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Global Capital Flows and the Role of Macroprudential Policy*

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Abstract

Can countercyclical bank capital requirements reduce the negative effects of global liquidity shocks? We use the Lehman Brothers bankruptcy as a natural experiment to document the role of the banking system as a transmission channel of global financial disturbances to domestic economies. Using granular and confidential data from the Bank of Portugal, our results suggest that in the aftermath of the Lehman collapse, domestic firms cut investment by 14% and employment by 2.3%. In order to evaluate the effectiveness of macroprudential regulation, we model an open-economy with a banking sector borrowing from domestic and international depositors. We show that, during a financial crises, in an economy with countercyclical bank capital requirements (compared with an economy with constant capital requirements): (i) gross domestic product falls 5 p.p. less and (ii) the fall in investment is 3 p.p. lower. We show that imposing countercyclical capital requirements entails a trade-off between lower volatility and lower economic activity. Overall, we find that countercyclical bank capital requirements may not be welfare improving for the Portuguese economy.

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1 Introduction

The 2008 financial crisis had its beginning in the U.S. but spilled over globally with severe economic consequences. In fact, in the aftermath of the great recession, global gross domestic product (GDP) fell by 8 p.p.. The importance of global financial cycles to capital inflows and asset prices has been widely recognized (Rey (2013)). Global banks serve as the main transmission channel, fueling financial shocks from core financial centers to domestic economies.[1] While there is a growing body of literature trying to establish the connection between shocks to banks' balance sheets and credit freezes, less is known about the impact of these negative shocks on economic indicators such as investment and employment. A weakened financial system and its negative consequences on the economy revived the need for rethinking policies prescriptions to deal with systemic risk in financial markets. At the forefront is the debate on the effectiveness of macroprudential regulation.[2]

In this paper, we make two main contributions. First, we show how the banking system served as a pass-through of global financial shocks, contributing to the decrease in economic activity in the aftermath of the recent financial crisis. We use the Lehman Brothers bankruptcy as a natural experiment. Exploiting the heterogeneus exposure of Portuguese banks to the international wholesale market, we show how a weakened banking sector responded by lowering credit supply, causing a decrease in investment and employment in Portugal. After documenting the causal link between global financial shocks and changes in the domestic economy, our second contribution uses a theoretical model to quantify the impact of imposing countercyclical bank capital requirements to curb down the impact of these exogenous disturbances. Our findings add to the important debate on alternative policies to deal with financial crisis by (i) quantifying the benefits of countercyclical bank capital requirements during a financial crisis and (ii) documenting and quantifying the trade-off the economy faces when implementing such policy.

The 2008 financial recession brought a liquidity drought in the international interbank wholesale market, spilling over to the Portuguese economy. In fact, after the Lehman Brothers collapse, credit growth started to decrease in Portugal.[3] Contemporaneous with the Lehman fall, investment and employment by Portuguese firms also

[1]A non-exhaustive list is: Cetorelli and Goldberg (2012), Cetorelli and Goldberg (2011), Kalemli-Ozcan et al. (2013), De Haas and Van Horen (2013), Haas and Lelyveld (2014).

[2]See, for example, Blanchard et al. (2010), bank for International Settlements-International Monetary Fund (2011), and bank for International Settlements-International Monetary Fund (2016).

[3]See Figure (9) in appendix (A.1).

collapsed. Two years after the Lehman fall, employment in Portugal decreased by 5.4% and gross fixed capital formation (GFCF) dropped by 14.3%.[4] From these sequence of events, one might be tempted to conclude that causality runs from disturbances in a core financial center to negative consequences for economies abroad. However, credit levels are the equilibrium outcome of maximizing decisions made by creditors and debtors. Banks may be unable or unwilling to supply credit to the productive side of the economy due to worsening international wholesale market conditions (*credit supply channel*). The same equilibrium credit level drop might also be caused by a fall in demand for credit. In fact, when economic conditions worsen, firms may have lower profitable investment opportunities or face lower demand for their products, leading to lower credit demand (*credit demand channel*).

We begin our paper by quantifying the importance of the banking system as a pass-through of the Lehman default shock to the Portuguese economy (*credit supply channel*). To that extent, we use highly granular and confidential data from the Bank of Portugal to build a dataset consisting of loan-level data covering virtually the entire population of banks and firms operating in the Portuguese territory. Portugal serves as a suitable test laboratory for our natural experiment for three main reasons: (i) the Lehman collapse was exogenous to the Portuguese economy (ii) there was no real estate bubble and (iii) Portuguese firms are highly dependent on credit from the banking sector.

Our identification strategy divides the causal chain into two parts. In the first part, we use a difference-in-difference design comparing lending before and after September 2008, exploiting the quasi-experimental variation in the dependence of Portuguese banks on international interbank markets. Our main identification strategy hinges on isolating a firm borrowing from banks with different exposure to international markets (Khwaja and Mian (2008)). We find that following the Lehman collapse, the drop in credit supply is higher for banks more dependent on international financial markets. After establishing the drop in credit supply following the Lehman fall, the second part of the causal link uses an instrumental variable approach to show how lower credit supply fuels into a drop in aggregate investment and employment. We report that a one-percentage point decrease in credit supply lowers investment by 1.05 percentage points and employment by 0.16 p.p.. A partial equilibrium analysis suggests that, during the 2004 – 2012 period, the liquidity shock to banks' balance sheet brought by the Lehman fall accounts for 2/3 of the aggregate drop in investment and a 39% share of the drop in aggregate employment. Therefore, we provide empirical evidence

[4] See Figures (11) and (12) in appendix (A.1).

supporting the hypothesis that the banking sector acts as a crucial pass-through of foreign disturbances to the real economy.

We continue our paper by outlining a structural model to study the effectiveness of macroprudential policy to deal with exogenous negative disturbances. Changes in credit supply due to exogenous shocks produce general equilibrium effects and spillovers that cannot be fully accounted for by our empirical methodology. Using a theoretical model offers several advantages: not only can we account for general equilibrium effects, but also it offers an interpretation of the causal relationships we find in the empirical section as well as a test laboratory for key counterfactual experiments. To that extent, we build an open-economy model with a banking sector borrowing from domestic and international depositors. We calibrate the model resorting to indirect inference to estimate key parameters. That is, we use the empirical model as an auxiliary model to calibrate the employment and investment block of the structural model.

Our main thought experiment studies the effect of imposing macroprudential policy in the form of countercyclical bank capital requirements in the spirit of Basel III. Imposing this type of friction has the benefit of correcting a moral hazard problem on the part of the banking sector as well as of eliminating over-leverage in the economy. We show how macroprudential policies can curb down leverage, improve banks' net worth and lower the dependence on foreign debt. We provide two main findings. First, countercyclical bank capital requirements lowers macroeconomic volatility. During a financial crisis, gross domestic product (GDP) becomes 5 p.p. less volatile, the fall in banks' net worth is 2 p.p. lower, and investment volatility decreases by 3 p.p.. Second, using simulated data we also document that the number of economic crises drops by 1 p.p.. However, the downside of macroprudential policy is a decrease in level of economic activity. In fact, we quantify how average GDP falls by 1 p.p. over the entire simulated data sample. Therefore, we show how imposing countercyclical capital requirements imply a *trade-off* between lower volatility and lower economic activity.

The intuition for this *trade-off* is that, during periods of economic prosperity, a banking system with countercyclical capital requirements is asked to hold more funds as net worth. Therefore, compared with an economy with constant capital requirements, it will be able to provide less credit, leading to less investment and lower economy activity. However, the upside of a banking sector with countercyclical capital requirements is that the financial sector builds a capital buffer that can be used during a financial crises, dampening the negative effects of disturbances in the financial system and maintaining credit to the real economy.

Finally, we study the welfare implications of imposing countercyclical capital requirements. Given the aforementioned *trade-off*, can countercyclical bank capital requirements be welfare improving? Overall, we find this type of policy not to be welfare improving for the Portuguese economy. However, the answer may depends on the state of the economy. We find that, when compared with constant bank capital requirements, having a banking sector with countercyclical capital requirements will be welfare improving if the economy (i) is in a recession, or (ii) has low aggregate credit.

Literature review: Our paper contributes to four strands of literature. First, we add to the literature that studies the international transmission of financial crises. Earlier examples are Peek and Rosengren (1997) and Peek and Rosengren (2000) that study the transmission of the Japanese banking crises to the United states. Although recent papers have provided empirical evidence of a credit drop following external liquidity shocks, the literature is still shy on the effect of such shocks on the real economy.[5] By building a rich dataset of loan-level data, this paper contributes to this literature by showing how a global shock to banks' balance sheets lowers investment and employment in Portugal.[6] Methodologically, we build on the work of Khwaja and Mian (2008).

Second, our paper also contributes to the literature on macroeconomic effects of macroprudential policy. Jiménez et al. (2017) studies the introduction of dynamic provision macroprudential tool in Spain. The authors provide empirical evidence on how countercyclical capital buffers can smooth credit in recessions. We build a structural model to complement and echo their findings. Besides echoing the positive effects of countercyclical bank capital requirements in recessions, we complement this study by quantifying the negative effects for long-run economic activity of these policy tools.[7]

[5]For example, Schnabl (2012) studies credit disturbances on Peruvian banks due to the Russian default. Iyer et al. (2014) uses the Portuguese credit register showing a credit drop following the 2007 interbank liquidity shock.

[6]Other example of work studying the impact of global shock on the real economy are Paravisini et al. (2015), who studies how a credit shortage affects exports, and Chodorow-Reich (2014), who provides evidence of a decrease in employment in the US in the aftermath of the 2008 financial crisis. Recent papers also study the impact of financial shocks on firm behavior, showing how leveraged firms tend to increase worker layoffs (e.g. Giroud and Mueller (2017) and Buera and Karmakar (2018)). Finally, a paper closer to ours is Cingano et al. (2016).

[7]Other examples of empirical studies are Igan and Kang (2011) that use the South Korean experience with loan-to-value and debt-to-income regulation to document how these type of policies can

Third, the model we develop in this paper is at the intersection of two literatures: the literature on credit market imperfections and the open-economy literature studying sudden-stop crises. Our theoretical framework builds on the work of Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) that introduces financial intermediaries in a standard business-cycle model[8]. Contrary to most of this literature, our main focus is on the international consequences of the 2007 – 2009 financial crises. To do so, we extend the aforementioned authors' framework by including international investors lending to the domestic banking sector. Also, as in the open-economy literature, the return on credit in our model depends on the foreign interest rate as well as on the level of foreign-debt-to-gdp. Finally, we also add a domestic regulator setting macroprudential policy. We contribute to this literature by analysing and quantifying the effectiveness of countercyclical bank capital requirements to curb down the negative effects of external shocks to the banking sector. A related set of papers also studies macroprudential policy in a similar framework. Aoki et al. (2016) focus on macroprudential capital taxes and Akinci and Queralto (2017) study the effectiveness of bank equity injections and constant bank capital requirements. Our paper differs from these studies by focusing on the recent Basel III accord implementation of countercyclical bank capital requirements.[9]

Fourth, capital flow reversals have been studied in the open-economy literature, arguing for capital controls and macroprudential policies aimed at correcting pecuniary externalities (e.g. Mendoza (2010), Bianchi (2011), Korinek (2018)). The literature on sudden stops stresses the need to reduce overborrowing in international markets, whereas our paper focus on reducing bank leverage by improving banks' net worth. Our results corroborate the need for macroprudential policy for financial stabilization.

The rest of the paper is organized as follows. In section (2) we provide a description of data, the empirical strategy and empirical results. In section (3) we analyse the robustness of our empirical findings. Section (4) provides a description of the theoretical model. Section (5) explains how we proceed with our quantitative exercise. In section (6) we analyse the mechanism through which capital flows fuel into the domestic economy. Section (7) studies the use of countercyclical bank capital requirements. We conclude in section (8).

control house price appreciation. Bruno et al. (2017) uses a panel of 12 Asian countries to show that macroprudential measures can curb down both bank inflows as well as bond inflows.

[8]Other examples are Kiyotaki and Moore (1997), Bernanke et al. (1999), and Brunnermeier and Sannikov (2014))

[9]Other papers studying capital requirements are Van den Heuvel (2008), Repullo and Suarez (2013) and Karmakar (2016).

2 A Natural Experiment on the impact of capital inflows on the domestic economy

This section has two main purposes. First, showing the causal impact of a foreign exogenous disturbance on the domestic supply of credit and subsequent impact on domestic aggregate macroeconomic variables. Second, it provides estimated parameters to inform the calibration exercise of the theoretical model in section (4). We use the Lehman brothers collapse to show how such episode can trigger a causal chain going from capital inflow reversals and an international shock to the balance sheet of Portuguese banks culminating in lower credit supply to Portuguese firms and subsequent drop in investment and employment. The section proceeds in five steps: Section (2.1) discusses the Portuguese economic and financial environment during the financial crisis. Section (2.2) describes the empirical setting and our data. Section (2.3) presents the identification strategy. Section (2.4) is the first step in the causal chain, showing how the Lehman fall resulted in lower credit supply. Section (2.5) is the second step and shows the fall in investment and employment due to the fall in credit supply.

2.1 Lehman Backruptcy and the Behavior of Portuguese firms and banks

In September 15, 2008 the Lehman Brothers investment bank filled for bankruptcy, making it the biggest bankruptcy case in US history, and becoming the most important chapter of the subprime mortgage crisis. The recession was triggered by a real state bubble and a sharp fall in housing prices. Although the subprime crisis had repercussions worldwide, on impact they did not affect the Portuguese economy. There are two main reasons why the subprime crisis had a smaller impact in Portugal: (i) Over the period $1970-2014$ the economy witnessed a flat path of real housing prices. (Lourenço and Rodrigues (2015)) (ii) Portuguese banks did hold a scarce exposure to mortgage-backed securities (MBS) and collateralized debt obligations (CDS).

Portugal is a small and open economy where the banking sector – due to low domestic savings – relies heavily on funds raised internationally. Moreover, the high reliance of firms on credit from the banking sector is a feature of the European market shared by Portuguese non-financial companies. The subprime mortgage crisis also brought distress to the international interbank market, leading to increases in interbank market spreads and market freezes. Although Portuguese banks hold a significant exposure to the international wholesale market – e.g. 17% of deposits and debt securities hold by German banks and 16.74% hold by banks outside the monetary union – aspects of the Portuguese regulation made investment on instruments like off-balance sheet vehicles funded by asset backet commercial paper (ABCP) more difficult. (Acharya and Schnabl (2010)) For this reason, Portuguese banks were not as affected by the ABCP market freeze that happened in the aftermath of the Lehman collapse. We use the heterogeneous exposure of Portuguese banks to the international interbank market as a source of variation to understand the effect of the Lehman default on the behavior of investment and employment. Although our focus is on supply side explanations, we knowledge the importance of demand side reasons for the decline several macroeconomic variables. Section (2.5) discusses the relative significance of both sources of variation.

2.2 Data

In this section we describe the data sources – and dataset construction – used to provide a causal link between credit supply by Portuguese banks and changes in investment and employment decisions by Portuguese firms. We build a comprehensive data set combining information from three administrative data sources: we match credit register data with bank's balance sheet data and firm's economic and balance sheet variables. The source of data is the Bank of Portugal which – being the supervisor and regulator of the Portuguese banking sector – holds confidential data on virtually all credit-market transactions made in the Portuguese territory.

The first dataset contains information on credit extended by Portuguese credit-granting institutions to households and non-financial corporations and is called "Central Credit Responsibility Database" (*central de responsabilidades de crédito*) (CCR onwards). The CCR is a confidential and very comprehensive dataset holding reports on all credit supplied by institutions operating in the Portuguese territory.[10] While most European central banks hold records of loans granted domestically, the Portuguese CCR holds special relevance since it is one of the most comprehensive country-wide CCR data sets, reporting all credit with a minimum loan registration of 50 euros.[11] For

[10]The following is a list of entities included in CCR: banks, saving banks, mutual agricultural credit banks, financial credit institutions, leasing companies, factoring companies, securitization companies, mutual guarantee societies, and financial companies for credit acquisitions.

[11]Since 2008 the Portuguese CCR reports all loans made by Portuguese banks to Portuguese non-financial institutions with a value higher than 50 euros. Before 2008 the minimum threshold was even lower – all loans above 10 euros were reported. Reporting threshold for the Spanish credit register is 6,000 EUR

this project we focus only on credit granted to non-financial corporations and exclude credit to individuals. The frequency of the data is monthly.

