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FERNANDO CARVALHAES BARBI

TRÊS ENSAIOS SOBRE POLÍTICA MONETÁRIA E CRÉDITO

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Tese defendida à Escola de Economia de São Paulo da Fundação Getúlio Vargas, como requisito para obtenção do título de Doutor em Economia.

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Dedico este trabalho a minha companheira, Soraia, a meus pais, Jurema e Luiz Roberto, e a minha irmã, Carla.

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ABSTRACT

In the first essay, "Determinants of Credit Expansion in Brazil", analyzes the determinants of credit using an extensive bank level panel dataset. Brazilian economy has experienced a major boost in leverage in the first decade of 2000 as a result of a set factors ranging from macroeconomic stability to the abundant liquidity in international financial markets before 2008 and a set of deliberate decisions taken by President Lula's to expand credit, boost consumption and gain political support from the lower social strata. As relevant conclusions to our investigation we verify that: credit expansion relied on the reduction of the monetary policy rate, international financial markets are an important source of funds, payroll-guaranteed credit and investment grade status affected positively credit supply. We were not able to confirm the importance of financial inclusion efforts. The importance of financial sector sanity indicators of credit conditions cannot be underestimated. These results raise questions over the sustainability of this expansion process and financial stability in the future.

The second essay, “Public Credit, Monetary Policy and Financial Stability”, discusses the role of public credit. The supply of public credit in Brazil has successfully served to relaunch the economy after the Lehman-Brothers demise. It was later transformed into a driver for economic growth as well as a regulation device to force private banks to reduce interest rates. We argue that the use of public funds to finance economic growth has three important drawbacks: it generates inflation, induces higher loan rates and may induce financial instability. An additional effect is the prevention of market credit solutions. This study contributes to the understanding of the costs and benefits of credit as a fiscal policy tool.

The third essay, “Bayesian Forecasting of Interest Rates: Do Priors Matter?”, discusses the choice of priors when forecasting short-term interest rates. Central Banks that commit to an Inflation Target monetary regime are bound to respond to inflation expectation spikes and product hiatus widening in a clear and transparent way by abiding to a Taylor rule. There are various reports of central banks being more responsive to inflationary than to deflationary shocks rendering the monetary policy response to be indeed non-linear. Besides that there is no guarantee that coefficients remain stable during time. Central Banks may switch to a dual target regime to consider deviations from inflation and the output gap. The estimation of a Taylor rule may therefore have to consider a non-linear model with time varying parameters.

This paper uses Bayesian forecasting methods to predict short-term interest rates. We take two different approaches: from a theoretic perspective we focus on an augmented version of the Taylor rule and include the Real Exchange Rate, the Credit-to-GDP and the Net Public Debt-to-GDP ratios. We also take an “atheoretic” approach based on the Expectations Theory of the Term Structure to model short-term interest. The selection of priors is particularly relevant for predictive accuracy yet, ideally, forecasting models should require as little a priori expert insight as possible. We present recent developments in prior selection, in particular we propose the use of hierarchical hyper-g priors for better forecasting in a framework that can be easily extended to other key macroeconomic indicators.

Keywords: public credit, financial stability, monetary policy, forecasting, Bayesian model averaging

RESUMO

O primeiro ensaio, "Determinantes da expansão do crédito no Brasil", analisa os determinantes do crédito usando um extenso conjunto de dados em painel sobre o sistema bancário. A economia brasileira teve um grande impulso na alavancagem na primeira década de 2000 como resultado de um conjunto de fatores que vão desde a estabilidade macroeconômica passando pela liquidez abundante nos mercados financeiros internacionais antes de 2008 até um conjunto de decisões deliberadas tomadas pelo presidente Lula para expandir o crédito, impulsionar o consumo e obter apoio político das camadas sociais mais baixas. Como conclusões verificamos que a expansão do crédito beneficiou-se da redução da taxa de juros, os mercados financeiros internacionais são uma fonte importante de recursos, o crédito garantido em folha de pagamento e o grau de investimento afetaram positivamente a oferta de crédito. Nós não fomos capazes de confirmar a importância dos esforços de inclusão financeira. A importância dos indicadores de sanidade do setor financeiro de condições de crédito não pode ser subestimada. Estes resultados levantam questões quanto à sustentabilidade desse processo de expansão e estabilidade financeira no futuro.

O segundo ensaio, "Crédito Público, Política Monetária e Estabilidade Financeira", discute o papel do crédito público. A oferta de crédito público no Brasil serviu para relançar a economia após a crise desencadeada pela quebra do banco Lehman-Brothers. Mais tarde, ele foi transformado em um motor de crescimento econômico bem como num dispositivo de regulação para forçar os bancos privados a reduzir as taxas de juros. Argumenta-se que a utilização de fundos públicos para financiar o crescimento econômico tem três desvantagens importantes: ele gera inflação, induz taxas de financiamento mais elevadas e pode induzir à instabilidade financeira. Um efeito adicional é impedir o desenvolvimento de soluções de crédito de mercado.

O terceiro ensaio, "Previsão Bayesiana de Taxas de Juros: as priors importam?", discute a escolha de priors para previsão das taxas de juros de curto prazo. Bancos Centrais que se comprometem com regimes de metas de inflação devem responder a variações nas expectativa de inflação e no hiato do produto de uma forma clara e transparente, respeitando a regra de Taylor. A estimativa de uma regra de Taylor pode ter que considerar um modelo não-linear com parâmetros variáveis no tempo. Este trabalho usa métodos de previsão bayesiana para as taxas de juro de curto prazo por duas abordagens diferentes. Por uma perspectiva teórica nos concentramos em uma versão aumentada da

regra de Taylor. Também testamos uma abordagem baseada na teoria das expectativas da estrutura a termo cauva de juros para modelar os juros de curto prazo. A seleção dos priores é particularmente relevante para a precisão da previsão, no entanto deseja-se usar prior robustas a falta de conhecimento prévio. Apresentamos os recentes desenvolvimentos na seleção de priors, em especial, propomos o uso de priors hierárquicas da família de distribuição hiper-geométrica.

Palavras-chave: crédito público, estabilidade financeira, política monetária, previsão, modelo de média bayesiana

SUMÁRIO

Determinants of Credit Expansion in Brazil

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Abstract

This paper analyzes the determinants of credit using an extensive bank level panel dataset. Brazilian economy has experienced a major boost in leverage in the first decade of 2000 as a result of a set factors ranging from macroeconomic stability to the abundant liquidity in international financial markets before 2008 and a set of deliberate decisions taken by President Lula's to expand credit, boost consumption and gain political support from the lower social strata. As relevant conclusions to our investigation we verify that: credit expansion relied on the reduction of the monetary policy rate, international financial markets are an important source of funds, payroll-guaranteed credit and investment grade status affected positively credit supply. We were not able to confirm the importance of financial inclusion efforts. The importance of financial sector sanity indicators of credit conditions cannot be underestimated. These results raise questions over the sustainability of this expansion process and financial stability in the future.

keywords bank credit, public credit, emerging markets, financial stability

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1 Introduction

During the presidential campaign in 2002, concern was raised about the future conduction of economic policy should the candidate from the leftist party, Luis Inácio Lula da Silva (Lula), be elected. Just a few months before election, Lula proposed in an open letter[1] that the main priority of his administration, besides respecting contracts and keeping inflation under control, would be to reduce external vulnerabilities by creating a strong domestic market[2] based on consumption. By catering to macroeconomic stability granting the central bank a *de facto* autonomy and by closing the social inequality gap with social transfer programs and an aggressive policy of real minimum salary appreciation, Lula created the political and economic conditions to radically reduce poverty and build an emerging middle class that would guarantee his reelection in 2006 (Hunter and Power (2007)) and keep being his loyal electoral base from 2010 on. Singer (2012) suggests that since 2010 Brazil lives a "New Deal atmosphere" born out of how the 2008 crisis was tackled.

The expansion of domestic demand was based on a set of political decisions that created the conditions for economic growth. According to Lima and Ferreira (2012) "credit expansion is a deliberate outcome of Lula's government economic policy"[3]. Ricci (2006), Souza and Lamounier (2010) and Singer (2012) concur that Lula's vision is based on: (a) the expansion of formal employment, (b) real increases to minimum wage and (c) the expansion of public and private supply of credit. These three economic policy directions are complemented with a series of microeconomic reforms in credit market rules and regulations that allow for the expansion of credit supply at reduced rates. It is not possible to understand the continuous expansion of the economy between 2003 and 2008 without a correct perception of the determinants of credit expansion.

Before the 2007/8 credit crunch crisis, economists paid little attention to credit and the financial markets frictions that might affect output. Both academia and policymakers focused

[1] "Carta ao Provo Brasileiro" was signed on June 22, 2002, at the beginning of the presidential campaign.

