents the impulse response of the consumption-to-output ratio to capital quality shocks.

6 Counterfactuals

For counterfactual experiments, we ask two questions. What would be the equilibrium results if the default risk in the banking sector could be completely eliminated? We also ask, what if households were not circumscribed by collateral constraints but instead paid risk premium which were positively associated with the amount of their debt? In this section, we do not take account of *how* to design the financial policy which can eliminate the default risks in the household and banking sectors. Instead, we compare equilibrium results from the benchmark economy to those from the standard SOE-RBC model with the debt-elastic risk premium.

In particular, for the model without collateral constraints, the debt-elastic interest rate, $R_t^D = \overline{\Psi} \cdot R_t^* + \tilde{\Psi} \cdot \left[\exp\left(D_t - \overline{D}\right) - 1\right]$[23] is substituted for the collateral constraint, $R_t^D \cdot D_t \leq m_H \cdot \mathbb{E}_t \left[W_{t+1} H_{t+1}\right]$ and still the banking sector borrows at the world interest rate, R_t^*. For the model without incentive constraints, we fix the shadow value of the bankers' net worth, μ_t^B at zero and so the marginal value of the net worth, $\overline{\omega}_t$ always equates to the marginal cost of one additional external debt in the banking sector, $\nu_t^{b^*}$. Table 6 and 7 show the representative statistics of each equilibrium and its welfare gains.

Long-run economic aggregates Table 6 shows the ergodic mean and the stochastic steady state of economic aggregates of interest. The second column presents the long-run aggregates of the benchmark model, "Model(Benchmark)" with both frictions at work. For the third and fourth columns, we report the results from shutting off only one of the incentive constraint and the collateral constraint in order, "Model(No I.C.)" and "Model(No C.C.)." The last column shows the long-run aggregates of the model, "Model(Neither)" with neither of the two financial frictions. Firstly, note that replacing the collateral constraint with the debt-elastic interest rate does not affect the long-run aggregates much by construction.[24] We chose parameter values for the debt-elastic interest rate to match the stochastic steady-state consumption of the benchmark model. Our focus of removing the collateral constraint is

[23] The welfare implication is highly dependent on parameter values of $\left\{\overline{\Psi}, \tilde{\Psi}, \overline{D}\right\}$. We set the risk premium parameter, $\overline{\Psi}$ to $\frac{1}{\beta \cdot R^*} = 1.0184$ and $\overline{D}$ to 0.0196 in order to obtain the same consumption level with the benchmark one in the stochastic steady state, $C = 0.5156$. We assign a small number, 0.001 to the elasticity term, $\tilde{\Psi}$ to hold the interest rate as constant as possible.

[24] Compare the second(third) column with the fourth(fifth) column.

Table 6: Long-run Economic Aggregates

Variable	Model (Benchmark)	Model (No I.C.)	Model (No C.C.)	Model (Neither)
		A. The Ergodic Mean		
C	0.5150	0.5895	0.5146	0.5891
H	0.3330	0.3808	0.3331	0.3807
NX	0.0077	0.0123	0.0082	0.0125
D	0.2066	0.2560	0.0426	0.0318
B^*	3.1749	5.2939	3.1767	5.2943
N	0.5769	0.2201	0.5766	0.2184
I	0.2000	0.2938	0.2001	0.2938
K	3.7519	5.5140	3.7534	5.5127
Y	0.7227	0.8957	0.7229	0.8954
		B. The Stochastic Steady State		
C	0.5156	0.5897	0.5156	0.5898
H	0.3332	0.3809	0.3333	0.3809
NX	0.0078	0.0123	0.0078	0.0123
D	0.2093	0.2591	0.0195	0.0195
B^*	3.1772	5.2934	3.1789	5.2935
N	0.5788	0.2211	0.5785	0.2211
I	0.2001	0.2938	0.2002	0.2938
K	3.7560	5.5145	3.7574	5.5145
Y	0.7234	0.8958	0.7236	0.8958

Note – The column with "Model(Benchmark)" shows the results from the model with the collateral constraint and the incentive constraint. The column with "Model(No I.C.)" presents the results from the model without the incentive constraint but with the collateral constraint. The column with "Model(No C.C.)" reports the results from the model without the collateral constraint but with the incentive constraint. The column with "Model(Neither)" reports the results from the model without both constraints. $\{C, H, NX, D, B^*\}$ denotes consumption, labor, net exports, household debt stock, and bank debt stock, respectively. $\{N, I, K, Y\}$ denotes bank net worth, investment, capital, and output, respectively.

on understanding how the constraint impacts upon household credit flows and consumption smoothing. We will discuss its impact at business cycle frequency in Table 7. More importantly, eliminating the incentive constraint, that is, completely removing the default risks in the banking sector affects the long-run equilibrium significantly. By comparing the second and third columns[25], we can see that bankers increase their leverage, $\frac{N+B^*}{N}$ by 285%. 47% increase in loans, $L(= N + B^*)$ to entrepreneurs raises long-run investment, I and capital, K by 47% for both and thus output, Y increases by 24%. Since the long-run output rises, households earn more labor income and their credit limit becomes more loosened. Therefore, households expand their borrowing, D by 24% and aggregate consumption, C goes up by 14%.

[25] Comparing the fourth and fifth columns has the same implication.

Business and credit cycle moments and welfare gains Table 7 reports the effects of collateral constraints and incentive constraints on the equilibrium at business cycle frequency. In the third column, we reproduces the data from the developed countries for the comparison to the results of counterfactual experiments. For the welfare analysis, we construct unconditional welfare measure by defining consumption-labor composite, $X_t \equiv C_t - \chi \cdot \frac{{H_t}^{1+\gamma}}{1+\gamma}$. Following Floden (2001), we decompose the consumption-labor composite equivalent variation, λ^X into two parts: level component, λ^X_{lev} and uncertainty component, λ^X_{unc}.[26] The level component, λ^X_{lev} captures the fraction of welfare gains obtained by the increase in the ergodic mean of the composite. The uncertainty component, λ^X_{unc} shows the fraction of welfare gains derived from reduced volatility of the composite.

First of all, observe that removing the financial friction in the banking sector has significant effects.[27] If there are neither moral hazard nor default risks in the banking sector, then the liquidity premium on banking sector is anchored at zero and the private-sector interest rate is almost equalized to the risk-free world interest rate.[28] Bankers do not need to accumulate so much retained earnings to extend their loan and the investment sector can get more external funding. These lead to more capital accumulation and hence output and consumption rise. We find that unconditional welfare benefits amount to 0.17% increase

[26] To be concrete, we compute unconditional welfare gain, λ^X by $\mathbb{E}\left[u\left(X_t^A\right)\right] = \mathbb{E}\left[u\left((1+\lambda^X)\cdot X_t^B\right)\right]$ where A and B indicate the allocation is from the different equilibrium. Define the level component as $1+\lambda^X_{lev} = \frac{\mathbb{E}[X_t^A]}{\mathbb{E}[X_t^B]}$ and the uncertainty component as $1+\lambda^X_{unc} = \frac{1-p^A}{1-p^B}$ where p^j is derived from $\mathbb{E}\left[u(X_t^j)\right] = u\left((1-p^j)\cdot \mathbb{E}\left[X_t^j\right]\right)$ for $j \in \{A, B\}$. Floden (2001) shows that $(1+\lambda^X) = (1+\lambda^X_{lev})(1+\lambda^X_{unc})$ holds for the standard CRRA utility and thus we can get $\lambda^X \approx \lambda^X_{lev} + \lambda^X_{unc}$. We defined consumption-labor composite, $X_t \equiv C_t - \chi \cdot \frac{{H_t}^{1+\gamma}}{1+\gamma}$ since consumption equivalent variation cannot be decomposed under the *GHH* preference. In particular, consumption equivalent variation, λ^C is computed by $\mathbb{E}\left[\frac{\left[C_t^A - \chi\cdot\frac{{H_t^A}^{1+\gamma}}{1+\gamma}\right]^{1-\sigma}}{1-\sigma}\right] = \mathbb{E}\left[\frac{\left[(1+\lambda^C)\cdot C_t^B - \chi\cdot\frac{{H_t^B}^{1+\gamma}}{1+\gamma}\right]^{1-\sigma}}{1-\sigma}\right]$. Consumption-labor composite equivalent variation, λ^X is computed by $\mathbb{E}\left[\frac{\left[C_t^A - \chi\cdot\frac{{H_t^A}^{1+\gamma}}{1+\gamma}\right]^{1-\sigma}}{1-\sigma}\right] = \mathbb{E}\left[\frac{\left[(1+\lambda^X)\cdot\left(C_t^B - \chi\cdot\frac{{H_t^B}^{1+\gamma}}{1+\gamma}\right)\right]^{1-\sigma}}{1-\sigma}\right]$

[27] Compare the fifth(seventh) column with the sixth(last) column.

[28] They are not exactly equalized. See $\mathbb{E}_t\left[R^K_{t+1}\right] = R_t^* + \frac{\mu_t^B \cdot m_B}{\mathbb{E}_t[\Omega_{t+1}]} + COV_t\left(\frac{-\Omega_{t+1}}{\mathbb{E}_t[\Omega_{t+1}]}, R^K_{t+1}\right)$ where μ_t^B is zero.

in one quarter's steady-state consumption. Output volatility is reduced by 11% and the relative volatility of investment decreases by almost one half. The ratio of net exports and business credit flows to output fluctuate less by 70% and 34% in terms of the size of their volatility relative to output. Business credit flows become more procyclical and household credit flows exhibit slightly milder comovement with output. On the other hand, consumption volatility itself decreases by 4% but its relative volatility rises due to considerably larger drop in output volatility. From the welfare decomposition, we find that the consumption-labor composite, $X_t \left(\equiv C_t - \chi \cdot \frac{{H_t}^{1+\gamma}}{1+\gamma}\right)$ becomes more volatile[29] and its ergodic mean gets higher. Thus, the level and uncertainty welfare gains amount to 0.45% and -0.04% in terms of one quarter's steady-state consumption-labor composite, respectively. By comparing the column, "Model(No C.C.)" with the column, "Model(Neither)", we can see that the implication of eliminating frictions in the banking sector is also generally maintained for the model of no collateral constraints. We find that the welfare gains from the increase in the ergodic consumption-labor composite are larger. Under no collateral constraints, the model predicts that the total welfare gains amount to 0.22% increase in one quarter's steady-state consumption.

Replacing the collateral constraint with the debt-elastic interest rate does not affect the equilibrium allocations of the financial and nonfinancial corporate sectors due to our assumption that agents in the production side are risk neutral. The only channel that households affect the supply side is through their labor supply decision, but the equilibrium labor is determined independently from households' consumption under the *GHH* preference. Therefore, output, investment, interest rates, and business credit flows do not change. However, households' debt decision has very different mechanism. Notice that the upward-sloping inverse supply curve in the bond market changes households' marginal cost of one additional

[29] The standard deviation of the simulated consumption-labor composite is 3.94% in the benchmark model, whareas it is 4.41% in the model of "No I.C."

debt as follows.

$$\begin{aligned} 1 &= \beta \cdot R_t^D \cdot \frac{\mathbb{E}_t\left[\left\{C_{t+1} - \chi \cdot \frac{{H_{t+1}}^{1+\gamma}}{1+\gamma}\right\}^{-\sigma}\right]}{\left\{C_t - \chi \cdot \frac{{H_t}^{1+\gamma}}{1+\gamma}\right\}^{-\sigma}}, \\ R_t^D &= \overline{\Psi} \cdot R_t^* + \tilde{\Psi} \cdot \left[\exp\left(D_t - \overline{D}\right) - 1\right]. \end{aligned} \tag{22}$$

Unlike the model with collateral constraints[30], the responses of debt holdings exhibit countercyclical movements and show symmetric patterns about the sign of each shock. Indeed, we verify that household credit flow-to-output ratio also exhibits the same pattern through the impulse responses on impact shown in Figure 12. Without the collateral constraint, households have better insurance against negative shocks, that is, they increase their borrowing for consumption smoothing. This leads to more volatile household credit flows and less volatile consumption. The relative consumption volatility gets down by 26% compared to the benchmark case. For the welfare implication, we find that the level effect on welfare gains is very dependent on parameterization of the debt-elastic interest rate and hence the value on total welfare gains, $\lambda^X = -.23\%$ and the level component, $\lambda^X_{lev} = -.29\%$ are not robust. However, we find that the welfare gains from having better insurance are robust over different parameterization. It amounts to 0.06% in terms of one quarter's steady-state consumption-labor composite over different parameterization for the debt-elastic interest rate.

[30] See Figure 9.

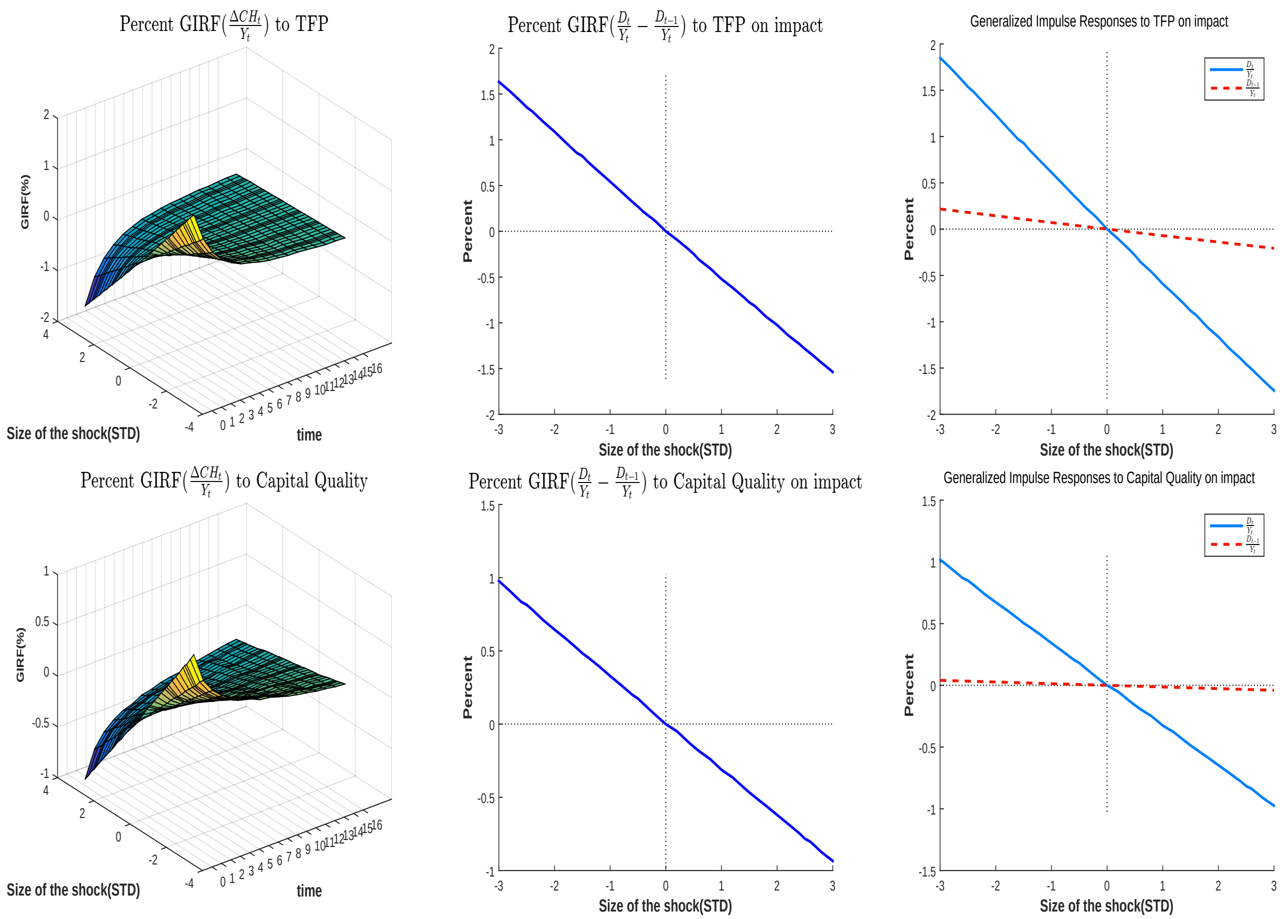


Figure 12: Generalized Impulse Responses to Shocks in Productivity and Capital Quality under the Debt-Elastic Interest Rate

Note – TFP stands for the productivity and ψ denotes the capital quality. The first row reports the impulse response of household credit flow-to-output ratio to TFP shock. The second row reports the impulse response of household credit flow-to-output ratio to capital quality shock.

Table 7: Business and Credit Cycle Statistics: Counterfactual Experiment

Moment	Data (**EM**)	Data (**DM**)	Data (Korea)	Model (Benchmark)	Model (No I.C.)	Model (No C.C.)	Model (Neither)
A. Volatility of Output, Consumption, Investment, Net Exports, Interest Rates, and Credit Flows							
$\sigma(Y)$	3.10 (.18)	2.02 (.05)	2.59 (.12)	2.60	2.31	2.60	2.32
$\sigma(C)$	3.53 (.40)	1.33 (.11)	3.39 (.41)	3.09	2.97	2.28	2.19
$\sigma(C)/\sigma(Y)$	1.14 (.06)	0.66 (.04)	1.31 (.10)	1.19	1.28	0.88	0.94
$\sigma(I)/\sigma(Y)$	2.56 (.11)	2.19 (.08)	2.17 (.12)	2.13	1.17	2.13	1.16
$\sigma(NX/Y)/\sigma(Y)$	0.81 (.07)	0.67 (.04)	1.10 (.08)	0.58	0.18	0.49	0.44
$\sigma(R)/\sigma(Y)$	0.30 (.04)	0.13 (.01)	0.14 (.01)	0.07	0.00	0.07	0.00
$\sigma(\Delta CH/Y)/\sigma(Y)$	0.50 (.06)	0.74 (.05)	1.10 (.12)	0.09	0.09	0.34	0.35
$\sigma(\Delta CF/Y)/\sigma(Y)$	1.36 (.13)	2.38 (.16)	1.87 (.27)	1.93	1.27	1.93	1.27
B. Correlation with Output							
$\rho(Y, Y_{-1})$	0.81 (.03)	0.82 (.02)	0.76 (.06)	0.78	0.72	0.78	0.72
$\rho(Y, C)$	0.83 (.03)	0.61 (.03)	0.77 (.04)	0.98	0.97	0.86	0.82
$\rho(Y, I)$	0.83 (.03)	0.75 (.02)	0.76 (.04)	0.67	0.66	0.67	0.66
$\rho(Y, \frac{NX}{Y})$	-.44 (.06)	-.00 (.05)	-.51 (.07)	-.42	-.48	0.11	0.51
$\rho(Y, R)$	-.38 (.08)	0.26 (.05)	-.74 (.03)	-.55	0.00	-.55	0.00
$\rho(Y, \frac{\Delta CH}{Y})$	0.42 (.03)	0.15 (.04)	0.56 (.05)	0.15	0.12	-.93	-.91
$\rho(Y, \frac{\Delta CF}{Y})$	0.34 (.03)	0.36 (.03)	0.34 (.03)	0.23	0.34	0.23	0.34
C. Frequency of Binding Constraints							
C.C.				46.3 %	44.0 %	N/A	N/A
I.C.				100.0 %	N/A	100.0 %	N/A
D. Welfare Comparison with respect to Model(Benchmark)							
λ^C				-	0.17%	-.10%	0.13%
λ^X				-	0.41%	-.23%	0.32%
λ^X_{lev}				-	0.45%	-.29%	0.29%
λ^X_{unc}				-	-.04%	0.06%	0.03%
E. Welfare Comparison with respect to Model(No I.C.)							
λ^C					-		-.03%
λ^X					-		-.09%
λ^X_{lev}					-		-.16%
λ^X_{unc}					-		0.07%
F. Welfare Comparison with respect to Model(No C.C.)							
λ^C						-	0.22%
λ^X						-	0.56%
λ^X_{lev}						-	0.60%
λ^X_{unc}						-	-.04%

Note – For details of data and notations, see tables 1 and 2. **EM** stands for emerging markets. **DM** denotes developed markets. The column with "Model(Benchmark)" shows the results from the model with the collateral constraint and the incentive constraint. The column with "Model(No I.C.)" presents the results from the model without the incentive constraint but with the collateral constraint. The column with "Model(No C.C.)" reports the results from the model without the collateral constraint but with the incentive constraint. The column with "Model(Neither)" reports the results from the model without both constraints. λ^C denotes consumption equivalent variation. λ^X stands for consumption-labor composite equivalent variation and λ^X_{lev} and λ^X_{unc} are its level and uncertainty components. See footnotes in the text for details.

7 Sensitivity Analysis

How sensitive are our results to alternative parameterization for the banking sector? How important is it to capture the precautionary savings behavior under the presence of occasionally binding constraints by the global nonlinear method? How different are our results from those of the model with *Bernanke-Gertler-Gilchrist* financial frictions? In this section, we explore these issues.

Alternative calibration for the banking sector The crucial parameters for the countercyclical interest rates are those three parameters from the banking sector: survival rate of the bankers, ϕ, fraction of divertible assets, m_B, and fraction of income transferred to new bankers, ξ. In this subsection, we vary these three variables and report the results. In doing so, we maintain our baseline strategy for calibration, that is, we target 4.7% annual interest rate and the leverage ratio of 6.5. Hence, we vary the value for the survival rate of the bankers, ϕ and then adjust values for the other two parameters, m_B and ξ in order to match the targeted levels of the interest rate and the leverage ratio in the deterministic steady state. Table 8 presents the results. When we reduce the value for ϕ, we can see that overall statistics considerably change in moving from $\phi = 0.92$ to $\phi = 0.88$ and then statistics are not abruptly changed in the range of $\phi \in [0.72, 0.88]$. Note that this result is from changing all three financial sector parameters, $\{\phi, m_B, \xi\}$ since we fix the steady state loan interest rate and the leverage ratio of the bankers. In decreasing the survival rate, ϕ, volatilities of all business cycles tend to increase and their comovements with output tend to be smaller. Especially, household credit flows are relatively more affected: as the flows become more volatile, collateral constraints are binding less frequently and their cyclical pattern becomes less procyclical or acyclical. Therefore, under our calibration, higher survival rate for the bankers induces less volatile and more procyclical household credit flows by making collateral constraints bind more frequently.

Precautionary savings behavior and comparison to the Bernanke, Gertler, and Gilchrist (1999) model Table 9 shows the results from two kinds of model variation. Firstly, we change the solution method from the global nonlinear method to the piecewise linearization with regime switching developed by Guerrieri and Iacoviello (2015). Our focus from this exercise is to understand how important to capture the precautionary savings motive under occasionally binding constraints.[31] Second, we change the model with *Gertler-Kiyotaki(2010)* (*GK*, henceforth) financial frictions to the model with *Bernanke-Gertler-Gilchrist* (*BGG*, henceforth) financial frictions. The solution method for the *BGG* model is the piecewise linearization with regime switching. For this exercise, we keep all parameter values used in the benchmark model except the elasticity of Tobin's Q with respect to investment, Φ_{KK}.[32] The details of the *BGG* model are relegated to the appendix F.

Firstly, by comparing the second column with the third column of Table 9, we can see that ignoring the precautionary savings motive by using regime-switching linearization makes collateral constraints binding more frequently: 46.4% vs. 57.2%. As a result, the positive comovement of household credit flows with output is exaggerated by 66%: 0.15 vs. 0.25, and consumption volatility is overestimated by 6%: 3.09 vs. 3.28. Other statistics are roughly comparable except output. Output volatility is also overestimated under the linearized solution by 4%: 2.60 vs. 2.70. Therefore, we can conclude that capturing the precautionary savings motive matters for precisely assessing the dynamic behavior of output, consumption, and household credit flows in our model.