The second dataset provides information on bank's balance sheet (BBS) and is extracted from the Monetary Financial Institutions Balance Sheet (*Balanço das Instituições Monetárias e Financeiras*). This data set is compiled by the central bank of Portugal, reporting detailed information on the assets and liabilities of the monetary financial institutions (MFIs) operating in Portugal. The original data in on at monthly frequency spanning 1997-2017.

The third source is a dataset on firm's financial and economic variables. The Central Balance Sheet Database (CBSD) (*central de balanços*) is a confidential data and is property of the central bank of Portugal, reporting accounting information spanning almost all firms operating in Portuguese territory. It provides very extensive information on employment, balance sheet and other economic variables. The frequency of the data is annual.

Our final dataset combines all three sources of information, encompassing 56 credit-granting institutions, more than 300.000 non-financial corporations and around 5 Million recorded loans.

Table (A.2) provides an overview on the characteristics of non-financial corporations present in our dataset. The first three columns report firm characteristics based on the level of exposure of banks – to international wholesale markets – that lend those firms. The last column reports values for the whole sample. Table (A.1) describes the situation of the banking sector along the most pertinent dimensions. The first three columns report bank descriptive statistics based on the level of exposure to international wholesale markets. The main take-away is that both groups of banks do not differ considerably along the reported dimensions.

2.3 Empirical Strategy

In this section we describe how we identify the causal impact of the Lehman collapse on domestic macroeconomic variables. Estimating the causal effect of capital inflow reversals on credit supply by Portuguese Banks to the non-financial sector poses several identification hurdles.

First, realized credit levels are the equilibrium outcome of maximizing decisions made by creditors and debtors. Figure (10) shows a dry-up of domestic bank's international interbank market borrowing. By itself, this fact is not evidence of a credit supply decline. Banks may be unable or unwilling to supply credit to the productive side of the economy due worsening international wholesale market conditions. But the same equilibrium credit level drop might also be due to a fall in demand for credit. In fact, when economic conditions worsen, firms may have lower profitable investment opportunities. For these reasons (and the below arguments) the time-series in figure 9 is not concluding evidence of a credit supply decline. Second, firm's unobserved characteristics might blur the identification exercise. During an economic downturn, it will be reasonable to argue that banks prefer lending to less riskier firms[12]. However, more capitalized firms also search for more credit during downturns since the demand for their products is less affected.

Third, firms can substitute borrowing sources or create new credit relationships (extensive margin). Fourth, even if banks receive a shock to their balance sheet, they may still find alternative lending sources. That is, after the Lehman collapse, even if Portuguese banks suffer from lack of international funding, they may be able to keep the same lending rate to Portuguese firms if alternative lending sources exist or if the bank could find room in the asset side of the bank's balance sheet. (Cetorelli and Goldberg (2011)) Finally, the matching between firms and banks may not be random. For example, weaker banks might specialize in lending to firms with higher credit risk. Suppose the Lehman collapse has a higher impact on the balance sheet of weaker banks. Intuition might leads us to conclude that those banks would decrease funding the most. However, the data might show an increase in credit. This could be due to higher credit demand, as is plausible that riskier firms need more funding during an economic downturn, leading us to conclude that the Lehman collapse culminated in a credit supply increase to Portuguese firms.

All of the above arguments pose a threat to the causal link between the Lehman bankruptcy and the drop in investment and employment in Portugal. To tackle this issues, we are going to perform our empirical analysis in two steps. First, we will show how the Lehman collapse caused a decrease in credit supply by Portuguese banks. Our main identification channel will focus on a given firm borrowing from two (or more) banks with different levels of exposure to global interbank markets. If a firm receives less credit from a bank more exposed to international credit markets then, *ceteris paribus*, we can conclude that an exogenous disturbance causes a fall in domestic credit supply. Specifically, we will construct a within-firm difference-in-difference model of credit. Second, we establish that a fall in credit supply led to an investment

[12]This is not necessarily the case as some banks – specially banks in worse financial conditions – might even prefer lending to riskier firms in search for yield. (ever-greening) (see, e.g., Jiménez et al. (2014))

drop by Portuguese firms. To perform this last step, we use an instrumental variable approach in which we use the weighted exposure of each firm to international markets as an instrument.[13] Therefore, our empirical model is

$$\Delta \ln(X_{f,t}) = \beta_1 + \beta_2 \Delta \ln(Credit_{f,t}) + \varepsilon_{f,t} \tag{1}$$

where $X = \{Investment, Employment\}$. The dependent variable is the log of total investment by firm f at time t and the independent variable is the log of overall credit supplied by the domestic banking sector to firm f during period t. The coefficient β_2 of regression (1) gives the elasticity of investment to credit supply. The following sections describe the steps needed to arrive at our main goal while addressing all identification problems recognized above.

2.4 From capital inflows to credit supply

This section is the first estimation step in our causal chain, identifying the causal relation between an exogenous disturbance and changes in domestic credit supply. We use the fall of Lehman Brothers as an exogenous shock. Our empirical design builds on a firm-bank level difference-in-difference specification comparing lending before and after the Lehman bankruptcy by exploiting the variation in bank exposure to international wholesale markets. The model is given by

$$\Delta \ln(Credit_{f,b,t}) = \alpha_i + \mu Bank\ Exposure_b + \gamma_{b,t} \mathbf{X}_{b,t} + \eta_{f,b,t} \tag{2}$$

where the dependent variable is average credit from bank b to firm f at time t. Time $t = \{Pre, Post\}$ takes two periods: the period before and after November 2008 (the quarter of the Lehman collapse).[14] Each period corresponds to four years. The independent variable corresponds to the ratio of interbank borrowing to total assets by domestic bank b from international institutions[15]. To correct for endogeneity concerns, we use information on *Bank Exposure* during the 2004 period. $Post_t$ is a dummy variable equal to one when $t = Post$.

[13] Amiti and Weinstein (2018) use a different methodology than ours to document the aggregate effect of credit supply on investment.

[14] We motivate our use of two periods – before and after the shock – and averaging along periods by the fact that economic variables tend to be correlated over time, leading to serially correlated errors. (Bertrand et al. (2004))

[15] These international lenders are comprised of international finance granting institutions providing deposits up to two years.

α_f is firm fixed effects, controlling for all time-invariant unobserved heterogeneity at the firm level. This within-firm specification serves as a proxy for the demand of credit. (Khwaja and Mian (2008)) This specification requires firms to hold credit relationship with at least two banks, which is true for 55% of firms in our dataset. γ_{bt} is a vector of variables controlling for bank's specific observable characteristics. The coefficient μ measures how changes in capital inflows through the banking channel influence credit supply by domestic banks.

$\mathbf{X}_{b,t}$ is a vector of bank observables that serve as controls. Namely, we include return on assets, serving as a proxy for Tobin's Q. As in (Cingano et al. (2016)), we also include Cash-hold-assets as control for financial frictions. Standard errors are clustered at the firm level. As further controls we also include cash flow, solvability, debt ratio and colateral. We show that results are robust to alternative clustering methods by running a model with standard errors clustered at the location-sector-size level.

The main identification assumption in our within-firm estimation of equation (2) is that banks and firms did not anticipate the exogenous shock and acted accordingly by changing their credit behavior. This seems an innocuous assumption as the Lehman collapse was due to financial disturbances originated in the US financial system and are unrelated with the Portuguese financial sector. To make sure our identification results hold, we use *Bank Exposure*$_b$ as the ratio of interbank deposits to total assets measured in 2004. Another assumption is the random matching between firms and banks. Section 3 discusses the validity of this assumption.

Results: Table (A.3) column (4) presents our main result for this subsection. The estimation of equation (2) shows how, following the fall of Lehman Brothers, banks more exposed to international interbank credit markets lower credit supply more than banks relying more on funding from the domestic market. This relationship is statistically significant and shows how a one percentage point increase in the ratio of bank's foreign liabilities to total assets predicts a reduction in credit supply of 0.792 percentage points. Using our initial intuition: a firm borrowing from two (or more) banks will see credit supply decreased by the more exposed bank *via-à-vis* remaining (less exposed) banks. Table (A.3) Column (3) reports results when we do not control for bank observables. We conclude that a country with a banking sector with more exposure to capital flows will have larger drop in credit supply following a negative disturbance arising in international financial markets.

Table (A.3) column (1) and (2) report the estimation results of equation (2) when we do not control for firm fixed-effects. Qualitative results using OLS are still in line with the results using the within-firm specification.

2.5 From credit supply to real outcomes

Having established in the previous subsection how foreign negative financial disturbances fuel into lower credit supply, this section provides evidence on the connection between lower credit supply and a decrease in aggregate investment and employment. The goal is to estimate equation (1) using the following model

$$\Delta \ln(X_{ft}) = \beta_1 + \beta_2 \Delta \ln(Credit_{ft}) \times Post_t + \varepsilon_{ft} \tag{3}$$

Where $X = \{investment, employment\}$ and β_2 measures the impact of credit supply on firm's investment (and employment) decisions.

So far we have been employing a firm-bank level estimation procedure. In contrast with the model in the previous section, the empirical model in this section is at the firm level. That means, we can no longer use within-firm estimation to disentangle credit supply from credit demand. To continue using only credit supply to explain changes in employment and investment following the Lehman bankruptcy, we perform the estimation using a 2SLS methodology where in the first stage we use *Bank Exposure* at the firm level as an instrument. We have defined capital flows before as the share of bank exposure (to international interbank market) to assets. In this section we revise the definition since we only operate at the firm level. We now define *Firm Exposure* as indirect exposure of each firm f to the international wholesale market, weighted by the share of credit from each bank b. (see section (3.1) for a detailed definition). The first stage model is defined as

$$\Delta \ln(Credit_{ft}) = \alpha_i + \mu \Delta(\overline{Firm\ Exposure}_f) + \gamma_{bt} \mathbf{X}_{bt} + \overline{\eta}_{ft} \tag{4}$$

where

$$\overline{Firm\ Exposure}_f = \sum_b w_{fb}(Bank\ Exposure_b)$$

weights w_{fb} representing the share of credit from bank b to firm i in 2004.

Unfortunately an OLS regression of (4) would be biased since the between-firm specification cannot account for firm fixed effects coefficient α_f. Recall our initial identification strategy intuition relies on controlling for within-firm effects: compare changes in the share of credit from banks with different levels of exposure to international financial markets to the same firm. Turns out we correct for the bias by substituting α_f using an estimated $\hat{\alpha_f}$ computed using equation (2)[16] (Bonaccorsi di Patti and Sette (2012)).

Results: Table (A.4) provides estimates for equation (3). Following the Lehman Brothers bankruptcy firms borrowing from domestic banks more exposed to international markets experience a larger decline in investment and employment. Column (3) shows how a one percentage point decrease in credit supply lowers investment by 1.045 percentage points. In other words, there is a 1.045 p.p. pass-through of the credit shock into investment. Column (5) shows how a one percentage point decrease in credit supply lowers employment by 0.164 percentage points. The smaller elasticity of employment to credit supply is not surprising as investment tends to be much more volatile than employment. Table (A.4) columns (2) and (4) report results for the same estimation for investment and employment, respectively, but without controlling for firm specific characteristics. Results remain economically and statistically significant. We can conclude that a negative disturbance in international financial centers has a sizeable negative impact on domestic macroeconomic variable, namely investment and employment.

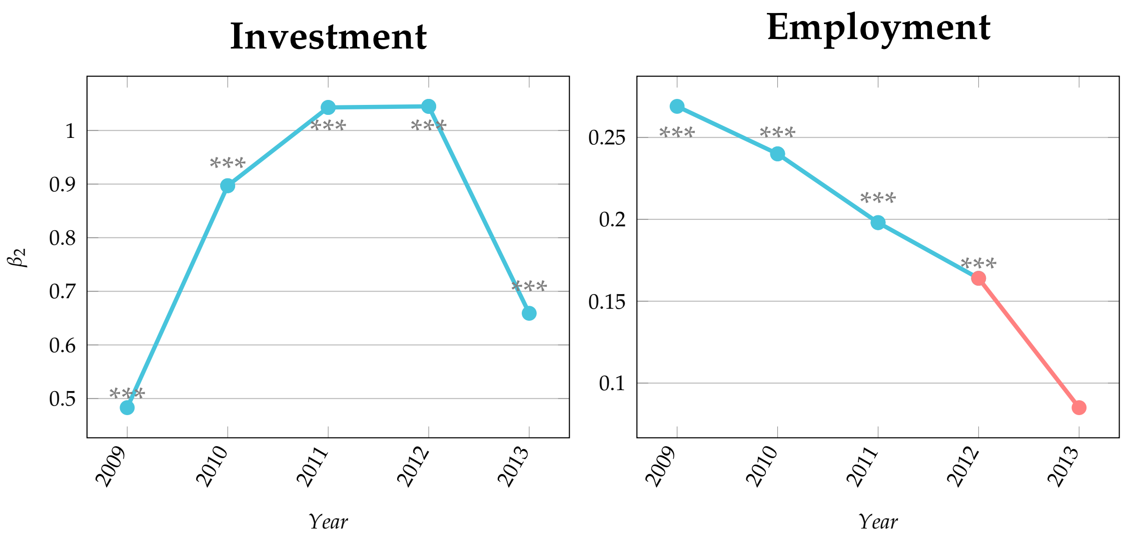
Aggregate implications: To provide some further economic meaning to our results, we can perform a (partial equilibrium) back of the envelope calculation to understand what was the aggregate impact of the banking channel as a pass-through of a global shock into the domestic economy. The average share of bank foreign liabilities over assets during the 2004 period was around 16%. For simplicity, we operate under the assumption that credit supply by banks not exposed to the international interbank market is constant (This is a conservative assumption since we could safely assume that these banks also decreased credit supplied to firms during the period of the shock). From table (A.3) we learn that a 1 p.p. increase in the share of foreign liabilities causes a 1.064 drop in credit supply. Thus, the aggregate drop in credit supply was 17%. From table (A.4) we have the coefficients from the impact of a drop in credit supply on investment and employment. Therefore, we can calculate a overall decrease in investment of 14.8% due to the drop in credit supply and also a aggregate drop in employment of 2.3% due to lower credit supply. Using aggregate values for the change in average investment and employment following the fall of Lehman Brothers,

[16]See Jiménez et al. (2018) for an alternative strategy to deal with bias created by not including firm fixed-effects.

we can arrive to an aggregate drop in employment of 6% and investment of 24%. We conclude that our back of the envelope calculation suggests that a liquidity shock in banks balance sheet accounts of 2/3 of the drop in investment over the pre and post period and a 38% share of the drop in employment.[17]

2.6 How persistent was the Lehman shock?

Figure 1: **Persistence of the Lehman collapse**



Notes: The right panel shows regression coefficients of equation (4) when the dependent variable is the change in logs of employment. The left panel shows regression coefficients of equation (4) when the dependent variable is the change in logs of investment. For each point in the x-axis the post period in equation (3) is defined as $\{2009, X\}$ *where X is the value in the x-axis. Standard errors are clustered at the firm level. The stars above each point represent statistical significance for each regression.*

So far we have concluded that the liquidity shock on bank's balance sheet provided by the Lehman fall has a significant pass-through on investment and employment decisions. How persistent is this shock? Figure (1) plots the coefficient of equation (3) for different time intervals of the *post* period. Following the Lehman Brothers bankruptcy, firms investment dropped by 0.5 p.p. compared with the period before the financial crisis. Employment also decrease by 0.25 p.p. on impact. The effect of the shock on investment is amplified over time and has a peak around the 2011 – 2012 period. This increase can be understood in light of the economic uncertainty generated by the financial crisis. As for employment, the effect of the shock is diluted over time

[17] Paravisini et al. (2015) also study the effect of a liquidity shock on real outcomes. They design a similar experiment and find that in Peru the share of missing volume of trade due to a credit shock was 16%.

as the effect looses power and statistical significance. In fact, the coefficient is no longer statistically significant in 2012. The stickiness of employment to the credit shock is to be expected as employment is less volatile than investment. As a caveat, the effect of the shock posterior to 2011 should be taken with caution as another major shock hit the domestic economy – the European sovereign debt crisis. The compound effect of the shock on investment amounts to 3.9 p.p. decrease and the accumulative effect on employment is around 0.9 p.p.