[2] "O desenvolvimento de nosso imenso mercado pode revitalizar e impulsionar o conjunto da economia, ampliando de forma decisiva o espaço da pequena e da microempresa, oferecendo ainda bases sólidas para ampliar as exportações. (...) [A]cima de tudo, vamos fazer um Compromisso pela Produção, pelo emprego e por justiça social."

[3] "Ressalte-se o fato de que a expansão do crédito é um desdobramento deliberado da política econômica do governo Lula, visando sustentar o crescimento econômico do país não apenas pelo atendimento da demanda internacional, mas também por meio do atendimento de maior demanda interna por produtos e serviços." (p.31)

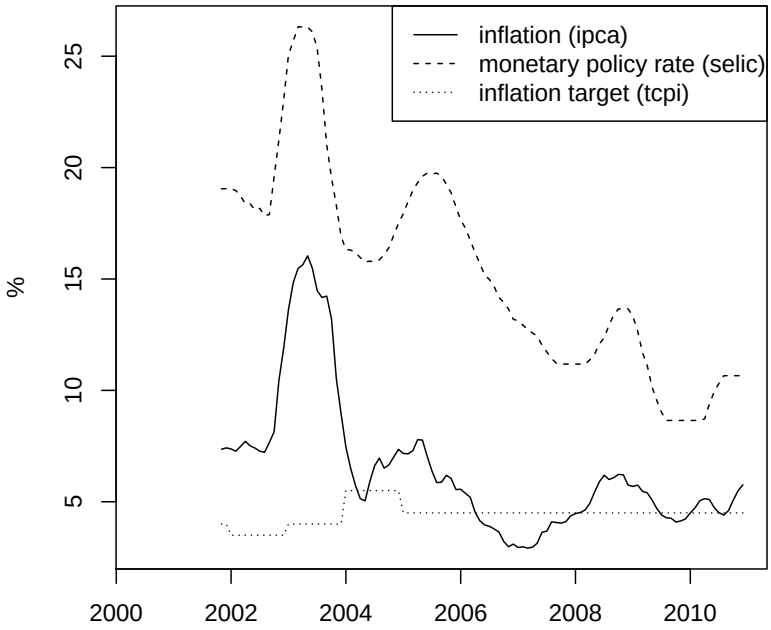
their attention to other more pressing topics: on the macro level, the monetary policy research agenda was dominated by inflation control mechanisms and on the micro level, market regulation was neglected as most believed that markets could self regulate themselves more efficiently than government agencies. The 2007/8 crisis showed that financial intermediation matters for macroeconomic stability. As Blanchard (2010) puts it, "the crisis has made clear that policymakers have to watch many targets, including the composition of output, the behavior of asset prices and the leverage of different agents". Brazil went through deep changes in the financial market. Before inflation control brought by Plan Real in 1994, the Brazilian banking system made most of its profit from rolling government's debt. After the taming of inflation, the banking sector underwent severe concentration and sanitization[4] processes as the surviving institutions reoriented their business models to increase lending to firms and households. Lima and Ferreira (2012) offer a detailed view of the financial system privatization period from 1996 to 2001 and the contraction in the number of public banks as state banks were closed or sold. The few remaining public banks stayed under federal control.

The surviving private institutions learned to profit from credit but as a considerable chunk of the consumers worked in informal activities, personal credit lagged behind as households had a hard time producing collaterals. Macroeconomic stability brought a new wave of investments and some social transfer programs tentatively implemented were raising average income while preparing the ground for the growth years that characterize the Lula Administration. Besides that, an increasing formalization rate in labor relations was key to pave the way for the credit expansion that would later happen.

Brazil adopted the Inflation Target monetary policy regime in 1999 after switching from an exchange-rate anchor put in place in 1994, in the first phase of the Plan Real. The new monetary regime relied heavily on the short-run interest rate (selic) as the Monetary Policy Rate (MPR), the instrument used to keep inflation on target. The convergence of inflation (figure 1) to target was achieved in 2006 and maintained since then under a stern policy of high interest rates that made domestic funding rather expensive. By the same token, since the later 1990 international liquidity increased, enticing big Brazilian banks to access the international financial markets for cheap funding. Eyzaguirre (2011) refers to this period as of a "double

[4]The sanitization of the banking system was conducted by the BCB in the PROER program.

Figure 1: Interest rates, actual and expected inflation trajectories



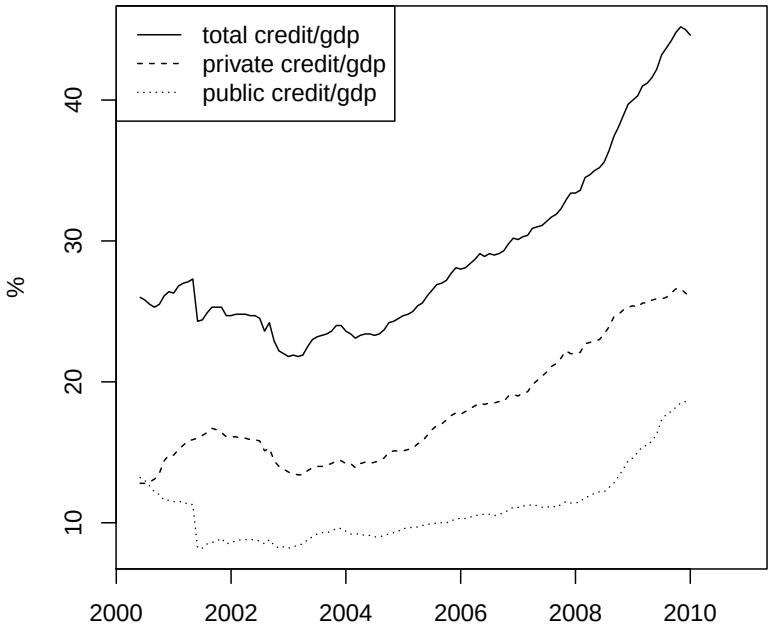
bonanza" to characterize the conjunction of easy foreign financing and the high terms of trade for Latin American commodity exporter countries.

Brazil was granted investment grade status in 2008, first by Standard & Poor's and later by Fitch. Moody's followed and also conferred it in 2009. This contributed to the inflow of funds supplementing the need for resources as domestic savings are not enough to sustain investment. As a side effect the Real appreciated and the competitiveness of the manufactured sector declined.

The Brazilian economy experienced a major boost in leverage from 2001 to 2010 (figure 2) as total credit expanded from 26.8% of GDP in 2001 to 48% in 2010. This movement is mainly credited to macroeconomic stability but also to institutional reforms that reduced the cost of credit for both households and firms. We briefly mention the new funding facility FIDC[5] created as a source of new funding for smaller banks. New payroll backed credit legislation

[5]Receivables Investment Funds (Fundos de Investimento em Direitos Creditórios) were created by the CMN Resolution 2907 of November 29, 2001 and are regulated by the CVM Instructions 356 (December 2001) and 393 (July 2003).

Figure 2: Expansion of Credit relative to GDP



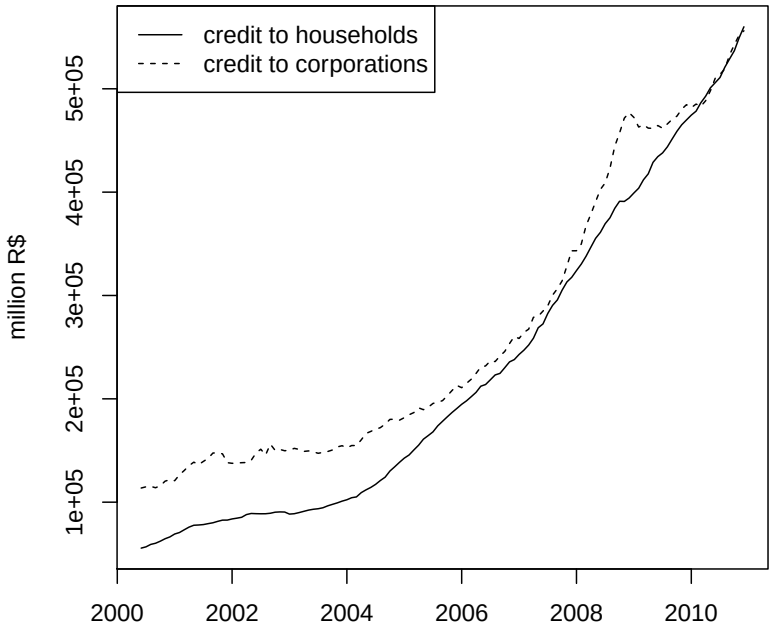
("crédito consignado") was passed by the end of President Lula's first year in power. In the beginning of 2005, bankruptcy legislation ("Lei de Falências") was passed in Congress that would speed up the capture of debtors assets.