Second, we compare the model of *GK* financial friction with the model of *BGG* financial friction by examining their simulated business cycle moments. Our focus of this exercise is on figuring out the quantitative difference between *GK* financial frictions and *BGG* financial frictions[33] since both approaches reveal the mechanism of the countercyclical interest rate. Since we solve the *BGG* model by linearization with regime switching, we compare the third column (Model, Benchmark, IG:2015) with the last column (Model, BGG:1999, IG:2015) of Table 9. The main finding is the sharp difference in the volatility of business credit flows: 4.99 vs. 1.05. Other statistics are approximately comparable. Why do those two models

[31] Comparison between the column with Model(Nonlinear) and the column with Model(IG:2015) shows the difference between nonlinear solution and piecewisely-linearized solution.

[32] For parameterization of the *BGG* model, we set Φ_{KK} at 0.0190. We fix the survival probability of *BGG* entrepreneurs at 0.99125. We set the monitoring cost parameter at 0.02 and the standard deviation of idiosyncratic productivity at 1.051549.

[33] Fernández and Gulan (2015) endogenizes the countercyclical interest rate by using the *BGG* financial friction.

have sharp contrast in the dynamics of business credit flows? Note that entrepreneurs in the GK model are just pass-through from the banking sector to the production sector. They do not accumulate any net worth to get funding from the bankers since the GK model assume that bankers have perfect technology to monitor the behavior of entrepreneurs and absorb all of their profits. On the other hand, in the BGG model, there are financial frictions between entrepreneurs and domestic bankers since entrepreneurs have private information and bankers must pay monitoring costs to verify their profits in the case of defaulting. Therefore, entrepreneurs accumulate their net worth to get external funding from bankers and their net worth accumulation acts as a buffer stock against external financing. In turn, the volatility of business credit flows is mitigated by the degree of net worth accumulation of entrepreneurs in the BGG model. On the other hand, in the GK model, bankers accumulate their net worth due to incentive constraints imposed by international lenders and there is no friction between domestic bankers and entrepreneurs. Hence, dynamics of business credit flows in the GK model are more in line with the empirical data in terms of volatility.

Table 8: Business and Credit Cycle Statistics: Sensitivity Analysis

Moment	Model	Model	Model	Model	Model	Model
Value for ϕ :	0.72	0.76	0.80	0.84	0.88	0.92
A. Relative Volatility of Consumption, Investment, Net Exports, Interest Rates, and Credit Flows						
$\sigma(Y)$	2.63	2.67	2.70	2.72	2.72	2.60
$\frac{\sigma(C)}{\sigma(Y)}$	1.35	1.33	1.30	1.27	1.24	1.19
$\frac{\sigma(I)}{\sigma(Y)}$	3.13	3.26	3.36	3.37	3.16	2.13
$\frac{\sigma(NX/Y)}{\sigma(Y)}$	1.07	1.10	1.11	1.08	0.99	0.58
$\frac{\sigma(R)}{\sigma(Y)}$	0.16	0.16	0.16	0.16	0.14	0.07
$\frac{\sigma(\Delta CH/Y)}{\sigma(Y)}$	0.24	0.20	0.16	0.13	0.10	0.09
$\frac{\sigma(\Delta CF/Y)}{\sigma(Y)}$	2.71	2.78	2.81	2.78	2.60	1.93
B. Volatility of Consumption, Investment, Net Exports, Interest Rates, and Credit Flows						
$\sigma(C)$	3.56	3.54	3.51	3.47	3.38	3.09
$\sigma(I)$	8.23	8.70	9.07	9.18	8.59	5.53
$\sigma(NX/Y)$	2.83	2.93	2.99	2.95	2.68	1.51
$\sigma(R)$	0.42	0.43	0.44	0.43	0.37	0.19
$\sigma(\Delta CH/Y)$	0.63	0.54	0.44	0.35	0.27	0.22
$\sigma(\Delta CF/Y)$	7.14	7.41	7.59	7.57	7.06	5.01
C. Correlation with Output						
$\rho(Y, Y_{-1})$	0.79	0.80	0.80	0.80	0.80	0.78
$\rho(Y, C)$	0.94	0.94	0.95	0.96	0.97	0.98
$\rho(Y, I)$	0.51	0.50	0.49	0.50	0.53	0.67
$\rho(Y, \frac{NX}{Y})$	-.33	-.32	-.32	-.32	-.34	-.42
$\rho(Y, R)$	-.41	-.42	-.44	-.45	-.48	-.55
$\rho(Y, \frac{\Delta CH}{Y})$	-.04	-.02	0.02	0.06	0.13	0.15
$\rho(Y, \frac{\Delta CF}{Y})$	0.16	0.16	0.16	0.16	0.17	0.23
D. Frequency of Binding Constraints						
C.C.	29.7 %	31.9 %	33.1 %	35.8 %	39.4 %	46.3 %
I.C.	99.4 %	99.2 %	99.2 %	99.5 %	99.9 %	100 %

Note − For details of notations, see tables 1 and 2. *C.C.* denotes the collateral constraint. *I.C.* stands for the incentive constraint. Each column reports the results from the benchmark model with the different parameter value of ϕ specified and different values for m_B and ξ adjusted for matching the target 4.7% interest rate and 6.5 leverage in the steady state.

Table 9: Business and Credit Cycle Statistics: Sensitivity Analysis

Moment	Model (Benchmark) (Nonlinear)	Model (Benchmark) (IG:2015)	Model (BGG:1999) (IG:2015)
A. Relative Volatility of Consumption, Investment, Net Exports, Interest Rates, and Credit Flows			
$\sigma(Y)$	2.60	2.70	2.75
$\frac{\sigma(C)}{\sigma(Y)}$	1.19	1.21	1.06
$\frac{\sigma(I)}{\sigma(Y)}$	2.13	2.05	2.01
$\frac{\sigma(NX/Y)}{\sigma(Y)}$	0.58	0.58	0.45
$\frac{\sigma(R)}{\sigma(Y)}$	0.07	0.07	0.02
$\frac{\sigma(\Delta CH/Y)}{\sigma(Y)}$	0.09	0.10	0.10
$\frac{\sigma(\Delta CF/Y)}{\sigma(Y)}$	1.93	1.85	0.38
B. Volatility of Consumption, Investment, Net Exports, Interest Rates, and Credit Flows			
$\sigma(C)$	3.09	3.28	2.90
$\sigma(I)$	5.53	5.52	5.53
$\sigma(NX/Y)$	1.51	1.56	1.23
$\sigma(R)$	0.19	0.19	0.05
$\sigma(\Delta CH/Y)$	0.22	0.26	0.27
$\sigma(\Delta CF/Y)$	5.01	4.99	1.05
C. Correlation with Output			
$\rho(Y, Y_{-1})$	0.78	0.79	0.80
$\rho(Y, C)$	0.98	0.98	0.99
$\rho(Y, I)$	0.67	0.66	0.76
$\rho(Y, \frac{NX}{Y})$	-.42	-.41	-.37
$\rho(Y, R)$	-.55	-.57	-.36
$\rho(Y, \frac{\Delta CH}{Y})$	0.15	0.25	0.32
$\rho(Y, \frac{\Delta CF}{Y})$	0.23	0.23	0.35
D. Frequency of Binding Constraints			
$C.C.$	46.4 %	57.2 %	61.8 %
$I.C.$	100 %	100 %	N.A.

Note − For details of notations, see tables 1 and 2. *C.C.* denotes the collateral constraint. *I.C.* stands for the incentive constraint. The column with "Model(Benchmark)" shows the results from the model with the collateral constraint and the incentive constraint. The column with "(Nonlinear)" reports the results from the global nonlinear method. The column with "(IG:2015)" presents the results from the linearized solution with regime switching developed by Guerrieri and Iacoviello (2015). The column with "(BGG:1999)" presents the results from the model with Bernanke, Gertler, and Gilchrist (1999) financial frictions solved by the method of Guerrieri and Iacoviello (2015).

8 Conclusion

This paper has introduced dual financial frictions in both the household sector and the banking sector to an otherwise standard SOE-RBC model. We have investigated the model mechanism to rationalize countercyclical interest rates, excessively volatile consumption, and procyclical credit flows. We have also evaluated the welfare implications of financial frictions.

Our model with dual financial constraints performs well in explaining overall pattern of volatilities and comovements of business and credit cycles but the model cannot generate volatile household credit flows. We show that the standard SOE-RBC model without collateral constraints can generate more volatile household credit flows but the direction of the comovement with output becomes the opposite to the data. Financial frictions between international lenders and domestic bankers impose an upper bound on leverage of the banking sector and countercyclical banking-sector leverage induces countercyclical real interest rates through the countercyclical shadow value of retained earnings.

When the default risk in the financial sector is completely eliminated, business cycle fluctuations become less volatile. Consumption volatility relative to output increases because the decrease in output volatility outweighs the drop in consumption volatility. We find that the economy without the banking friction is better off by the increase in the steady-state level of consumption-labor composite which exceeds the welfare loss incurred by increased uncertainty. On the other hand, replacing collateral constraints with debt-elastic interest rates leads to better consumption insurance by allowing for more borrowing in response to negative income shocks but this leads to strongly countercyclical household credit flows which are at odds with the data.

Finally, we compare two economies by eliminating the default risk in the banking sector. More elaborate policy analysis would include unconventional monetary and credit policies which were practiced by U.S. FRB and the European Central Bank. We are working on this direction of policy intervention.

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A Appendix: Recursive Competitive Equilibrium

In this section, we characterize the recursive competitive equilibrium. Our solution method is policy time iteration and results from the global nonlinear solution are presented in the main text. Let's denote the aggregate state vector by $\mathbb{S} = [D, B^*, K, z, \psi]$. Hereafter, we set the world interest rate to a constant R^*. Households' problem in the recursive form is given by

$$\begin{aligned}
v^H(d;\mathbb{S}) &= \max_{\{c,h,d'\}} \left\{ \frac{\left[c - \chi \cdot \frac{h^{1+\gamma}}{1+\gamma}\right]^{1-\sigma}}{1-\sigma} + \beta \mathbb{E}_{\mathbb{S}} \left[v^H(d';\mathbb{S}') \right] \right\} \\
s.t. \quad & c + R^D \cdot d = W(\mathbb{S}) \cdot h + d' + \Pi^F(\mathbb{S}) + \Pi^B(\mathbb{S}) \\
& R^D \cdot d' \leq m_H \cdot \mathbb{E}_{\mathbb{S}} \left[W(\mathbb{S}') H(\mathbb{S}') \right] \\
& \mathbb{S}' = \mathbf{\Gamma}(\mathbb{S})
\end{aligned}$$

where $R^D = R^*$ holds and $\mathbf{\Gamma}(\cdot)$ stands for the vector of the law of motion for the aggregate state variables which are taken as given by private agents. Households' efficiency conditions are represented by

$$\begin{aligned}
W(\mathbb{S}) &= \chi \cdot h(d;\mathbb{S})^\gamma \\
1 &= R^D \cdot \beta \mathbb{E}_{\mathbb{S}} \left[\frac{\left\{ c(d';\mathbb{S}') - \chi \cdot \frac{h(d';\mathbb{S}')^{1+\gamma}}{1+\gamma} \right\}^{-\sigma}}{\left\{ c(d;\mathbb{S}) - \chi \cdot \frac{h(d;\mathbb{S})^{1+\gamma}}{1+\gamma} \right\}^{-\sigma}} \right] + R^D \cdot \mu^H(\mathbb{S}) \\
0 &= \mu^H(\mathbb{S}) \cdot \left\{ m_H \cdot \mathbb{E}_{\mathbb{S}} \left[W(\mathbb{S}') H(\mathbb{S}') \right] - R^D \cdot d'(d;\mathbb{S}) \right\}
\end{aligned}$$

where $\mu^H(\mathbb{S}) \geq 0$ and $m_H \cdot \mathbb{E}_{\mathbb{S}} \left[W(\mathbb{S}') H(\mathbb{S}') \right] \geq R^D \cdot d'(d;\mathbb{S})$ must hold.

The bank's problem also admits a recursive representation and is defined as

$$\begin{aligned}
v^B(n;\mathbb{S}) &= \max_{\{l, b^{*'}, n'\}} \mathbb{E}_{\mathbb{S}} \left\{ \frac{1}{R^*} \left[(1-\phi) \cdot n' + \phi \cdot v^B(n';\mathbb{S}') \right] \right\} \\
s.t. \quad & l = n + b^{*'} \\
& n' = R^K(\mathbb{S}') \cdot l - R^* \cdot b^{*'} \\
& v^B(n;\mathbb{S}) \geq m_B \cdot l \\
& \mathbb{S}' = \mathbf{\Gamma}(\mathbb{S})
\end{aligned}$$

The economy-wide net-worth, external debt, and loan of the banking sector are respectively defined as $N = \int_0^\infty n \, dF(n)$, $B^{*'} = \int_0^\infty b^{*'}(n) \, dF(n)$, and $L = \int_0^\infty l(n) \, dF(n)$. The law of motion for the economy-wide net worth of the banking sector can be rewritten as

$$N(\mathbb{S}') = (\phi + \xi) \cdot q^K(\mathbb{S}) K'(\mathbb{S}) \cdot R^K(\mathbb{S}') - \phi \cdot R^* \cdot B^{*'}(\mathbb{S})$$

where the state-contingent loan rate is given by

$$R^K(\mathbb{S}') = \frac{\theta_K \frac{Y(\mathbb{S}')}{K'(\mathbb{S})} + \psi' \cdot q^K(\mathbb{S}') \cdot (1-\delta)}{q^K(\mathbb{S})}$$

Aggregate efficiency conditions of the banking sector are defined by

$$\begin{aligned}
\mu^B(\mathbb{S}) \cdot m_B &= \mathbb{E}_{\mathbb{S}}\left[\frac{1}{R^*}(1-\phi+\phi\cdot\overline{\omega}(\mathbb{S}'))\cdot\left\{R^K(\mathbb{S}') - R^*\right\}\right] \\
\overline{\omega}(\mathbb{S}) &= \frac{\mathbb{E}_{\mathbb{S}}\left[\frac{1}{R^*}(1-\phi+\phi\cdot\overline{\omega}(\mathbb{S}'))\cdot R^*\right]}{1-\mu^B(\mathbb{S})} \\
\mu^B(\mathbb{S})\cdot\overline{\omega}(\mathbb{S})\cdot N(\mathbb{S}) &= \mu^B(\mathbb{S})\cdot m_B \cdot L(\mathbb{S}) \\
V^B(\mathbb{S}) &= \int_0^\infty v^B(n;\mathbb{S})\, dF(n) = \overline{\omega}(\mathbb{S})\cdot N(\mathbb{S})
\end{aligned}$$

where $\mu^B(\mathbb{S}) \geq 0$ and $\overline{\omega}(\mathbb{S})\cdot N(\mathbb{S}) \geq m_B \cdot L(\mathbb{S})$ must hold by the complementary slackness.

The efficiency conditions in the nonfinancial corporate sector can be summarized in the recursive form as follows.

$$\begin{aligned}
L(\mathbb{S}) &= q^K(\mathbb{S})\cdot K'(\mathbb{S}) \\
Y(\mathbb{S}) &= z\cdot\{\psi K\}^{\theta_K}\cdot H(\mathbb{S})^{\theta_H} \\
\theta_H \cdot \frac{Y(\mathbb{S})}{H(\mathbb{S})} &= W(\mathbb{S})\cdot[1+m_W\cdot(R^*-1)] \\
K'(\mathbb{S}) &= (1-\delta)\cdot\psi K + \Phi\left(\frac{I(\mathbb{S})}{\psi K}\right)\psi K \\
q^K(\mathbb{S}) &= \frac{1}{\phi_{K1}\cdot(1-\Phi_{KK})}\cdot\left[\frac{I(\mathbb{S})}{\psi K}\right]^{\Phi_{KK}} \\
\log(z') &= \rho_z\cdot\log(z) + \epsilon^{z'} \\
\log(\psi') &= \epsilon^{\psi'}
\end{aligned}$$

where ϵ^z and ϵ^ψ are *i.i.d* normal random shocks with zero mean. Therefore, a *recursive competitive equilibrium* of the economy is defined by value functions for households and bankers $\{v^H, v^B\}$, policy functions for households $\left\{c, h, d'\right\}$ and policy functions for bankers $\left\{l, b^{*'}, n'\right\}$ such that, given prices $\{W, R^K, q^K\}$, **(i)** households' and bankers' value functions and policies satisfy their efficiency conditions; **(ii)** the market for entrepreneurs' claims clears, $q^K(\mathbb{S})\cdot K'(\mathbb{S}) = L(\mathbb{S}) = \int_0^\infty l(n)\ dF(n)$; **(iii)** the labor market clears, $h(D;\mathbb{S}) = H(\mathbb{S})$; **(iv)** the market for goods clears, $Y(\mathbb{S}) = C(\mathbb{S}) + I(\mathbb{S}) + NX(\mathbb{S})$, $NX(\mathbb{S}) = R^D\cdot D - D'(\mathbb{S}) + R^*\cdot B^* - B^{*'}(\mathbb{S}) + (R^*-1)\cdot B^{W*}(\mathbb{S})$, and $B^{W*}(\mathbb{S}) = m_W\cdot W(\mathbb{S})H(\mathbb{S})$; **(v)** the perceived law of motion, $\mathbf{\Gamma}(\cdot)$ is consistent with agents' optimization: $D'(\mathbb{S}) = \mathbf{\Gamma}_D(\mathbb{S}) = d'(D;\mathbb{S})$, $B^{*'}(\mathbb{S}) = \mathbf{\Gamma}_{B^*}(\mathbb{S}) = \int_0^\infty b^{*'}(n;\mathbb{S})\, dF(n)$, and $K'(\mathbb{S}) = \mathbf{\Gamma}_K(\mathbb{S})$.

B Appendix: Numerical Solution

Our model features two occasionally binding constraints which make computation more involved. These two constraints make the grid points for the state space asymmetric. In addition, the asset market is incomplete and bankers' incentive constraints depend on Tobin's Q giving rise to the pecuniary externality. Since the planner's allocation is different from the competitive equilibrium allocation, the curse of dimensionality renders the standard value function iteration infeasible. Instead, we solve the model by policy time iteration. In particular, we used the combination of a parameterized expectations algorithm and a generalized stochastic simulation algorithm suggested in Christiano and Fisher (2000), Judd, Maliar, and Maliar (2011), and Judd, Maliar, Maliar, and Tsener (2016). It is known that parameterizing expectation terms rather than endogenous state policy functions produces more accurate solution in the presence of occasionally binding constraints.[34] We dealt with the issue of asymmetric grid points for the state space by applying a generalized stochastic simulation algorithm. This method enables us to approximate the nonlinear solution on the state grid points which are actually visited in the simulation path. Denoting the state variables by $\mathbb{S} = [D, B^*, K, z, \psi]$, we can specify recursive equilibrium conditions as

$$
\begin{aligned}
&[H(\mathbb{S})] && \chi \cdot H(\mathbb{S})^{1+\gamma} = \frac{\theta_H Y(\mathbb{S})}{1+m_W \cdot (R^*-1)} \\
&\left[\mu^H(\mathbb{S})\right] && \mu^H(\mathbb{S}) = \frac{1}{R^D} - \beta \cdot \mathbb{E}_{\mathbb{S}} \left[\frac{\left\{ C(\mathbb{S}') - \chi \frac{H(\mathbb{S}')^{1+\gamma}}{1+\gamma} \right\}^{-\sigma}}{\left\{ C(\mathbb{S}) - \chi \frac{H(\mathbb{S})^{1+\gamma}}{1+\gamma} \right\}^{-\sigma}} \right] \geq 0 \\
&\left[D'(\mathbb{S})\right] && \mu^H(\mathbb{S}) \cdot \left[m_H \cdot \mathbb{E}_{\mathbb{S}} \left\{ \frac{\theta_H Y(\mathbb{S}')}{1+m_W \cdot (R^*-1)} \right\} - R^D \cdot D'(\mathbb{S}) \right] = 0 \\
&[C(\mathbb{S})] && C(\mathbb{S}) + I(\mathbb{S}) + NX(\mathbb{S}) = Y(\mathbb{S}) \\
&[NX(\mathbb{S})] && NX(\mathbb{S}) = R^D \cdot D - D'(\mathbb{S}) + R^* \cdot B^* - B^{*'}(\mathbb{S}) + (R^*-1) \cdot m_W \cdot \chi \cdot H(\mathbb{S})^{1+\gamma} \\
&[Y(\mathbb{S})] && Y(\mathbb{S}) = z \cdot \{\psi \cdot K\}^{\theta_K} \cdot H(\mathbb{S})^{\theta_H} \\
&[I(\mathbb{S})] && I(\mathbb{S}) = \left[\frac{1}{\phi_{K1}} \left\{ K'(\mathbb{S}) \cdot (\psi K)^{-\Phi_{KK}} + (\delta - 1 - \phi_{K2}) \cdot (\psi K)^{1-\Phi_{KK}} \right\} \right]^{\frac{1}{1-\Phi_{KK}}} \\
&\left[q^K(\mathbb{S})\right] && q^K(\mathbb{S}) = \frac{1}{\phi_{K1} \cdot (1-\Phi_{KK})} \cdot \left[\frac{I(\mathbb{S})}{\psi K} \right]^{\Phi_{KK}} \\
&\left[K'(\mathbb{S})\right] && \mathbb{E}_{\mathbb{S}} \left[\tilde{\Lambda} \cdot \left(1 - \phi + \phi \cdot \overline{\omega}(\mathbb{S}')\right) \left(\frac{\theta_K \cdot \frac{Y(\mathbb{S}')}{K'(\mathbb{S})} + \psi' \cdot q^K(\mathbb{S}') \cdot (1-\delta)}{q^K(\mathbb{S})} \right) \right] = \overline{\omega}(\mathbb{S}) \cdot (1 - \mu^B(\mathbb{S})) + \mu^B(\mathbb{S}) \cdot m_B \\
&[\overline{\omega}(\mathbb{S})] && \overline{\omega}(\mathbb{S}) \cdot (1 - \mu^B(\mathbb{S})) = \mathbb{E}_{\mathbb{S}} \left[\tilde{\Lambda} \cdot \left(1 - \phi + \phi \cdot \overline{\omega}(\mathbb{S}')\right) R^* \right] \\
&\left[\mu^B(\mathbb{S})\right] && \mu^B(\mathbb{S}) = \max \left(0, 1 - \frac{\mathbb{E}_{\mathbb{S}} \left[\tilde{\Lambda} \cdot \left(1-\phi+\phi \cdot \overline{\omega}(\mathbb{S}')\right) R^* \right]}{m_B} \cdot \frac{N(\mathbb{S})}{q^K(\mathbb{S}) K'(\mathbb{S})} \right) < 1 \\
&\left[B^{*'}(\mathbb{S})\right] && B^{*'}(\mathbb{S}) = q^K(\mathbb{S}) K'(\mathbb{S}) - N(\mathbb{S}) \\
&[N(\mathbb{S})] && N(\mathbb{S}) = (\phi + \xi) \cdot \left[\theta_K \cdot Y(\mathbb{S}) + \psi \cdot q^K(\mathbb{S}) \cdot (1-\delta) K \right] - \phi \cdot R^* \cdot B^*
\end{aligned}
$$

where $R^D = R^*$ and $\tilde{\Lambda} = \frac{1}{R^*}$ hold. The algorithm solves for a set of nonlinear equations including the Euler equations and the Kuhn-Tucker conditions by approximating expectation terms as third-order ordinary

[34] See Christiano and Fisher (2000)

polynomial following Judd, Maliar, and Maliar (2011) and Judd, Maliar, Maliar, and Tsener (2016). To be more specific, we approximate five expectation terms:

$$\begin{aligned}
EQ^{MU}(\mathbb{S}) &\equiv \mathbb{E}_{\mathbb{S}}\left[\left\{C(\mathbb{S}^{'}) - \chi\frac{H(\mathbb{S}^{'})^{1+\gamma}}{1+\gamma}\right\}^{-\sigma}\right] \approx \exp\left(\mathcal{P}^{MU}(\log(\mathbb{S}); \mathbf{b}^{MU})\right)\\
EQ^{Y}(\mathbb{S}) &\equiv \mathbb{E}_{\mathbb{S}}\left[Y(\mathbb{S}^{'})\right] \approx \exp\left(\mathcal{P}^{Y}(\log(\mathbb{S}); \mathbf{b}^{Y})\right)\\
EQ^{R}(\mathbb{S}) &\equiv \mathbb{E}_{\mathbb{S}}\left[\tilde{\Lambda}\cdot\left(\theta_K\cdot\frac{Y(\mathbb{S}^{'})}{K^{'}(\mathbb{S})} + \psi^{'}\cdot q^K(\mathbb{S}^{'})\cdot(1-\delta)\right)\right] \approx \exp\left(\mathcal{P}^{R}(\log(\mathbb{S}); \mathbf{b}^{R})\right)\\
EQ^{\nu_l}(\mathbb{S}) &\equiv \mathbb{E}_{\mathbb{S}}\left[\tilde{\Lambda}\cdot\overline{\omega}(\mathbb{S}^{'})\cdot\left(\theta_K\cdot\frac{Y(\mathbb{S}^{'})}{K^{'}(\mathbb{S})} + \psi^{'}\cdot q^K(\mathbb{S}^{'})\cdot(1-\delta)\right)\right] \approx \exp\left(\mathcal{P}^{\nu_l}(\log(\mathbb{S}); \mathbf{b}^{\nu_l})\right)\\
EQ^{\overline{\omega}}(\mathbb{S}) &\equiv \mathbb{E}_{\mathbb{S}}\left[\tilde{\Lambda}\cdot\overline{\omega}(\mathbb{S}^{'})\right] \approx \exp\left(\mathcal{P}^{\overline{\omega}}(\log(\mathbb{S}); \mathbf{b}^{\overline{\omega}})\right)
\end{aligned}$$

where each polynomial term is defined as $\mathcal{P}(\log(\mathbb{S}); \mathbf{b}) = b_0 + b_1\log(D) + b_2\log(B^*) + b_3\log(K) + b_4\log(z) + b_5\log(\psi) + \cdots + b_j\log(K)\log(z)\log(\psi) + \cdots + b_n[\log(\psi)]^3$ up to the third order. The exact algorithm proceeds as follows:

(0) Guess initial values for $\tilde{\mathbf{b}}^0 = \left[\mathbf{b}^{MU,0}, \mathbf{b}^{Y,0}, \mathbf{b}^{R,0}, \mathbf{b}^{\nu_l,0}, \mathbf{b}^{\overline{\omega},0}\right]$.[35] Set the initial state, $\mathbb{S}_0$ to the deterministic steady state and obtain $5,000$ realizations of random disturbances for the process of productivity, z and capital quality, ψ. The initial state, $\mathbb{S}_0$ and the sequence of $5,000$ exogenous shock realizations must be the same over iterations for the convergence.