3 Robustness check

3.1 What if firms can substitute borrowing sources?

The results reported in section (2.4) pertain to existing credit relationship and do not take into account the formation – or destruction – of new firm-bank connections (extensive margin). In fact, if firms can easily find other sources of credit then our quantitative results might be less reliable. The regression including the extensive margin should still report a negative impact of capital inflows, but the elasticity should be higher as includes existing and new firm-bank connections. To surpass this issue we turn the analysis to the firm level and look at the change in total credit before and after the shock. To that extent, we create a new dependent variable measuring the average foreign bank exposure of each firm before the Lehman collapse. We estimate a difference-in-differences specification of equation (4).

Table (A.5) columns (1) and (2) show the results of regression (2). As expected, the qualitative findings of section (2.4) hold, but quantitatively we find a stronger elasticity of credit supply to bank exposure to global capital flows.

3.2 What if firms and banks are not randomly matched?

One of the main identification assumptions made in section (2.3) was the random matching between banks and firms so as to create comparable treated and non-treated populations. The main treat to identification is thus that results to not stem from the banking lending channel but for some other unrelated reasons. For example, it may be that weak banks lend more to certain firms based on unobservable characteristics. This concern can be ruled out as we use firm fixed-effects. Another treat to identification is the existence of a common shock affecting both banks and firms. Due to information asymmetries, suppose more international banks specialize in lending to bigger firms. These type of firms might be more affected by the Lehman shock since they might be more exposed to the business cycle, thus decreasing credit supply at the same time international banks decrease credit demand. To account for this, in table A.6 column (5) and (6) show estimates for equation 2 also using district and firm-sector fixed effects. Results are still economic and statistically significant and the main conclusion remains: international disturbances foster a decrease in credit supply.

Yet another reason why firms might be matched with specific banks is due to some banks specializing in lending to a group of firms based on observable characteristics. That is, we need to evaluate whether banks with different exposure to international financial markets also differ in the type of firms they provide loans. Table A.2 shows descriptive statistics for firm characteristics for group of banks with different exposure to foreign interbank markets. Banks in column (0) are banks less exposed whereas banks in column (2) are more exposed to international deposits. We can conclude that banks more exposed tend to lend to both better firms – as measured by return on assets (ROA), profitability and amount of non performing loans (NPL) – as well as bigger firms – as measured by the total amount of assets. To account for this firm heteregeneity, we re-estimate equation 2 now controlling for firm characteristics. Table A.3 columns (2), (4) and (6) confirm our previous results of a negative impact of international exogenous shocks on the banking channel of credit supply.

3.3 What if credit demand differs among banks?

A concern related with the non-random matching between banks and firms is the homogeneity of credit demand. Our identification strategy, besides using only those firms that have multiple banking relationships, also assumes homogeneous credit demand across all lenders. In this sub-section, we relax this assumption by dropping the firm fixed effects and using industry-location fixed effects as documented in Degryse et al. (2018). In this way, we keep all firms in the sample and also allow their credit demand to be heterogeneous across different banks. The unit of comparison is now a firm belonging to a particular sector in a particular location. Table A.6 column (5) and (6) report estimates for equation 2 using district and firm-sector fixed effects. Results continue to be statistically and economically robust.

3.4 Common trend assumption

What if weaker firms are matched with weaker banks and that event places firms in the pre-sample on a different trajectory path? This may expose our results as spurious since we will only be caption pre-existing (pre-sample) trends. We test for the validity of the common trend assumption by performing a placebo test. We re-access our results of 2.3 by defining a new timing for the shock and re-estimating equation 3 this time defining the timing of the exogenous shock as being in 2012 rather than October 2008.[18] The results of table A.7 shows a non-statistically significant causal impact of a placebo shock occurring in 2012 on the investment decision of Portuguese firms, thus confirming our parallel trend assumption is valid.

3.5 Is the sample a good representation of the population?

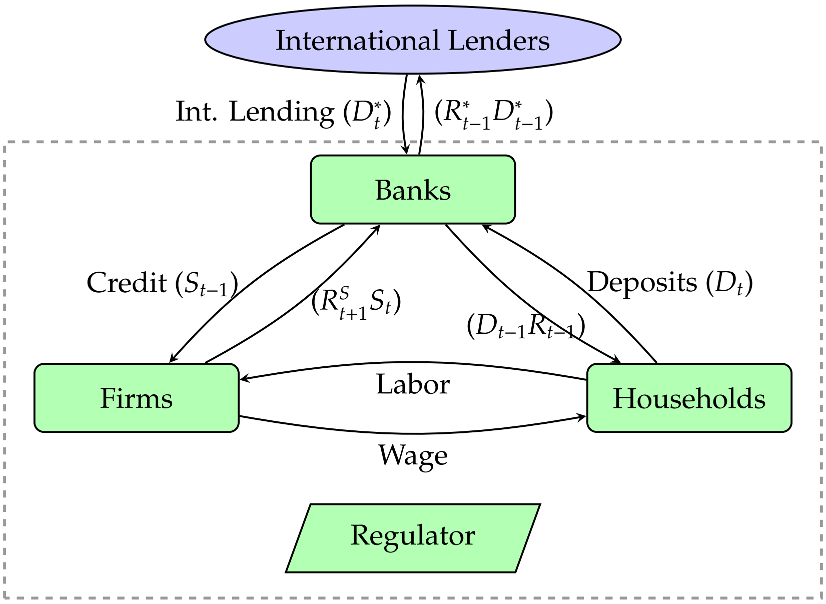
Our main identification strategy throughout section (2) was based on firms that have credit relations with at least two banks. Although this is valid for 55% of firms in our sample, the methodology employed in section (2) – based on Khwaja and Mian (2008) – can be seen as a weakness of our analysis. The remaining subset – including potentially smaller non-financial corporations – might provide us with different conclusions. Is it possible that the sample underlying our study is not representative of the entire population of firms? To address that concern, we look at the first step in our causal chain, but instead of using within-firm fixed effects, we run a ordinary least squares estimation instead. Table (A.3) column (1) shows our fixed effects results still hold. Both the sign and the statistical significance of model (2) remain the same.

4 An Open-Economy model with a banking sector

Having established that international banks act as a pass-through channel of global capital inflows into the real economy, we now develop a general equilibrium model to understand what would have happened in this sort of framework if there have been alternative policies. By design, the empirical model cannot not address all general equilibrium forces or speak to the spillover effects of exogenous disturbances to the banking sector. However, it will be key in our calibration exercise in which we

[18]Our dataset runs from 2005 – 2016, thus making it impossible to choose a placebo period previous to our main estimation exercise.

Figure 2: Model Structure



use the model of section (2.3) as an auxiliary model to pin-down key model parameters.

The economy is modelled as a open economy RBC model with a banking sector as in (Gertler and Karadi (2011)) and (Aoki et al. (2016)). Time is discrete and indexed as $t = 1, 2, 3, \ldots$. The economy is populated by five types of agents: Households, capital (and final) goods producers, a banking sector, international lenders, and a government agency in charge of financial sector regulation. Figure (2) summarizes the interaction between economic agents. Household members can assume one of two tasks: bankers or workers. Workers supply their labor endowment to final output firms and place their wealth as one-period (risk-free) deposits on banks. In the canonical real business cycle model there is no role for financial intermediation. I follow (Gertler and Karadi (2011)) and introduce bankers as financial intermediaries channelling household's deposits to finance firms. Besides household deposits, bankers also receive funds from international lenders and invest in state contingent claims issued by non-financial intermediaries. Due to lower monitoring costs, banks intermediate the flow of funds from depositors to firms. There are two goods in the economy: a perishable consumption good and a capital good. There are three types of firms: capital goods producers, final goods producers, and non-financial intermediaries. It is a stochastic economy with three sources of uncertainty: leverage constraint shock, world interest rate shock and capital quality shock.

The next sections introduce the agents and the relevant equilibrium concept.

4.1 Households

Households are divided into two type of members: Depositors and Bankers. Depositors have measure $(1-f)$ and bankers measure f. Each period workers supply labor, H_t, to final output firms and deposits their wealth, D_{t-1}, in banks. Π_t are profits to the household from ownership of non-financial corporations and banks. The remaining funds are consumed, C_t. The representative depositor solves the following optimization problem

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t\left(\frac{C_t^{1-\gamma}}{1-\gamma}-\zeta_0\frac{H_t^{1+\zeta}}{1+\zeta}\right)\right] \tag{5}$$

subject to

$$C_t+D_t=w_tH_t+\Pi_t+R_{t-1}D_{t-1} \tag{6}$$

Where β is the discount factor and $\mathbb{E}_t$ is the expectation operator. R_t is the non-state contingent return on deposits and w_t the wage rate.

4.2 Producers

We now consider the production size of the economy. There are two types of goods: perishable consumption goods and durable goods. There are also three types of non-financial firms: capital good producers, final goods producers, and non-financial intermediaries. Non-financial intermediaries purchase capital goods from capital producers, store capital for one period and finally rent capital to final good producers. The timing of events is the following: at the end of period $t-1$ non-financial intermediaries issue S_{t-1} state contingent claims (bought by Banks) and use this securities to purchase from capital good producers K_{t-1} units of capital goods at price Q_{t-1}. By no-arbitrage condition, in equilibrium the price of each unit of capital equals the price of each unit of securities issued by intermediaries. That is, $Q_{t-1}K_{t-1}=Q_{t-1}S_{t-1}$. At the beginning of period t final good producers pay price Z_t for each unit of capital goods rented from non-financial intermediaries. Final good producers use capital and labor to produce final output goods. At the end of period t, final producers return $(1-\delta)K_t$ units of undepreciated capital to non-financial intermediaries that re-sell those units of capital to capital producers at price Q_t. Let Ψ_t be a capital quality shock. Therefore, the return on each unit of capital is

$$R_t^K=\left(\frac{Z_t+(1-\delta)Q_t}{Q_{t-1}}\right)\Psi_t \tag{7}$$

4.2.1 Final Good Producers

A set of perfect competitive final good firms combine capital and labor to produce final output goods using the following technology

$$Y_t = A_t(\Psi_t K_{t-1})^{\alpha_K}(H_t)^{1-\alpha_K} \tag{8}$$

Where A_t is a technology shock and Ψ_t is a capital quality shock. Since the market structure is one of perfect competition and technology exhibits constant returns to scale, I will consider a representative final goods firm. The first order conditions with respect to capital and labor are:

$$Z_t = \alpha_K \frac{Y_t}{\Psi_t K_t} \tag{9}$$

$$W_t = (1-\alpha_K)\frac{Y_t}{H_t} \tag{10}$$

4.2.2 Capital Producers

At the end of the period, capital good producers purchase economy wide stock of undepreciated capital from non-financial intermediaries at price Q_t to produce new units of capital goods. The objective is to choose an investment level, I_t, to maximize

$$\max_{I_t} \left[Q_t K_t - (1-\delta)\Psi_t Q_t K_{t-1} - I_t\right] \tag{11}$$

The law of motion for capital is

$$K_t = (1-\delta)\Psi_t K_{t-1} + \Phi\left(\frac{I_t}{\Psi_t K_{t-1}}\right)\Psi_t K_{t-1} \tag{12}$$

As in (Bocola (2016)), I use the following functional form for Φ: $\Phi_t(x) = a_1 x^{1-\zeta_k} + a_2$. The first order condition is

$$Q_t = \left[\frac{I_t}{\delta \Psi K_{t-1}}\right]^{\zeta_k} \tag{13}$$

4.3 Bankers

Bankers intermediate funds between international depositors and domestic depositors and the productive side of the economy – the firms. As discussed in the beginning of this section, the canonical real business cycle model has no role for financial intermediation. I assume that bankers are more efficient at monitoring the productive sector than households, creating a role for bankers to channel depositor's savings to fund firm's investment projects.

There is a continuum of bankers indexed by $i \in [0, 1]$. Banker i starts each period with a given amount of domestic deposits, D_{it}, paying a return, R_t, and foreign deposits, D^*_{it}, paying return R^*_t. Both returns are non-state contingent. Bankers also purchase state-contingent claims, S_{it}, on firm's investment project returns, R^K_t. bankers' net worth, N_{it+1} evolves according to

$$N_{i,t+1} = R^S_{t+1} Q_t S_{i,t} - R_t D_{i,t} - R^*_t D^*_{i,t} \tag{14}$$

Bankers become involved in maturity transformation, holding long term assets and borrowing in short-term deposits. In particular, bankers receive one-period risk free deposits from domestic depositors and international depositors and purchase firm claims on the return of physical capital sold by non-financial intermediators. The balance sheet of bank i is

$$Q_t S_{it} = D_{it} + N_{it} + D^*_{it} \tag{15}$$

Where Q_{it} is the market price of claims.

Bankers lack full commitment on fulfilling debt obligations with both domestic and foreign creditors, raising a moral hazard problem that limits the ability of bankers from raising funds from both type depositors. In particular, at the beginning of period t bankers receive funds from domestic and foreign depositors, bankers decide whether to divert a certain fraction of assets. If Bankers decide to default on debt obligations then they face bankruptcy and become depositors. Default happens stochastically with probability $(1 - \theta)$. In such case, bankers returns its net worth to the household and exists the financial intermediation industry. For this reason, creditors impose a incentive compatibility constraint such that bankers do not have reasons to default. I follow Aoki et al. (2016) and assume bankers can divert a fraction Φ_t of asset's market value

$$V^b_{j,t} \geq \underbrace{\theta^b_t \left[1 + \frac{\mu}{2}\left(\frac{D^*_t}{Q_t S_t}\right)^2\right]}_{\Phi_t} Q_t S_t \tag{16}$$

Banker's optimizing decision problem is thus

$$V^b_{j,t}(n_{j,t}) = \max_{\{S_{j,t}, D_{j,t}, D^*_{j,t}\}} \left\{\mathbb{E}_t \Lambda_{t,t+1}\left[(1-\theta)n_{j,t+1} + \theta V^b_{j,t+1}(n_{j,t+1})\right]\right\} \tag{17}$$

subject to (15), (14), and (16).

Proposition 1: Banker's value function is linear in net worth

$$V^b_{j,t}(n_{j,t}) = \phi_{j,t} n_{j,t} \tag{18}$$

Proof: See Appendix (C.2).

Aggregation: As Proposition (1) shows, the individual banker's problem is homogeneous of degree one in banker's specific net worth and does not depend on other banker's specific variables. Each Banker makes optimizing decisions based on its own net worth position. This allow us to use a symmetric equilibrium and aggregate across banks. This feature becomes useful as we only need to keep track of banks aggregate net worth and not the distribution of net worth across banks.

4.4 International Lenders

The country is a small-open economy and the domestic interest rate depends on the world's interest rate (Akinci and Queralto (2017), Schmitt-Grohe and Uribe (2003))

$$R_t = \frac{1}{\beta} + \varphi_R(e^{\frac{D^*_t}{Y_t} - \frac{\bar{D}}{\bar{Y}}} - 1) + e^{R^*_t - 1} - 1 \tag{19}$$

Where $\bar{D}$ is the steady-state domestic debt and R^*_t is the stochastic world's interest rate following an AR(1) process.

4.5 Market Equilibrium

The capital market clearing condition equates claims on assets issued by non-financial intermediaries and the aggregate capital stock

$$S_t = K_t \tag{20}$$

The aggregate resource constraint is

$$Y_t = C_t + I_t + D_t^* - R_t^* D_{t-1}^* \tag{21}$$

The net worth of surviving bankers can be written as

$$N_t^S = \theta N_t = \theta \left[(R_t^K - R_{t-1}) Q_{t-1} K_{t-1} + D_{t-1}^* \left(R_{t-1} - R_{t-1}^* \right) + R_{t-1} N_{t-1} \right] \tag{22}$$

net worth of new bankers

$$N_t^N = \iota (1-\theta) Q_{t-1} K_{t-1} \tag{23}$$

Aggregate net worth

$$\begin{aligned} N_t &= N_t^S + N_t^N && (24) \\ &= \theta \left[(R_t^K - R_{t-1}) Q_{t-1} K_{t-1} + D_{t-1}^* \left(R_{t-1} - R_{t-1}^* \right) + R_{t-1} N_{t-1} \right] && (25) \\ &+ \iota (1-\theta) Q_{t-1} K_{t-1} && (26) \end{aligned}$$

4.6 Equilibrium Concept

Let $\mathbb{S}_t = \{K, P, I, \Psi, R^*, \theta_b\}$ be the state vector. A *stationary recursive competitive equilibrium* is a set of value functions for households, V^h, and bankers, V^b, policy functions for households, $\{C, H, D\}$, and for bankers, $\{D, D^*, S\}$ such that, given value functions and policy functions both households and bankers can solve their maximization problems subject to market clearing conditions.