Brazil has gone through some profound changes in the last decade that explain the expansion of the credit market. On the supply side, a series of structural microeconomic reforms increased property rights of creditors and created a market for credit portfolios that would increase the recycling of liquidity. Some four events must be mentioned: the first reform was the creation of FIDC. This financial instrument was created to allow small and medium banks to generate funds by selling their credit portfolios.

A second innovation was payroll-backed loans legislation[6] passed in 2003 that allowed lenders to automatically deduce principal and interest payments directly from the credit takers' payroll: this credit modality is the single most important source of credit for individuals today. A third reform is the new bankruptcy legislation passed in 2005 to facilitate the recovery of

[6]In January 2004 this credit modality represented 34% of personal loans and grew to 69% in December 2010.

Figure 3: Evolution of Credit for Households and Firms



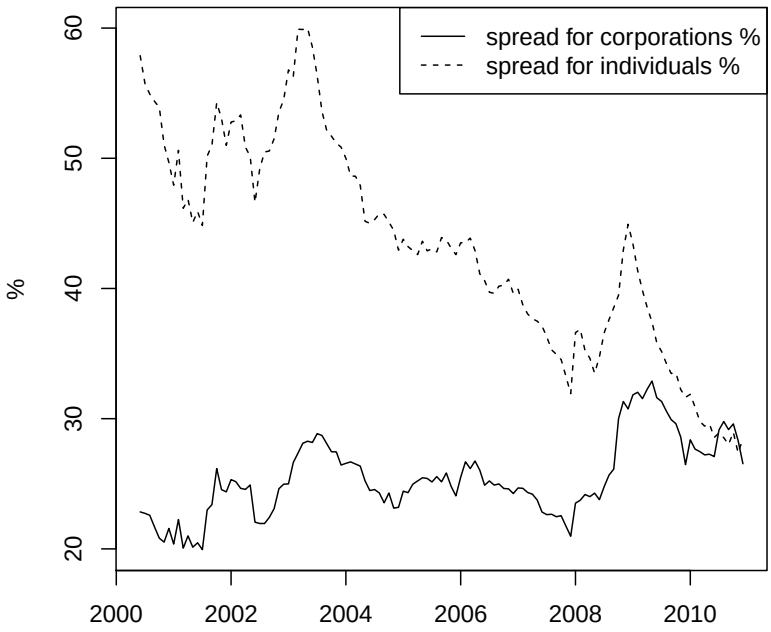
assets by creditors.

As a result, the stock of credit for individuals reached the same levels of credit to corporations (Figure 3) while spreads for these two categories converged by the end of 2010 (Figure 4).

On the demand side, a steady increase in real wages (figure 5), including minimal wages, a steady decrease of unemployment and a series of social transfer programs were adopted as government policy to reduce social inequalities and increase consumption from the lower social classes. At the same time that the population got better educated: comparing PNAD[7] results from 1992 to 2007 the percentage of workers with 11 or more years of education went from 18.40% in 1992 to 39.6% in 2007. The lower end also showed improvements as illiteracy rate reduced from 17.2% in 1992 to 9.6% in 2009 considering all the population above 15 years old. As more educated workers are more productive, education improvement suggests that real wage is increasing in for workers in general.

[7]Pesquisa Nacional por Amostra de Domicilios (national household survey) available at www.ibge.gov.br

Figure 4: Spreads for Corporations x Individuals (%)

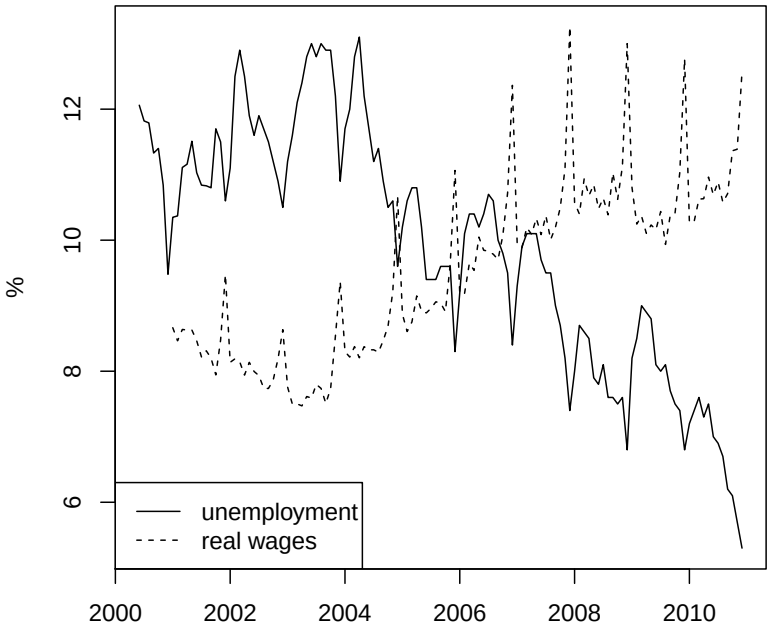


The official employment report (RAIS[8]) shows that during the Lula Administration some 15 millions formal jobs were created (in both private and public sectors) for a total of 44 million people regularly employed. Formal employment was a priority to ensure economic growth. Special attention was dedicated to labor intensive sectors such as construction and small businesses. Fiscal stimulus in the form of payroll taxes rebates were offered to companies to keep employees and the result is that formal employment reached historical full employment rates.

Another factor with implications to both supply and demand of credit is the fact that the country gained credibility as it reached macroeconomic stability. As inflation converged to target, the Brazilian Central Bank (BCB) gained credibility and *de facto* (but not *de jure*) independence to conduct monetary and regulatory policies. As the BCB adopted a more transparent and predictable approach to policy-making Brazil was granted investment grade status in 2008, first by Standard & Poor's and later by Fitch. Moody's followed and also

[8]Características do Emprego Formal segundo a Relação Anual de Informações Sociais - 2010.

Figure 5: Evolution of formal employment and real wages

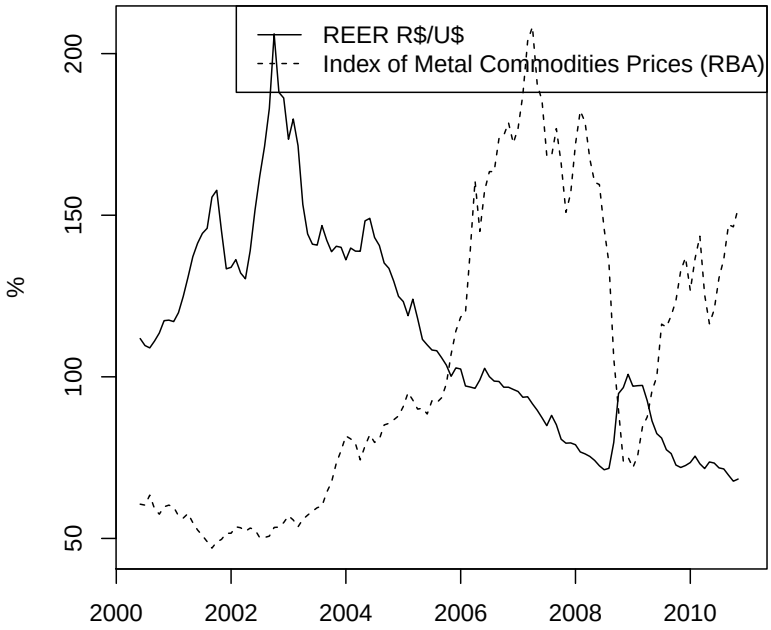


conferred it in 2009. This contributed to the inflow of funds supplementing the need for resources as domestic savings are beneath the necessary level to sustain investment. This inflow complements another one originated in a terms-of-trade shock in commodities prices since 2003 (Figure 6). As Brazil is a big exporter of metals and food commodities, a side effect to these inflows is the appreciation of the domestic currency.

All these micro and macroeconomic changes conflate to explain the expansion of the credit market that changed the face of consumption and investment even at the high levels of interest rates practiced by the BCB. This work is unique in the large sample of banks considered and the degree of details provided by data retrieved in the accounting records. It makes two contributions. The first is to perform intervention analysis to test a series of events that may explain temporary and permanent shocks to the domestic credit market. These events are credit ensured by payroll legislation, the achievement of investment grade, Lehman's demise, Lula's candidacy for Presidency and his first year in government.

The second contribution is to untangle the relation between funding channels for credit

Figure 6: REER and Metal Commodities Prices



expansion and macroeconomic variables such as GDP, industrial production, unemployment, inflation, exchange rate and minimum wage. Minimum wage is not generally used in the literature but in Brazil it has added relevance because it is not only an indicator of wage costs but also a key index for social security transfers to pension recipients. Hunter and Power (2007) further explain that "[M]ost Brazilian salaries are in some way linked to the minimum wage as a unit of reference, so increases in the minimum wage have a ripple effect in consumer spending and throughout the economy."