(1) Simulate the model for $5,000$ periods by solving equilibrium conditions. In each period, the state vector, $\mathbb{S} = [D, B^*, K, z, \psi]$ pins down the expectation terms, $EQ(\mathbb{S})$ from their approximated polynomials, $\exp\left(\mathcal{P}(\log(\mathbb{S}); \mathbf{b}^0)\right)$. Then we solve for every endogenous variable either by using its closed-form formulation or by using one-dimensional root-finding numerical method.[36]

(2) After obtaining all simulated state values of $\{\mathbb{S}_t\}_{t=0}^{5,000}$, we calculate the set of one step-ahead conditional expectations, $\left[EQ^{MU}, EQ^{Y}, EQ^{R}, EQ^{\nu_l}, EQ^{\overline{\omega}}\right]$ by using numerical integration methods.[37]

(3) Derive a new set of polynomial coefficients, $\tilde{\mathbf{b}}^1$ by regressing the log of the conditional expectations, $\left\{EQ_t^{MU}, EQ_t^{Y}, EQ_t^{R}, EQ_t^{\nu_l}, EQ_t^{\overline{\omega}}\right\}_{t=1}^{5,000}$ obtained in step **(2)** on their approximated polynomials of which arguments are given by $\{\log(\mathbb{S}_t)\}_{t=0}^{4,999}$ from step **(1)**.

[35] For the initialization of polynomial coefficients, we simulate the model by using a piecewise linear algorithm with regime switching developed in Guerrieri and Iacoviello (2015). This method can capture inequality constraints which bind occasionally. However it cannot take account of precautionary behavior linked to the possibility that a constraint may become binding in the future.

[36] We implemented the bisection method for finding $K^{'}(\mathbb{S})$. Other endogenous variables are pinned down by their closed-form formulation.

[37] We used Gauss-Hermite quadrature method with 3 nodes. For each node, we compute the one step-ahead shock process by $\log(z^{'}) = \rho_z\cdot\log(z) + \epsilon_i^z$ and $\log(\psi^{'}) = \epsilon_j^{\psi}$ for $i, j = 1, 2, 3$.

(4) If $\tilde{\mathbf{b}}^1$ and $\tilde{\mathbf{b}}^0$ are close enough, then stop. If not, update $\tilde{\mathbf{b}}^0$ by setting $\tilde{\mathbf{b}}^0 = \lambda_b \tilde{\mathbf{b}}^1 + (1 - \lambda_b) \cdot \tilde{\mathbf{b}}^0$ and go back to step **(1)**.

C Appendix: Accuracy of numerical solution

Following Judd (1992) and Judd, Maliar, Maliar, and Tsener (2016), we check the accuracy of the numerical solution for the benchmark model by computing Euler equation errors over simulation. In particular, we define Euler equation errors as

$$
\begin{aligned}
EEE_t^{MU} &= \left| \beta \cdot R_t^D \cdot \frac{\mathbb{E}_t\left[\left\{C_{t+1} - \chi \cdot \frac{{H_{t+1}}^{1+\gamma}}{1+\gamma}\right\}^{-\sigma}\right]}{\left\{C_t - \chi \cdot \frac{{H_t}^{1+\gamma}}{1+\gamma}\right\}^{-\sigma}} + R_t^D \cdot \mu_t^H - 1 \right| \\
EEE_t^{\nu^l} &= \left| \frac{\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}(1 - \phi + \phi \cdot \overline{\omega}_{t+1}) \cdot \left(\frac{\theta_K \cdot \frac{Y_{t+1}}{K_{t+1}} + \psi_{t+1} \cdot q_{t+1}^K \cdot (1-\delta)}{q_t^K}\right)\right]}{\overline{\omega}_t(1 - \mu_t^B) + \mu_t^B \cdot m_B} - 1 \right| \\
EEE_t^{\nu^b} &= \left| \frac{\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}(1 - \phi + \phi \cdot \overline{\omega}_{t+1}) \cdot R_t^*\right]}{\overline{\omega}_t \cdot (1 - \mu_t^B)} - 1 \right|
\end{aligned}
$$

where $\tilde{\Lambda}_{t,t+1}$ is defined as $\tilde{\Lambda}_{t,t+1} = \frac{1}{R_t^*}$.

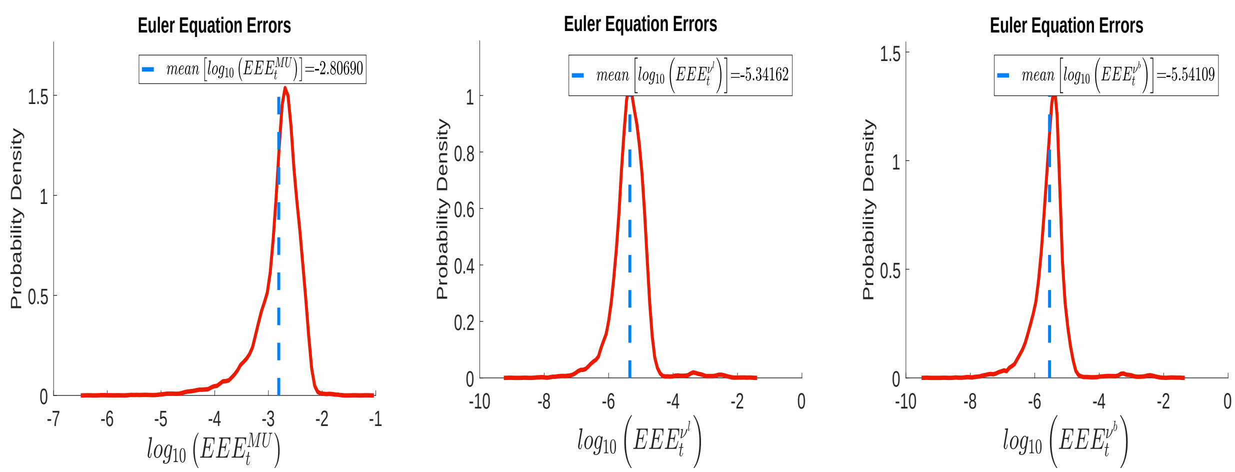

Figure 13: The Kernel-smoothed histogram of Euler equation errors

On average, Euler equation errors are on the order of -3 for the household's euler equation and -5 for the banker's euler equations. These numbers are comparable to values reported in Bocola (2016) and Akinci and Queralto (2017), which implies that they are within reasonable tolerance.

D Appendix: Can alternative specifications generate procyclical credit flows to households?

In this section, we investigate whether other alternative specifications of the model can generate procyclical credit flows to households. Our focus is on examining whether we need two occasionally binding constraints, the collateral constraint and the incentive constraint, to match business and credit cycles of emerging economies. From Table 10, the answer to this question is "yes": we need collateral constraints to generate procyclical household credit flows. All alternative models are solved by piecewise-linearization with regime switching developed by Guerrieri and Iacoviello (2015).

Alternative specification 1 In the previous literature, the SOE model with the debt-elastic interest rate generates countercyclical net exports and excessively volatile consumption by using highly persistent productivity process.[38] We investigate whether the same approach can generate countercyclical household credit flows. To this end, we replace collateral constraints of the benchmark model with debt-elastic interest rates. We parameterize the debt-elastic interest rate as we did with the model without collateral constraints in Section 6. Then we fixed the persistence and the size of the TFP process at 0.9999 and 0.00013 to match the output volatility. We removed the capital quality shock in order to clearly see the effect of the persistence of the productivity process. The fifth column in Table 10 shows the result. Note that the alternative approach can generate highly volatile consumption and countercyclical net exports as in the previous literature: the relative volatility of consumption is 1.01 and the correlation of net exports with output is −0.13. However, it produces acyclical household credit flows: the correlation coefficient with output is given by −0.02, which is at odds with the data.

Alternative specification 2 For the second experiment, we assume that the household borrows funds from domestic banks, not from the international financial market and the loan to households does not induce any financial friction for the bankers. The interest rates at which households and bankers borrow are dependent on the economy-wide external borrowing, B_t^*. The household's problem is given by

$$\max_{\{C_t, H_t, D_t\}} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\left[C_t - \chi \cdot \frac{H_t^{1+\gamma}}{1+\gamma}\right]^{1-\sigma}}{1-\sigma}$$

$$s.t. \quad C_t + R_{t-1}^D \cdot D_{t-1} = W_t H_t + D_t + \Pi_t^F + \Pi_t^B$$

The nonfinancial corporate firm sector is exactly the same with the benchmark model. However, bankers

[38] The productivity process which is very persistent brings about countercyclical net exports and excessively volatile consumption because it reduces the marginal utility of future consumption relative to that of current consumption.

now solve the following problem.

$$v_t(n_t) = \max_{\{l_t, d_t, b_t^*, n_{t+1}\}} \mathbb{E}_t \sum_{\tau=t+1}^{\infty} \left(\frac{1}{\Pi_{h=t}^{\tau-1} R_h^*} \right) (1-\phi)\phi^{\tau-(t+1)} \cdot n_\tau$$

$$s.t. \quad \begin{cases} l_t + d_t = n_t + b_t^* \\ n_{t+1} = R_{t+1}^K \cdot l_t - R_t^D \cdot (b_t^* - d_t) \\ v_t(n_t) \geq m_B \cdot l_t \end{cases}$$

where l_t denotes the loan extended to entrepreneurs and d_t denotes the amount of the household's borrowing from the bankers, which implies $D_t = \int_0^\infty d_t(n)\, dF_t(n)$ in aggregate. The interest rate, R_t^D is determined by $R_t^D = \overline{\Psi} \cdot R_t^* + \tilde{\Psi} \cdot \left[\exp\left(B_t^* - \overline{b}^*\right) - 1\right]$. In this alternative model, the net exports, NX_t is given by $NX_t = R_{t-1}^D B_{t-1}^* - B_t^* + (R_{t-1}^D - 1) \cdot B_t^{W*}$, where the working capital loan is defined as $B_t^{W*} = m_W W_t H_t$. We assign $\frac{1}{\beta \cdot R^*}$ and 0.001 to $\overline{\Psi}$ and $\tilde{\Psi}$, respectively. We set $\overline{b}^*$ at 2.05. We recalibrate banking-sector parameters, $\{\phi, m_B, \xi\}$ as $\{0.9500, 0.5660, 0.0051\}$. We verify in the sixth column of Table 10 that this specification generates strongly countercyclical household credit flows: the correlation coefficient is -0.94. We checked that this property held for the other values for banking-sector parameters.

Alternative specification 3 For the third alternative specification, we extend the model of the second alternative specification in a way that the loan to households also incurs financial frictions for the bankers. Specifically, bankers solve the following problem.

$$v_t(n_t) = \max_{\{l_t, d_t, b_t^*, n_{t+1}\}} \mathbb{E}_t \sum_{\tau=t+1}^{\infty} \left(\frac{1}{\Pi_{h=t}^{\tau-1} R_h^*} \right) (1-\phi)\phi^{\tau-(t+1)} \cdot n_\tau$$

$$s.t. \quad \begin{cases} l_t + d_t = n_t + b_t^* \\ n_{t+1} = R_{t+1}^K \cdot l_t + R_t^D \cdot d_t - R_t^* \cdot b_t^* \\ v_t(n_t) \geq m_B \cdot \{l_t + m_D \cdot d_t\} \end{cases}$$

Note that under this specification, bankers can divert m_B portion of the loan to entrepreneurs, l_t and $m_B \cdot m_D$ fraction of the loan to households, d_t, which implies the loan rate to households, R_t^D is endogenously determined through the efficiency condition of the loan to households, d_t. The last column in Table 10 shows the results. We recalibrate the banking-sector parameters, $\{\phi, m_B, m_D, \xi\}$ as $\{0.7000, 0.23883, 0.87658, 0.013085\}$, respectively. We can see that the credit flows to households exhibit negative correlation with output: the correlation coefficient is -0.83. We tested with several alternative parameter values and obtained the same result for the cyclicality of household credit flows.

Table 10: Business and Credit Cycle Statistics: Alternative Model Experiment

Moment	Data (**EM**)	Data (Korea)	Model (Benchmark)	Model (Spec.1)	Model (Spec.2)	Model (Spec.3)
A. Volatility of Output, Consumption, Investment, Net Exports, Interest Rates, and Credit Flows						
$\sigma(Y)$	3.10 (.18)	2.59 (.12)	2.60	2.73	2.89	2.64
$\frac{\sigma(C)}{\sigma(Y)}$	1.14 (.06)	1.31 (.10)	1.19	1.01	1.13	0.64
$\frac{\sigma(I)}{\sigma(Y)}$	2.56 (.11)	2.17 (.12)	2.13	1.01	1.90	2.51
$\frac{\sigma(NX/Y)}{\sigma(Y)}$	0.81 (.07)	1.10 (.08)	0.58	0.04	0.48	0.52
$\frac{\sigma(R)}{\sigma(Y)}$	0.30 (.04)	0.14 (.01)	0.07	0.00	0.05	0.11
$\frac{\sigma(\Delta CH/Y)}{\sigma(Y)}$	0.50 (.06)	1.10 (.12)	0.09	0.00	0.27	0.65
$\frac{\sigma(\Delta CF/Y)}{\sigma(Y)}$	1.36 (.13)	1.87 (.27)	1.93	0.07	1.35	1.85
B. Correlation with Output						
$\rho(Y, Y_{-1})$	0.81 (.03)	0.76 (.06)	0.78	1.00	0.82	0.79
$\rho(Y, C)$	0.83 (.03)	0.77 (.04)	0.98	1.00	0.82	0.97
$\rho(Y, I)$	0.83 (.03)	0.76 (.04)	0.67	0.99	0.79	0.57
$\rho(Y, \frac{NX}{Y})$	-.44 (.06)	-.51 (.07)	-.42	-.13	-.14	0.36
$\rho(Y, R)$	-.38 (.08)	-.74 (.03)	-.55	0.00	-.70	-.48
$\rho(Y, \frac{\Delta CH}{Y})$	0.42 (.03)	0.56 (.05)	0.15	-.02	-.94	-.83
$\rho(Y, \frac{\Delta CF}{Y})$	0.34 (.03)	0.34 (.03)	0.23	0.00	0.26	0.21

Note – For details of data and notations, see tables 1 and 2. **EM** stands for emerging markets. The column with "Model(Benchmark)" shows the results from the model with the collateral constraint and the incentive constraint. The column with "Model(Spec.j)" with $j \in \{1, 2, 3\}$ presents the results from the jth alternative model in the text.

E Appendix: Unconventional Credit Policy

In this section, we investigate the welfare implication of credit policies. Gertler and Kiyotaki (2010) described three unconventional financial policies: lending facilities (direct lending), liquidity facilities (discount window lending), and equity injections. In particular, we focus on direct lending to the nonfinancial corporate sector by the central bank. The solution method for characterizing the equilibrium under the unconventional policy is piecewise-linearization with regime switching developed by Guerrieri and Iacoviello (2015).

Direct lending For the policy experiment, we suppose that the central bank is willing to facilitate lending to the nonfinancial corporate sector. The central bank directly intermediate η_t portion of total loan, L_t. In doing so, the central bank must pay efficiency costs, Γ_t which are proportional to total amount of government intermediated loans, $\Gamma_t = \tau_1 \cdot \eta_t L_t + \tau_2 \cdot (\eta_t L_t)^2$ where $\tau_1 > 0$, $\tau_2 > 0$, and $\eta_t \geq 0$. Note that the central bank never defaults and thus government intermediated loans, $\eta_t L_t$ do not incur any financial friction other than the efficiency costs, Γ_t. The portion of government intermediated loans, η_t is dependent on the private-sector spread as follows.

$$\eta_t \quad = \quad \kappa^G \cdot \left\{ \mathbb{E}_t \left[R^K_{t+1} - R^*_t \right] - \eta^{tgt} \right\}$$

where η^{tgt} denotes the spread target set by the government and κ^G stands for the smoothing parameter for the policy. Bankers solve the same problem described in the benchmark model, but total loans to entrepreneurs, L_t are now divided into two parts: private-sector intermediated loans, L^P_t and government intermediated loans, $\eta_t L_t$ where $q^K_t \cdot K_{t+1} = L_t = L^P_t + \eta_t L_t$ holds. Therefore, the aggregate balance sheet of the banking sector is now given by

$$\begin{aligned}
L^P_t &= \int_0^\infty l_t(n)\, dF_t(n) \\
L^P_t &= N_t + B^*_t \\
N_t &= \phi \cdot \left\{ R^K_t \cdot L^P_{t-1} - R^*_{t-1} \cdot B^*_{t-1} \right\} + \xi \cdot R^K_t L^P_{t-1} \\
q^K_t \cdot K_{t+1} &= L_t = L^P_t + \eta_t \cdot L_t
\end{aligned}$$

The government budget and the national income identity are described by

$$\begin{aligned}
\Gamma_t + \eta_t L_t &= T_t + R^K_t \cdot \eta_{t-1} L_{t-1} \\
Y_t &= C_t + I_t + NX_t + \Gamma_t \\
NX_t &= R^D_{t-1} D^*_{t-1} - D^*_t + R^*_{t-1} B^*_{t-1} - B^*_t + \left(R^*_{t-1} - 1 \right) \cdot B^{W*}_t
\end{aligned}$$

where the credit policy is financed by the lump-sum tax on households, T_t. Table 11 presents the results. Note that we solve the model with financial policies by using the method of Guerrieri and Iacoviello (2015).

Hence, we also present the results from the benchmark model solved by Guerrieri and Iacoviello (2015) for the comparison. We set efficiency cost parameters, τ_1 and τ_2 at 0.000010 and 0.0003 following Dedola, Karadi, and Lombardo (2013). The spread target, η^{tgt} is set to be zero. The smoothing parameter for the policy, κ^G is chosen to be 78 in order to maximize the steady-state consumption, which implies that 75% of total loans to entrepreneurs are intermediated by the government.

In order to clearly see the effect of the unconventional policy from Table 11, we compare the sixth column with the last column. Output becomes 10% less volatile and the welfare gains in terms of quarterly steady-state consumption amount to 0.40%. Note that consumption gets 5% more volatile and household credit flow-to-output ratio is now acyclical under the financial policy.[39] The household credit flow-to-output ratio becomes more volatile: 0.10 vs. 0.30 and the collateral constraint is now less frequently binding: 57.2% vs. 42.9%.

Under the government financial policy, entrepreneurs finance their funds from the banking sector by 25% and from the government sector by 75%. Due to this reduction in the private-sector intermediated loans, the banking sector now does not depend on external financing as much: the steady-state external borrowing of the banking sector is reduced from 3.1806 to 0.79581. In aggregate, net exports decrease from 0.0077 to 0.0029 and the government transfers net proceeds from its intermediated loans to households. Therefore, households' consumption increases from 0.51573 to 0.51807 in the steady state. The consumption volatility increases under the credit policy since the covariance of output and investment becomes smaller and the covariance of investment and net exports becomes less negative to the extent that they exceed total reduction in volatilities of output, investment, and net exports.[40] In sum, under the unconventional financial policy, the economy is better off by the increase in the level of consumption which exceeds its welfare loss incurred by higher consumption volatility.

[39] The correlation coefficient of household credit flows with output is given by -0.02.

[40] Note that consumption volatility can be decomposed as follows: $var(C) \approx var(Y - I - NX) = var(Y) + var(I) + var(NX) - 2cov(Y, I) - 2cov(Y, NX) + 2cov(I, NX)$ under the credit policy.

Table 11: Business and Credit Cycle Statistics: Financial Policy

Moment	Data (**EM**)	Data (**DM**)	Data (Korea)	Model (Benchmark) (Nonlinear)	Model (Benchmark) (IG:2015)	Model (Fin. Pol.) (IG:2015)
A. Volatility of Output, Consumption, Investment, Net Exports, Interest Rates, and Credit Flows						
$\sigma(Y)$	3.10 (.18)	2.02 (.05)	2.59 (.12)	2.60	2.70	2.42
$\frac{\sigma(C)}{\sigma(Y)}$	1.14 (.06)	0.66 (.04)	1.31 (.10)	1.19	1.21	1.42
$\frac{\sigma(I)}{\sigma(Y)}$	2.56 (.11)	2.19 (.08)	2.17 (.12)	2.13	2.05	1.19
$\frac{\sigma(NX/Y)}{\sigma(Y)}$	0.81 (.07)	0.67 (.04)	1.10 (.08)	0.58	0.58	0.40
$\frac{\sigma(R)}{\sigma(Y)}$	0.30 (.04)	0.13 (.01)	0.14 (.01)	0.07	0.07	0.00
$\frac{\sigma(\Delta CH/Y)}{\sigma(Y)}$	0.50 (.06)	0.74 (.05)	1.10 (.12)	0.09	0.10	0.30
$\frac{\sigma(\Delta CF/Y)}{\sigma(Y)}$	1.36 (.13)	2.38 (.16)	1.87 (.27)	1.93	1.85	1.08
B. Correlation with Output						
$\rho(Y, Y_{-1})$	0.81 (.03)	0.82 (.02)	0.76 (.06)	0.78	0.79	0.74
$\rho(Y, C)$	0.83 (.03)	0.61 (.03)	0.77 (.04)	0.98	0.98	0.90
$\rho(Y, I)$	0.83 (.03)	0.75 (.02)	0.76 (.04)	0.67	0.66	0.72
$\rho(Y, \frac{NX}{Y})$	-.44 (.06)	-.00 (.05)	-.51 (.07)	-.42	-.41	-.40
$\rho(Y, R)$	-.38 (.08)	0.26 (.05)	-.74 (.03)	-.55	-.57	-.50
$\rho(Y, \frac{\Delta CH}{Y})$	0.42 (.03)	0.15 (.04)	0.56 (.05)	0.15	0.25	-.02
$\rho(Y, \frac{\Delta CF}{Y})$	0.34 (.03)	0.36 (.03)	0.34 (.03)	0.23	0.23	0.35
C. Frequency of Binding Constraints						
C.C.				46.3 %	57.2 %	42.9 %
I.C.				100.0 %	100.0 %	100.0 %
D. Welfare Comparison with respect to Model(Benchmark)(Nonlinear)						
λ^C				-	0.08%	0.49%
λ^X				-	0.21%	1.22%
λ^X_{lev}				-	0.24%	1.37%
λ^X_{unc}				-	-.03%	-.15%
E. Welfare Comparison with respect to Model(Benchmark)(IG:2015)						
λ^C					-	0.40%
λ^X					-	0.99%
λ^X_{lev}					-	1.12%
λ^X_{unc}					-	-.13%

Note – For details of data and notations, see tables 1 and 2. **EM** stands for emerging markets. **DM** denotes developed markets. The column with "Model(Benchmark)(Nonlinear)" shows the results from the benchmark model with the collateral constraint and the incentive constraint solved by the global nonlinear method. The column with "Model(Benchmark)(IG:2015)" presents the results from the benchmark model solved by Guerrieri and Iacoviello (2015). The column with "Model(Fin. Pol.)(IG:2015)" reports the results from the benchmark model under the government financial policy, *direct lending*, solved by Guerrieri and Iacoviello (2015). *C.C.* denotes collateral constraints and *I.C.* denotes incentive constraints. λ^C denotes consumption equivalent variation. λ^X stands for consumption-labor composite equivalent variation and λ^X_{lev} and λ^X_{unc} are its level and uncertainty components. See footnotes in the text for details.