5 Quantitative analysis

In this section presents functional forms for the theoretical model and describes the calibration strategy.

5.1 Calibration and functional forms

Table 1: **Calibrated Parameter Values**

Description	Parameter	Value	Target / Source
Households and Producers			
Discount factor	β	0.991	*Bank of Portugal*
Capital Share	α_K	0.263	Author's Calculation
Capital dep. rate	δ	0.027	Author's Calculation
Coef. of Relative Risk Aversion	γ	1	Standard
Inverse Frisch elasticity	ζ	0.65	Empirical Coefficient
Labor Disutility	ζ_0	4.9	Labor-Output ratio = 33%
Banks			
Survival rate	θ	0.95	Bocola (2016)
Adjustment costs	ζ_k	0.03	Empirical Coefficient
Divertable share	μ	0.256	Frequency of fin. crises 5%
Start-up share	ι	0.007	Bocola (2016)
International			
Debt elast. of interest rate	φ_R	0.001	
foreign debt/output ratio	$\bar{D}$	0.5	Foreign debt-Output ratio = 400%

Notes: Appendix B.2 provides further details on the calibration strategy and data sources.

The parameters of the model are calibrated. Table (1) reports these numerical values. The frequency of the model is quarterly.

External calibration: Some parameters are standard in the literature when calibrating the U.S. economy. Given we are calibrating our model to the Portuguese economy, we choose to re-compute several parameters as such mapping would not be accurate. The value of the discount factor parameter can be inferred directly from the real domestic interest rate. We use data on Portuguese government bond yields for the period 2005 – 2015. The parameter governing capital share is computed using the share of capital income over total income in the domestic economy. See appendix (B.2) for a description of the procedures and data sources. The depreciation of capital is calculated using the perpetual inventory method. Data on Investment and GDP and consumption of fixed capital comes from the *OECD annual national accounting*.

The parameter governing the banker's survival probability is set to 0.95 as in Bocola (2016). We use a value of 0.007 for the start-up share also following Bocola (2016).

Internal calibration: The remaining parameters are internally calibrated. The internal calibration is a mixture of simulated method of moments (SMM) and indirect inference. The parameter governing labor disutility, and the debt-to-output ratio parameter are chosen to target data moments. We use indirect inference to calibrate the frisch elasticity parameter and the adjustment cost parameter. To that extent, we use the empirical values found in section (2.3) to inform our calibration strategy.

We proceed as follows. The SMM estimator is

$$\widehat{b_{N,T}}(W) = \arg\min_b \left[\sum_{t=1}^{T} \left(M_T(x_t) - \frac{1}{N} \sum_{i=1}^{N} M_N(y(u_t^i,\ b)) \right) \right]' W_T^{-1} \left[\sum_{t=1}^{T} \left(M_T(x_t) - \frac{1}{N} \sum_{i=1}^{N} M_N(y(u_t^s,\ b)) \right) \right] \quad (27)$$

Where b ia a 4×1 vector of parameters. Let $\{x_t\}_{t=1}^T$ be a sequence of observed data. Also, let $M_T(x_t)$ the moments from observed data. Also, let $\{y_n(u^s, b)\}_{n=1}^N$ be a sequence of simulated data, depending on the vector of structural shocks and coefficient values. $M_N(y(u^s, b))$ are the model moments from the simulated data. The $M_T(x_t)$ vector contains both data moments, but also the empirical coefficients from section (2.3).

We try to match a labor-to-output ratio equal to 33%. We also target the ratio of external debt to output. The annual value for Portugal is around 100% in recent years. Since the model is at a quarter frequency, we target a value of 400% of external debt to GDP.

The remaining parameters are estimated using the method of indirect inference. Indirect inference is a method similar to simulated method of moments, but differs in the use of an *auxiliary model* that can be viewed as a reduced form of the structural model. In our case, the reduced form model of section (2.3) can be seen as a mapping from the structural model along some dimensions. To be concrete, we proceed by estimating the coefficient of frisch elasticity and investment adjustment costs. The reduced form model in section (2.3) is used as an auxiliary model in which the causal impact of credit supply on employment is going to help inform estimation of the employment block of the model, whereas the effect of credit supply on investment accounts for the estimation of the investment adjustment cost parameter. That is, we regress external credit on employment (and investment) using data simulated from the model and require the regression coefficient to match the counterpart coefficient calculated in section (2).

To be specific, we match the empirical and simulated coefficients as

$$M_T(x_t) - M_N(y_t) = \Omega_E - \Omega_S$$

Where the empirical coefficent is the product of the two-step causal impact of credit supply on macroeconomic variables. Therefore, we use the coefficients from section (2.4) and (2.5). From the section (2.4) we have that the impact of credit supply on employment is 0.164 and the effect of a drop in credit supply on investment is 1.045. The coefficients using the model simulation are computed as

$$\log(X^S) = \Omega_S \log(Credit^S) \tag{28}$$

Where $X^S = \{Employment, Investment\}$.

As we can see in table (2), the model does relatively well matching the estimation of credit on employment, but it does not came as close when matching the investment regression.

Table 2: **Indirect Inference**

	Aux. Model	Theo. Model	Aux. Model	Theo. Model
	Δ ln Invest	Δ ln Invest	Δ ln Employ	Δ ln Employ
Δ ln Credit	1.045***	0.822	0.164***	0.155
	(0.201)		(0.0444)	
N	41064	2000	306271	2000
Sector FE	✓		✓	

Table (3) reports the calibration performance. The model finds it hard to match the ratio of foreign debt-to-output as in the data. This happens because the 100% debt-to-gdp ratio takes into account public debt, and the model does not contain a government sector.

Table 3: **Internal Calibration**

Description	Parameter	Target	Data	Model
Inverse Frisch elasticity	ζ	Aux. Model	0.164	0.155
Investment Adjustment costs	ζ_k	Aux. Model	1.045	0.822
Labor Disutility	ζ_0	$\frac{L}{Y}$ = 33%	0.33	0.48
foreign debt/ouput ratio	$\bar{D}^*$	$\frac{\bar{D}^*}{Y}$ = 93%	93	24.8

5.2 Numerical solution

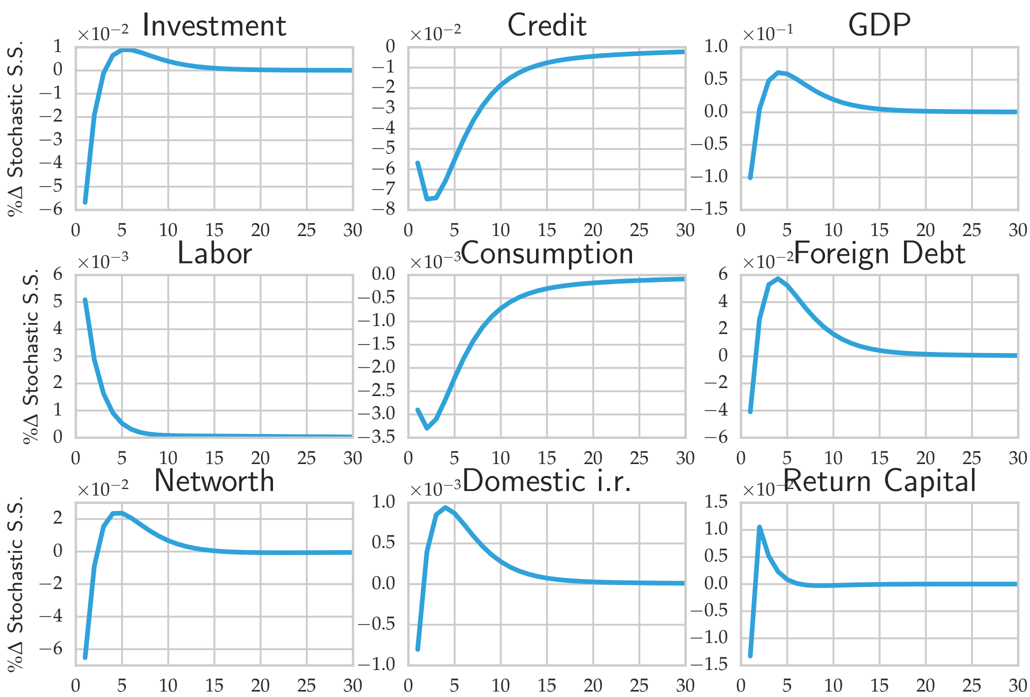
The model of section (4) is solved using numerical methods to look for a global solution. The need for solving a non-linear version of the model stems from the fact the occasionally binding constraints creates non-differentiability in decision rules. The problem is amplified as the area in which these kinks arise is not known *a−priori*. Moreover, solving the model using local solutions would require unrealistic large shocks to produce endogenous crises. Finally, our exercise uses welfare comparisons that require the behavior of non-linear models to account for uncertainty. Specifically, we use projection with time iteration. Given the size of the state space, the grid is constructed using the *ε-distinguishable* grid method (Maliar and Maliar (2015)) to surpass the curse of dimensionality. The model features a occasionally binding constraint which requires the solution for decision rules to be a convex combination of decision rules when the economy is in period of crisis and in normal times. A detailed explanation of the numerical solution method is provided in appendix (C.3)

6 Bank pass-through of foreign shocks

Section (2.3) shows how international financial disturbances can influence aggregate macroeconomic variables in the domestic economy. The quantitative model of section (4) features stochastic international disturbances in in two ways: (i) in the form of international interest rate shocks and (ii) shocks to the collateral constraint of banks. We can understand this second type of shock as a sudden exogenous event that negatively affects the domestic banking system. To understand the model's dynamics, this section introduces the reaction of our calibrated economy to a shock to the collateral constraint of banks. Figure (3) shows the generalized impulse response functions of keys macroeconomic variables to a 1% increase in the collateral constraint shock (*vis-à-vis* the stochastic steady state). The economy's behavior depends on the point in which we start the simulation. Figure (3) is computed starting the economy from the stochastic steady state.

On impact, the shock has a negative effect on the financial sector. Due to the sudden exogenous disturbance to the banking system, domestic banks cut credit to the economy and their net worth diminishes. The drop in credit leads to a decrease in investment. Households respond to the initial increase in the domestic interest rate by switching current consumption for future consumption and save in the form of bank deposits. Both the decrease in investment and the decrease in consumption contribute to the drop in gross domestic product.

Figure 3: **Colateral constraint shock and Model dynamics**



Notes: Graphs plot the generalized impulse response functions for a positive 1% shock to colateral constraint of banks. Variables are reported as percentage deviations from the stochastic steady state, computed by model simulation initialized at the mean of the ergodic distribution. Appendix (C.4) presents the computational algorithm to compute the generalized impulse response functions.

Appendix (C.7) Figure (18) displays the behavior the economy when hit by a shock to the foreign interest rate. The path of variables is similar, but the behavior of the domestic and foreign interest rate is counterfactual with the actual path of both variables around the 2008 financial crisis. As can be seen in Figure (13) in appendix (A.1), there was a sharp drop in foreign and domestic interest rates, which is at odds with the behavior of both variables in our theoretical model.

7 Macroprudential Policy

In this section, we quantify the ability of macroprudential policy – in the form of time-varying bank capital requirements – to curb-down the impact of foreign negative disturbances. Section 7.1 compares constant capital requirements with the newly (Basel III) introduced time-varying bank capital requirements. Section 7.2 discusses and quantifies the trade-off between lower volatility and lower output. Section 7.4 analysis the welfare implications of macroprudential regulation.

7.1 The behavior of the economy with macroprudential policy

In section (2), we documented the pass-through of exogenous disturbances to the domestic economy via the banking sector. We might ask what kind of policies are best suited to deal with this negative events. Specially during financial crisis, countries see their policy toolkit severely constrained. Several countries lack effective monetary policy, either because monetary policy is set abroad (as is the case of countries in the European Monetary Union) or because monetary policy is fixed at the zero lower bound. On the other hand, during periods of economic recession fiscal policy is severely restrained due to tighter government budget constraints. What is the role of macroprudential policies to deal with exogenous disturbances? This section tackles this question by arming the domestic policy maker with a specific type of macroprudential policy, namely countercyclical capital requirements.

During economic recessions, banks' equity and asset prices decrease. To meet with capital requirements, the banking system needs to cut on credit supply. This drop in financial intermediation lowers investment and consumption, leading to a prolonged recession. To address the potential problems caused by pro-cyclical bank capital regulation, the Basel III accord by the committee on Banking supervision (BSBS) suggested the use of counter-cyclical bank capital requirements to all its member countries. To sum up, before Basel III financial institutions had to keep a constant fraction of capital as equity. With Basel III the fraction of capital bank's require to hold becomes time-varying and countercyclical. We model the introduction of Basel III by allowing the fraction of bank's capital requirement to become time-varying. Therefore, the coefficient of the constraint on banks' activity (equation (16)), becomes a function both of the fixed capital requirement, θ, but also depends on the difference between aggregate capital to output ratio and the steady state value of that same ratio. The time-varying capital requirement is therefore modelled as

$$\theta_t^{Basel\ III} = \theta_t + \rho \left(\frac{K_t}{Y_t} - \frac{K^{SS}}{Y^{SS}} \right)$$

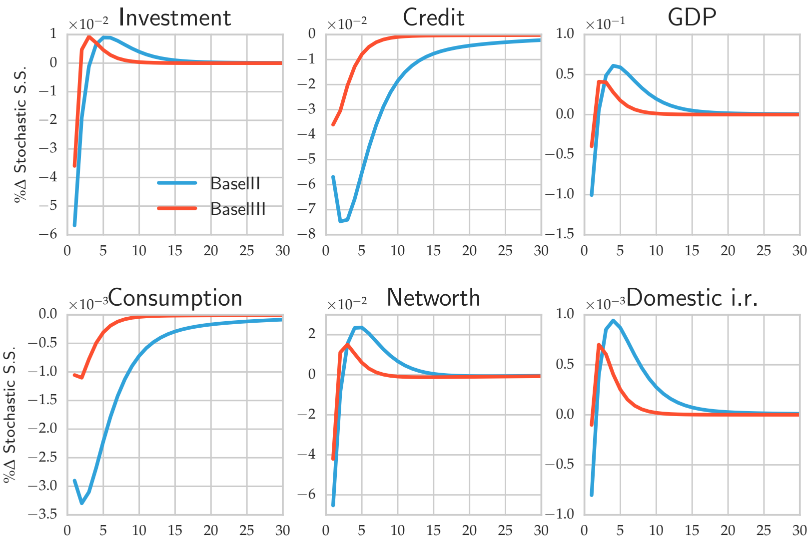
Figure (4) compares the short-run behavior of key macroeconomic and financial variables following a 1% point increase in the exogenous shock to the colateral constraint of banks. Following the sudden exogenous impact on banks' balance sheet, domestic banks cut credit to the corporate sector, leading to lower investment and overall lower economic activity. The main motivation for time-varying macroprudential policy is to allow the productive sector to continue getting credit even in times of distress. As we can see from figure (4), allowing for Basel III type of policy translates into a smaller drop in banks' net worth as well as a smaller decrease in total credit. This lower decrease in credit make the corporate sector be less capital constrained and spurs greater aggregate investment. The intuition is the following. As figures (6) and (7) show, with time-varying capital requirements, during good times banks are asked to hold more capital. If there is a sudden drop international distress and banks find it harder to finance abroad, the drop in credit allocated to firms is smaller due to this bank capital buffer. A healthier financial sector translates into a smaller drop in gross domestic product.

7.2 Macroprudential during economic slumps

How does the introduction of macroprudential regulation changes the nature of economic recessions? In the previous section we were able to isolate the impact of a foreign shock – in the form of higher cost of funding – to understand the effect of macroprudential regulation. However, a country is subject to a constant stream of diverse shocks hitting the economy. In this section we use our structural model and look at the typical economic recession. We use the following shocks: (i) a foreign interest rate shock, (ii) a foreign distress shock and (iii) a shock to loan quality.