As the minimum salary is an index and a floor to salaries in the private sector it is also an income redistribution tool. According to Neri (2010) "between 2003 and 2009, Brazilians per capita average income raised by 4.72% in real terms going from R$ 478 to R$ 630 per month. The income source that increased most is social programs (12.9%) influenced by the expansion of Bolsa Família created in 2003. After that comes the income share from social security related to minimum wage. The effects of minimum wage hikes that raised more than 45% during this period, created pressure not only by the value of the base benefit but also by the increasing

participation of the elder in population income, given the aging of the population". Hunter and Power (2007) concur: "[T]he real increase in the purchasing power of the minimum wage was approximately 23 percent in Lulas first term. This, combined with cash injections from the poverty-reducing income transfer program, the Bolsa Família, has had a palpable effect on the local economies of smaller and less developed municipalities, which depend heavily on small-scale personal spending for their livelihood." Programa Bolsa Família (PBF) is the most visible social transfer program. In 2003 it transferred some R$ 570 million, in 2006 this grew up to R$ 7.5 billion. In 2010 the program received R$ 13.46 billion, some 0.4% of GDP, to support more than 13.5 million families.

This paper is organized in five sections besides this introduction. The second part presents the credit channel and offers a brief literature review to conclude with some pending questions that this work will investigate. The third part is a list of empirical models to be tested. The fourth part presents and discusses empirical results, while the last part concludes.

2 Literature review

The very existence of the banking system is based on the concept of liquidity provisioning. Banks recycle liquidity by taking deposits and turning them into loans. The principle of Delegated Monitoring (Diamond (1984)) states that monitoring of credit takers is made more efficiently by banks. According to Calomiris and Kahn (1991) depositors do not have to monitor banks as long as they may credibly threaten bankers with liquidation at any time. Bankers have incentives to act prudently to keep in business. They have to face maturity mismatch concerns as their assets (loans) usually have longer maturities then their liabilities (deposits) so whenever they anticipate delinquency upheavals they influence the supply of credit to ensure their good reputation. This is why the structure of the banking system is a concern for policymakers: the medium may distort the message[9].

There is an extensive literature on how interest rate shocks propagate to the real economy through the credit channel. Most of it shows how lenders influence the contraction process by

[9]We paraphrase Marshall McLuhan ("the medium is the message") as the message conveyed by movements in the monetary policy rate (selic) may be distorted by the banking system through the bank lending channel.

redirecting credit to more reliable firms ("flight to quality") or simply by reducing the supply of credit (credit rationing). We briefly review some of the more relevant results in credit literature to contextualize our research.

Stigliz and Weiss (1981) credit rationing model explains the adverse selection process in the credit market that happens when interest rates increase: as the more trustworthy customers leave for cheaper financing source only the credit takers less likely to repay remain. To avoid the deterioration of the borrower profile, banks ration credit to the most risky projects in order to preserve their profit margins.

The Kyiotaki and Moore (1997) credit model argues that as only part of production can be collateralized, the lending allocation is suboptimal: constraints imposed on creditors on their capacity to recuperate assets from borrowers make them lend less than socially desirable. The paper emphasizes the importance of institutions to protect lenders as a mean to increase economic surplus.

Bernanke, Gertler and Gilchrist (1996) propose the concept of Financial Accelerator that is at the heart of the broad credit channel by exposing the dynamics of a contractionary shock that spreads through corporate balance-sheets when collateral assets lose value. Credit constrained firms reduce investments and soon the product will be negatively affected in a process that will drag all the economy down. As lenders perceive big companies as more reliable to repay, more transparent and cheaper to monitor, with smaller information gathering/agency costs, they turn their resources to these borrowers and reduce credit to riskier, smaller firms, in a process the authors call 'flight to quality'.

Kashiap and Stein (2000) verify that the impact of monetary policy in terms of lending behavior is stronger in banks with less liquid balance sheets, the smaller banks that have less deposits to fund its loan operation. As noted by Cetorelli (2008) "the key Kashiap and Stein insight is that monetary policy influences lending activity by altering the sensitivity of lending to balance sheet health".

Alencar (2011) verify the existence of a complete pass-through from Monetary Policy Rate to the lending rates while observing some stickiness in time deposit rates (Certificate of Deposit) that could be explained by the lack of competition in the bank funding market. The pass-through effect is analyzed by customer category (corporate and retail) and time-lag. The

author reaches two major conclusions: while pass-through is faster to corporate loans, it is higher for retail (personal) loans in the long-run. The paper also observes higher loan rates and interest spreads in banks with large market shares, a phenomenon that could be explained by the market power hypothesis stated by Berger (1995). This is rather unexpected since bigger banks face lower funding costs and would imply important differences in the composition of bank spread according to bank size. Also relevant to our analysis is the fact that corporate loans are more sensitive to bank related variables (size and funding inefficiency being the most relevant factors) than retail rates that are more sensitive to the monetary policy rate (selic), its volatility and market structure (higher concentration leading to higher spreads). The author conjectures that this might be caused by higher competition in the corporate loan market. Finally the debt maturity of also affects the pass-through effect: the shorter the maturity the fastest is the transmission of movements in the MPR to loan rates. This is of special relevance since the majority of outstanding credit has short maturity. The author analyzed data from the Brazilian credit market and showed that the long run coefficients of bank loan interest rates are heavily linked to market structure (concentration), seconded by their own volatility, to default rate and finally to the MPR at a much lower degree. These results pave our choices for macroeconomic indicators as discussed in the next section.

The monetary policy rate is a key component of the cost of credit that it influences twice: directly as the opportunity cost of creditors and indirectly by affecting credit spread. Koyama et al. (2008) decompose the banking spread into six components: loan default costs, operational costs, reserve requirements, taxes, cross subsidies in credit lines and the cost of deposit insurance. This insight leads us to consider in our dataset the provision to bad debt as a proxy for precautionary behavior.

The first victim of the 2008 crisis may well have been the myth of the decoupling of business cycles between developed and emerging economies. According to Mori and Holland (2010), the transmission happened through three channels: reduction in commodities prices, decrease in exports of manufactured products and fall of the interest rates in the developed economies. Concerning the direct consequences to the Lehman Brothers demise in September 2008, Mesquita and Torós (2010) report that between August 2008 and January 2009 deposits in small banks flew to bigger institutions who experienced an increase in deposits by 20%

while small and medium sized banks lost deposits at rates of 11% and 23% respectively. The authors present the series of measures taken by the BCB to supply liquidity to the market in 2008/2009 with special attention to the smaller institutions. In this context, the reserve requirements were relaxed but bigger banks could only access these funds to purchase credit portfolios from the smaller banks. This measure was seen as an orderly way of supplying liquidity to smaller institutions as direct access to the BCB refinance lines is usually shrouded in stigma. The authors also observe that the situation was critical since the short maturity of funding could jeopardize banks already facing liquidity mismatchs. The solution was the creation of a new deposit securitization mechanism, DPGE[10] ,to allow smaller institutions access to funding through time deposits.

On the supply side of credit, Calani et al. (2010) document the importance of credit standards in the supply of credit. According to data obtained by surveying senior loan officers in Chile, the authors verify that the most relevant factors to explain commercial credit demand in Chile are: (1) the cost of credit, (2) the MPR (an important component of the cost of credit) and (3) the expansion of the economy. On the supply side, the authors show the overwhelming importance of nonperforming loans distantly followed by the cost of credit as the major determining factors.

Tabak et al. (2010) bring three relevant results as they empirically verified that "during periods of loosening/tightening monetary policy, banks increase/decrease their loans. Moreover, our results illustrate that large, well-capitalized and liquid banks absorb better the effects of monetary policy shocks. We also find that low interest rates lead to an increase in credit risk exposure, supporting the existence of a risk-taking channel". These results are important as they give some clues about the sources of vulnerability the Brazilian financial sector maybe exposed to. First, MPR is distorted and delayed by an important part of the banking system (small and medium banks) that usually represent the key funding source for small and medium companies. Besides, these results also suggest that some sort of financial vulnerability may be building up inside banks that are taking increasingly more risk.

Gambacorta and Marques-Ibanez (2011) verify that important changes happened to the

[10]DPGE (Depósito a Prazo com garantia Especial do FGC) committed depositors to at least 6 months with a R$ 20 million value cap.

monetary policy transmission mechanism after 2008. According to the authors, traditional bank-specific characteristics (size, liquidity and capitalization) have lost relevance to explain the bank lending channel while short-term funding and securitization became more important. They suggest these changes could be permanent and not a mere reflection of the thigh credit markets. The authors support the need for closer coordination between monetary policies and financial stability requirements.