F Appendix: The SOE model with *Bernanke-Gertler-Gilchrist* Entrepreneurs

One of our goals is to evaluate the performance of the model with two distinct financial frictions: limited commitment and costly state verification. The *Gertler-Kiyotaki* (GK, henceforth) banking model is based on limited commitment and moral hazard and the *Bernanke-Gertler-Gilchrist* (BGG, henceforth) model is built upon costly state verification. In this section, we introduce BGG financial frictions into the SOE model and compare the model performance with the GK model. The model with BGG entrepreneurs has the same efficiency conditions from households, final goods firms, and capital producing firms. Therefore, we focus on describing the optimal contract between entrepreneurs and bankers.

F.1 Entrepreneurs

The difference of the BGG model from the GK model is that entrepreneurs take a dominant role in building financial frictions and bankers get zero profits.[41] Each entrepreneur purchases capital, k_{t+1} from capital producers and use his own technology to produce the effective units of capital, $\omega_{t+1}k_{t+1}$ where ω_{t+1} is the idiosyncratic investment shock which is uncertain in making a decision on purchasing k_{t+1} at time t. The individual entrepreneur accumulates wealth and exits with i.i.d. probability $(1-\phi)$ in each period. The same number of new entrepreneurs enter the market. By allowing for exiting, the entrepreneurial sector never accumulates enough equity to be exempt from the need for external financing. When the entrepreneur exits, he transfers his accumulated net worth to households. Since entrepreneurs cannot operate without any resource, each new entrant is provided with start-up funds from households. Hence, Π_t^B is the net profit tranfer from entrepreneurs, i.e., funds transferred from exiting entrepreneurs minus the funds transferred to new entrants.

In period t, each entrepreneur issues l_t securities to the domestic banks and purchases capital, k_{t+1} from capital producers at a price, q_t^K. Then the capital turns into the effective units of $\omega_{t+1}k_{t+1}$ through his own investment technology. The shock, ω_{t+1} is idiosyncratic to each entrepreneur and follows unit-mean log normal distribution with the time-varying standard deviation, σ_t^ω, that is, $\log(\omega) \sim N(-\frac{(\sigma_t^\omega)^2}{2}, (\sigma_t^\omega)^2)$ with $\mathbb{E}(\omega) = 1$.

Note that the idiosyncratic shock, ω_{t+1} is uncertain when the entrepreneur decides on how much of capital, k_{t+1} he purchases at time t. Each entrepreneur can be identified by the level of his accumulated net worth, n_t which is the state variable for the individual entrepreneur. His balance sheet is given by

$$q_t^K k_{t+1} \quad = \quad n_t + l_t$$

[41] On the contrary, bankers accumulate their net-worth and entrepreneurs earn zero profit in the GK model.

The entrepreneur makes a debt contract with the bank at a state-contingent gross loan rate, Z^L_{t+1}. Therefore when the idiosyncratic shock[42] and the aggregate shock[43] at time $t+1$ are realized, the ex-post profit for each non-defaulting entrepreneur is given by

$$R^K_{t+1} q^K_t \cdot \omega_{t+1} k_{t+1} - Z^L_{t+1} l_t$$

F.2 The Debt Contract between Entrepreneurs and Banks

The key friction in this model is that the idiosyncratic investment shock, ω is private information of entrepreneurs and it is costly for the creditor bank to verify the level of revenue of an entrepreneur when the bank seizes the entrepreneur's assets in the event of defaulting. From the entrepreneur's ex-post profit, we can define a cutoff value, $\bar{\omega}_{t+1}$ which is given by

$$R^K_{t+1} q^K_t \cdot \bar{\omega}_{t+1} k_{t+1} \equiv Z^L_{t+1} l_t$$

If the realization of ω_{t+1} is higher than the threshold, $\bar{\omega}_{t+1}$, then the entrepreneur can pay back his debt. On the contrary, if the realized ω_{t+1} is below the cutoff, $\bar{\omega}_{t+1}$, the entrepreneur defaults and its creditor bank pays a proportional cost, μ to monitor the entrepreneur and confiscates the remaining assets. Therefore the expected payoff of the bank from extending the loan is given by

$$\underbrace{\int_{\bar{\omega}_{t+1}}^{\infty} Z^L_{t+1} l_t \; d\Xi_t(\omega)}_{\text{from solvent entrepreneurs}} + \underbrace{(1-\mu) \int_0^{\bar{\omega}_{t+1}} \omega R^K_{t+1} q^K_t k_{t+1} \; d\Xi_t(\omega)}_{\text{from insolvent entrepreneurs}}$$

where $\Xi_t(\omega)$ stands for the cumulative density function of the idiosyncratic shock, ω. The bank finances its loan by borrowing b^*_t from the external capital market at a world interest rate, R^*_t. The banking sector is assumed to be perfectly competitive and risk neutral. Hence, the bank's zero profit condition must hold for every state of the aggregate uncertainty:

$$\int_{\bar{\omega}_{t+1}}^{\infty} Z^L_{t+1} l_t \; d\Xi(\omega) + (1-\mu) \int_0^{\bar{\omega}_{t+1}} \omega R^K_{t+1} q^K_t k_{t+1} \; d\Xi(\omega) = R^*_t \cdot b^*_t$$

where the bank borrows by the same amount with that of loans extended to entrepreneurs and thus $l_t = b^*_t$ is satisfied.

At time $t-1$, the debt contract between an entrepreneur and a bank specifies the loan amount, l_{t-1} and the state-contingent loan rate, Z^L_t maximizing the entrepreneur's expected profits subject to the bank's

[42]The shock to ω_{t+1} is idiosyncratic.

[43] The rate of return of capital, R^K_{t+1} is fixed after aggregate shocks to TFP(z) and capital quality(ψ) at $t+1$ are realized.

participation constraint:

$$\max_{\{l_{t-1},Z_t^L\}} \mathbb{E}_{t-1}\left[\int_{\bar{\omega}_t}^{\infty}\left(R_t^K\cdot\omega q_{t-1}^K k_t - Z_t^L l_{t-1}\right)d\Xi_t(\omega)\right]$$

$$s.t. \qquad \int_{\bar{\omega}_t}^{\infty} Z_t^L l_{t-1}\, d\Xi_t(\omega) + (1-\mu)\int_0^{\bar{\omega}_t}\omega R_t^K q_{t-1}^K k_t\, d\Xi_t(\omega) = R_{t-1}^* \cdot l_{t-1}$$

where the cutoff value, $\bar{\omega}_t$ is related to the choice of loan rate, Z_t^L and the capital, k_t is associated with the choice of the loan amount, l_{t-1} through the identities:

$$\begin{aligned} R_t^K q_{t-1}^K \cdot \bar{\omega}_t k_t &= Z_t^L l_{t-1} \\ q_{t-1}^K k_t &= n_{t-1} + l_{t-1} \end{aligned}$$

Note that n_{t-1} is the state variable at time $t-1$. Therefore we can choose $\{k_t, \bar{\omega}_t\}$ instead of choosing $\left\{l_{t-1}, Z_t^L\right\}$. Following Bernanke, Gertler, and Gilchrist (1999), define functions:

$$\begin{aligned} \Gamma_t(\bar{\omega}_t) &\equiv \bar{\omega}_t \cdot (1-\Xi_t(\bar{\omega}_t)) + G_t(\bar{\omega}_t) \\ G_t(\bar{\omega}_t) &\equiv \int_0^{\bar{\omega}_t} \omega\, d\Xi_t(\omega) \end{aligned}$$

Then the debt contract can be rewritten in a more convenient form to solve:

$$\max_{\{k_t,\bar{\omega}_t\}} \mathbb{E}_{t-1}\left[(1-\Gamma_t(\bar{\omega}_t))\, R_t^K q_{t-1}^K k_t\right]$$

$$s.t. \qquad [\Gamma_t(\bar{\omega}_t) - \mu G_t(\bar{\omega}_t)] \cdot R_t^K q_{t-1}^K k_t = R_{t-1}^* \cdot \left\{q_{t-1}^K k_t - n_{t-1}\right\}$$

Notice that the choice of k_t is not state-contingent but the choice of $\bar{\omega}_t$ should be state-contingent on the aggregate uncertainty. Hence the efficiency conditions are given by

$$\begin{aligned} \frac{q_t^K K_{t+1}}{N_t} \cdot \mathbb{E}_t\left[(1-\Gamma_{t+1}(\bar{\omega}_{t+1}))\, R_{t+1}^K\right] &= \mathbb{E}_t\left[\frac{\Gamma_{\omega,t+1}(\bar{\omega}_{t+1})}{\Gamma_{\omega,t+1}(\bar{\omega}_{t+1}) - \mu G_{\omega,t+1}(\bar{\omega}_{t+1})} \cdot R_t^*\right] \\ [\Gamma_t(\bar{\omega}_t) - \mu G_t(\bar{\omega}_t)] \cdot \frac{R_t^K}{R_{t-1}^*} &= 1 - \frac{N_{t-1}}{q_{t-1}^K K_t} \end{aligned}$$

where Γ_ω and G_ω are partial derivatives with respect to ω and we aggregate the individual choice variables through

$$
\begin{aligned}
N_t &= \int_0^\infty n \, dF_t(n) \\
L_t &= \int_0^\infty l_t(n) \, dF_t(n) \\
K_{t+1} &= \int_0^\infty \omega_{t+1} k_{t+1}(n) \, dF_t(n) = \mathbb{E}(\omega) \cdot \int_0^\infty k_{t+1}(n) \, dF_t(n) \quad \text{by the law of large numbers}
\end{aligned}
$$

Note that $\mathbb{E}(\omega) = 1$ by assumption and we denote the time-t distribution of the continuum of entrepreneurs with the net worth n by $F_t(n)$.[44]

Now what remains for completing the model is the description of net worth dynamics and transfers to households. Let's denote the time-t economy-wide ex-post profits of entrepreneurs by V_t. Then the ex-post profit is given by

$$
V_t = (1 - \Gamma_t(\bar{\omega}_t)) \, R_t^K q_{t-1}^K K_t
$$

The aggregate net worth in the entrepreneurial sector at time t is composed of two parts: one is the aggregate profit of entrepreneurs who survived from the last period and the other is the transfer from households to new entrants. The transfer is assumed to be a fraction, Ω of households' labor income. Then the aggregate net worth at t is

$$
N_t = \phi \cdot V_t + \Omega \cdot W_t H_t
$$

Therefore the net transfer to households is the aggregate profit of exiting entrepreneurs net of transfers to new entrants:

$$
\Pi_t^B = (1 - \phi) \cdot V_t - \Omega \cdot W_t H_t
$$

[44]Note that the distribution of entrepreneurs' net-worth, $F_t(n)$ is different from the distribution of the idiosyncratic investment shock ω, $\Xi_t(\omega)$.

where variables related to the log-normal distribution are defined by

$$
\begin{aligned}
&(\sigma_t^\omega) && \sigma_t^\omega = \sigma^\omega \cdot A_{t-1}^\omega \\
&(A_t^\omega) && \log(A_t^\omega) = \rho_{A_\omega} \cdot \log(A_{t-1}^\omega) + \epsilon_t^\omega \\
&(\mu_t^\omega) && \mu_t^\omega = -\tfrac{(\sigma_t^\omega)^2}{2} \\
&(\xi_t(\bar{\omega})) && \xi_t(\bar{\omega}) = \tfrac{1}{\bar{\omega}\sigma_t^\omega\sqrt{2\pi}} \exp\left(-\tfrac{(\ln(\bar{\omega})-\mu_t^\omega)^2}{2\cdot(\sigma_t^\omega)^2}\right) \\
&(\Xi_t(\bar{\omega})) && \Xi_t(\bar{\omega}) = \textstyle\int_0^{\bar{\omega}} \xi_t(\omega)d\omega \\
&(\Gamma_t(\bar{\omega})) && \Gamma_t(\bar{\omega}) = \bar{\omega} \cdot (1 - \Xi_t(\bar{\omega})) + G_t(\bar{\omega}) \\
&(G_t(\bar{\omega})) && G_t(\bar{\omega}) = \textstyle\int_0^{\bar{\omega}} \omega\xi_t(\omega)d\omega \\
&(\xi_{\omega,t}(\omega)) && \xi_{\omega,t}(\omega) = \left(\tfrac{-1}{\omega}\right) \cdot \left[1 + \tfrac{\ln(\omega)-\mu_t^\omega}{(\sigma_t^\omega)^2}\right] \cdot \xi_t(\bar{\omega}) \\
&(\Gamma_{\omega,t}(\bar{\omega})) && \Gamma_{\omega,t}(\bar{\omega}) = 1 - \Xi_t(\bar{\omega}) \\
&(\Gamma_{\omega\omega,t}(\bar{\omega})) && \Gamma_{\omega\omega,t}(\bar{\omega}) = -\xi_t(\bar{\omega}) \\
&(G_{\omega,t}(\bar{\omega})) && G_{\omega,t}(\bar{\omega}) = \bar{\omega} \cdot \xi_t(\bar{\omega}) \\
&(G_{\omega\omega,t}(\bar{\omega})) && G_{\omega\omega,t}(\bar{\omega}) = \xi_t(\bar{\omega}) + \bar{\omega} \cdot \xi_{\omega,t}(\bar{\omega})
\end{aligned}
$$

Note that the risk shock, σ_t^ω affects the economy with one-time lag as in Christiano, Motto, and Rostagno (2014).

F.3 Equilibrium Conditions

$$
\begin{aligned}
&(\lambda_t) && \lambda_t = \left\{ C_t - \chi \frac{H_t^{1+\gamma}}{1+\gamma} \right\}^{-\sigma} \\
&(H_t) && \chi \cdot H_t^{\gamma} = W_t \\
&(D_t) && \frac{1}{R_t^D} = \mathbb{E}_t \left[\Lambda_{t,t+1} \right] + \mu_t^H \\
&(\mu_t^H) && \mu_t^H \cdot \left\{ m_H \cdot \mathbb{E}_t \left[W_{t+1} H_{t+1} \right] - R_t^D \cdot D_t \right\} = 0 \\
&(\Lambda_{t-1,t}) && \Lambda_{t-1,t} = \beta \cdot \frac{\lambda_t}{\lambda_{t-1}} \\
&(C_t) && C_t + I_t + NX_t + \mu G_t(\bar{\omega}_t) R_t^K q_{t-1}^K K_t = Y_t \\
&(NX_t) && NX_t = R_{t-1}^D \cdot D_{t-1} - D_t + R_{t-1}^* B_{t-1}^* - B_t^* + (R_{t-1}^* - 1) \cdot B_t^{W*} \\
&(B_t^{W*}) && B_t^{W*} = m_W W_t H_t \\
&(R_t^K) && R_t^K = \frac{\theta_K \cdot \frac{Y_t}{K_t} + q_t^K \cdot (1-\delta) \cdot \psi_t}{q_{t-1}^K} \\
&(W_t) && \theta_H \cdot Y_t = W_t \cdot H_t \cdot \left\{ 1 + m_W \cdot \left(R_{t-1}^* - 1 \right) \right\} \\
&(Y_t) && Y_t = z_t \cdot \{\psi_t K_t\}^{\theta_K} \cdot H_t^{\theta_H} \\
&(I_t) && K_{t+1} = (1-\delta) \cdot \psi_t K_t + \Phi \left(\frac{I_t}{\psi_t K_t} \right) \psi_t K_t \\
& && \Phi \left(\frac{I_t}{\psi_t K_t} \right) = \phi_{K1} \cdot \left(\frac{I_t}{\psi_t K_t} \right)^{1-\Phi_{KK}} + \phi_{K2} \\
&(q_t^K) && q_t^K = \frac{1}{\phi_{K1} \cdot (1-\Phi_{KK})} \cdot \left[\frac{I_t}{\psi_t K_t} \right]^{\Phi_{KK}} \\
&(L_t) && q_t^K \cdot K_{t+1} = L_t + N_t \\
&(B_t^*) && B_t^* = L_t \\
&(K_{t+1}) && \frac{q_t^K K_{t+1}}{N_t} \cdot \mathbb{E}_t \left[\left(1 - \Gamma_{t+1}(\bar{\omega}_{t+1})\right) R_{t+1}^K \right] = \mathbb{E}_t \left[\frac{\Gamma_{\omega,t}(\bar{\omega}_{t+1})}{\Gamma_{\omega,t}(\bar{\omega}_{t+1}) - \mu \cdot G_{\omega,t}(\bar{\omega}_{t+1})} \cdot R_t^* \right] \\
&(\bar{\omega}_t) && \left(\Gamma_t(\bar{\omega}_t) - \mu \cdot G_t(\bar{\omega}_t) \right) \frac{R_t^K}{R_{t-1}^*} = 1 - \frac{N_{t-1}}{q_{t-1}^K \cdot K_t} \\
&(V_t) && V_t = \left(1 - \Gamma_t(\bar{\omega}_t)\right) R_t^K q_{t-1}^K K_t \\
&(N_t) && N_t = \phi \cdot V_t + \Omega W_t H_t \\
&(z_t) && \log(z_t) = \rho_z \cdot \log(z_{t-1}) + \epsilon_t^z \\
&(\psi_t) && \log(\psi_t) = \rho_\psi \cdot \log(\psi_{t-1}) + \epsilon_t^\psi
\end{aligned}
$$

F.4 Mechanism: Countercyclical Interest Rate

In this section, we inspect the mechanism of the BGG model in reproducing the countercyclical interest rate. Figure 14 shows that the model with the BGG entrepreneurs have different effect on the demand side of the loan market. The loan demand curve shifts to the left in the GK model, but now it shifts outward in the BGG model. The loan supply curve shifts to the right in both models. In the BGG model, the supply side is more elastic to the change in the interest rate than the demand side[45] and thus the effect from the supply side is dominant. Therefore, the positive TFP shock increases the equilibrium loan amount and lowers the interest rate in both models.

[45] Notice that the slope of the demand curve is steeper than that of the supply curve.

Table 12: Calibrated Parameters for the SOE model with BGG Entrepreneurs

Param.	Description	Value	Source
β	Households' discount rate	0.9800	Aguiar-Gopinath(2007)
σ	Relative risk aversion	2.0000	Aguiar-Gopinath(2007)
γ	Frisch labor elasticity parameter	0.6000	Neumeyer-Perri(2005)
χ	Labor disutility parameter	2.8485	1/3 steady-state labor
m_H	Household debt-to-income ratio	0.4271	29% steady-state household debt-to-output ratio
R^*	The world interest rate	1.0020	Long-run U.S. 3M T-Bill real rate (1960-2016)
θ_K	Capital share in production	0.3200	Aguiar-Gopinath(2007)
θ_H	Labor share in production	0.6800	CRTS Cobb-Douglas technology
m_W	Fraction of Working Capital	1.0000	Neumeyer-Perri(2005)
δ	Capital depreciation rate	0.0500	Aguiar-Gopinath(2007)
ϕ_{K1}	Tobin's Q parameter	0.8922	27% steady-state investment-to-output ratio
ϕ_{K2}	Tobin's Q parameter	-.0067	Steady-state Tobin's Q normalized to one, $q^K = 1$
Φ_{KK}	Tobin's Q parameter	0.0190	Matching Data Moments: $\frac{\sigma(I)}{\sigma(Y)}$
ϕ	The survival prob. of entrep.	0.9913	Matching Data Moments
Ω	Income transfer to new entrep.	0.0010	Fernandez-Gulan(2015)
μ	Costly state verification param.	0.0200	Matching Data Moments
σ^ω	The steady-state STD of idio. shock	1.0515	Matching Data Moments
μ^ω	The steady-state mean of idio. shock	$\mu_\omega = -\frac{\sigma_\omega^2}{2}$	unit-mean log-normal ω
ρ_z	Persistence of TFP shock	0.6632	Matching Data Moments
σ^z	Size of TFP shock	0.0092	Matching Data Moments
σ^ψ	Size of capital quality shock	0.0055	Matching Data Moments

The following equations represent curves for the loan demand and supply of the BGG model in Figure 14.

$$\begin{aligned}
\text{Demand:}\quad & \hat{L}_t = \hat{N}_t + \frac{q^K K}{L} \cdot \left[\frac{\Gamma_{\omega\omega}(\Gamma_\omega - \mu G_\omega) - \Gamma_\omega(\Gamma_{\omega\omega} - \mu G_{\omega\omega})}{\Gamma_\omega(\Gamma_\omega - \mu G_\omega)} + \frac{\Gamma_\omega}{1-\Gamma}\right] \cdot \bar{\omega}\mathbb{E}_t\hat{\bar{\omega}}_{t+1} - \frac{q^K K}{L} \cdot \mathbb{E}_t\hat{R}^K_{t+1} \\
\text{Supply:}\quad & \hat{L}_t = \hat{N}_t + \frac{q^K K}{N} \cdot \left[\frac{\Gamma_\omega - \mu G_\omega}{\Gamma - \mu G}\right] \cdot \bar{\omega}\mathbb{E}_t\hat{\bar{\omega}}_{t+1} + \frac{q^K K}{N} \cdot \mathbb{E}_t\hat{R}^K_{t+1}
\end{aligned}$$

All coefficients are positive and the positive shock to TFP increases variables: $\left\{\hat{N}_t, \mathbb{E}_t\hat{\bar{\omega}}_{t+1}\right\}$. Hence, the demand and supply curves shift to the right and the equilibrium is determined through the relative size of the interest-rate elasticity of the loan in the demand and supply side.

Since $\frac{K}{N}$ is much larger than $\frac{K}{L}$ in the steady state, the loan supply is more elastic to the change in the interest rate and hence the equilibrium interest rate falls after the positive shock to productivity.

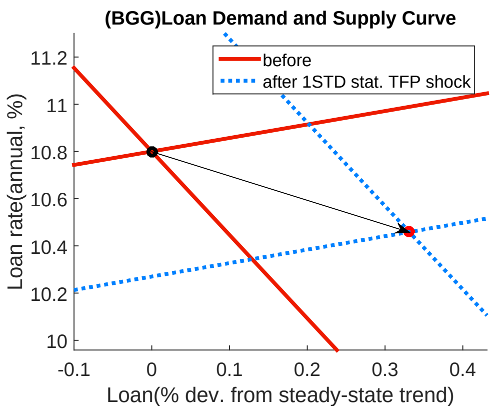

Figure 14: The effect of the 1STD productivity shock on the loan market

G Appendix: Data Description

We collect data for the list of Emerging Markets(EM): Argentina(ARG), Brazil(BRA), Chile(CHL), Colombia(COL), Korea(KOR), Mexico(MEX), Thailand(THA), and Turkey(TUR). For a group of Developed Markets(DM), we gather data for countries: Australia(AUS), Austria(AUT), Belgium(BEL), Canada(CAN), Denmark(DNK), Finland(FIN), Netherland(NLD), Portugal(PRT), Spain(ESP), Sweden(SWE), and Switzerland(CHE). We summarize specification of all data of each country in tables 13, 14, 15, and 16.