Figure (5) shows the behavior of the economy during an economic downturn. The

Figure 4: **Impulse response functions (with macroprudential policy)**



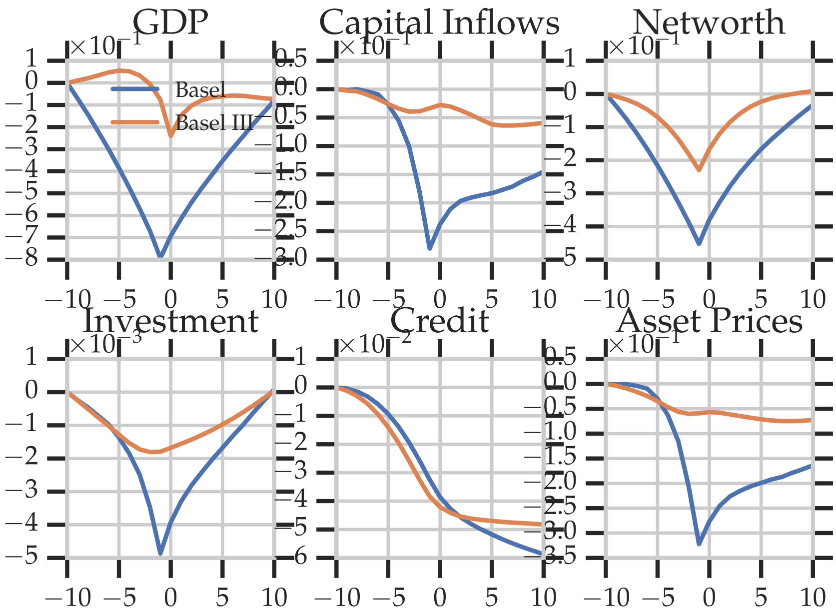
Notes: The figure shows impulse response functions for a positive shock to the foreign interest rate. The blue line is the model with macroprudential policy as in Basel II whereas the orange line pertains to the model including time-varying macroprudential policy. Variables are reported as percentage deviations from the stochastic steady state. Computed by model simulation initialized at the ergodic distribution. Appendix (C.4) presents the computational algorithm to compute the generalized impulse response functions.

blue line shows a recession for an economy without time varying macroprudential tools for selected economic and financial variables. As expected, there is a fall in output, bank's net worth and asset prices. During the same period, domestic firms also cut down on investment. The red line also plots variables during a typical economic recession, but this time in an economy with time-varying macroprudential regulation. Imposing time-varying capital requirements will smooth recessions as output and bank's net worth are substantially less volatile. The intuition is as before: As figures (6) and (7) show, time-varying capital requirements incentivize the build-up of capital buffers during economic expansions, that can be used during times of financial distress. Quantitatively, we find that during a financial crisis gross domestic product (GDP) becomes 5 p.p. less volatile, the fall in banks net worth is 2 p.p. smaller and investment decreases 3 p.p. less.

7.3 Trade-off: lower volatility versus lower economic activity

It is worthwhile looking at the behavior of key variables not only during an economic downturn but during good times. Figure (8) plots the density function of GDP, total credit, capital inflows, and banks' net worth using the entire simulation path.

Figure 5: **Typical Economic crisis**



Notes: The panels are constructed as follows. Start by simulating $N = 1000$ realizations of length $T = 1000$ for each case – with and without time-varying macroprudential policy. Initialize each simulation at the ergodic mean. For each realization, isolate 10 periods before and after the economic crisis event. An economic crisis is defined as an event where output, net worth and investment are 10 p.p. below their respective steady states. The panels report the means across simulations. The horizontal axis plots time minus initial period of the crisis event. The vertical axis measures the variable in % deviations from its value at $t = -10$.

Figure 6: **Banks' Balance Sheet in Normal Times**

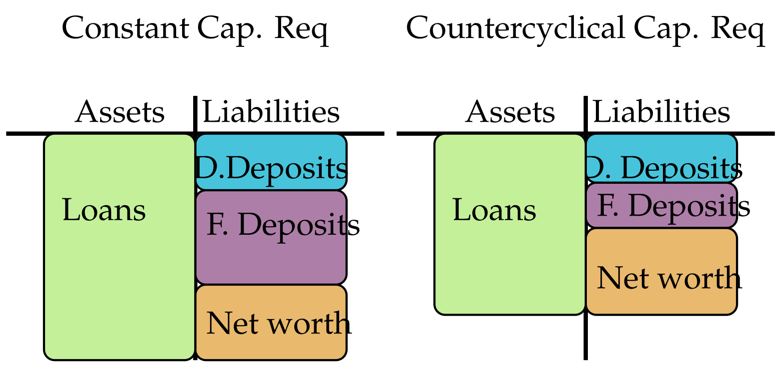
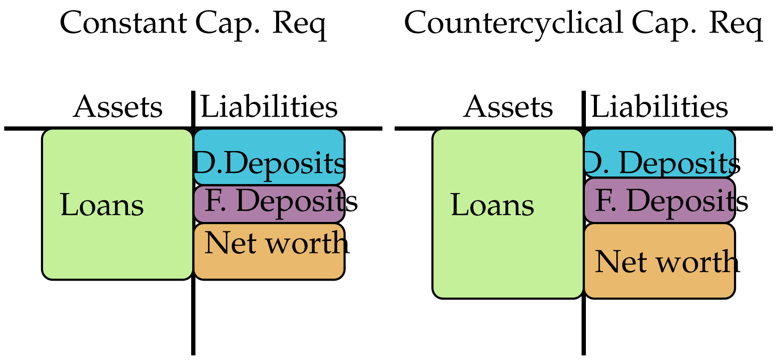


Figure 7: **Banks' Balance Sheet in Recessions**

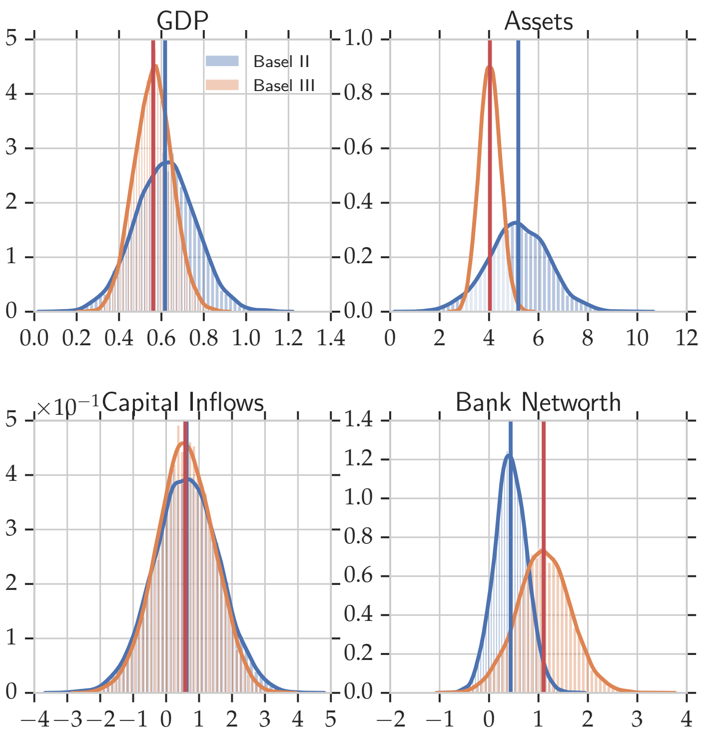


With Basel III type of macroprudential policy, the economy visits regions of both lower and higher GDP with less frequency. There are also lower credit boom periods in the economy with time-varying capital requirements, since this type of policy requires banks to hold a higher share of capital. The requirement set forward by the Basel III framework implies that average net worth is higher than with the previous type of policy. The periods of high capital inflows are also less frequent, as the distribution of capital inflows has less volatility. This is specially important for countries facing sudden-stop type of crisis as was the case of several South-American countries and some European countries in the recent sovereign debt crisis of 2011. We can conclude that the Basel III framework implies that: (i) GDP, banks' net worth and total credit have a lower mean and bank's net worth is higher, on average and that (ii) economic variables have lower volatility. Quantitatively, comparing the entire simulated data sample for both type of policies, we report an average fall of GDP by 3 p.p., average capital inflows drop by 8 p.p. and the average bank credit to the economy falls by 7 p.p.. Moreover, with time-varying macroprudential policy the frequency of financial recessions is also diminished. With Basel III capital requirements the number of economic crises drops by 1 p.p. compared with the baseline case.

Therefore, allowing the policy maker to introduce time-varying policies will result in an average decrease in output *vis-à-vis* the economy with constant policy, leading us to conclude that the introduction of time-varying macroprudential policy entails a trade-off between both short-run reduction in output growth versus lower volatility and lower the probability of a future economic slump, as the economy is less leveraged.[19]

[19] An additional cost of macroprudential policy not incorporated in this exercise is the risk-taking incentive by the banking sector. For example, Jiménez et al. (2017) studies the implementation of pro-cyclical capital regulation in Spain, finding that banks with higher capital requirements supply credit to riskier firms.

Figure 8: **Density across simulations**



Notes: The panels are constructed as follows. Start by simulating N = 1000 realizations of length T = 1000 for each case – with and without time-varying macroprudential policy. Initialize each simulation at the ergodic mean. The panels report the density across simulations. The horizontal axis plots grid point values for the state space. Vertical lines represent the mean of each distribution

This trade-off hints to the fact that welfare consequences of setting macroprudential policies are not straightforward. If the time-varying capital requirements will curb down output, it will also deleverage the economy and prevent future economic slumps. This is due to the break of the standard fire-sale mechanism where a negative shock will force banks to sell assets causing a drop in asset prices. This drop will hurt banks' balance sheet and force them to cut lending even more, entering a fire-sale spiral. Lower leverage will prevent this mechanism and that is the improvement macroprudential policy brings to the economy.

7.4 Macroprudential policies and Welfare

In the previous section we have documented how setting time-varying capital requirements entails a trade-off. This section looks at the welfare consequences of setting this type of macroprudential policy.

Our aim is to compare the lifetime utility of a representative household living in an economy with countercyclical capital requirements versus an the same economy but instead of Basel III type of bank capital requirements, the economy features constant capital requirements as in the previous Basel accords. Let **S** be the state of the economy, and V and $\bar{V}$ be the lifetime value function in the economy with countercyclical capital requirements and constant capital requirements, respectively. Define consumption equivalent welfare, Δ as

$$V((1+\Delta)c(\mathbf{S}), l(\mathbf{S})) = \bar{V}(\bar{c}(\mathbf{S}), \bar{l}(\mathbf{S})) \tag{29}$$

We find that $\Delta = 1.95\%$. That is, the representative household requires 1.95% more consumption every quarter to be as happy in a world with countercyclical capital requirements as he is in a world with constant capital requirements. Summing up, our results show that the representative household prefers higher economic and financial volatility in exchange for higher (average) lifetime consumption.

How does welfare depend on current economic conditions? Figure (15) in the appendix shows consumption equivalence values for an economy with different levels of capital and productivity. That is, to quantify the welfare consequences of this policy change we ask the following question: By what percentage to we need to increase the representative's agent consumption in the economy with constant capital requirements so that she is indifferent between living in the world with constant bank capital requirements and living in the world with time-varying capital requirements? The red area depicts steady state transitions where imposing countercyclical macroprudential policies decreases welfare whereas in the blue region welfare increases.

As figure (15) shows, for an economy that has low levels of aggregate capital, imposing time-varying capital requirements will increase welfare. This outcome is expected as Basel III policies lower bank capital in sucn periods, which increase credit and economic activity. When the economy is highly leveraged, imposing higher capital requirements seems to decrease welfare. This is due to the trade-off discussed in the previous section: the benefit of time-varying capital requirements during an economic recession is lower volatily, but at the expense of lower economic activity. Economic agents seem to prefer higher output and consumption to lower volatility. The right panel of figure (15) shows that imposing counter-cyclical requirements during a recession has positive effects on welfare, since it allows the economy to recover at a higher pace. Households are worse off in the new steady state compared with the old one if we impose macroprudential policies when the economy is in a boom period. The intuition is as before: results suggest that lower financial volatility is not enough to compensate economic agents for the loss of output.

8 Conclusion

This paper started by showing empirically how capital inflows through the banking sector spillover and influence macroeconomic conditions. We have shown how the 2008 US financial crisis induced Portuguese firms to reduce investment and employment. We then moved to build a theoretical model to study how we can design policies to mitigate this negative foreign disturbances to the domestic economy.

Our main policy experiment studies the introduction of time-varying and countercyclical macroprudential policy is the spirit of Basel III. We show how macro prudential policies can curb down leverage, improve banks' net worth and lower the dependence on foreign debt. We provide two main findings. First, time-varying macroprudential regulation will lower macroeconomic volatility. Second, we also document that the number of economic crisis drops by 1 p.p.. However, the down-side of macroprudential policy is a decrease in level of economic activity. Therefore, we show that imposing time-varying capital requirements implies a trade-off between lower volatility and lower economic activity. We also show how such policies can be welfare improving. A key result from our study is that the benefits of imposing macroprudential policies depends crucially on the timming and economic conditions. Macroprudential policies are indeed welfare improving but only if imposed during economic recessions. We also show that for low values of aggregate capital, countercyclical capital requirements on the banking system produce positive welfare effects.

These results have obvious implications for the important policy debate over alternative responses to financial crisis, as they can inform policy-makers to the benefits of macroprudential policies and crucially when to apply such policy instruments. As a caveat, this policy prescriptions are model dependent as the theoretical model is calibrated to a small-open economy without independent monetary policy and may lack external validity. Much more empirical studies are needed to confirm the benefits of such policy instruments. This is an example of a fruitful avenue for future research.