Guo and Stepanyan (2011) study a panel dataset of emerging economies before and after the 2008 crisis and conclude that "foreign capital is a mixed blessing for credit growth in EMEs. Countries that relied more heavily on foreign borrowing to finance domestic credit, notably some European EMEs, in general experienced the largest swings of credit growth before and after the crisis, while countries that relied less on foreign borrowing, e.g. EMEs in Latin America and Asia, fared much better during the crisis. Given the volatility of capital flows to EMEs, a banking sector that is dependent on foreign capital for funding may prove vulnerable to external shocks and could also be prone to boom-bust cycles. Therefore, macro-prudential policies should be particularly vigilant to foreign-capital fueled credit booms, which could reverse course very quickly. (...) Building a robust domestic deposit base could be a key for sustained and stable credit growth. As is evident from our analysis, countries that experienced little or no deceleration of credit growth during the crisis were all supported by relatively robust/stable domestic deposit growth."

Jimenez et al. (2012a,b) observe that in times of crisis bank balance sheets affect the supply of credit while firms leverage determines its capacity to get new loans. The authors analyzed an extensive dataset of corporate loans to conclude that credit supply fluctuates more for less capitalized banks and for those with less assets. Curiously these factors are not significant in good times when the expanding GDP is the key driver for new loan grants. The precautionary measures to reinforce bank capital in good times seem to be best way to prevent an important retraction of loans in bad times.

3 The models

A number of studies of credit treat the identification of supply and demand determinants to explain the credit level. We take a different approach. From the banks perspective, we first explore the different bank funding channels that lead to the stock of liquid assets available for credit operations. We study the determinants of the four main channels of resources: cash deposits, time deposits, interbank and foreign lending. The second step is to relate these channels to the pool of liquid resources (netfunds) and a set of macroeconomic and control variables. In the last step we model the flow of loans from this pool of liquid resources in relation to key macroeconomic variables. By taking this approach we separate the two processes: fund gathering and credit concession.

We use a board definition of credit, encompassing both free and channeled (earmarked) credit. This is done to simplify the analysis as the scope of this paper is not concerned with the allocation of resources between the different credit channels. This methodological note is due here since in Brazil a significant share of credit is earmarked . The most relevant earmarked credit for our discussion probably is destined to the construction sector as it generates a significant demand for low-qualified workforce. Notably the popular housing program "Minha Casa Minha Vida" received the major part of resources available in the PAC stimulus package. Lundberg (2011) further elaborates on the different destinations of earmarked credit, that also contemplate resources to finance agricultural production and infra-structure long-term investments.

As the first contribution of this work is to unwind the funding channels for credit expansion, we propose a simple credit model, we then analyze each component to understand the basic relations between these components and macroeconomic variables. The basic model is derived from the accounting rule that equates assets (loans) to liabilities primarily in the form of debt:

$$Loans_{it} = Capital_{it} + Deposits_{it} + Interbank_{it} + Foreign_{it} + NPL_{it} + \epsilon_{it}$$

There are for sources of funding (fundsource): cash deposits, time deposits, interbank lending and foreign debt. A fifth source, savings deposit accounts ("cadernetas de poupança"),

was also studied but empirical tests did not result fruitful for our analysis and we will later suggest a possible explanation. We model each of these sources to test which factor(s) are determinant for the allocation of resources to be lent by the banks. All models control for bank characteristics (size, liquidity and capital) and the short-term interest rate (selic).

Model 1 relates minimum wage (minwage) and price stability (measured by the inflation index ipca) to cash - highly liquid - deposits. We expect that cash deposits maintain a positive relation with minimum wage and with price levels:

$$fundsource_{it} = SLC_{it} + selic_t + minwage_t + ipca_t + \epsilon_{it}$$

where SLC stands for size, liquidity and capital.

Model 2 relates economic activity indicators such as GDP, industrial production (indprod) and unemployment (unemp) to funding: we expect that a higher activity generates more funding, while a lower unemployment rate guarantees a higher volume of resources, salaries, deposited at the banks:

$$fundsource_{it} = SLC_{it} + selic_t + gdp_t + indprod_t + unemp_t + \epsilon_{it}$$

Model 3 takes the foreign funding perspective and relates rear exchange rate (rer), libor and fed funds rates. We expect to see a positive relation between the internalization of foreign funds and the domestic currency appreciation. We expect that this flow increases as risk-free rates abroad plunge: libor is tied to funds coming from Europe while Fed Funds rate relates to US originated funds:

$$fundsource_{it} = SLC_{it} + selic_t + rer_t + libor_t + fedfunds_t + \epsilon_{it}$$

Finally, model 4 puts into perspective the perception of risk presented by the financial institution measured by three different indicators. We expect a negative relation with the Non Performing Loans (NPL) indicator, a positive relation with the precautionary indicator for provisions to bad debt and a negative relation to leverage as measured by the outstanding loan stock in relation to assets. The level of capital-to-loans is also a key indicator of risk but

as capital is already controlled for there is no need to include another regressor that would present a strong collinearity with an already existing regressor:

$$fundsource_{it} = SLC_{it} + npl_{it} + provisions_{it} + leverage_{it} + selic_t + \epsilon_{it}$$

In this context leverage is the loanstock/assets ratio that indicates a propensity to lend (and take risks) of the financial institution.

A last remark is that funding is not perfectly related to the amount available since there are some monetary policy tools, such as reserve requirements and capital requirements, that affect each funding category differently according to central bank policies. To isolate the effect of these different rates, we also observe an aggregate measure of liquid assets that will be directly available to be lent. This indicator (netfunds) is modeled with the different sources of funding so we may have an idea of how relevant each funding source actually. The results are presented in table 7 and will be analyzed in the next section.

Model estimation is done using as much as possible bank level data to build a panel dataset. Models are estimated with a fixed effects framework with robust estimators. As an instrument for credit demand we consider industrial production, as did Tabak et al. (2010), and the external funding channel. We assume that the supply of credit was severely impacted by the liquidity restrictions imposed on foreign lenders.

Another contribution of this work is to perform intervention analysis with a set of events that are relevant to explain temporary and permanent shocks to the domestic credit market. The events we studied (table 4) are briefly explained here. Candidate Lula's campaign to Presidency in 2002 generated concerns about the future of economic policy. In the past, as a union leader, Lula argued in favor of Brazilian defaulting on its debts with IMF and an image of Lula being a rogue leader was formed in the financial market. The BCB had to raise interest rates on the third quarter of 2002 to reduce capital evasion from the country as the October election approached. The second event controlled in our data is President Lula first year in power. As President Lula chose a former private bank officer to head BCB and honored contracts from his predecessor, the market grew confident in him and the country lived some five years of permanent growth. FIDC was created as a source of new funding for

smaller banks in July 2003 and the new payroll backed credit legislation was passed by the end of Lulas first year in power. In the beginning of 2005, a new bankruptcy legislation was passed in Congress that would speed up of creditors assets. It is still unclear whether the piece of legislation reached its full potential as the Justice system is still plagued with the same old issues. In 2007, the Bear Stearns filing for bankruptcy is another relevant event that is controlled for. The investment grade status granted by three credit agencies (S&P, Fitch and Moodys) in 2008/2009 are treated as three different events. The final event is Lehman Brothers demise in September 2008.

Traditionally the banking sector is studied under three perspectives: by institution size, nationality and ownership. The size cleavage is justified by difference in access to funds. The big banks have an extensive number of branches where they can collect funds, either free (cash deposits) or remunerated (time deposits). They also have international outreach for funding either by debt or by equity (bank notes). The small and medium-sized banks either recur to borrowing from the bigger institutions or to sale of their credit portfolios to the big banks. We do not enforce this cleavage in our analysis since our focus is in the relation of the financial system as a whole with and macroeconomic variables.

In Brazil banks are not allowed to issue commercial papers (with the notable exception of their leasing affiliates). Their key funding sources are deposits: cash, time and savings. Debt is the second best source of funds and it exists in three forms: (a) big banks contract credit abroad, (b) big banks lend to smaller ones and (c) all banks negotiate in the interbank market. The interbank market is mainly used for short-period financing as the interest rate is high and closely follows the short-term interest rate defined by the Central Bank. One key measure is the reduction of this basic interest rate as, we will see, it affects cash deposits, the main source of funds for banks.

4 Data and Results

We use panel data on bank balance sheets publically available on the BCB website and classified under the COSIF accounting plan, the standard classification for Brazilian financial institutions. In the Appendix we present the data sources and COSIF accounts used to calculate the

regressors. We also detail the four dummies related to institutional breaks (investgrade, payroll) and time events (lehman, lula) that might affect credit supply and/or demand. Models are estimated with a fixed effects framework with robust estimators. All models were estimated with year dummies and constants (results omitted).

Table 1 and 2 presents the sources of data and the descriptive statistics of the regressors and is divided in two parts: the top part presents panel data available for each bank, while the lower part brings the time series data that was incorporated in the panel. For the 11 years in the sample, from 2000 to 2010, we observe data twice a year, in June and December, when banks consolidate balance sheets. The choice is conditioned by the availability of loan information that started in 2000. The end of the sample coincides with the end of Lula's presidency as we focus on getting a clear picture of the Lula Administration (2003-2010). President Dilma (2011-2014) later continued the economic policies started by President Lula (notably the steady reduction of short-term interest rates) and deepened credit policy by increasing positively the supply of credit by public banks[11].