National Accounts The source of National Account data for both EM and DM is the IMF's International Financial Statistics database. The details are in tables 13 and 14. Our measure of output(Y) is GDP net of government final consumption(G). Consumption(C) is household final consumption expenditure, investment(I) is gross fixed capital formation and net exports(NX) are exports(EX) minus imports(IM). All are downloaded in local currency unit. We use GDP deflators to render these data in real terms and then remove seasonal components by using the U.S. Census Bureau's X13-ARIMA software. Output, consumption, and investment in terms of SAAR are logged and then HP filtered. Net exports are divided by output and then HP filtered.

Real Interest Rates and Credit Flows in EM We downloaded J.P. Morgan Emerging Markets Bond Index(EMBI) and total credit data from datastream. The data on total credit to households and to private non-financial corporations are from Bank for International Settlements "Long series on total credit to the private non-financial sector" database. The details are referred to the table 15. Following Schmitt-Grohé and Uribe (2016)[46], we construct the emerging market real interest rate as the sum of the EMBI spread and the 3-month U.S. Treasury bill rate deflated by U.S. CPI inflation. Specifically, we use the following equation:

$$1 + r_t \quad = \quad \left[(1+s_t)(1+i_t)\mathbb{E}_t\left(\frac{1}{1+\pi_{t+1}}\right)\right]^{\frac{1}{4}}$$

where r_t is the emerging market real interest rate in quarterly terms. s_t, i_t, and π_t denote respectively EMBI spread, U.S. 3-month Treasury bill rate, and U.S. CPI inflation rate in annual terms. In order to create the time series for $\mathbb{E}_t\left(\frac{1}{1+\pi_{t+1}}\right)$, we use quarterly data on the U.S. Consumer Price Index(P_t) from 1960:Q1 to 2016:Q3 and conduct the following regression:

$$\begin{aligned}\frac{1}{1+\pi_{t+1}} &\equiv \frac{P_t}{P_{t+1}} \\ &= \beta_1 + \beta_2\frac{P_{t-1}}{P_t} + \beta_3\frac{P_{t-2}}{P_{t-1}} + \epsilon_{t+1}\end{aligned}$$

Then we take the fitted component as a proxy for $\mathbb{E}_t\left(\frac{1}{1+\pi_{t+1}}\right)$. Both U.S. Treasury bill rate and U.S. CPI

[46] See the description of Argentina Data in the online appendix of Schmitt-Grohé and Uribe (2016)

are from St. Louis FRED database. The gross real interest rate is logged and then HP filtered.

We derive the credit flow from the first difference of total credit time series. That is, credit flow to households at time t, ΔCH_t is constructed as $CH_t - CH_{t-1}$ and credit flow to private non-financial firms at time t, ΔCF_t is derived from $CF_t - CF_{t-1}$. CH stands for total credit to households and non-profit institutions serving households. CF denotes total credit to private non-financial corporate firms. Both CH and CF are end-of-period stocks. We deflate credit flows by GDP deflators and then remove seasonal components by using the U.S. Census Bureau's X13-ARIMA software. Credit flows in terms of SAAR are divided by output and then HP filtered.

Total credit is provided by domestic banks, all other sectors of the economy and non-residents.[47] Credit covers loans and debt securities[48] and captures the outstanding amount of credit at the end of the reference quarter.

We are aware that the EMBI is the index of dollar-denominated sovereign bonds, not the index of bonds issued by private sectors in emerging market countries. Therefore, the better measures for real interest rates in the model might be the interest rates constructed from an index of the spread of emerging market corporate bonds. JP-Morgan launched the Corporate Emerging Markets Bond Index, CEMBI as of 2007. Fernández and Gulan (2015) compared the business-cycle statistics of EMBI- and CEMBI-based interest rates and found they were highly correlated, but CEMBI-based real rates were more countercyclical and volatile than EMBI-based measures. As in Fernández and Gulan (2015), we used EMBI-based real rates for the model calibration due to the scarcity of CEMBI data relative to EMBI data.

Real Interest Rates and Credit Flows in DM We obtain the nominal interest rate and consumer price index in each country of developed markets from the OECD's Main Economic Indicators dataset. Total credit data are downloaded from datastream. The specification of the data is in the table 16. The nominal interest rate is the local-currency denominated 3-month interest rate. We use CPI inflation to construct the real interest rate. In particular, the real interest rate, r_t in quarterly terms is defined by

$$1 + r_t = \left[(1+i_t)\mathbb{E}_t\left(\frac{1}{1+\pi_{t+1}}\right)\right]^{\frac{1}{4}}$$

where i_t and π_t are respectively the local-currency denominated nominal interest rate and the CPI inflation rate in annual terms. We construct the time series for $\mathbb{E}_t\left(\frac{1}{1+\pi_{t+1}}\right)$ by taking the fitted component from the regression: $\frac{1}{1+\pi_{t+1}} = \beta_1 + \beta_2\frac{1}{1+\pi_t} + \beta_3\frac{1}{1+\pi_{t-1}} + \epsilon_{t+1}$. The gross real interest rate is logged and then HP filtered. We construct the credit flow in DM by following the same procedure used for creating the credit flow in EM.

[47] To be more specific, lenders include non-financial corporations, financial corporations (central banks, other domestic depository corporations and other financial institutions), general government, households, non-profit institutions serving households, rest of the world (internationally active banks and other sectors).

[48] Debt securities include bonds and short-term paper.

Table 13: Data Details: National Accounts

Emerging Markets		GDP	G	C	I	EX	IM	GDP Deflator
ARG	Code	AGI99B.A	AGI91FA.A	AGI96FA.A	AGI93EA.A	AGI90CA.A	AGI98CA.A	AGI99BIPC
	Period			1994:Q1 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			NSA				
BRA	Code	BRI99B..A	BRI91F..A	BRI96F..A	BRI93E..A	BRI90C..A	BRI98C..A	BRI99BIPC
	Period			1995:Q1 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			NSA				
CHL	Code	CLI99B..A	CLI91F..A	CLI96F..A	CLI93E..A	CLI90C..A	CLI98C..A	CLI99BIPC
	Period			2002:Q4 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			NSA				
COL	Code		CBI91F.CB	CBI96F.CB	CBI93E.CB	CBI90C.CB	CBI98C.CB	
	Period			2000:Q1 - 2016:Q1				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			SA				
KOR	Code	KOI99B..A	KOI91F..A	KOI96F..A	KOI93E..A	KOI90C..A	KOI98C..A	KOI99BIPC
	Period			1980:Q1 - 2004:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			NSA				
MEX	Code	MXI99BACB	MXI91FACB	MXI96FACB	MXI93EACB	MXI90CACB	MXI98CACB	MXI99BIRH
	Period			1994:Q4 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			SA				
THA	Code	THI99B..A	THI91F..A	THI96F..A	THI93E..A	THI90C..A	THI98C..A	THI99BIPC
	Period			1997:Q3 - 2006:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			NSA				
TUR	Code	TKI99B..A	TKI91F..A	TKI96F..A	TKI93E..A	TKI90C..A	TKI98C..A	TKI99BIPC
	Period			1999:Q4 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			NSA				

Source − International Financial Statistics, IMF

Note − Output(Y) is GDP net of government expenditure(G). G is government(public) final consumption expenditure. C is household(private) final consumption expenditure. I is gross fixed capital formation. EX/IM is exports/imports of goods and services.

Code stands for datastream mnemonic. $R/N/I$ indicates Constant Prices(R) or Current Prices(N) or Price Index(I). SA/NSA means seasonally adjusted(SA) or not seasonally adjusted(NSA). LCU stands for local currency unit.

Table 14: Data Details: National Accounts (continued)

Developed Markets		GDP	G	C	I	EX	IM	GDP Deflator
AUS	Code	AUI99B.CB	AUI91F.CB	AUI96F.CB	AUI93E.CB	AUI90C.CB	AUI98C.CB	AUI99BIRH
	Period			1978:Q1 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			SA				NSA
AUT	Code	OEI99B..A	OEI91F..A	OEI96F..A	OEI93E..A	OEI90C..A	OEI98C..A	OEI99BIPC
	Period			1999:Q1 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			NSA				
BEL	Code	BGI99B..A	BGI91F..A	BGI96F..A	BGI93E..A	BGI90C..A	BGI98C..A	BGI99BIPC
	Period			1999:Q1 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			NSA				
CAN	Code	CNI99BACB	CNI91FACB	CNI96FACB	CNI93EACB	CNI90CACB	CNI98CACB	CNI99BIRH
	Period			1977:Q3 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			SA				NSA
DNK	Code	DKI99B..A	DKI91F..A	DKI96F..A	DKI93E..A	DKI90C..A	DKI98C..A	DKI99BIPC
	Period			1995:Q1 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			NSA				
FIN	Code	FNI99B..A	FNI91F..A	FNI96F..A	FNI93E..A	FNI90C..A	FNI98C..A	FNI99BIPC
	Period			1999:Q1 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			NSA				
NLD	Code	NLI99B.CB	NLI91F.CB	NLI96F.CB	NLI93E.CB	NLI90C.CB	NLI98C.CB	NLI99BIRH
	Period			1991:Q1 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			SA				NSA
PRT	Code	PTQ99BWCB	PTQ91FWCB	PTQ96FWCB	PTQ93EWCB	PTQ90CWCB	PTQ98CWCB	PTQ99BIRF
	Period			1999:Q1 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			SA				NSA
ESP	Code	ESI99B.CB	ESI91F.CB	ESI96F.CB	ESI93E.CB	ESI90C.CB	ESI98C.CB	ESI99BIRH
	Period			1999:Q1 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			SA				NSA
SWE	Code	SDI99B..A	SDI91F..A	SDI96F..A	SDI93E..A	SDI90C..A	SDI98C..A	SDI99BIPC
	Period			1982:Q3 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			NSA				
CHE	Code	SWI99B.CB	SWI91F.CB	SWI96F.CB	SWI93E.CB	SWI90C.CB	SWI98C.CB	SWI99BIRH
	Period			1999:Q4 - 2016:Q2				
	Currency			LCU				
	R/N/I			Current Prices				Price Index
	SA/NSA			SA				NSA

Source − International Financial Statistics, IMF

Note − Output(Y) is GDP net of government expenditure(G). G is government(public) final consumption expenditure. C is household(private) final consumption expenditure. I is gross fixed capital formation. EX/IM is exports/imports of goods and services.

Code stands for datastream mnemonic. $R/N/I$ indicates Constant Prices(R) or Current Prices(N) or Price Index(I). SA/NSA means seasonally adjusted(SA) or not seasonally adjusted(NSA). *LCU* stands for local currency unit.

Table 15: Data Details: Interest Rates and Total Credits

Emerging Markets		EMBI spread	CH	CF
ARG	Code	JPMPARG(SSPRD)	AGBLCAHAA	AGBLCANAA
	Currency	US $	LCU	LCU
	Period		1994:Q1 - 2016:Q2	
	R/N/I		Current Prices	
	SA/NSA		NSA	
BRA	Code	JPMPBRA(SSPRD)	BRBLCAHAA	BRBLCANAA
	Currency	US $	LCU	LCU
	Period		1995:Q1 - 2016:Q2	
	R/N/I		Current Prices	
	SA/NSA		NSA	
CHL	Code	JPMGCHI(SSPRD)	CLBLCAHAA	CLBLCANAA
	Currency	US $	LCU	LCU
	Period		2002:Q4 - 2016:Q2	
	R/N/I		Current Prices	
	SA/NSA		NSA	
COL	Code	JPMBCOL(SSPRD)	CBBLCAHAA	CBBLCANAA
	Currency	US $	LCU	LCU
	Period		2000:Q1 - 2016:Q1	
	R/N/I		Current Prices	
	SA/NSA		NSA	
KOR	Code	JPMGKOC(SSPRD)	KOBLCAHAA	KOBLCANAA
	Currency	US $	LCU	LCU
	Period	1994:Q1 - 2004:Q2	1980:Q1 - 2004:Q2	
	R/N/I		Current Prices	
	SA/NSA		NSA	
MEX	Code	JPMPMEX(SSPRD)	MXBLCAHAA	MXBLCANAA
	Currency	US $	LCU	LCU
	Period		1994:Q4 - 2016:Q2	
	R/N/I		Current Prices	
	SA/NSA		NSA	
THA	Code	JPMGTHA(SSPRD)	THBLCAHAA	THBLCANAA
	Currency	US $	LCU	LCU
	Period		1997:Q3 - 2006:Q2	
	R/N/I		Current Prices	
	SA/NSA		NSA	
TUR	Code	JPMPTUR(SSPRD)	TKBLCAHAA	TKBLCANAA
	Currency	US $	LCU	LCU
	Period		1997:Q3 - 2006:Q2	
	R/N/I		Current Prices	
	SA/NSA		NSA	

Source − JP Morgan(*EMBI spread*), BIS(*CH*, *CF*)

Note − *EMBI spread* is the difference between the rate of return of 3 month emerging market sovereign bonds and the 3 month risk-free world interest rate. *CH* stands for total credit to households and non-profit institutions serving households. *CF* stands for total credit to private non-financial corporate firms. *CH* and *CF* are end-of-period stocks.

Code stands for datastream mnemonic. *R/N/I* indicates Constant Prices(*R*) or Current Prices(*N*) or Price Index(I). *SA/NSA* means seasonally adjusted(*SA*) or not seasonally adjusted(*NSA*). *LCU* stands for local currency unit.

Table 16: Data Details: Interest Rates and Total Credits (continued)

Developed Markets		NR	CH	CF	CPI
AUS	Code		AUBLCAHAA	AUBLCANAA	
	Currency	LCU	LCU	LCU	
	Period		1978:Q1 - 2016:Q2		
	R/N/I		Current Prices		Price Index
	SA/NSA		NSA		
AUT	Code		OEBLCAHAA	OEBLCANAA	
	Currency	LCU	LCU	LCU	
	Period		1999:Q1 - 2016:Q2		
	R/N/I		Current Prices		Price Index
	SA/NSA		NSA		
BEL	Code		BGBLCAHAA	BGBLCANAA	
	Currency	LCU	LCU	LCU	
	Period		1999:Q1 - 2016:Q2		
	R/N/I		Current Prices		Price Index
	SA/NSA		NSA		
CAN	Code		CNBLCAHAA	CNBLCANAA	
	Currency	LCU	LCU	LCU	
	Period		1977:Q3 - 2016:Q2		
	R/N/I		Current Prices		Price Index
	SA/NSA		NSA		
DNK	Code		DKBLCAHAA	DKBLCANAA	
	Currency	LCU	LCU	LCU	
	Period		1995:Q1 - 2016:Q2		
	R/N/I		Current Prices		Price Index
	SA/NSA		NSA		
FIN	Code		FNBLCAHAA	FNBLCANAA	
	Currency	LCU	LCU	LCU	
	Period		1999:Q1 - 2016:Q2		
	R/N/I		Current Prices		Price Index
	SA/NSA		NSA		
NLD	Code		NLBLCAHAA	NLBLCANAA	
	Currency	LCU	LCU	LCU	
	Period		1991:Q1 - 2016:Q2		
	R/N/I		Current Prices		Price Index
	SA/NSA		NSA		
PRT	Code		PTBLCAHAA	PTBLCANAA	
	Currency	LCU	LCU	LCU	
	Period		1999:Q1 - 2016:Q2		
	R/N/I		Current Prices		Price Index
	SA/NSA		NSA		
ESP	Code		ESBLCAHAA	ESBLCANAA	
	Currency	LCU	LCU	LCU	
	Period		1999:Q1 - 2016:Q2		
	R/N/I		Current Prices		Price Index
	SA/NSA		NSA		
SWE	Code		SDBLCAHAA	SDBLCANAA	
	Currency	LCU	LCU	LCU	
	Period		1982:Q3 - 2016:Q2		
	R/N/I		Current Prices		Price Index
	SA/NSA		NSA		
CHE	Code		SWBLCAHAA	SWBLCANAA	
	Currency	LCU	LCU	LCU	
	Period		1999:Q4 - 2016:Q2		
	R/N/I		Current Prices		Price Index
	SA/NSA		NSA		

Source − OECD Main Economic Indicators(R, CPI), BIS(CH, CF)

Note − NR denotes the local-currency denominated 3 month nominal interest rate. CPI denotes consumer price index. CH stands for total credit to households and non-profit institutions serving households. CF stands for total credit to private non-financial corporate firms. CH and CF are end-of-period stocks.

Code stands for datastream mnemonic. $R/N/I$ indicates Constant Prices(R) or Current Prices(N) or Price Index(I). SA/NSA means seasonally adjusted(SA) or not seasonally adjusted(NSA). *LCU* stands for local currency unit.

H Appendix: GMM Estimation of Business Cycle Statistics

In this section, we explain how we construct GMM estimates of business cycle statistics. We illustrate how to get the correlation coefficient of consumption and output, $\rho_{c,y}$ and the standard deviation of consumption, σ_c and output, σ_y. Other estimates can be obtained in the same manner. The moment conditions for this case are given by

$$\mathbb{E}\left[f(x_t,\psi)\right] \equiv \mathbb{E}\begin{bmatrix} \frac{c_t y_t}{\sigma_c \cdot \sigma_y} - \rho_{c,y} \\ c_t^2 - \sigma_c^2 \\ y_t^2 - \sigma_y^2 \end{bmatrix} = 0$$

where c_t and y_t are respectively cyclical components of HP-filtered log of consumption and output. x_t and ψ are defined by $x_t = [c_t, y_t]'$ and $\psi = [\rho_{c,y}, \sigma_c, \sigma_y]'$. We choose $\hat{\psi}$ to minimize

$$\Omega_T(\psi) = \left[\frac{1}{T}\sum_{t=1}^{T} f(x_t,\psi)\right]' W_T \left[\frac{1}{T}\sum_{t=1}^{T} f(x_t,\psi)\right]$$

where T is the number of observations. The weighting matrix W_T is approximated by following Newey and West (1987) with Bartlett windows.[49]

$$\begin{aligned} \Gamma_j &= \frac{1}{T}\sum_{t=j+1}^{T} f(x_t,\psi) f(x_{t-j},\psi)' \\ \omega_j &= 1 - \frac{j}{J+1} \\ S_0 &= \Gamma_0 + \sum_{j=1}^{J} \omega_j \left(\Gamma_j + \Gamma_j'\right) \\ \hat{W}_T &= S_0^{-1} \end{aligned}$$

To find out GMM estimates $\hat{\psi}$, we follow the algorithm suggested in Burnside (1999)[50]. Standard errors of $\hat{\psi}$ are derived from

$$\begin{aligned} \underset{N\times K}{dg} &\equiv \frac{1}{T}\sum_{t=1}^{T} \frac{\partial f(x_t,\hat{\psi})}{\partial \psi} \\ \underset{K\times K}{V} &= \frac{1}{T}\left[dg' \hat{W}_T dg\right]^{-1} \end{aligned}$$

[49] The bandwidth J should increase in the number of observations. For example, Ruge-Murcia (2012) used $J = \left\lfloor 4 \cdot \left(\frac{T}{100}\right)^{\frac{2}{9}} \right\rfloor$. But we set J to 5 as in Burnside (1999).

[50] See p42 - p48 in Burnside (1999). The algorithm is an adapted version of Hansen, Heaton, and Ogaki (1992)

where N is the number of moment restrictions and K is the number of parameters. The standard error of each parameter is square root of the corresponding diagonal element in the variance-covariance estimate V. The derivative dg is numerically approximated by

$$\underset{N\times K}{dg} \approx \frac{1}{T}\sum_{t=1}^{T}\begin{pmatrix} \frac{f_1(x_t,\hat{\psi}+\Delta\hat{\psi}_1)-f_1(x_t,\hat{\psi}-\Delta\hat{\psi}_1)}{2\Delta\psi_1} & \frac{f_1(x_t,\hat{\psi}+\Delta\hat{\psi}_2)-f_1(x_t,\hat{\psi}-\Delta\hat{\psi}_2)}{2\Delta\psi_2} & \cdots & \frac{f_1(x_t,\hat{\psi}+\Delta\hat{\psi}_K)-f_1(x_t,\hat{\psi}-\Delta\hat{\psi}_K)}{2\Delta\psi_K} \\ \frac{f_2(x_t,\hat{\psi}+\Delta\hat{\psi}_1)-f_2(x_t,\hat{\psi}-\Delta\hat{\psi}_1)}{2\Delta\psi_1} & \frac{f_2(x_t,\hat{\psi}+\Delta\hat{\psi}_2)-f_2(x_t,\hat{\psi}-\Delta\hat{\psi}_2)}{2\Delta\psi_2} & \cdots & \frac{f_2(x_t,\hat{\psi}+\Delta\hat{\psi}_K)-f_2(x_t,\hat{\psi}-\Delta\hat{\psi}_K)}{2\Delta\psi_K} \\ \vdots & \vdots & & \vdots \\ \frac{f_N(x_t,\hat{\psi}+\Delta\hat{\psi}_1)-f_N(x_t,\hat{\psi}-\Delta\hat{\psi}_1)}{2\Delta\psi_1} & \frac{f_N(x_t,\hat{\psi}+\Delta\hat{\psi}_2)-f_N(x_t,\hat{\psi}-\Delta\hat{\psi}_2)}{2\Delta\psi_2} & \cdots & \frac{f_N(x_t,\hat{\psi}+\Delta\hat{\psi}_K)-f_N(x_t,\hat{\psi}-\Delta\hat{\psi}_K)}{2\Delta\psi_K} \end{pmatrix}$$

where $\underset{K\times 1}{\hat{\psi}} = [\hat{\psi}_1, \hat{\psi}_2, \cdots, \hat{\psi}_K]' = [\hat{\rho}_{c,y}, \hat{\sigma}_c, \hat{\sigma}_y]'$ and $\underset{1\times 1}{\Delta\psi_k} = \frac{\max(\hat{\psi}_k, 10^{-2})}{10^5}$ for $k \in \{1, 2, \cdots, K\}$. $\underset{K\times 1}{\Delta\hat{\psi}_k}$ is defined as $\Delta\hat{\psi}_1 = [\Delta\psi_1, 0, 0, 0, \cdots, 0]'$, $\Delta\hat{\psi}_2 = [0, \Delta\psi_2, 0, 0, \cdots, 0]'$, $\Delta\hat{\psi}_3 = [0, 0, \Delta\psi_3, 0, \cdots, 0]'$ and so on.