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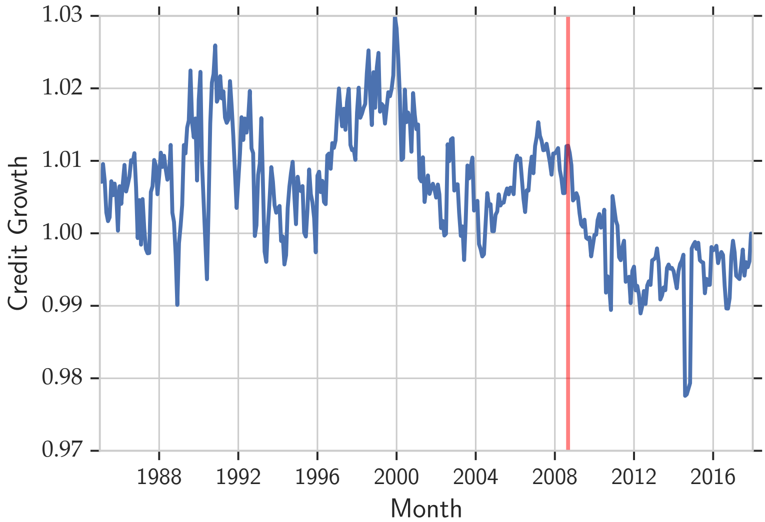
A Empirical Appendix

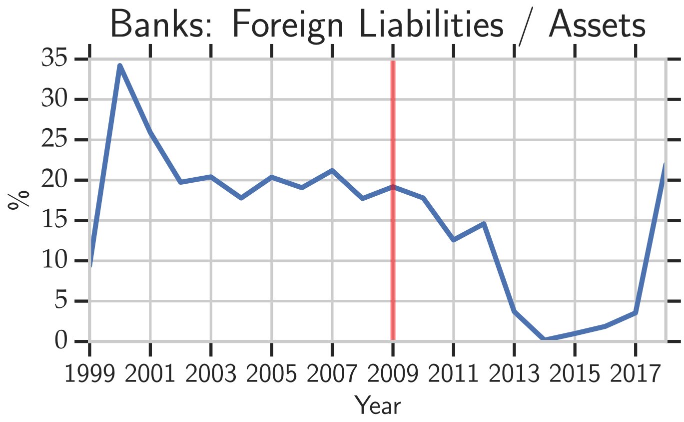
A.1 Figures

Figure 9: Credit Growth



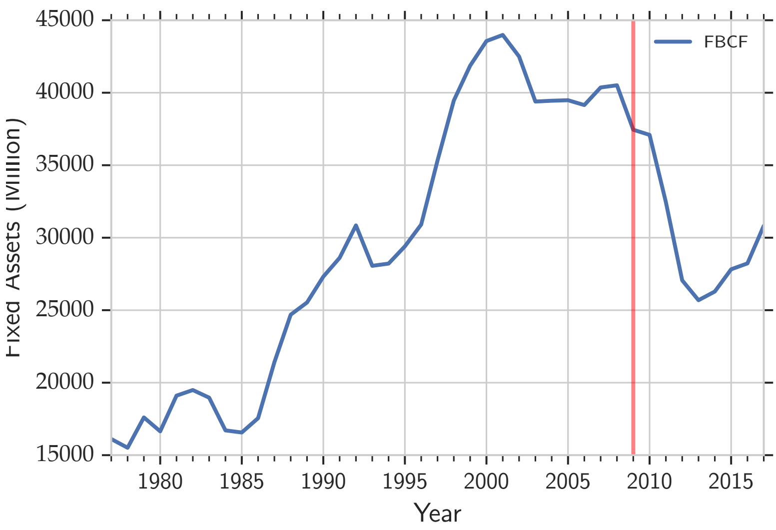
Notes: The figure reports loan growth from credit granting institutions to non-financial corporations in Portugal during 1985 – 2018*. The time-series was transformed using a moving-average. The frequency is monthly. The source is the Bank of Portugal BPStat database. The time series name is Síntese monetária - Crédito interno a SNF.*

Figure 10: Exposure of Banks to International Inter-bank Borrowing Market



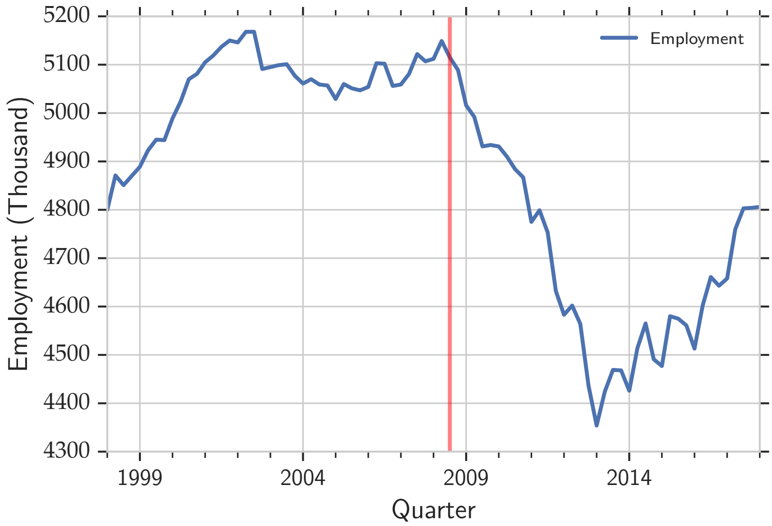
Notes: The figure reports the exposure of domestic banks to the international interbank loan market. The time-series is constructed as the ratio of short-term deposits and securities of international credit-granting institutions to domestic banks over total assets. The frequency is yearly. The source is the Bank of Portugal BPlim database.

Figure 11: Gross Fixed Capital Formation



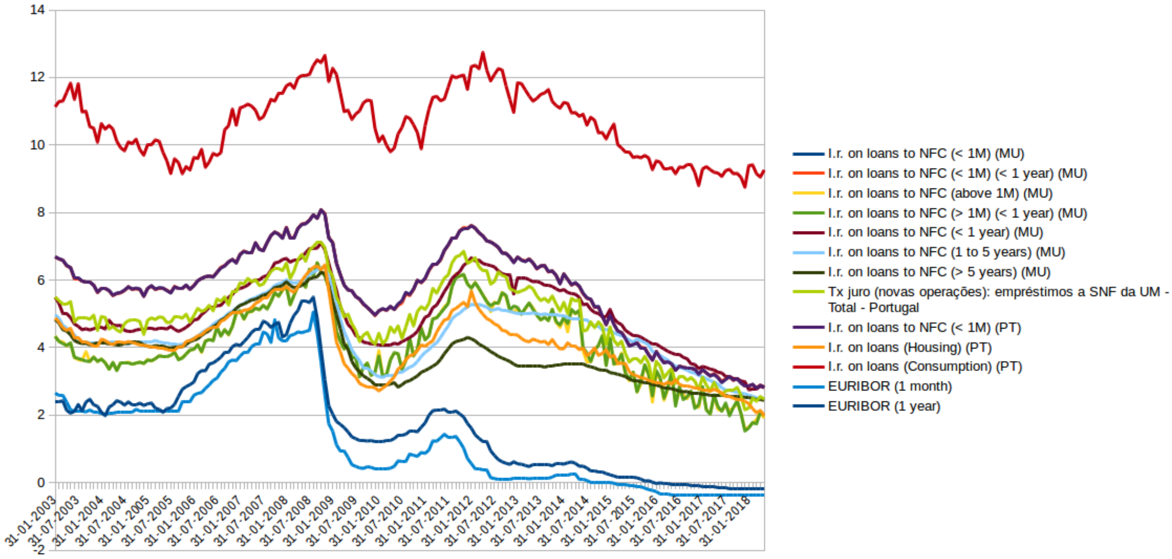
Notes: The figure reports gross fixed capital formation in Portugal during 1977 − 2017. *The series was transformed into constant prices using a deflator with base in* 2011. *The frequency is yearly. The source is the Bank of Portugal BPStat database.*

Figure 12: Employment



Notes: The figure reports Employment in Portugal during 1998 – 2018*. The frequency is quarterly. The source is the Instituto Nacional de Estatística and was accessed using the Bank of Portugal BPStat database.*

Figure 13: Domestic Interest rates



Notes: The figure reports several interest rates for the Portuguese economy during 2003 – 2018. *Most timeseries report credit interest rates by Banks operating in Portugal to non-financial corporations (NFC) both from the monetary union (MU) or specifically within Portuguese borders (PT). The remaining timeseries pertain to bank credit offered to Portuguese households for consumption and housing purchases. The frequency is monthly. The source is Bank of Portugal BPStat database.*

A.2 Descriptive statistics

Table A.1: Descriptive Statistics (Banking Sector)

	Low exposure	Medium exposure	High exposure	Total
liquidity	0.0488	0.000175	0.000408	0.0167
	(0.177)	(0.000571)	(0.00174)	(0.104)
capital ratio	0.742	0.352	0.0256	0.370
	(1.373)	(1.373)	(0.105)	(1.134)
NPL	0.0505	0.0550	0.0378	0.0472
	(0.0495)	(0.101)	(0.0457)	(0.0692)
bank size	2.723	3.536	4.006	3.426
	(1.658)	(1.723)	(1.136)	(1.593)
overdue	0.00454	0.00263	0.00143	0.00275
	(0.0102)	(0.00567)	(0.00282)	(0.00669)
Observations				80

Notes: The table reports mean coefficients and standard deviation in parentheses. The period is 2007:Q1. The variables were constructed as follows. Liquidity is the ratio of cash-on-hand to assets. Capital ratio represents the ratio of Bank capital to total assets. non-performing loans (NPL) is the share of loans in default over assets. Bank size is the log of Bank total assets and overdue is the ratio of loans in default over.

Table A.2: Descriptive Statistics (Firms)

	Low exposure	Medium exposure	High exposure	Total
Cash Flow	-618.6	14021.5	103176.8	35292.9
	(1819054.1)	(1712936.1)	(7936334.1)	(4679678.1)
ROA	-12.86	0.0606	-0.202	-5.559
	(5900.2)	(111.4)	(29.07)	(3861.3)
solvability	60.35	410.1	12.85	129.9
	(15853.3)	(116448.9)	(3916.7)	(58433.1)
cash-hold assets	0.133	0.120	0.110	0.122
	(0.647)	(0.207)	(0.270)	(0.462)
profitability	-22.12	9.483	-0.105	-7.062
	(7255.3)	(1723.0)	(24.26)	(4791.7)
NPL	0.154	0.0843	0.0920	0.118
	(0.345)	(0.261)	(0.274)	(0.307)
assets	1478411.1	3136406.4	9577860.9	4401416.5
	(32436045.4)	(46595181.4)	(212503342.0)	(123003365.7)
firm age	21.74	24.60	23.76	23.10
	(11.41)	(13.77)	(13.22)	(12.68)
investment	40954.6	172103.8	377108.0	177523.3
	(4936562.3)	(10261442.7)	(8180104.4)	(7569306.3)
Observations				381280

Notes: The table reports mean coefficients and standard deviation in parentheses. The period is 2007:Q1. The variables were constructed as follows. return on earnings (ROA) represents the ratio of cash flow on assets. Solvability is the ratio of equity on liabilities. non-performing loans (NPL) is the share of loans in default over assets. Investment is constructed using tangible as intangible assets.

A.3 Empirical Results

Table A.3: Global financial flows and credit supply

	(1)	(2)	(3)	(4)
	Δln(credit)	Δln(credit)	Δln(credit)	Δln(credit)
ln(Bank Exposure)	-3.830***	-0.592***	-4.941***	-0.792**
	(0.0851)	(0.117)	(0.302)	(0.390)
Bank size		0.132***		0.176***
		(0.00344)		(0.00892)
Capital ratio		8.608***		12.56***
		(1.402)		(3.931)
Liquidity ratio		755.6***		1084.3***
		(89.99)		(220.1)
N	424588	424588	424588	424588
r2	0.000937	0.00352	0.661	0.663
FE			✓	✓

*Notes: The table shows results for the estimation of equation (2). "Bank Exposure" is the share of bank liabilities from international credit institutions. "Bank size" is the logarithm of bank assets. "Capital ratio" is the share of capital on total bank assets. "Liquidity ratio" is the share of cash on total bank assets. Standard errors in parentheses. Standard errors are clustered at the firm level. *, **, and *** indicate significance at the* 0.1, 0.05 *and* 0.01 *level.*

Table A.4: Transmission of global financial flows to the Macroeconomy

	(1)	(2)	(3)	(4)	(5)
	Δln(credit)	Δln(Investment)	Δln(Investment)	Δln(Employment)	Δln(Employment)
Firm exposure Cap.Flows	-1.731***				
	(0.301)				
Δ ln Credit		1.004***	1.045***	0.158***	0.164***
		(0.201)	(0.235)	(0.0444)	(0.0471)
cash Flow			7.74e-09*		6.64e-10***
			(4.28e-09)		(1.58e-10)
ROA			0.349***		-0.000000180
			(0.0700)		(0.000000248)
solvability			-0.0000739		9.88e-08
			(0.000164)		(0.000000133)
Third-party debt			-4.45e-10		1.05e-10***
			(3.56e-10)		(2.10e-11)
Debt ratio			-0.000000284		1.67e-08
			(0.000000669)		(1.79e-08)
Colateral			0.235*		0.00809
			(0.130)		(0.00560)
Cash-hold Assets			0.148		0.0326***
			(0.194)		(0.00648)
N	344082	41064	41052	306271	305459
r2	0.0000963				
Sector FE		✓	✓	✓	✓

*Notes: The table shows results for the estimation of equation (3). "Capital Inflows" is the share of bank liabilities from international credit institutions. The variables were constructed as follows. return on earnings (ROA) represents the ratio of cash flow on assets. Solvability is the ratio of equity on liabilities. Debt ratio is the share of third-party debt on equity. Colateral is the ratio of fixed assets on total assets. Cash-hold Assets is the sum of cash and checking accounts. deposits Standard errors are clustered at the firm level. *, **, and *** indicate significance at the* $0.1, 0.05$ *and* 0.01 *level.*

Table A.5: Global financial flows and credit supply (extensive margin)

	(1)	(2)
	Δ ln(Credit)	Δ ln(Credit)
Weighted Cap. F.	-3.211***	-0.730***
	(0.158)	(0.169)
Estimated FE	1.000***	0.999***
	(0.00110)	(0.00110)
Bank Size		0.0965***
		(0.00264)
Capital Ratio		1.306
		(1.256)
Liquidity Ratio		788.6***
		(54.69)
N	423162	423162
r2	0.659	0.661
FE		

*Notes: The table shows results for the estimation of equation (4). "Weighted Capital Inflows" is the firm weighted share of bank liabilities from international credit institutions. "Bank size" is the logarithm of bank assets. "Capital ratio" is the share of capital on total bank assets. "Liquidity ratio" is the share of cash on total bank assets. Standard errors in parentheses. Standard errors are clustered at the firm level. *, **, and *** indicate significance at the* 0.1, 0.05 *and* 0.01 *level.*

Table A.6: Global financial flows and credit supply

	(1)	(2)	(3)	(4)	(5)	(6)
	Δln(credit)	Δln(credit)	Δln(credit)	Δln(credit)	Δln(credit)	Δln(credit)
Capital inflows	-0.140***	-0.144***	-0.0960***	-0.116***	-0.117***	-0.119***
	(-10.91)	(-9.71)	(-22.37)	(-23.39)	(-20.95)	(-21.19)
cash flow		6.99e-10		-1.62e-09*		-1.48e-09*
		(0.93)		(-2.01)		(-2.32)
ROA		-0.000000210		9.89e-08		0.000000199
		(-0.01)		(0.73)		(0.81)
solvability		-0.0000243		-1.48e-08		-1.33e-08
		(-1.92)		(-1.09)		(-1.12)
Debt		-3.57e-10		6.12e-11		-2.45e-11
		(-0.32)		(0.53)		(-0.19)
Debt ratio		-4.13e-08		-2.76e-09		-4.85e-09
		(-0.70)		(-0.22)		(-0.37)
colateral		-0.708**		-0.00669		-0.00790
		(-2.58)		(-1.73)		(-1.43)
cash hold assets		-1.061***		-0.128**		-0.157**
		(-3.87)		(-2.92)		(-2.62)
N	426951	331157	426951	331157	327387	324464
r2	0.659	0.649	0.000425	0.000895	0.0398	0.0404
ar2	0.100	0.121				
Firm FE	✓	✓			✓	✓
District-Sector FE					✓	✓

*Notes: The table shows results for the estimation of equation (2). "Capital Inflows" is the share of bank liabilities from international credit institutions. The variables were constructed as follows. Return on earnings (ROA) represents the ratio of cash flow on assets. Solvability is the ratio of equity on liabilities. Debt ratio is the share of third-party debt on equity. Colateral is the ratio of fixed assets on total assets. Cash-hold Assets is the sum of cash and checking accounts. deposits Standard errors are clustered at the firm level. *, **, and *** indicate significance at the* 0.1, 0.05 *and* 0.01 *level.*

Table A.7: Transmission of global financial flows to domestic firms(Placebo test)

	(1)	(2)
	Δln(investment)	Δln(investment)
Δln(credit)	0.714	0.727
	(1.69)	(1.72)
est fe	-0.663	-0.677
	(-1.58)	(-1.61)
ROA		0.345^{***}
		(5.47)
solvability		-0.000448
		(-1.25)
Debt		$-8.66e-10^{**}$
		(-3.06)
Debt ratio		-0.0000702
		(-0.65)
cash flow		$1.35e-08^{**}$
		(2.85)
N	27576	27569
r2	.	.
ar2		

Table A.8: Transmission of global financial flows

	Δln(credit)
Capital inflows	-4.144***
	(-9.71)
Cash Flow	6.99e-10
	(0.93)
ROA	-0.000000210
	(-0.01)
Solvability	-0.0000243
	(-1.92)
Third-Party debt	-3.57e-10
	(-0.32)
Debt Ratio	-4.13e-08
	(-0.70)
Colateral	-0.708**
	(-2.58)
Cash-hold Assets	-1.061***
	(-3.87)
N	331157
r2	0.649
ar2	0.121
Sector-Location FE	✓

*Notes: The table shows results for the estimation of equation (2). "Capital Inflows" is the share of bank liabilities from international credit institutions. The variables were constructed as follows. Return on earnings (ROA) represents the ratio of cash flow on assets. Solvability is the ratio of equity on liabilities. Debt ratio is the share of third-party debt on equity. Colateral is the ratio of fixed assets on total assets. Cash-hold Assets is the sum of cash and checking accounts. deposits Standard errors are clustered at the firm level. *, **, and *** indicate significance at the* 0.1, 0.05 *and* 0.01 *level.*

B Data Appendix

B.1 Data sources

Domestic interest rate: Domestic interest rate is calculated using the cost of credit to households on housing and consumption (TAEG). The data source is the Bank of Portugal BPStat dataset. It was calculated as the weighted interest on both housing and consumption

$$R_t^{Data} = \gamma TAEG_t^H + (1-\gamma)TAEG_t^C$$

Where γ is the ratio of housing credit over total credit. The data was collected as annualized net interest rate. I proceed by converted in into real quarterly gross interest rate using the following formula

$$R_t = \left(1 + \frac{R_t^{Data}}{100}\right)^{\frac{1}{4}}$$

The data source for the consumer price index (CPI) is the Bank of Portugal BPStart database. The data length is $2003 : Q1 - 2015 : Q4$. Finally, the domestic interest rate is computed in real terms using the CPI.