To understand the equilibrium between supply and demand it would be good to have data on the quantity as well as about the price of credit. Quantity data is at hand in great detail (by financial institution) but unfortunately there is no available data on the particular interest rate each institution offered. The existing data is in aggregated format and we decided not to use it since the relation to the specific bank characteristics is lost.

We do not study the determinants of domestic raised equity but as this funding source composes the liquid funds in the banks, we take them into account as an aggregate when we analyze liquid assets (table 8). The accounting data on foreign funding encompasses all funds obtained in foreign currencies such as equities and bonds sold abroad. Table 6 shows that these funding sources can not be overlooked.

From table 2 we can rank the sources of funding by their size: foreign resources, time deposits, cash deposits and finally interbank funds. This ranking will be latter confirmed in table 8 when we analyze the determinants of liquid assets (netfunds) suggesting that foreign funding is indeed an important source of resources for the Brazilian financial system. This may vary from bank to bank (particularly when distinguishing between small and big banks)

[11]Barbi (2013) analyzes potential financial stability concerns related to this expansion.

but the key concept is that the system as a whole relies on external funding to supply credit domestically. The risk of foreign borrowing raised by Guo and Stepanyan (2011) was such a concern that the whole apparatus of Brazilian public banks was mobilized to smooth the impact of the 2008 Lehman financial shockwave (Barbi (2013). Needless to remember that all the exchange rate depreciation risk is bore by the banks, leaving them vulnerable to exchange rate volatility. We may suppose that one reason for the Brazilian central bank to manage a dirty float exchange rate regime is to prevent shocks to the financial system.

A final word about two financial inclusion indicators: the number of bank accounts opened per year (depbank) and the number of credit cards (ccard) activated per year. These data are available in yearly basis so we replicate the observation for the June and December records of each year.

Table 3 presents the determinants of cash deposits. Models 1 to 5 all have in common controls for the size, liquidity and capital of each bank, and the basic cost of opportunity for cash resources (selic). The higher the short-term interest rate (selic), the more expensive is maintaining extremely liquid assets, so a negative correlation is expected as in models 1 to 4. Another robust result is the relevance of bank total assets (size) and liquidity to explain cash positions: a positive relation suggests that bigger institutions receive proportionally more cash deposits than the others. This may be due to the intrinsic guarantee a valuable banking brand offers to depositors as suggested by Diamond and Rajan (2012), but also because bigger banks have a wider network of agencies were the deposits are made. The cost of maintaining a network of agencies is repaid by the collection of remunerated and non-remunerated deposits. The perceived bank risk does not seem relevant to depositors as the coefficient for NPL is not significant. In accordance with Calomiris and Kahn (1991), provision for bad dept are positively related to cash deposits suggesting the preference of depositors for prudent banks. A bank with more cash deposits is more liquid and may lend more, although this result is only marginally significant. A final result that may not be robust is the positive relation between cash deposits and the real exchange rate (rer) in model 3. The coefficient is rather large (0.7) when compared to the others so we tentatively infer that an inflow of resources that causes a real appreciation of the domestic currency reflects in the level of cash deposits. We also tested model 5 including a regressor that indicates the number of bank accounts opened that year

(depbank) as well as the number of credit cards (ccard) activated per year. Results were not significant and were omitted.

Table 4 presents the conditioning of time (remunerated) deposits. Banks with more assets and more liquid positions perform better in capturing these deposits. It must be noted that these deposits are not generally ensured by government or the FGC ("Fundo Garantidor de Crédito"). The interesting result is a robust negative relation with capital that can be explained by considering that smaller banks, with lower capital, pay a premium to sell their certificates of deposit in the market. As these small and medium sized banks do not have an extensive network of agencies and have little or no access to international financial markets, they are likely to have recourse to this source of funding. Also noteworthy is the lack of statistical relevance of the level of short-term interest rate (selic). Although all coefficients are negative, they are not statistically significant. If they were significant, we might explain that as investors are risk averse, when government bonds yield more (selic rises), time deposits fall. Another surprising results is that average investor in bank certificates may not be concerned with bank risks, as long as the institution has a solid asset position, this is why NPL and provisions are not relevant but size and liquidity are. As a bank lends more it needs more funds so the leverage coefficient is positive and significant. A final note is the positive relation of GDP in model 5: although expected it is not robust.

A conspicuously absent analysis is about the determinants of savings deposits ("cadernetas de poupança"). We tested different models including whether minimum wage could somehow explain these deposits. It so happens that it does not explain savings, suggesting that the average saver is not remunerated in terms of this wage indicator. We may expect that recipients of low wages do consume all of their income and the savings mechanism is used by higher income depositors.

Table 5 presents the conditioning of interbank lending. The first notable result is the positive relation between short-term interest rates and the dependent variable. The pecking order determines that funding in the interbank market is the least desirable as the rates in this market are usually above the others. It is an alternative for banks to finance their short-term illiquid positions before resorting to the central bank liquidity assistance channel that bears a high reputational cost and is shrouded in stigma , as noted by Mesquita and Torós (2010). The

higher the short-term rate, the less able are the banks to finance themselves with time deposits as discussed above, so banks are more likely to access the interbank market in scenarios of high short-term interest rates. Some authors also suggest that the credit takers in this market are generally middle or small-size banks, while the lenders are the big national institutions. The positive leverage coefficient in models 4 and 5 suggest that banks with higher leverage (here defined as the ratio of loans to assets) tend to access this source of funds. Who might be the credit takers? As the industrial production coefficient is significant and positively related to interbank credit, as indicated in models 2 and 5, we may infer that banks participate in this market to get resources to lend to corporations . The industrial production index indicates the level of activity in the industrial sector, proxying corporate credit needs. As the financing horizon is basically on the short term (after all there are other much cheaper sources of funds of one can spare some time to get them) the resources obtained on this market will probably feed some short-term corporate credit lines (such as hot money) to avoid maturity mismatches. The fact that the coefficient for the real exchange rate is positive in models 3 and 5 suggest some relation with international trade activities. As the coefficient for GDP in model 2 is significant but not robust as occurs with the coefficients of libor m model 3 and ipca in model 1, we will not interpret these results further.

Table 6 presents some statistics of the composition of external funding considering all forms of funding: bond, equity and loan syndication. The overall amounts went from US$ 16.7 billion in 2004 up to U$ 73.7 billion in 2007. Bonds are the preferred instruments, representing from 13% in 2007 up to 58% in 2011 of the total inflow of resources. This distribution elicits the investors preference for security.

Table 7 reports the determinants of foreign funding. We might expect that either the real exchange rate or some international interest rate, either libor or fed funds, would be statistically significant. The real exchange rate is marginally significant in model 3 with a negative coefficient indicating that an appreciation of the real reduces foreign financing but this result is not confirmed in model 5. We are unable to conclude that banks go abroad to take advantage of the carry trade opportunities created by the interest rate hiatus (selic is historically maintained well above fed funds or libor rate). The coefficient for industrial production is negative in models 2 and 5 suggesting some form of counter-cyclicality of the

credit supply but these results are only marginally significant. Some might argue that we should control for some form of bank credit rating. We believe that the risk-related regressors included in the models (NPL, provisions and leverage) convey the necessary information to foreign lenders besides the banks balance-sheets as indicated by the positive coefficients for size, liquidity and capital in all five models. The interesting fact to note is the signs for NPL and provisions: a negative coefficient for provisions and positive coefficient for NPL suggesting that banks increase risky-taking the more they rely on foreign funds. The sign for leverage is positive as expected (more leverage requires more funds). When we estimate a first difference version of this model (omitted results) the only significant coefficients are related to size and leverage, both with the same signs of the presented models.

Banks have basically two constraints to operate in the credit market: the availability of liquid assets ("netfunds") and the obligation to comply with capital requirements, therefore the only real endogenous limitation to credit operation is the existence of funds. In table 8 all models suggest the relevance of the three dimensions of bank characteristics: size, liquidity and capital. Capital coefficients are always bigger suggesting a prevalence of this dimension. This is somewhat surprising since liquidity was expected to be more relevant for credit decisions, this may be because banks are not liquidity but capital constrained. A second set of results gives the relative weights of each source of funds. In all models all the sources are statistically relevant, the coefficients rank is: foreign funding, time deposits, cash deposits and interbank loans. Recalling results from table 2, the mean value for these four regressors follow the same order. There are two subtle differences between the coefficients in these models and the averages presented in table 2. In this table the averages are less significant in the presence of strong heterogeneity among individual banks (what is clear if one considers the dispersion of size and capital within the sample). Another factor is the different reserve requirement rates imposed by the monetary authority that might distort the composition of the pool of funds (but do not). Finally the payroll intervention variable is significant in most models (1, 2 and 3), while the investment grade dummy is significant for all models. Both have positive signs as expected. Interestingly neither lula or lehman dummies were significant suggesting that banks target a level of liquid funds and will adjust their composition according to the context. As we did for cash deposits, we also tested the inclusion of the financial inclusion regressors,

depbank and ccard. Results were again not significant and were omitted to save space.