H.1 Argentina

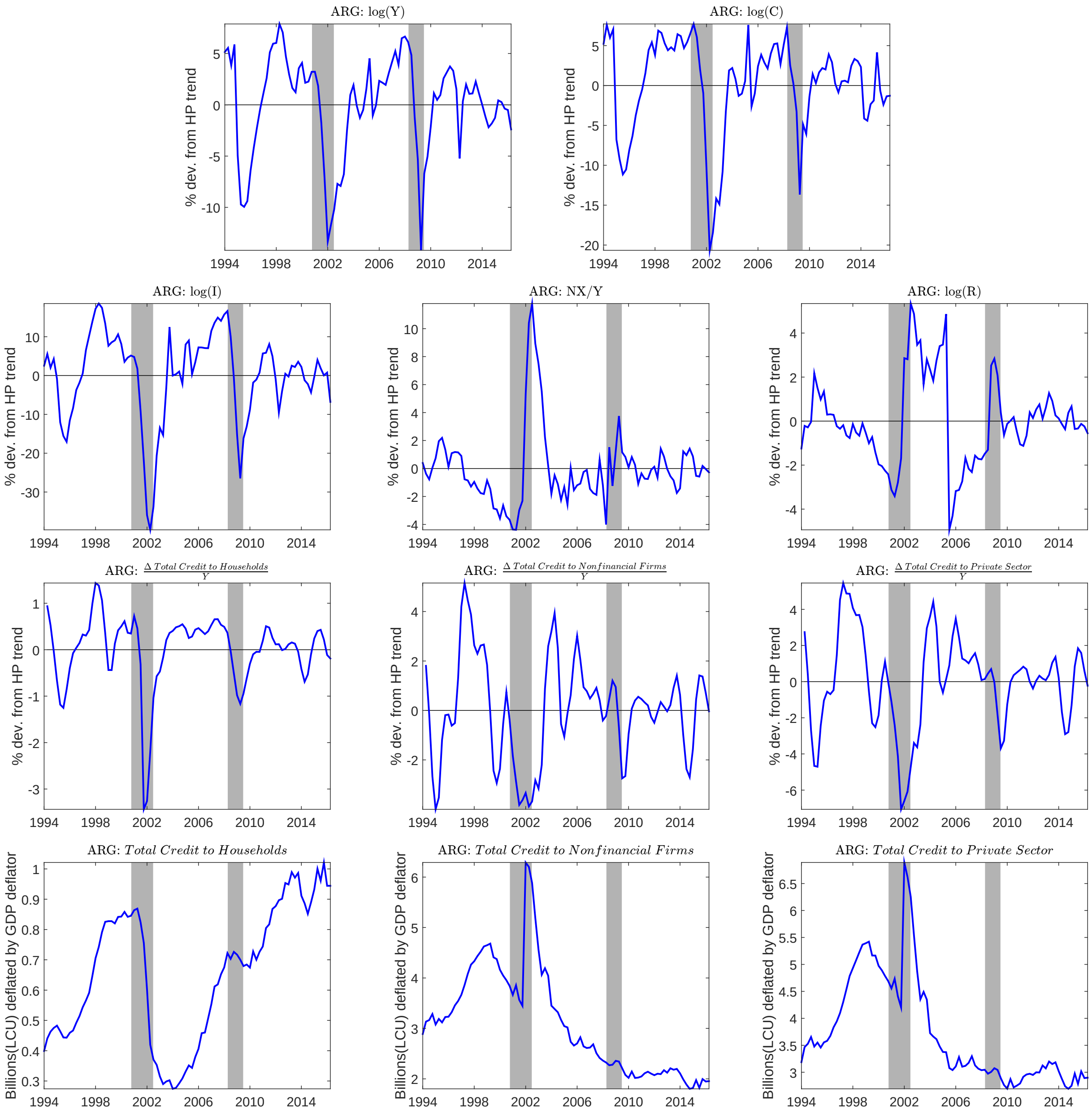

Figure 15: Cyclical Components and Total Credits

H.2 Brazil

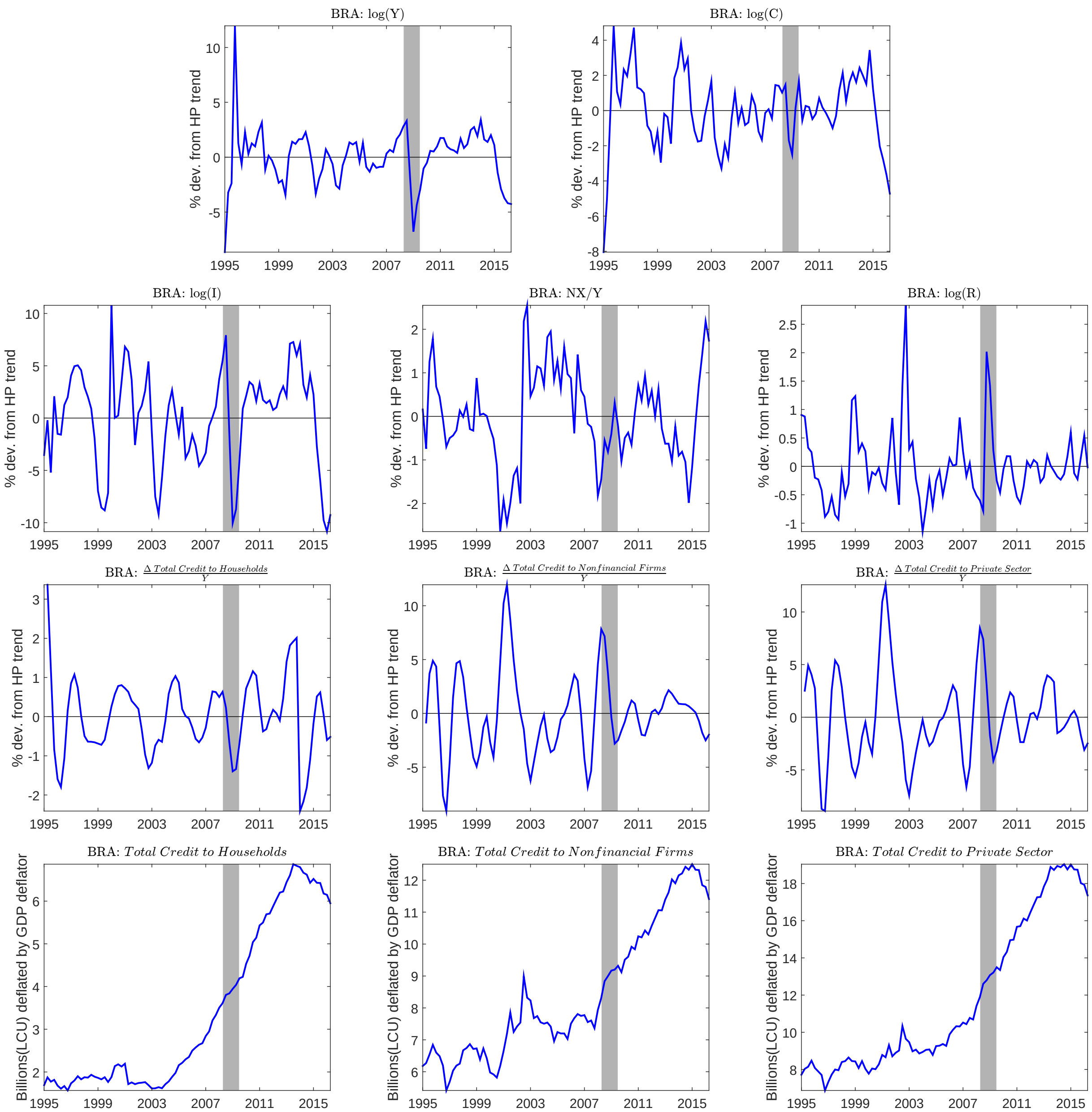

Figure 16: Cyclical Components and Total Credits

H.3 Chile

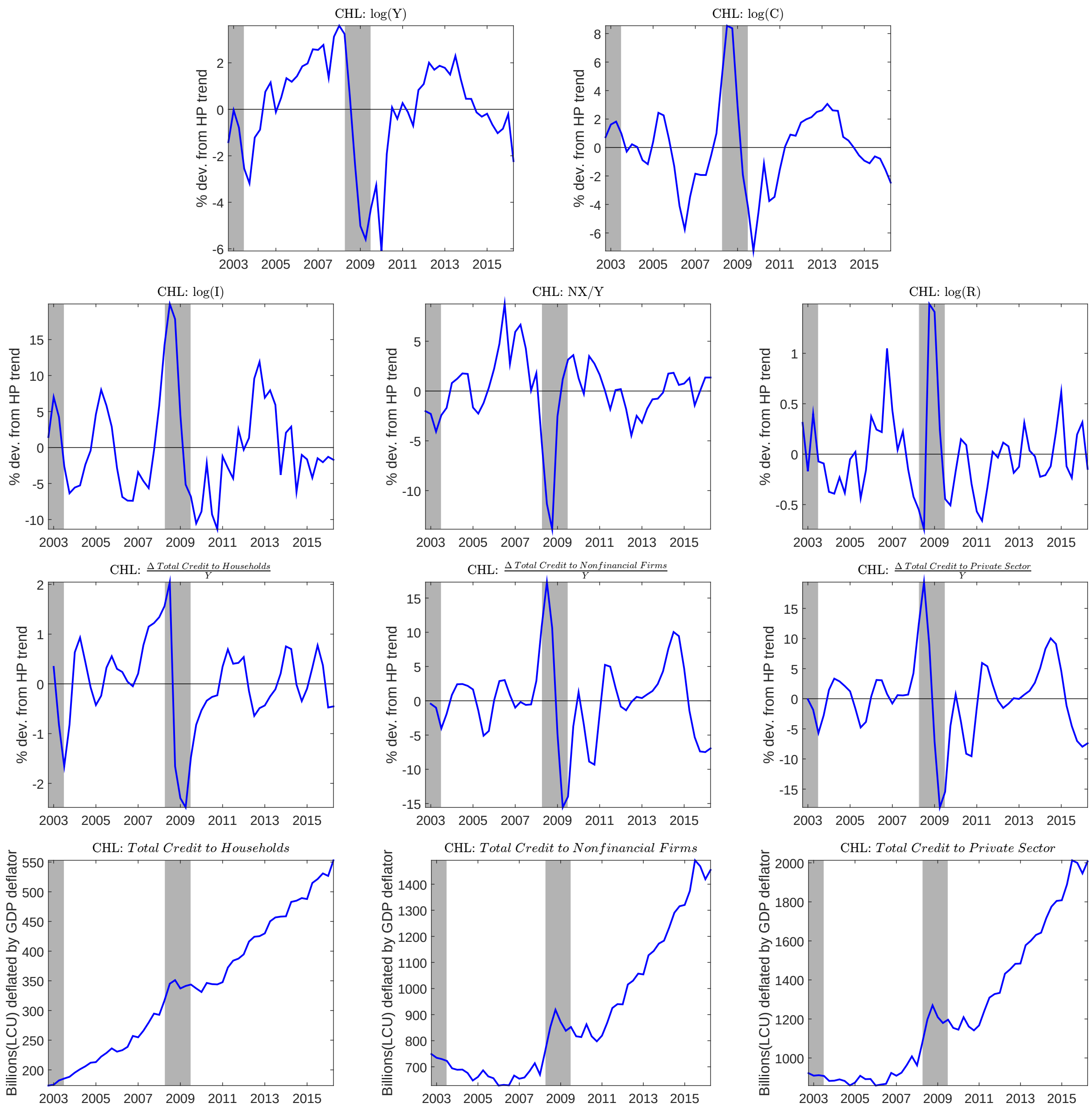

Figure 17: Cyclical Components and Total Credits

H.4 Colombia

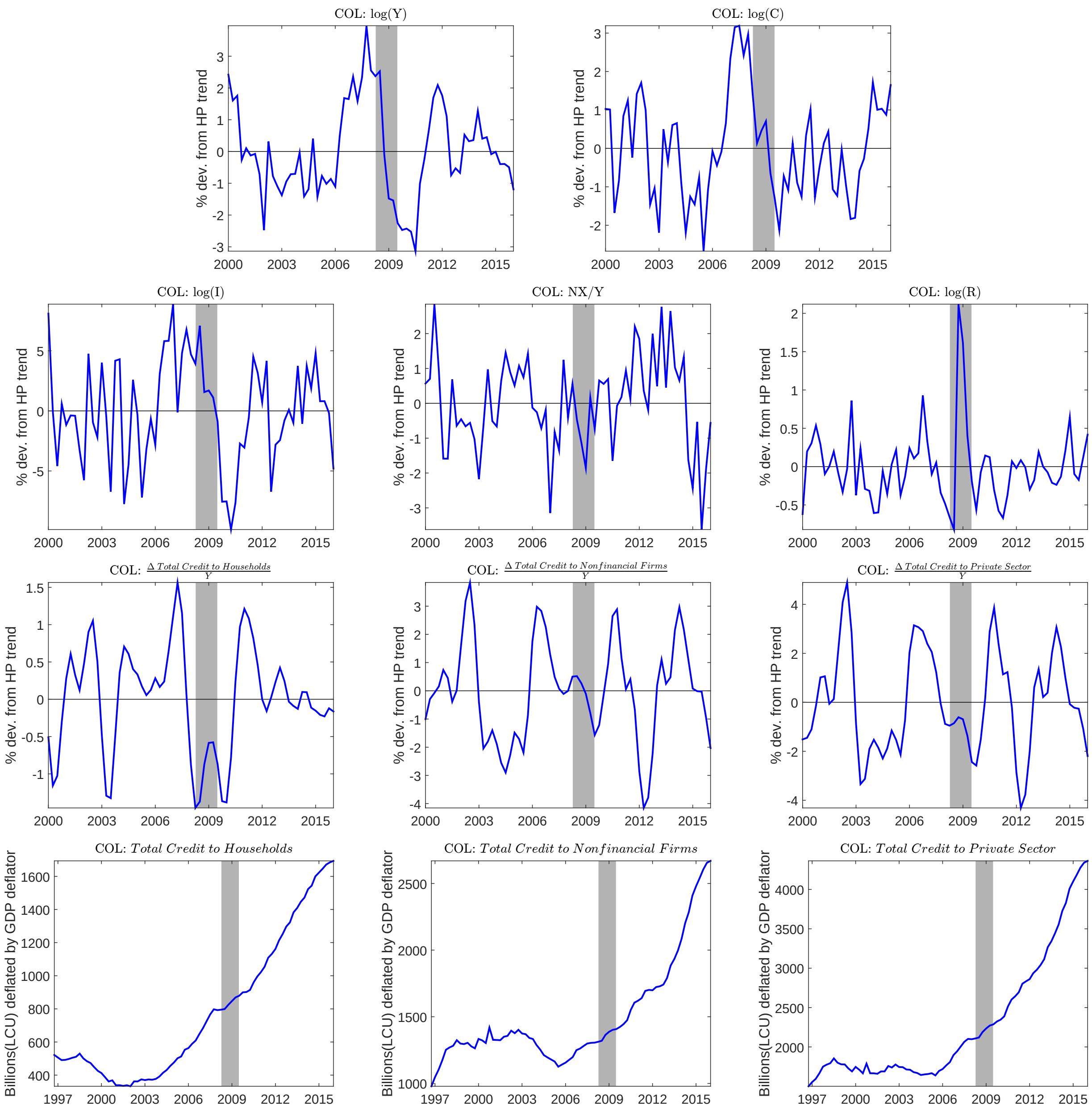

Figure 18: Cyclical Components and Total Credits

H.5 Korea

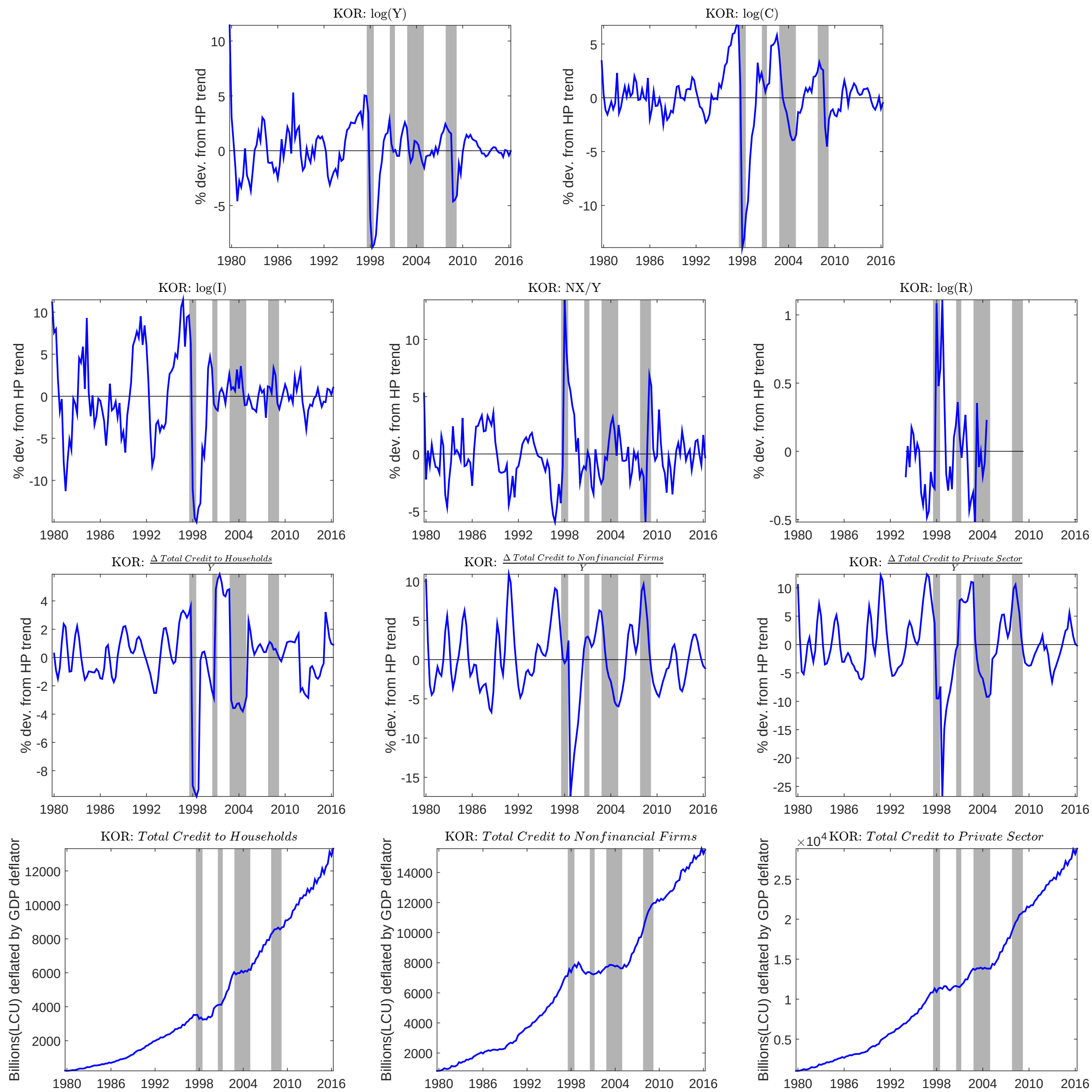

Figure 19: Cyclical Components and Total Credits

H.6 Mexico

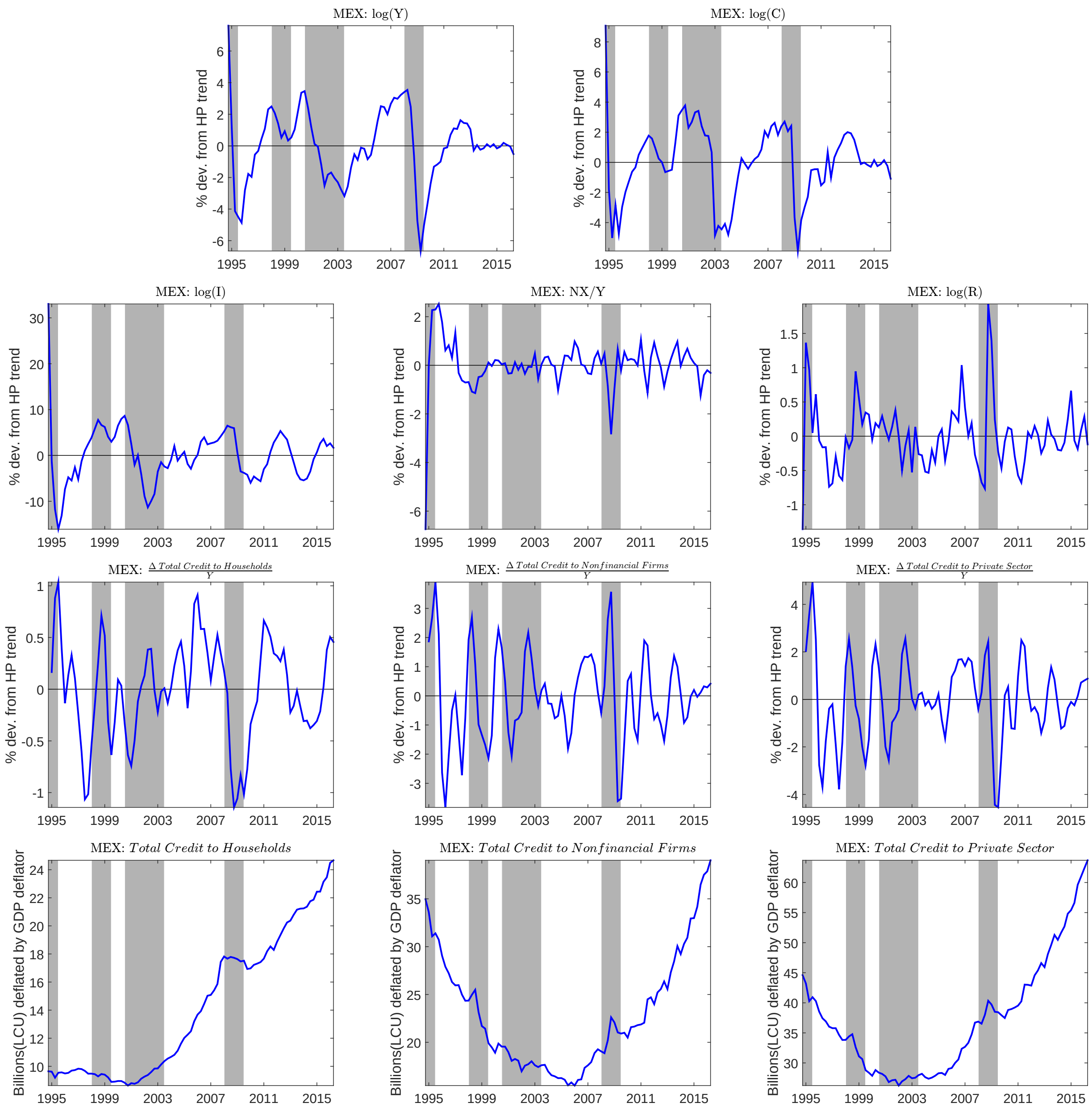

Figure 20: Cyclical Components and Total Credits

H.7 Thailand

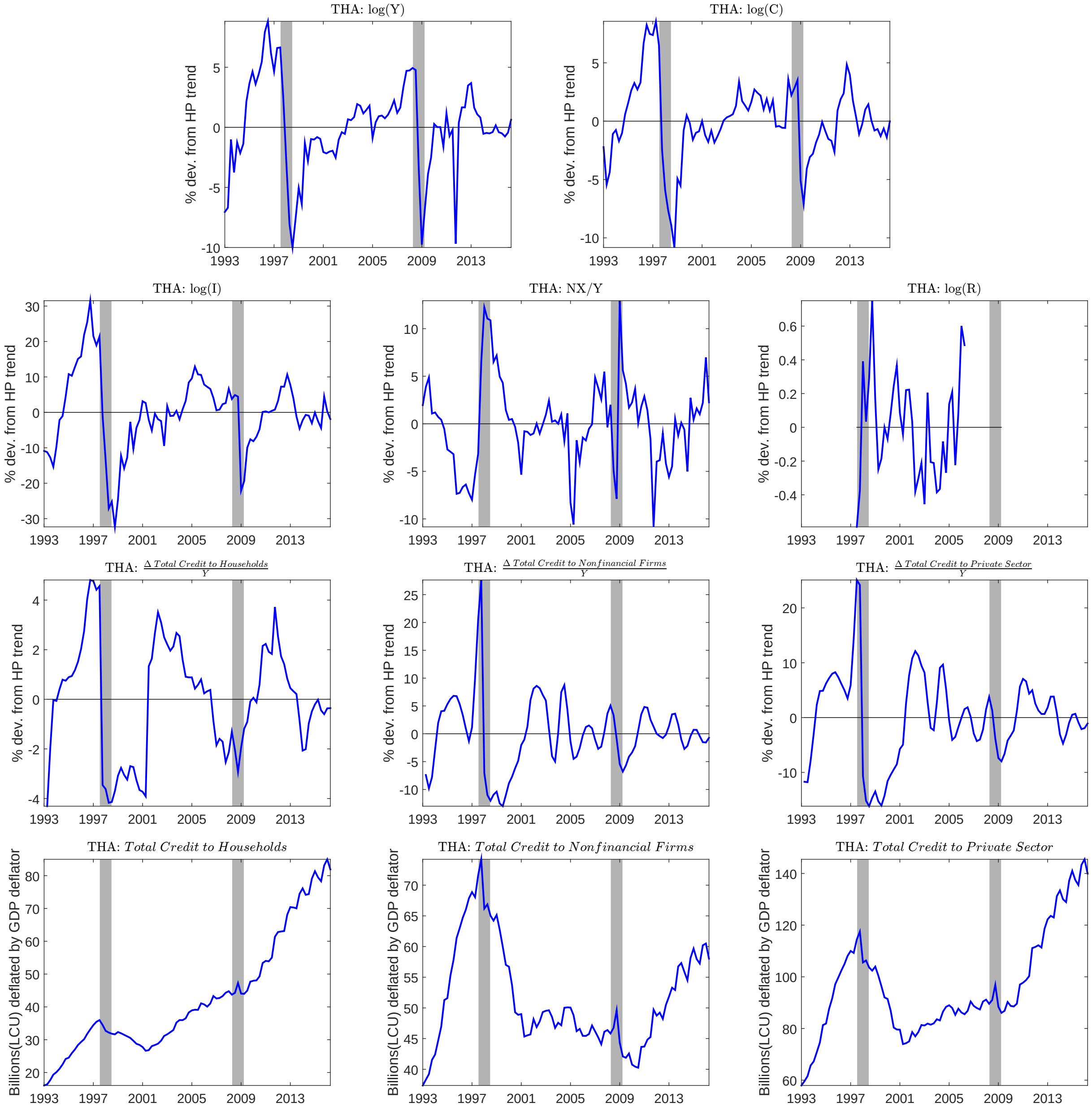