Foreign interest rate: There is no good data on cost of interbank loans from international banks to domestic Portuguese banks. It is although possible to gather data on interest rates paid on deposits made by foreign NFI and households on domestic banks. The (?) shows this are highly correlated with the Euro Interbank Offered Rate (EURIBOR). Thus, I use foreign interest rate as 3 months EURIBOR. The data length and frequency is $2003 : Q1 - 2015 : Q4$. EURIBOR was transformed into quarterly gross interest rate using the above formula. Finally, EURIBOR is expressed in real terms using Euro-area CPI. The data source for the consumer price index (CPI) is the Bank of Portugal BPStart database (the same data series as in EuroStat).

Gross Domestic Product: The data source for quarterly gross domestic product (GDP) at constant prices is the IMF database. I transform into real per capita GDP using total population collected from the Bank of Portugal BPStat database. I extract the cyclical component using an HP filter with 1600 penalty (the standard value for quarterly data).

B.2 Calibration

Share of labor income Share of labor income is calculated as the ratio of labor income to total income

$$(1-\alpha) = \frac{CE}{GDP - HHGPS + CFC - T}$$

Where CE is compensation of employees, GDP is gross domestic product (expenditure), CFC is household consumption of fixed capital and T is taxes net of transfers. Variables are computed as their average over 1980 – 2015. The data sources is the *OECD annual national accounting*.

Depreciation rate The depreciation rate is computed using the perpetual inventory method. Data on Investment and GDP and consumption of fixed capital comes from the *OECD annual national accounting*.

Total factor productivity Total factor productivity (TFP) is computed using the Solow residual method. The capital stock is computed using the perpetual inventory method. After linear de-trending the TFP sequence, I proceed by estimating an AR(1) process of the residual to compute the auto-correlation and standard deviation of the TFP process. Data on working population is from the *AMECO database*.

C Computational Appendix

C.1 Equilibrium Conditions

$$1 = \beta \mathbb{E}_t \left(\frac{c_{t+1}}{c_t} \right)^{-\gamma} R_t \tag{30}$$

$$\psi_t = \mu_t^K \phi_t + \mu_t^N + \mu_t^* \phi_t x_t \tag{31}$$

$$\lambda_t \theta \gamma x_t = \mathbb{E}_t \beta \left(\frac{c_{t+1}}{c_t} \right)^{-\gamma} (1 - \theta + \theta \psi_{t+1}) \left(R_t - \frac{e_{t+1}}{e_t} R_t^* \right) x_t \tag{32}$$

$$0 = \lambda_t \left[\psi_t - \theta \left(1 + \frac{\gamma}{2} x_t^2 \right) \phi_t \right] \tag{33}$$

$$H_t = \left[\frac{(1 - \alpha_K - \alpha_M) A_t (\Psi_t K_{t-1})^{\alpha_K} M_t^{\alpha_M}}{\chi c_t^{\gamma}} \right]^{\frac{1}{\varrho + \alpha_K + \alpha_M}} \tag{34}$$

$$x_t = \frac{e_t D_t^*}{K_t D_t} \tag{35}$$

$$
\begin{aligned}
\phi_t &= \frac{K_t Q_t}{N_t} && (36)\\
N_t &= \theta\left[R_t^K Q_{t-1} K_{t-1} - e_t D_{t-1}^* R_{t-1}^*\right] + P_{t-1} && (37)\\
P_t &= \theta\left[R_t(N_t - Q_t K_t) + e_t D_t^* R_t\right] + \iota(1-\theta) Q_t K_t && (38)\\
K_t &= (1-\delta)\Psi_t K_{t-1} + \left[a_1\left(\frac{I_t}{\Psi_t K_{t-1}}\right)^{1-\varrho} + a_2\right]\Psi_t K_{t-1} && (39)\\
Q_t &= \left[\frac{I_t}{\delta \Psi K_{t-1}}\right]^{\varphi} && (40)\\
Y_t &= A_t(\Psi K_{t-1})^{\alpha_K}(M_t)^{\alpha_M}(H_t)^{1-\alpha_K-\alpha_M} && (41)\\
Y_t &= C_t + I_t + Ex_t - e_t M_t && (42)\\
D_t^* &= R_t^* D_{t-1}^* + M_t - \frac{1}{e_t} Ex_t && (43)\\
Ex_t &= e_t^{\varphi} && (44)\\
R_t^K &= \left(\frac{\alpha_K \frac{Y_t}{\Psi_t K_{t-1}} + (1-\delta) Q_t}{Q_{t-1}}\right)\Psi_t && (45)\\
R_t^* &= \frac{1}{\beta} + \varphi\left[\exp\left(\frac{D_t^*}{Y_t} - \bar{D}\right) - 1\right] + \exp(R_t^* - 1) - 1 && (46)
\end{aligned}
$$

C.2 Proof of Proposition 1

Combine equation (15) and equation (14) to get

$$
N_{it+1} = (R_{it+1}^K - R_{it}) Q_{it} K_{it} + R_{it} N_{it} + e_{it}\left(R_{it} - \frac{e_{it+1}}{e_{it}} R_{it}^*\right) D_{it}^* \qquad (47)
$$

Use the guess that the banker's value function is a linear function of bankers' net worth, $V_{it} = \psi_{it} n_{it}$. Substitute the guess and (47) into (17)

$$
\psi_{it} n_{it} = \max_{\{K_{it}, D_{it}, D_{it}^*\}} \left\{\mathbb{E}_t \Lambda_{t,t+1}(1-\theta+\theta\psi_{it+1})\left[n_{it+1}\right]\right\} \qquad (48)
$$

Substitute (47) into (50)

$$
\begin{aligned}
\psi_{it} n_{it} &= \max_{\{K_{it}, D_{it}, D_{it}^*\}} \left\{\mathbb{E}_t \hat{\Lambda}_{t,t+1}\left[(R_{it+1}^K - R_{it}) Q_{it} K_{it} + R_{it} N_{it} + e_{it}\left(R_{it} - \frac{e_{it+1}}{e_{it}} R_{it}^*\right) D_{it}^*\right]\right\}\\
&+ \lambda_{it}\left[\psi_{it} n_{it} - \theta\left[1 + \frac{\gamma}{2}\left(\frac{e_t D_t^*}{Q_t K_t}\right)^2\right] Q_t K_t\right] \qquad (49)\\
&\Leftrightarrow
\end{aligned}
$$

$$
\begin{aligned}
\psi_{it} &= \max_{\{\phi_{it}, x_{it}\}} \left\{ \mathbb{E}_t \hat{\Lambda}_{t,t+1} \left[(R^K_{it+1} - R_{it}) \underbrace{\frac{Q_{it}K_{it}}{n_{it}}}_{\phi_{it}} + R_{it} + \underbrace{\frac{e_{it}D^*_{it}}{K_{it}D_{it}}}_{x_{it}} \underbrace{\frac{Q_{it}K_{it}}{n_{it}}}_{\phi_{it}} \left(R_{it} - \frac{e_{it+1}}{e_{it}} R^*_{it} \right) \right] \right\} \\
&+ \lambda_{it} \left[\psi_{it} - \theta \left(1 + \frac{\gamma}{2} x_{it} \right)^2 \phi_{it} \right]
\end{aligned}
$$

The first order conditions are

$$
x_{it}: \quad \mathbb{E}_t \hat{\Lambda}_{t,t+1} \left(R_{it} - \frac{e_{it+1}}{e_{it}} R^*_{it} \right) = \lambda_{it} \theta \gamma x_{it} \tag{50}
$$

$$
\phi_{it}: \quad \mathbb{E}_t \hat{\Lambda}_{t,t+1} (R^K_{it+1} - R_{it}) + \mathbb{E}_t \hat{\Lambda}_{t,t+1} \left(R_{it} - \frac{e_{it+1}}{e_{it}} R^*_{it} \right) x_{it} = \lambda_{it} \theta \left(1 + \frac{\gamma}{2} x_{it} \right)^2 \tag{51}
$$

and the envelope theorem gives

$$
\psi_{it} = \frac{\mathbb{E}_t \hat{\Lambda}_{t,t+1} R_{it}}{1 - \lambda_{it}} \tag{52}
$$

Plugging back into the guess

$$
V_{it} = \frac{\mathbb{E}_t \hat{\Lambda}_{t,t+1} R_{it}}{1 - \lambda_{it}} n_{it} \tag{53}
$$

confirming the conjecture that the banker's value function is a linear function of bankers' net worth.

C.3 Solution Algorithm

We solve the quantitative model using a global solution method combining collocation and time iteration (Judd (1998)). The mode has three endogenous and three exogenous state variables. The vector of state variables is

$$
\mathbb{S}_t = \{K, P, D^*, R^*, \theta, \Psi\}
$$

The vector of control variables is

$$
\mathbb{C}_t = \{C, \psi, D^{*'}\}
$$

The most robust method to solve our model is value function iteration. However, the size of the state space makes it infeasible to solve for a sufficiently high number of grid points. For that reason, we have to resort to alternative methods. The best methods to solve a model with a large state space – and surpass the curse of dimensionality – are the smolyak method (Malin et al. (2011)) and the ε-distinguishable grid method (Maliar and Maliar (2015)). We opt for the later. One of the main reasons the model needs to be solved with a global solution method is the presence of an occasionally binding constraint. This constraint imposes a descontinuity into decision rules. For this reason, we approximate control variables using a piecewise smooth function of the following form

$$\mathbb{X} = (1 - \mathbf{1}_b)\gamma_{nb}\mathbf{T}_{nb} + \mathbf{1}_b\gamma_b\mathbf{T}_b$$

Where $\mathbb{X} = \{C, \psi, D^{*'}\}$ and $\mathbf{1}_b$ is an indicator function taking the value of one when the capital requirement constraint is binding. $\mathbf{T}$ is a vector of Chebyshev polynomials and γ are the corresponding parameters.

The algorithm of the numerical solution is the following

Step 1: Initialization

1. Choose initial values for state variables $\mathbb{S}_0 = \{K_0, P_0, D^*_0, R^*_0, \theta_0, \Psi_0\}$ and T
2. Draw a vector of random values from a normal distribution $\{\epsilon^{R^*}_{t+1}, \epsilon^{\theta}_{t+1}, \epsilon^{\Psi}_{t+1}\}_{t=0,\dots,T-1}$ and compute the vector of exogenous shocks $\{R^*_{t+1}, \theta_{t+1}, \Psi_{t+1}\}_{t=0,\dots,T-1}$
3. choose parameters γ_b, γ_{nb}
4. choose integration nodes ϵ and weights w

Step 2: Build the ε-distinguishable grid

1. Simulate the model using initial values and chosen parameters
2. Construct the ε-distinguishable grid for state variables.

   $\mathbb{G}_m = \{K_m, P_m, D^*_m, R^*_m, \theta_m, \Psi_m\}_{m=1,\dots,M}$

Step 3: Compute the solution for control variables

1. For each $\mathbb{G}_m$ grid point, use parameters γ_b, γ_{nb} to compute the value of control variables for the binding and non-binding state.
2. Start by assuming constraint does not bind and use parameters γ_{nb}, solve for all endogenous variables using the model's equilibrium conditions
3. at every grid point, check if the constraint binds. If so, compute controls for the binding case using γ_b and re-compute endogenous variables.
4. Evaluate conditional expectations

Step 4: Find parameter values that solve the system

1. Find new parameter values $\gamma_b^{new}, \gamma_{nb}^{new}$ by regressing
2. update parameter guess as

$$\begin{aligned}\gamma_b^i &= \gamma_b\alpha + \gamma_b^{new}(1-\alpha) \\ \gamma_{nb}^i &= \gamma_{nb}\alpha + \gamma_{nb}^{new}(1-\alpha)\end{aligned}$$

3. Evaluate convergence as

$$|\gamma^i - \gamma^{new}| < tol$$

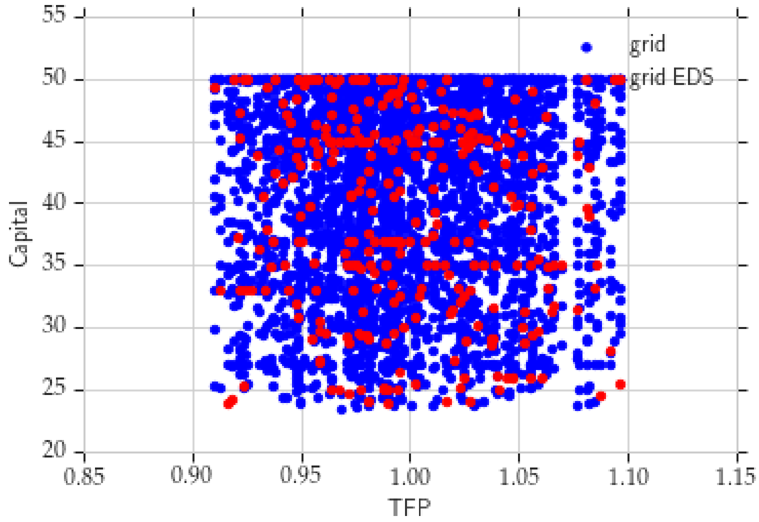
4. Iterate on steps 3 and 4 until converge

Notes: Solving models numerically and globally using projection methods is faster and more accurate, but it is also less robust and requires a good initial guess. We solve the model using Dynare to arrive at a good initial guess for policy parameters. The grid is solved with the ε-distinguishable grid method. The main advantage of the ε-distinguishable grid construction is that we can define a grid only on points visited in equilibrium, thus avoiding the cost of solving the model in points of the state space never visited in equilibrium. This is specially valuable when solving models with a high number of state variables. The grid construction follows two steps: (i) simulate the model. This first step has the advantage of eliminating points laying outside a high-probability set. (ii) Using the simulated points, construct a grid of points that are ε-distant amongst them. This second step has the advantage of eliminating redundant points. The EDS algorithm is explained in detail in (Maliar and Maliar (2015)). Although the authors provide MATLAB code for the grid construction, we have implemented our own code in FORTRAN, exploiting the speed this kind of lower-level programming language as to offer. Figure (14) is an example of the grid constructed with the ε-distinguishable grid method.

C.4 Generalized Impulse Response Functions

Impulse response functions show the effect on macroeconomic variables from a shock hitting the economy at some point in time, when no other shocks are present. This concept becomes troublesome when dealing with nonlinear models since the effect of some innovation may depend on (i) the state of the economy (ii) the sign and magnitude

Figure 14: Simulated grid and ε-distinguishable grid



Notes: The scatter plot presents the collection of points on the capital and productivity grid. The model simulation points are plotted in blue and the grid points for capital and productivity constructed with the ε-distinguishable grid method.

of the shock at t and (iii) the sign and magnitude of shocks from time t to $t + h$. In this paper I use the concept of Generalized Impulse Response Functions (GIRF) as in Koop et al. (1996). Since the dynamics of variables may depend on the state of the economy (that is, the history of past shocks), the start the algorithm from the stochastic steady state. That is, the resting point of the system with no shocks hitting the economy, but in which agents take future surprises into account. The behavior of variables is also a function of the future path of shocks, therefore I compute GIRF by using an expectation operator condition on the history of shocks. The algorithm to construct GIRF is the following:

1. Compute the model stochastic steady state.
2. Draw M sequences of shocks of length T, $\{\varepsilon_{m,t}\}_{m=1,t=1}^{M,T}$. I use $M = 30.000$ and $T = 1000$ and discard the first 500.
3. For each $m = 1, \ldots, M$ sequence of shocks, simulate the model. Save M sequences of simulated variables, $\{V_{m,t}^{no\ shock}\}_{m=1,t=1}^{M,T}$.
4. Using the same sequence of M shocks, simulate the economy, but this time, in period 501, impose a negative 3% TFP shock. Compute the sequence of simulated variables, $\{V_{m,t}^{shock}\}_{m=1,t=1}^{M,T}$

5. The GIRF at each time $t+n$ for a variable V is

$$GIRF_n^V(u_t, \Omega_{t-1}) = \frac{\mathbb{E}\left[V_{t+n}^{shock} | u_t, \Omega_{t-1}\right]}{\mathbb{E}\left[V_{t+n}^{no\ shock} | \Omega_{t-1}\right]} - 1 \tag{54}$$

where u_t is the innovation at time t.