Finally tables 9 and 10 present the determinants of loans, in levels and first differences. The results are basically the same. The amount of assets is positively related to the capacity to supply credit. Liquidity is reduced by the concession of loans in models 1 and 4. Capital is positively related to loans in models 2 and 3, as expected: the level of capital is a binding constraint to lending. Surprisingly the interest rate is not significant in any model. This has a sad interpretation as suggested by Figure 4: the average spread rate for non-earmarked funds is so much higher than the short-term rate (MPR) that the final price of credit actually is more dependent on the level of default (NPL) faced by financial institutions. An increase in the MPR should be very large to generate the desired effects in reducing the level of economic activity. The two hikes in the MPR in 2005 and 2008 were sizeable, 5% and 3% respectively, and effective in reducing actual inflation (ipca) as can be seen in figure 1.

The negative relation between credit supply and NPL is well documented in the literature, see Alencar (2011) and Alfaro et al. (2004). This results concurs with Calomiris and Powell (2000) that studied the banking system in Argentina, they explain that "market discipline encourages banks to respond to increases in default risk by limiting asset risk or lowering leverage". The positive coefficient for provisions only suggests a precautionary attitude as the volume of NPL is expected to increase in absolute terms. If screening is well conducted, and standards for credit concession are not softened as reported by Calani et al. (2010), the proportion of NPL to loans should keep stable as indicates table 11. The positive relation with netfunds is expected, since these constitute the resource pool to originate the loans. The coefficient of industrial production is positive, as more production begets demand for corporate credit, while the negative coefficient of unemployment suggests that employment level affects the demand for loans by individuals for the reasons already discussed.

The separation in netfunds (table 8) and loanstock (tables 9 and 10) is not only didactic but also performs the important task of separating the process of fund acquisition to the decision of credit concession. The intervention variables were not significant in the loanstock regressions but were relevant to explain the origin of funds.

It might be argued that there may be simultaneity between loanstock and netfunds: liquid funds come from deposits because once a loan is received it is deposited in the bank that

issued the credit. In this case the coefficient for netfunds would be biased and not consistent. To test this hypothesis, we propose to instrument netfunds in the regression using as the variables liquid, capital and unemployment. In table 12 model 1 indicates that these variables are not significant to explain loanstock but are significant to explain netfunds (model 2). We instrument (Schaffer (2005)) netfunds in the loanstock regression in model 3. With this setup, it is difficult to understand how netfunds is not related to loanstock as indicated in model 3. We suspect of sample heterogeneity so we split the sample among public and private institutions. Model 4 indicates that loanstock is correlated to size, netfunds, npl and provisions for private banks, while model 5 shows that loanstock is correlated to netfunds, gdp, npl e provisions in public banks. The fact that coefficients for netfunds have different signs in models 4 and 5 suggests that the effects were compensating each other and rendering the coefficient too small to be significant in model 3. All the other results from model 3 are confirmed in models 4 and 5 so they are considered robust.

Model 5 also suggests that public bank credit is positively related to gdp. Some might expect a negative coefficient to indicate that public credit is counter-cyclical but this would be a wrong interpretation, the correct test would require a crisis dummy to test whether public credit is pro or counter-cyclical in bad times. The counter-cyclical result is confirmed in Barbi (2013).

An interesting result is the negative relation of netfunds to loanstock in the public sector, while being positive in the private sector as expected. As the source of financing is not a constraint for public banks, they are not limited by their liquid funds and the more aggressively they participate in the market, the more depleted are their stock of liquid funds. The coefficient for the private banks (0.168) is well below the one suggested in models 5 of table 9 (0.639) and table 10 (0.413) suggesting that the previous estimations were indeed biased but consistent.

The key result is that irrespective of the ownership of the bank, NPL and provisions are always significant to explain the concession of loans. Public banks look more cautious than private banks (higher provisions coefficients: 0.750 against 0.466 for private banks). As such, probably the best any government can do to ensure the long-term supply of credit is to guarantee that financial risks are under control and the credit system is sane.

5 Conclusions

As the first important conclusion to our investigation we verify the importance in the reduction of the monetary policy rate (selic) to assure the supply of credit. Figure 1 shows that this processes started in 2000 and continued through the years only to be temporarily interrupted to deter inflation spikes. The overall picture is that there exists a firm long-term commitment to both inflation control and economic growth.

We also verified the statistical relevance of both the payroll guaranteed legislation and investment-grade status were relevant microeconomic shocks to explain the credit expansion. Payroll guaranteed legislation is a good example of the microeconomic reform agenda that should be carried away further to improve public governance.

Finally the importance of sanity indicators of credit conditions (NPL, provisions and leverage) cannot be overstated. The IMF 2012 Financial System Stability Assessment for Brazil states that "Despite considerable progress in recent years, capital market development remains constrained by the low duration and high interest rate environment. Further progress will take time and be contingent upon maintaining a stable macro-financial environment, but could be spurred by financial sector reforms, including providing incentives for longer duration and infrastructure investments, as well as refocusing BNDES to support private long-term finance." The case for the reduction of the public banking sector is further made in Barbi (2013) where the author also discusses the possible nefarious implications for financial stability of the expanding public credit.

In his letter of intentions in 2002, candidate Lula proposed other legislation reforms (notably in labor regulations, social security rules and tax legislation) there were not implemented in his 8 years in power. Some believe that he is saving them for the a future campaign, in which poverty reduction might loose first priority status towards the construction of a more efficient State, a State that gives back more from the huge chunk of taxes it takes away.

Appendix.COSIF accounts

Loans stock is the sum of accounts 14300002, 16100004, 16200007, 16300000, 16400003, 16500006, 16600009, 16700002, 16800005, 16910005, 16995006, 17100003, 17300009, 17500005, 17700001, 17800004, 17910004, 17920001, 17995005, 18100002, 18275009, 18278006, 18820007, 18600007, 18835009, 18875007, 18878004, 18880009, 18910003, 18995004, 23200007, 24180009, 24199801, minus the accounts 14399006, 18880205, 49206009, 49207008, 49214008, 49217005, 49236000, 49248005, 49285006, 49908008, 49909007.

Non Performing Loans (NPL) is the sum of accounts 31600008, 31700001, 31800004, 31900007. These are the credit operations more than 90 days due and classified under levels E, F, G and H.

Loan Loss Provisions (provisions) is the sum of accounts 16900008, 17900007 e 18900006.

Bank Size is Total Assets as reported in account 39999993.

Bank Capital is the account 61100004.

Liquid Assets is the sum of accounts 11000006, 12100008 minus the accounts (12130009 and 42340003), and minus the smallest value of accounts (12120002 and 42220006), 12200001, 12300004, 12500000, 12600003, 12900002, 13100007, 13200000, 13400006, 13500009, 13600002, 13700005, 13800008, 18570003, 18575008, 18580000, 18590007.

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Table 1: Data Sources

Regressor	Description	Source
capital	bank capital	COSIF
cash	cash holdings	COSIF
depositcash	cash deposits	COSIF
deposittime	time deposits	COSIF
extfund	external (foreign) funds	COSIF
interbank	funds exhanged in the Interbank market	COSIF
liquid	liquid assets	COSIF
loanstock	loan protfolio	COSIF
netfunds	net funding	COSIF
npl	non performant loans (loans due past 90 days)	COSIF
provisions	provisions for bad credit	COSIF
size	total assets	COSIF
fedfunds	Official interest rate United States	BCB 18152
gdp	GDP monthly - current prices (R$ mil.)	BCB 4380
ccard	Number of new credit cards activated	DSPV
deflator	Implicit deflator	BCB 1211
depbank	Bank deposit accounts (in thousands)	DSPV
ipca	Broad National CPI (IPCA) Monthly % var.	BCB 433
libor	Interest on deposits in LIBOR US$ (3 months)	BCB 3840
indprod	Industrial Production Index (2002=100)	BCB 13609
minwage	Minimum wage (annual)	BCB 1619
reer	Real eff.exch.rate index (IPCA) Jun/94=101	BCB 11752
rer	Real exch.rate index (IPCA) Jun/94=100	BCB 11753
selic	Interest rate (annual) - % p.y.	BCB 4189
unemp	Open unemployment rate (metropolitan region)	BCB10777

DSPV is Diagnóstico do Sistema de Pagamentos de Varejo do Brasil. Adendo estatístico 2010. BCB