Figure 21: Cyclical Components and Total Credits

H.8 Turkey

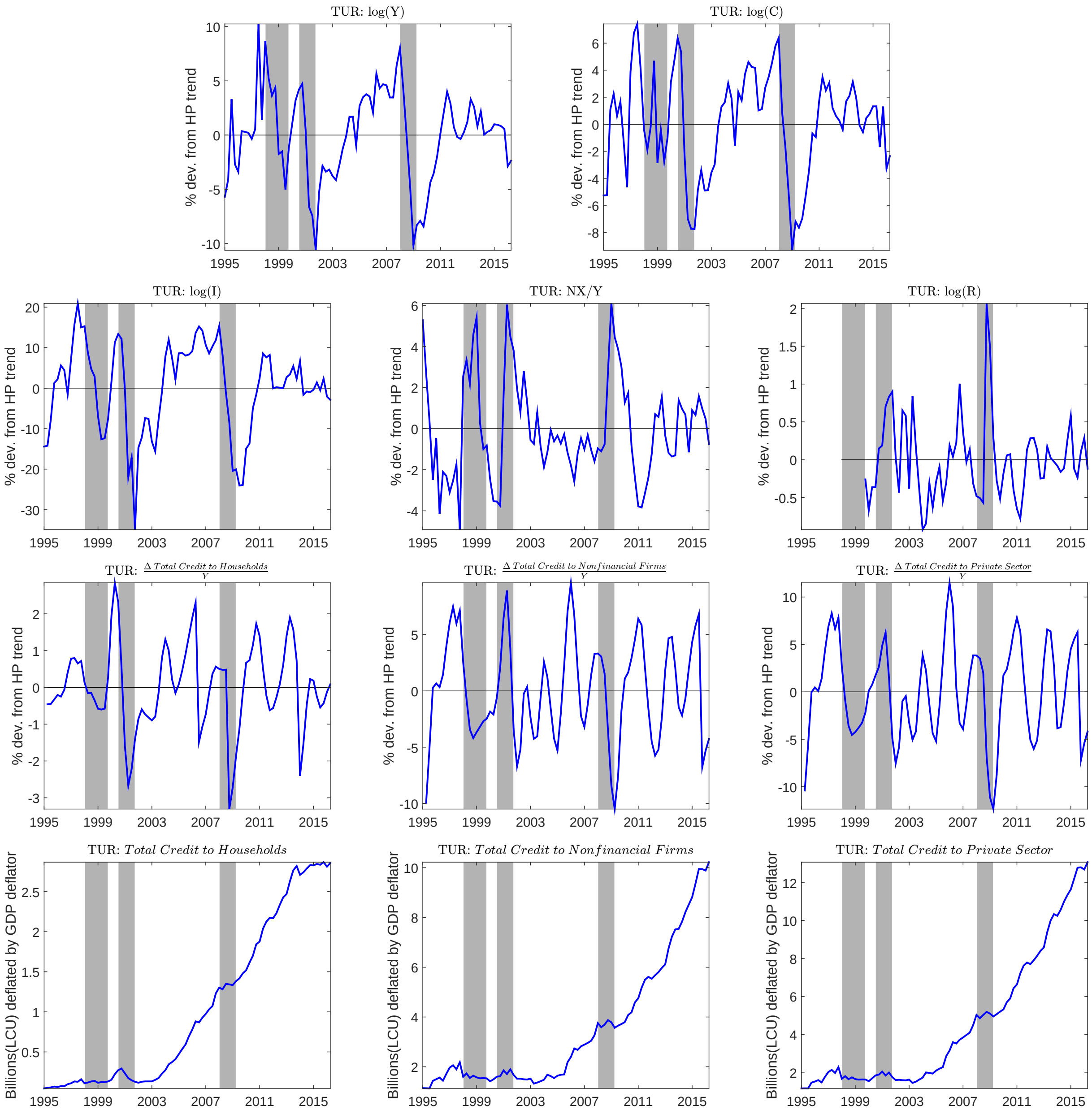

Figure 22: Cyclical Components and Total Credits

H.9 Australia

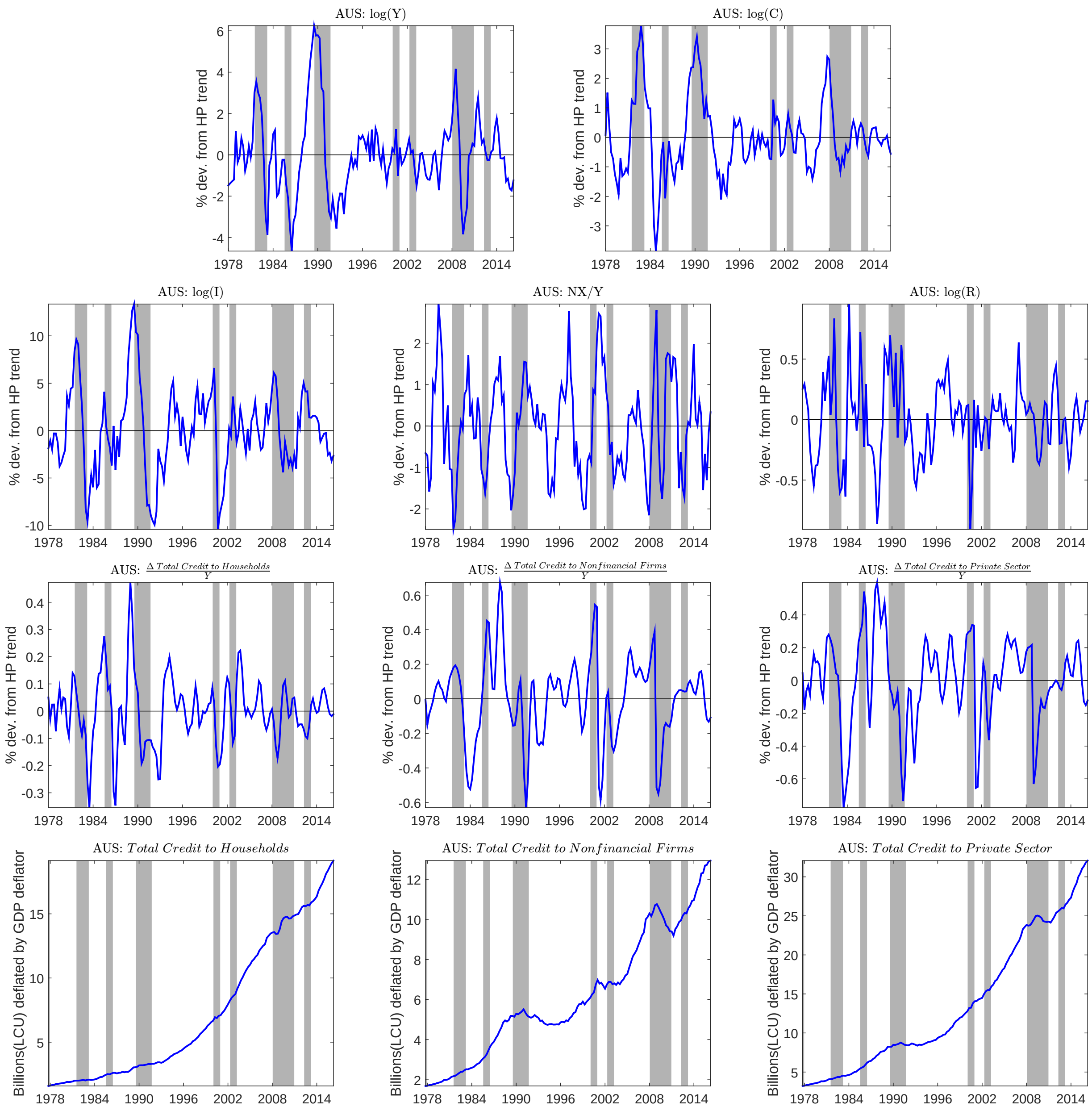

Figure 23: Cyclical Components and Total Credits

H.10 Austria

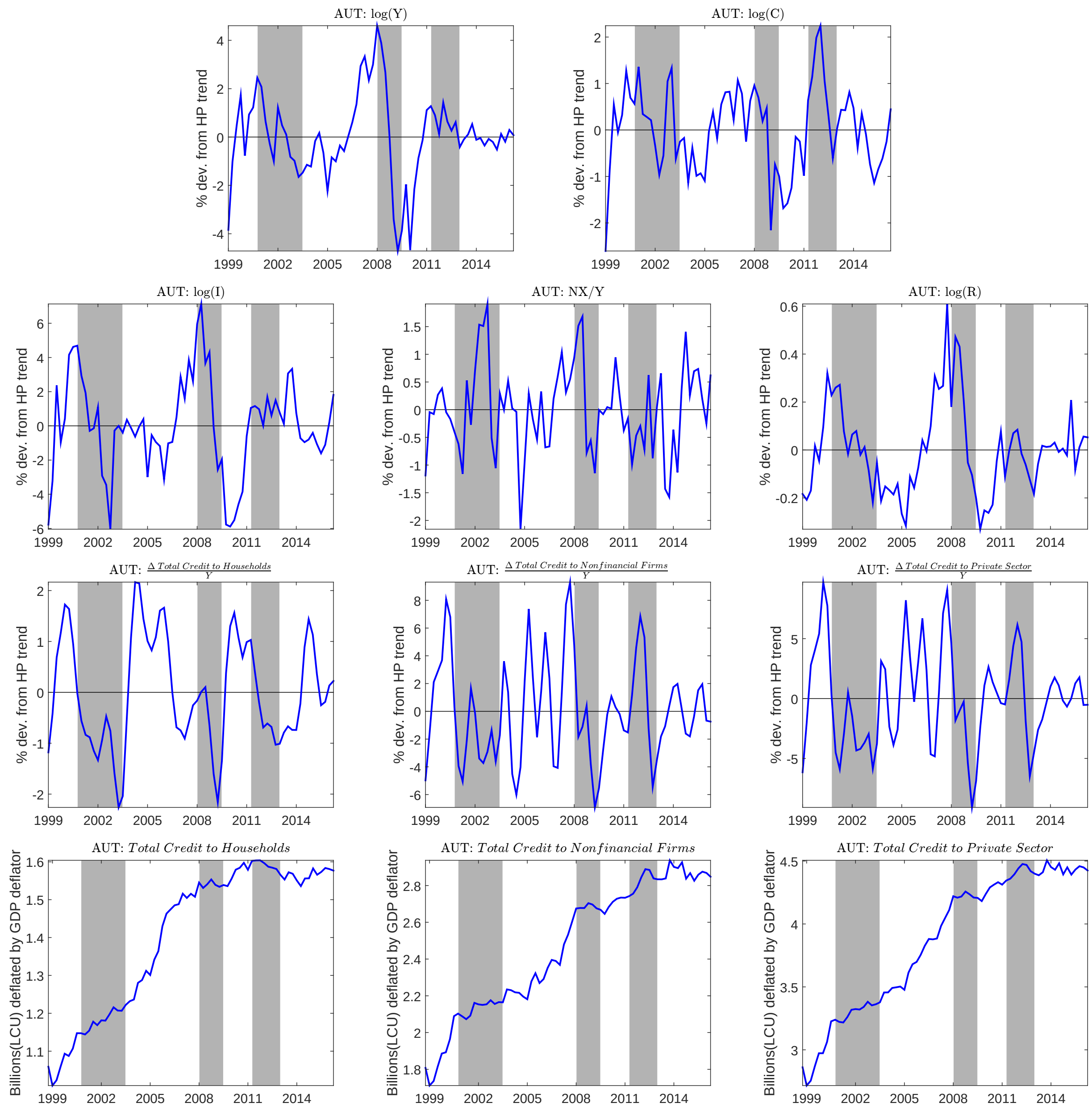

Figure 24: Cyclical Components and Total Credits

H.11 Belgium

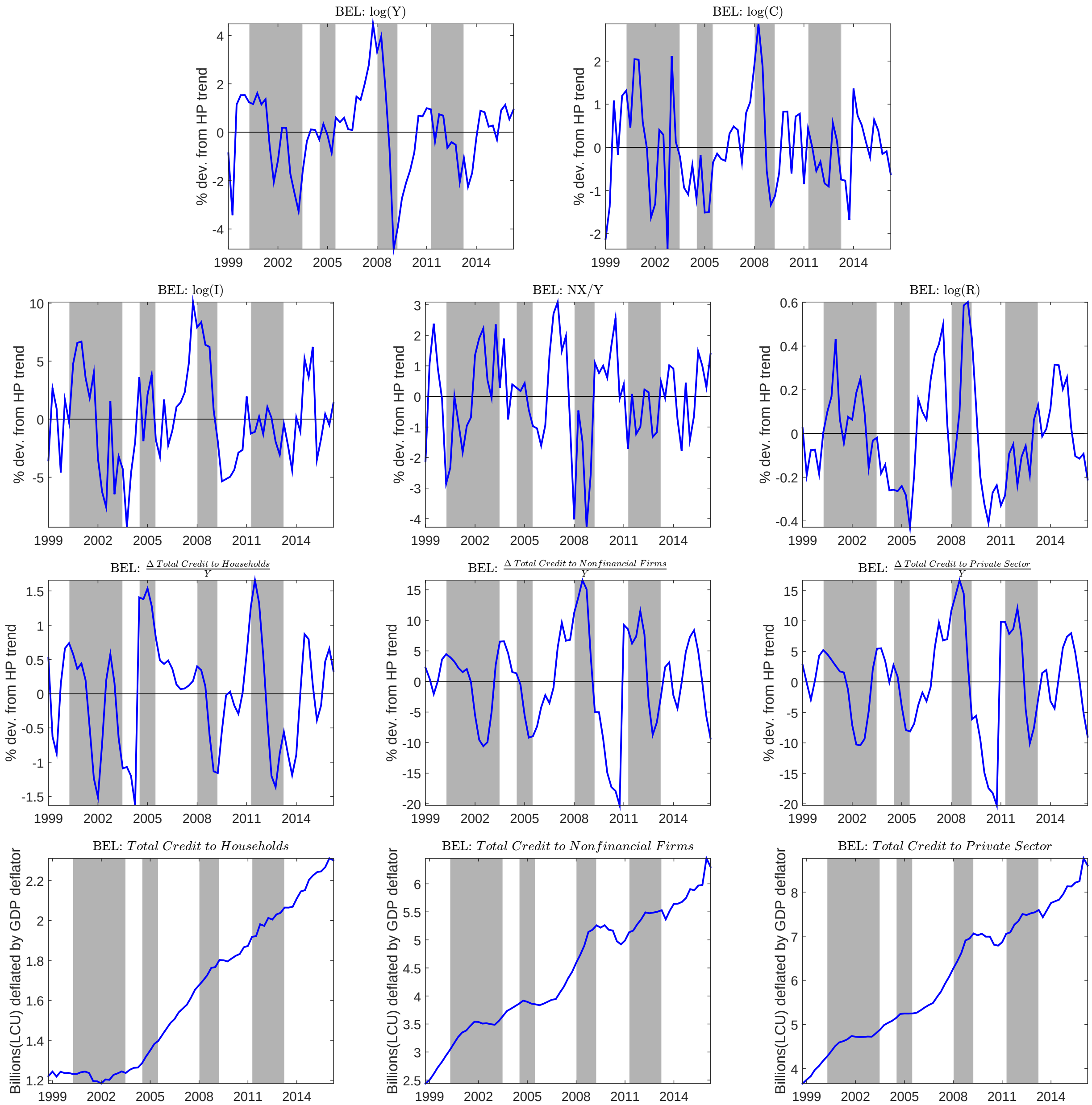

Figure 25: Cyclical Components and Total Credits

H.12 Canada

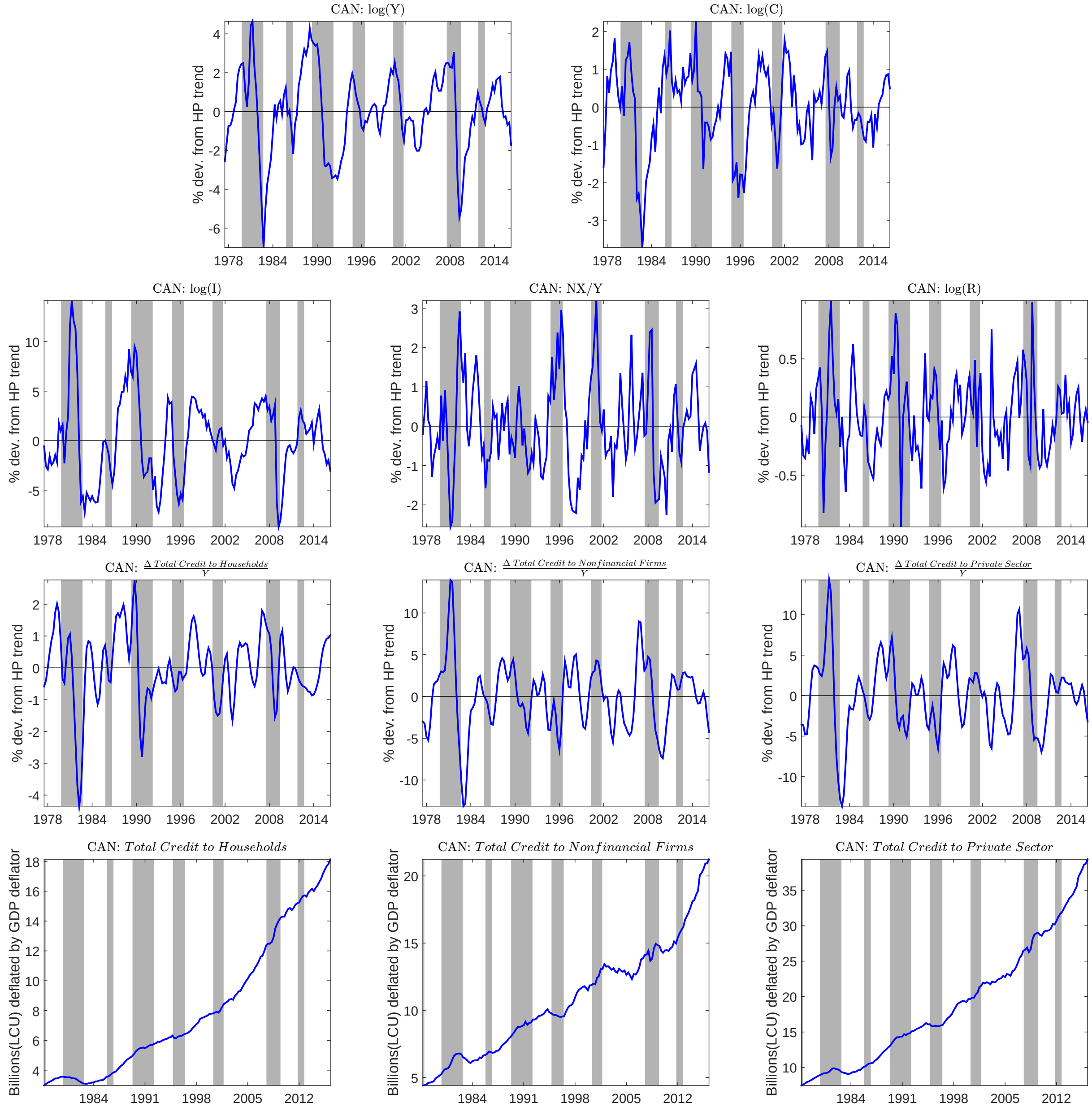

Figure 26: Cyclical Components and Total Credits

H.13 Denmark

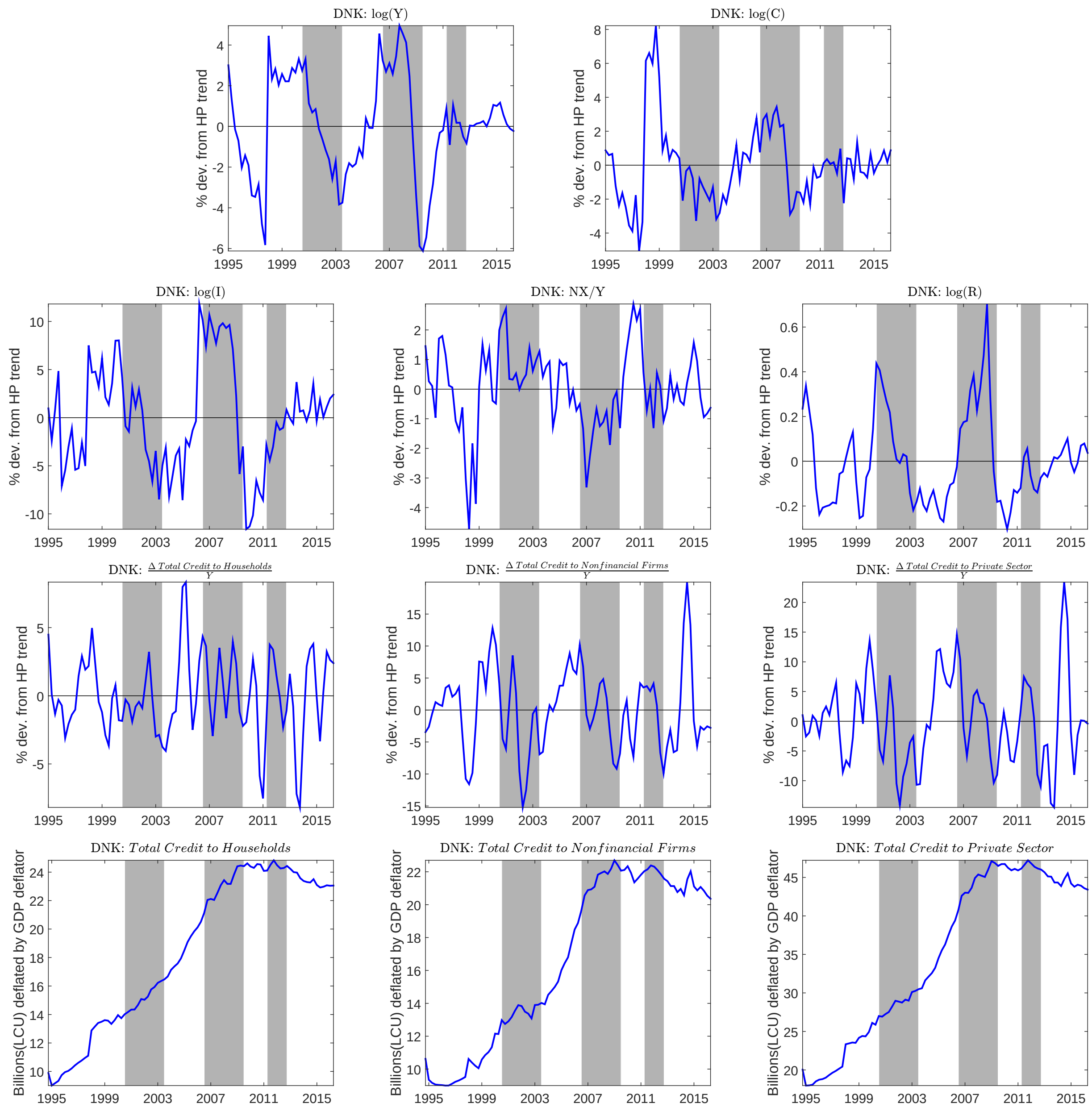