C.5 Particle Filter

Our goal in this section is to find a way to track the evolution of an economic system. We use the hidden Markov model (HMM) (also known as state space model). The problem we are considering can be seen as the problem of estimating sequentially the values of some latent states, $\mathbf{S}_t$, given the values of an observed process $\{\mathbf{Y}_1, \ldots, \mathbf{Y}_t\}$, at some period of time,t. Define a non-linear state space model as

$$\begin{aligned} \mathbf{Y}_t &= f(\mathbf{S}_t; \alpha) + \eta_t, \qquad \eta_t \sim N(0, \Sigma) & (55) \\ \mathbf{S}_t &= g(\mathbf{S}_{t-1}, \varepsilon_t; \alpha), \qquad \varepsilon \sim N(0, I) & (56) \end{aligned}$$

Where the first equation is a measurement function and the second equation is a state transition function. Let α be a vector of structural parameters, $\mathbf{S}_t = \{K_t, P_t, D_t^f, A_t, \Psi_t, R_t^f\}$ be the vector of state variables and $\mathbf{Y}_t$ the vector of observable variables. Observed variables are GDP, foreign interest rates and the time-series of foreign interbank borrowing. The following exposition is based on Andrieu et al. (2010).

The problem becomes calculating recursively the state S_t given observations $\mathbf{Y}_{1:t}$. That is, since the system is stochastic, we aim to construct the pdf $p(\mathbf{S}_t|\mathbf{Y}_{1:t})$. By Bayes rule we have

$$p(\mathbf{S}_{1:t}|\mathbf{Y}_{1:t}) = \frac{p(\mathbf{S}_{1:t})p(\mathbf{Y}_{1:t}|\mathbf{S}_{1:t})}{p(\mathbf{Y}_{1:t})} \tag{57}$$

Where $p(\mathbf{Y}_{1:t}) = \int p(\mathbf{S}_{1:t}, \mathbf{Y}_{1:t}) dS_{1:t}$. We can see $p(\mathbf{S}_{1:t})$ as the prior distribution and $p(\mathbf{Y}_{1:t}|\mathbf{S}_{1:t})$ as the likelihood function.

If we plug the unnormalized posterior in (57) we have

$$p(\mathbf{S}_{1:t}|\mathbf{Y}_{1:t}) = p(\mathbf{S}_{1:t}, \mathbf{Y}_{1:t-1}) \frac{f(\mathbf{S}_t|\mathbf{S}_{t-1})g(\mathbf{Y}_t|\mathbf{S}_t)}{p(\mathbf{Y}_t|\mathbf{Y}_{1:t-1})} \tag{58}$$

Integrating out $S_{1:t}$ in (58)

$$p(\mathbf{S}_t|\mathbf{Y}_{1:t}) = \frac{p(\mathbf{S}_t, \mathbf{Y}_{1:t-1})g(\mathbf{Y}_t|\mathbf{S}_t)}{p(\mathbf{Y}_t|\mathbf{Y}_{1:t-1})} \tag{59}$$

Where

$$p(\mathbf{S}_t, \mathbf{Y}_{1:t-1}) = \int f(\mathbf{S}_t|\mathbf{S}_{t-1})p(\mathbf{S}_{t-1}|\mathbf{Y}_{1:t-1})dS_{t-1} \tag{60}$$

Is called the Chapman-Kolmogorov equation.

Note that using the state space equations (55) and an initial value of $p(\mathbf{S}_1|\mathbf{Y}_1)$ we could solve recursively for $p(\mathbf{S}_t|\mathbf{Y}_{1:t})$ using (59) and (60). The particle filter is going to rely on this recursion. At first, the system may seem deceivingly simple. This is because a numerical approximation to $p(\mathbf{S}_t|\mathbf{Y}_{1:t})$ by a recursive exploration of (59) and (60) requires the computation of intractable integrals. If the state space model was linear and errors were gaussian, then we could rely on the Kalman filter. Since our model is non-linear we need to resort to numerical simulation. That is, we are going to generate samples from the target distribution and compute the required integrals by approximation. A further issue is how to sample from the required distributions. In most cases we do not know how to draw random samples. The literature fixed this problem by using a clever trick called importance sampling (IS). The importance sampling method requires an importance (also called proposal) density $q_t(\mathbf{S}_{1:t})$ with the following three characteristics: (i) That whenever the target distribution is positive, so is the proposal distribution. That is, $p_t(\mathbf{S}_{1:t}) > 0 \Rightarrow q_t(\mathbf{S}_{1:t}) > 0$. (ii) We should pick a distribution q such that it is easy to sample from (after all, that was our initial motivation). For example, pick a normal or uniform distribution. (iii) q should have a support larger than p, the target distribution. The trick boils down to multiplying and dividing the target distribution by the importance distribution. Using (59) that would mean doing

$$p(\mathbf{S}_t|\mathbf{Y}_{1:t}) = \frac{\frac{\gamma_t(\mathbf{S}_{1:t})}{q_t(\mathbf{S}_{1:t})}q_t(\mathbf{S}_{1:t})}{Z_t} \tag{61}$$

Where $\gamma_t(\mathbf{S}_{1:t}) = p(\mathbf{S}_t, \mathbf{Y}_{1:t-1})g(\mathbf{Y}_t|\mathbf{S}_t)$ and $Z_t = \int w_t(\mathbf{S}_{1:t})q_t(\mathbf{S}_{1:t})dS_{1:t}$. In this way, we can find the estimate by drawing from q instead of drawing from p.

Although important sampling solves our initial problem, it is not adequate for a recursive estimation. Therefore, we will use a sequential importance sampling method (SIS) in which we choose an importance distribution that allows us to carry all steps recursively. The importance sampling is chosen so as to have the following form

$$
\begin{aligned}
q_t(\mathbf{S}_{1:t}) &= q_{t-1}(\mathbf{S}_{1:t-1})q_t(\mathbf{S}_t|\mathbf{S}_{1:t-1}) && (62)\\
&= q_1(\mathbf{S}_1)\prod_{t=2}^{T} q_t(\mathbf{S}_t|\mathbf{S}_{1:t-1}) && (63)
\end{aligned}
$$

That is, at time $t = 1$ we sample $\mathbf{S}_1^i$ from $q_1(\mathbf{S}_1)$. Then, at time $t = k$ we draw $\mathbf{S}_k^i$ from $q_k(\mathbf{S}_k|\mathbf{S}_{1:k-1}^i), k = 2, \ldots, T$.

A final problem with the sequential importance sampling method is that the variance of $\mathbf{S}^i$ increases (possibly) exponentially with the passage of time. If we think of a filter as spreading particles and giving those particles some weight according to how close they are to the true state of the economy at some point in time, with the passage of time few particles will have most of the probability mass, while the remaining particles become almost with no mass. The solution to this problem is called *resampling*. With SIS, an approximation $\hat{p}_t(\mathbf{S}_{1:t})$ to some distribution $p_t(\mathbf{S}_{1:t})$ is based on weighted samples from $q_t(\mathbf{S}_{1:t})$, not according to $P_t(\mathbf{S}_{1:t})$. The *resampling* part of the algorithm will sample from the sample distribution, $\hat{p}_t(\mathbf{S}_{1:t})$, rather than from the importance distribution, $q_t(\mathbf{S}_{1:t})$. We do so by selecting $\mathbf{S}_{1:t}^i$ with probability W_t^i. Intuitively, we are going to kill the particles with low weights and creating N offsprings of particles with high weights. We can see *resampling* as a kind of "survival of the fittest" for a tracking system.

In conclusion, a particle filter is a sequential importance sampling with resampling in which we approximate a posterior distribution with a set of samples, called particles. We can see this particles as a guess of the true state of the economy. This particles will be propagated and updated according to the state space model.

Particle Filter Algorithm:

Step 1: Initialization

1. Set $t = 1$.
2. For each particle $i = 1, \ldots, N$, compute $\mathbf{S}_0^i$ using the model's ergodic distribution and set weights $w_0^i = \frac{1}{N}, i = 1, \ldots, N$

Step 2: Prediction For each $i = 1, \ldots, N$ and each $t \geq 2$,

1. Draw $\mathbf{S}_t^i$ from the importance distribution $q_t(\mathbf{S}_t|\mathbf{S}_{1:t-1}^i)$

2. Compute particle weights

$$w_t^i = \frac{g(\mathbf{Y}_t|\mathbf{S}_t^i)f(\mathbf{S}_t|\mathbf{S}_{t-1}^i)}{q(\mathbf{S}_t|\mathbf{Y}_t, \mathbf{S}_{t-1})}$$

Step 3: Resampling For each $i = 1, \ldots, N$ and each $t \geq 2$,

1. Resample particles $\mathbf{S}_t^i$ using weights W_t^i to obtain N new equally-weighted particles $\{\frac{1}{N}, \bar{\mathbf{S}}_{1:t}^i\}$

Step 4: If $t = T$ then stop. Otherwise, set $t = t + 1$ and go back to step 1.

Notes: We use $N = 100,000$ particles. Regarding the importance distribution, given that crisis periods are usual events (events in the tails of the distribution) we resort to an importance distribution following a normal distribution in which the first moment is defined as in Bocola (2016). That is, we find the center of the distribution by minimizing (with penalty) the distance between the observable and the value computed using the transition equation. The resampling stage uses the stratified resampling method.

C.6 Welfare calculation

Let $V^C(\mathbb{S})$ be the expected lifetime utility of an agent in state $\mathbb{S}$ in a stationary equilibrium with constant bank capital requirements and let $V^T(\mathbb{S})$ be the expected lifetime utility of an agent in state $\mathbb{S}$ in a stationary equilibrium with time-varying capital requirements. Suppose we increase the representative agent's consumption in each period – and in each state – in the model with constant capital requirements by Δ.

$$V^C(\mathbb{S}) = \mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t\left(\frac{C_t^{1-\gamma}}{1-\gamma}(1+\Delta) - \zeta_0\frac{H_t^{1+\zeta}}{1+\zeta}\right)\right] \tag{64}$$

Using the fact that our calibration defines $\gamma = 1$, we have that

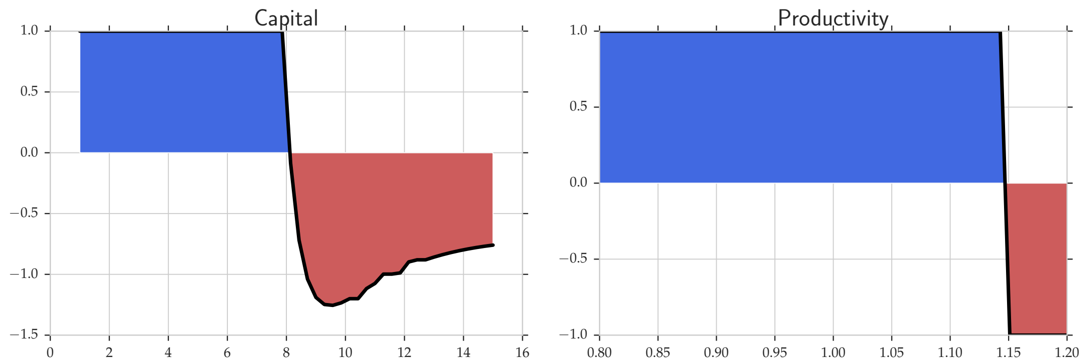
$$\begin{aligned} V^C(\mathbb{S},\Delta) &= \mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t\left(\ln\left[c_t(1+\Delta)\right] - \zeta_0\frac{H_t^{1+\zeta}}{1+\zeta}\right)\right] &(65)\\ &= \ln(1+\Delta) + V^C(\mathbb{S}) &(66)\end{aligned}$$

On the other hand, welfare from both types of macroprudential policy equalized if

$$V^C(\mathbb{S},\Delta) = V^T(\mathbb{S}) \tag{67}$$

$$\begin{aligned} & \Leftrightarrow & & \quad (68) \\ \ln(1+\Delta) + V^C(\mathbb{S}) &= V^T(\mathbb{S}) & & \quad (69) \\ & \Leftrightarrow & & \quad (70) \\ \Delta &= \exp\left[V^T(\mathbb{S}) - V^C(\mathbb{S})\right] - 1 & & \quad (71) \end{aligned}$$

Figure 15: **Macroprudential and Welfare**



Notes: The panels are constructed as follows. Compute the welfare value at each state space point for the model with constant capital requirements and the model with time-varying capital requirements. The y-axis report the consumption equivalent value computed as in appendix (C.6). The horizontal axis plots grid point values for the relevant state space.

C.7 Other Graphs

Figure 16: Actual and Filtered Output

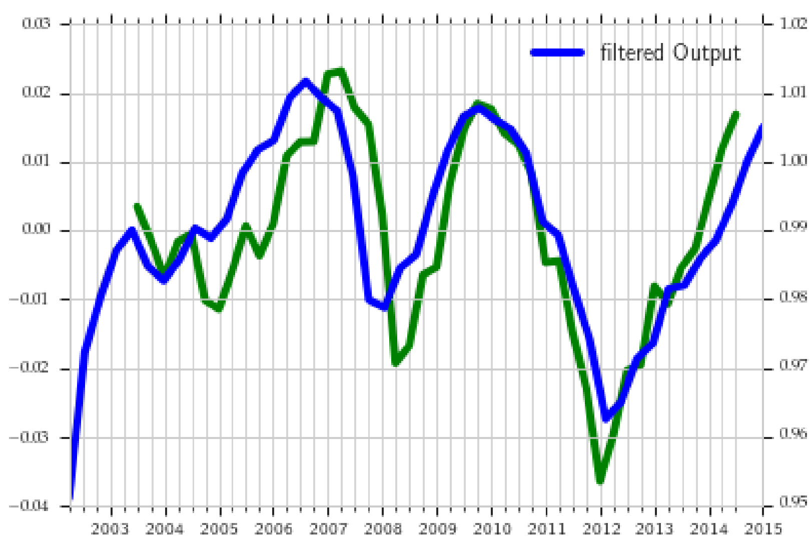


Figure 17: Actual and Filtered Foreign interest rate

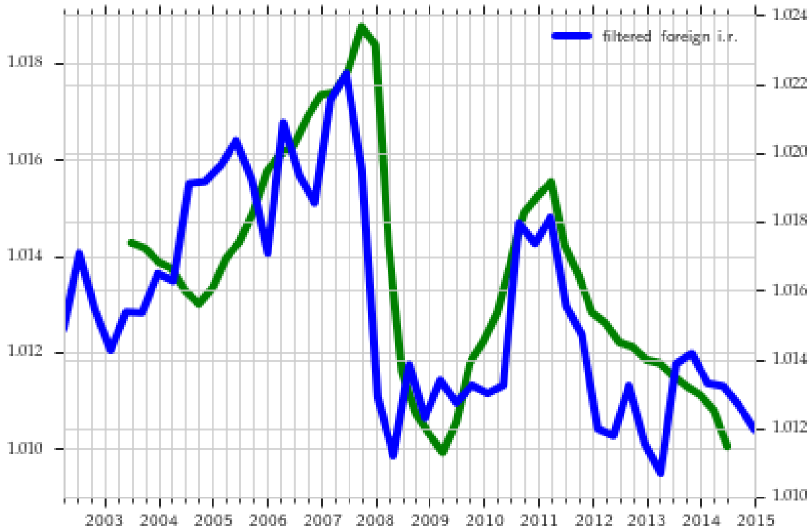


Figure 18: GIRF - Foreign Interest Rate