Figure 27: Cyclical Components and Total Credits

H.14 Finland

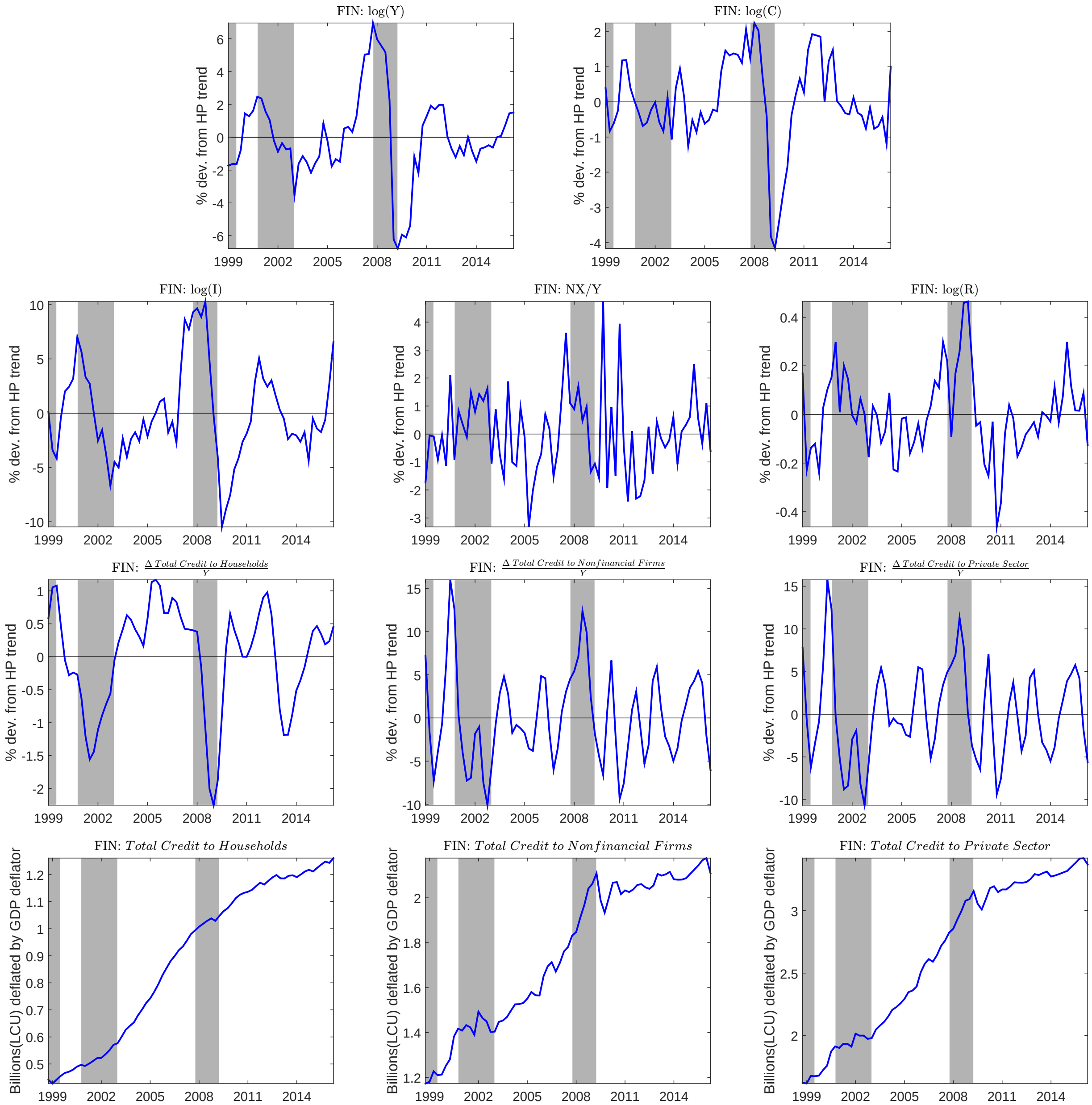

Figure 28: Cyclical Components and Total Credits

H.15 Netherland

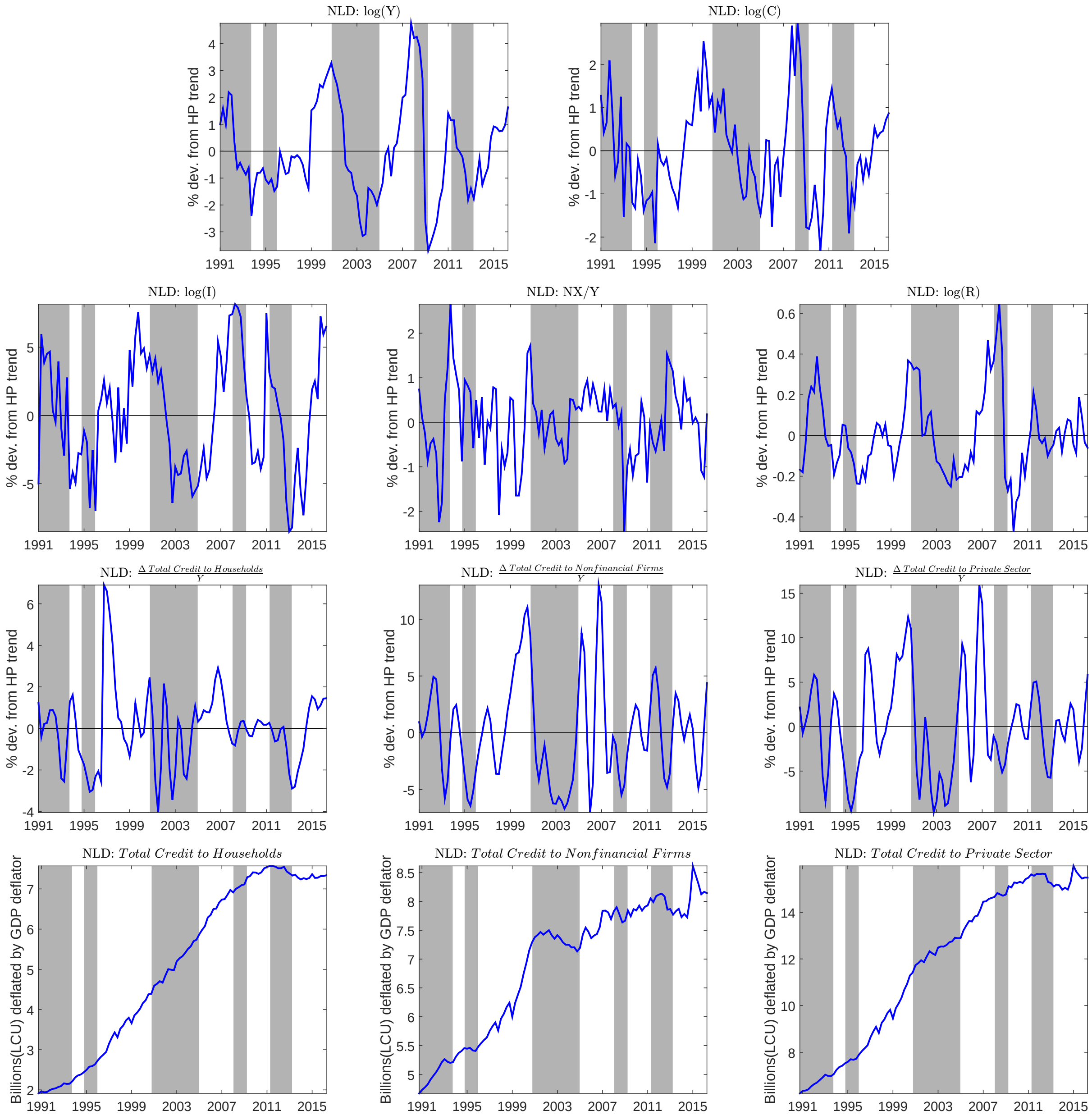

Figure 29: Cyclical Components and Total Credits

H.16 Portugal

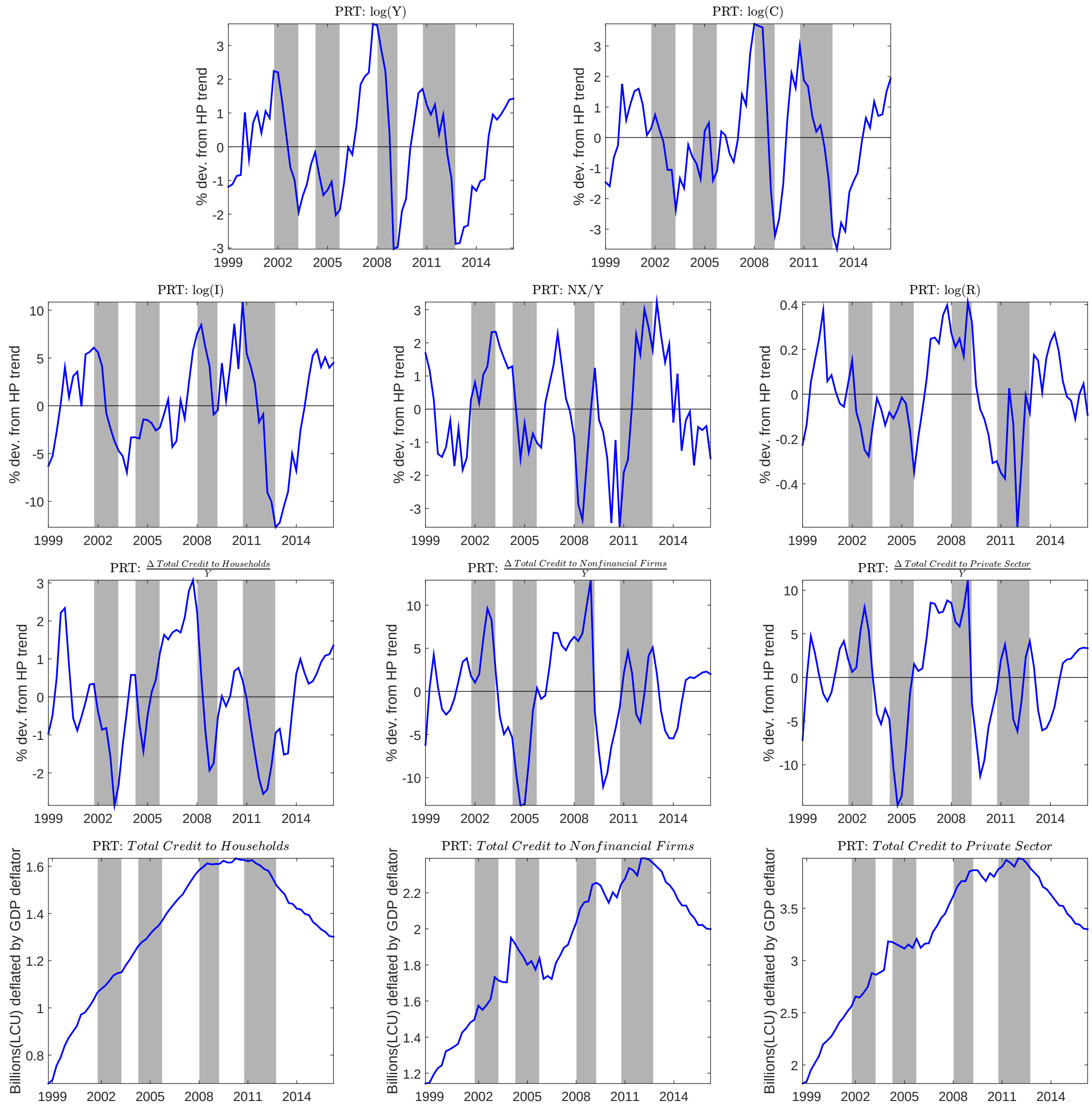

Figure 30: Cyclical Components and Total Credits

H.17 Spain

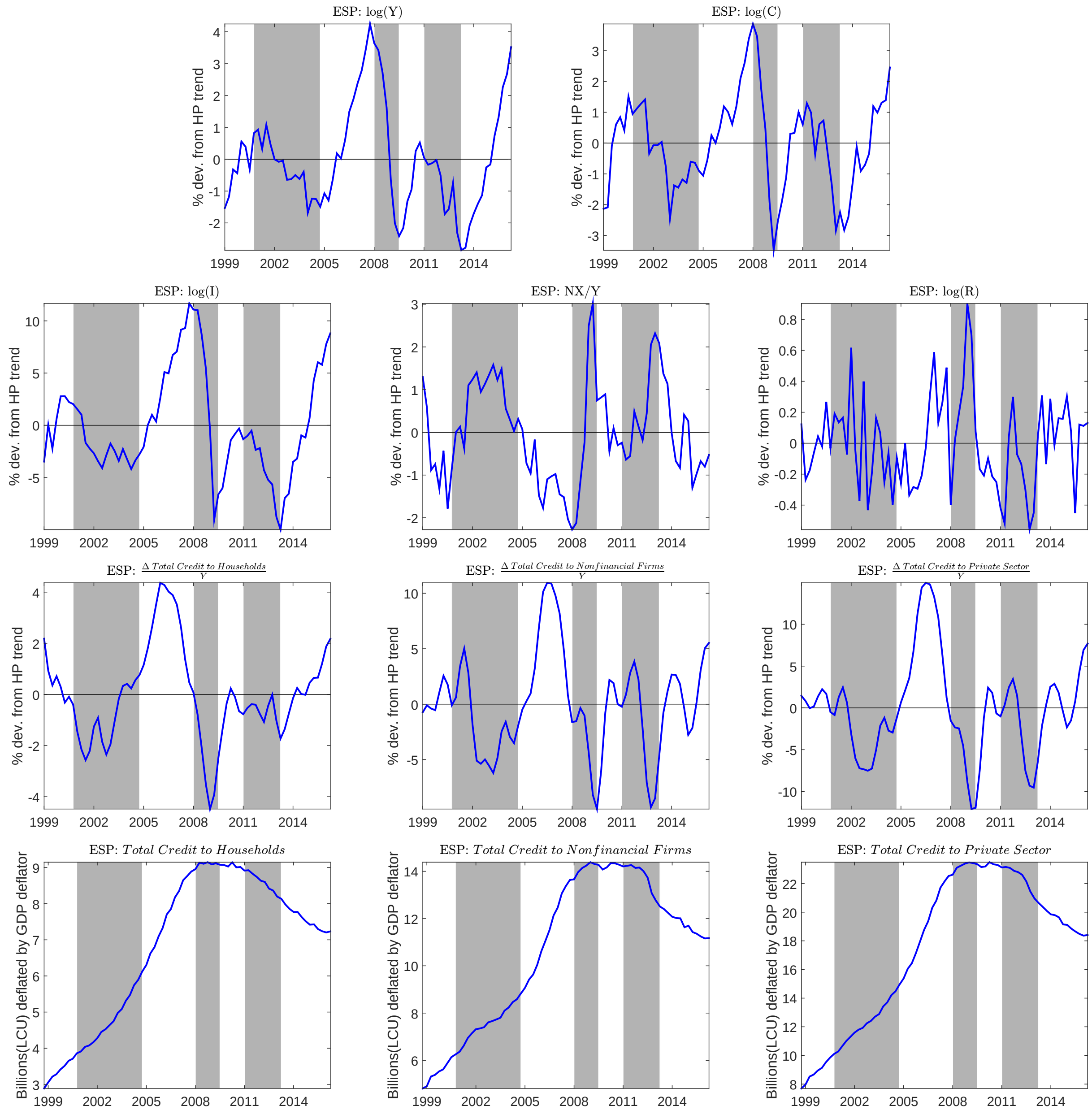

Figure 31: Cyclical Components and Total Credits

H.18 Sweden

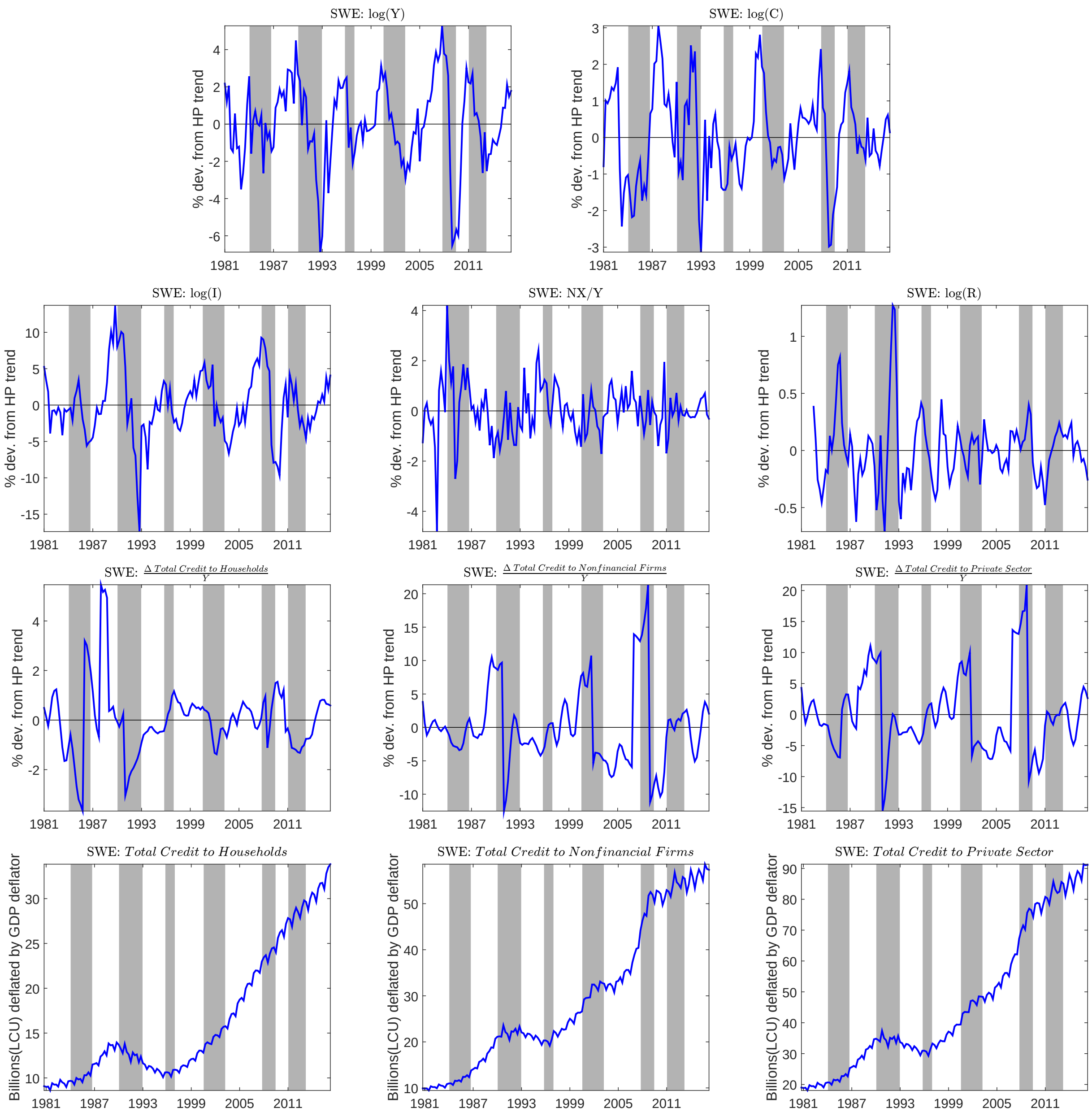

Figure 32: Cyclical Components and Total Credits

H.19 Switzerland

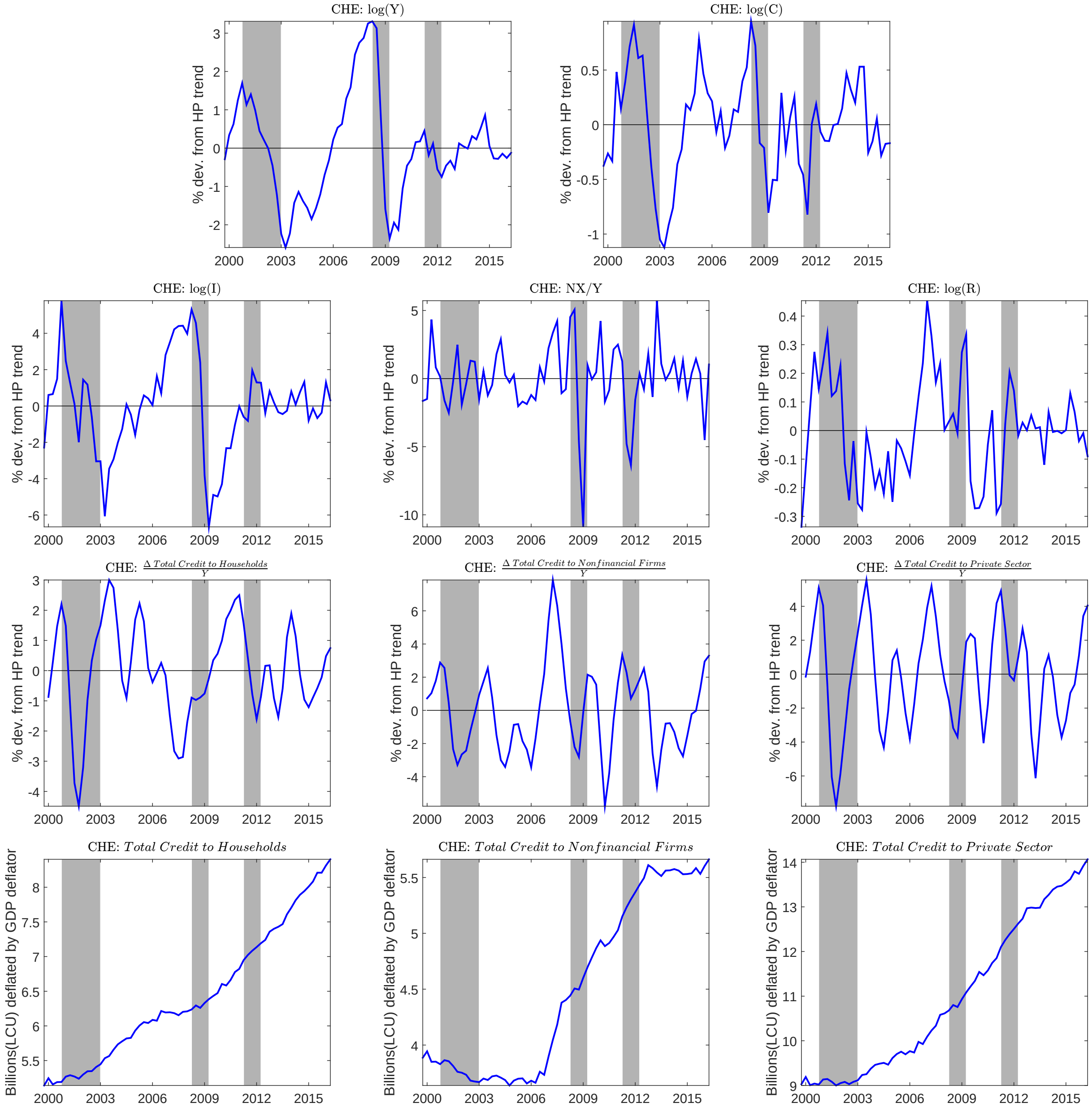

Figure 33: Cyclical Components and Total Credits