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std.Dev	Min	Max
Bank level data					
capital	4693	18.4377	1.7082	14.5075	24.8637
cash	3174	11.4543	4.0534	1.0280	22.8866
depositcash	3099	15.5580	3.4155	0.0262	24.7266
deposittime	3404	18.5297	2.5784	4.0985	26.2636
foreign	2255	18.5659	2.5178	1.9676	24.5004
interbank	3086	14.9389	3.8726	1.2907	26.1188
leverage*	4024	86.5301	7.4169	22.7285	96.6262
liquid	4692	19.0602	2.4669	8.1497	26.7195
loanstock	4024	19.1499	2.5527	3.9722	26.6950
netfunds	4680	19.9056	2.1038	10.9475	27.0999
npl	4024	9.1211	16.5084	0.0000	100.0000
provisions	3995	15.9433	2.7971	3.5056	23.6515
size	4693	21.8553	2.4946	14.9501	29.5379
Time series (common to all banks)					
ccard	11	11.1428	0.6074	10.2888	12.0750
depbank	11	11.4680	0.2507	11.0612	11.8584
fedfunds	22	2.3739	2.1705	0.0000	6.5000
gdp	22	11.6239	0.1252	11.4246	11.8764
indprod	22	4.6808	0.1191	4.4554	4.9049
ipca	22	0.4791	0.4579	-0.2100	2.1000
libor	22	2.6187	2.1689	0.0000	6.7900
minwage	22	5.7342	0.4275	5.0173	6.4329
rer	22	1.0457	0.2385	0.6529	1.5045
selic	22	15.0984	4.4268	8.3900	26.0900
unemp	22	4.6952	0.0180	4.6568	4.7274

*The leverage regressor is calculated as loanstock/size and represents the degree of exposure of the institution.

Table 3: Sources of Funding: Cash Deposits

depositcash	M1	M2	M3	M4	M5
size	0.452***	0.449***	0.453***	0.429***	0.423***
	(0.128)	(0.128)	(0.128)	(0.143)	(0.143)
liquid	0.174*	0.174*	0.173*	0.203**	0.203**
	(0.101)	(0.102)	(0.101)	(0.0932)	(0.0940)
capital	-0.115	-0.121	-0.114	-0.187	-0.196
	(0.126)	(0.127)	(0.126)	(0.118)	(0.119)
selic	-0.0289***	-0.0200*	-0.0271***	-0.0246***	-0.0136
	(0.00930)	(0.0119)	(0.0101)	(0.00936)	(0.0144)
gdp		0.728			0.336
		(0.664)			(1.179)
indprod		-0.0140			0.221
		(0.508)			(0.794)
unemp		-3.170			-5.405
		(3.649)			(5.198)
minwage	0.0681				-0.602
	(0.212)				(0.476)
ipca	0.0633				0.00493
	(0.0522)				(0.0937)
rer			0.613*		0.247
			(0.330)		(0.582)
libor			0.0582		-0.0224
			(0.123)		(0.135)
fedfunds			-0.108		-0.0216
			(0.116)		(0.121)
npl				-0.00299	-0.00298
				(0.00618)	(0.00614)
provisions				0.126**	0.128**
				(0.0498)	(0.0496)
leverage				0.0473*	0.0469*
				(0.0248)	(0.0248)
Observations	2,608	2,608	2,608	2,608	2,608
R-squared	0.134	0.135	0.135	0.182	0.184
Number of banks	180	180	180	180	180

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4: Sources of Funding: Time Deposits

deposittime	M1	M2	M3	M4	M5
size	0.507***	0.506***	0.505***	0.544***	0.542***
	(0.103)	(0.104)	(0.103)	(0.107)	(0.108)
liquid	0.302***	0.302***	0.303***	0.317***	0.318***
	(0.0795)	(0.0794)	(0.0792)	(0.0780)	(0.0781)
capital	-0.236**	-0.232**	-0.233**	-0.318***	-0.315***
	(0.105)	(0.106)	(0.106)	(0.116)	(0.117)
selic	-0.00912	-0.00370	-0.00310	-0.00887	0.00327
	(0.00588)	(0.00645)	(0.00606)	(0.00623)	(0.00889)
gdp		0.731			1.857*
		(0.534)			(0.963)
indprod		0.487*			0.485
		(0.250)			(0.534)
unemp		1.853			1.860
		(2.343)			(3.241)
minwage	0.390**				0.315
	(0.151)				(0.329)
ipca	-0.0296				-0.106
	(0.0287)				(0.0824)
rer			0.337*		-0.400
			(0.201)		(0.432)
libor			-0.0110		0.0596
			(0.0733)		(0.0859)
fedfunds			0.0543		0.00535
			(0.0633)		(0.0702)
npl				-0.00198	-0.00202
				(0.00513)	(0.00516)
provisions				0.0506	0.0526
				(0.0347)	(0.0349)
leverage				0.0577**	0.0571**
				(0.0228)	(0.0229)
Observations	2,876	2,876	2,876	2,876	2,876
R-squared	0.273	0.274	0.274	0.313	0.315
Number of bank	204	204	204	204	204

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 5: Sources of Funding: Interbank Funding

interbank	M1	M2	M3	M4	M5
size	0.574***	0.578***	0.571***	0.543***	0.550***
	(0.143)	(0.144)	(0.143)	(0.149)	(0.150)
liquid	0.0984	0.0951	0.0966	0.130	0.128
	(0.0943)	(0.0950)	(0.0944)	(0.0934)	(0.0946)
capital	0.0137	0.0367	0.0183	-0.0835	-0.0589
	(0.145)	(0.145)	(0.145)	(0.151)	(0.150)
selic	0.0304**	0.0376**	0.0496***	0.0343***	0.0421**
	(0.0133)	(0.0157)	(0.0143)	(0.0132)	(0.0175)
gdp		-3.246***			-2.981*
		(1.006)			(1.724)
indprod		2.938***			2.817***
		(0.715)			(1.036)
unemp		-5.725			-3.072
		(5.961)			(8.495)
ipca	-0.199**				0.0282
	(0.0896)				(0.132)
rer			0.636		0.750
			(0.477)		(0.772)
libor			0.374**		0.309
			(0.173)		(0.246)
fedfunds			-0.121		-0.295
			(0.156)		(0.207)
npl				-0.00388	-0.00394
				(0.00500)	(0.00506)
provisions				0.0795	0.0801
				(0.0662)	(0.0669)
leverage				0.0652***	0.0643***
				(0.0217)	(0.0217)
Observations	2,469	2,469	2,469	2,469	2,469
R-squared	0.101	0.111	0.104	0.130	0.143
Number of bank	196	196	196	196	196

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6: Brazilian Banks External Financing

	2004	2005	2006	2007	2008	2009	2010	2011
Bond Issuance	9,716	17,769	12,304	9,917	6,485	9,797	31,605	21,996
	58.29%	64.65%	39.41%	13.45%	23.11%	24.73%	47.48%	58.16%
Equity Issuance	1,831	3,783	11,177	39,243	10,435	12,963	24,633	8,834
	10.98%	13.76%	35.80%	53.22%	37.19%	32.72%	37.01%	23.36%
Loan Syndication	5,123	5,934	7,738	24,578	11,140	16,857	10,327	6,991
	30.73%	21.59%	24.79%	33.33%	39.70%	42.55%	15.51%	18.48%
Total	16,670	27,486	31,219	73,737	28,060	39,617	66,565	37,820
	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

IMF Global Financial Stability Report 2009, 2012
(In millions of U.S. dollars)

Table 7: Sources of Funding: Foreign Funding

foreign	M1	M2	M3	M4	M5
size	0.470***	0.469***	0.470***	0.734***	0.739***
	(0.102)	(0.102)	(0.102)	(0.103)	(0.104)
liquid	0.201***	0.198***	0.197***	0.173***	0.169***
	(0.0683)	(0.0688)	(0.0687)	(0.0625)	(0.0632)
capital	0.500***	0.494***	0.496***	0.300**	0.299**
	(0.145)	(0.147)	(0.146)	(0.138)	(0.140)
selic	0.00677	-0.00599	0.00245	0.0116	-0.00959
	(0.0103)	(0.0119)	(0.0105)	(0.0101)	(0.0162)
gdp		-0.914			-0.734
		(0.975)			(1.647)
indprod		-0.917**			-1.945*
		(0.421)			(0.986)
unemp		0.447			6.856
		(4.152)			(5.216)
ipca	-0.0504				0.0698
	(0.0429)				(0.135)
rer			-0.480		0.0940
			(0.354)		(0.692)
libor			0.148		0.0105
			(0.138)		(0.124)
fedfunds			-0.122		0.0772
			(0.111)		(0.0992)
npl				0.0116**	0.0117**
				(0.00500)	(0.00506)
provisions				-0.0664**	-0.0704**
				(0.0300)	(0.0299)
leverage				0.138***	0.139***
				(0.0246)	(0.0247)
Observations	1,890	1,890	1,890	1,890	1,890
R-squared	0.169	0.171	0.170	0.228	0.231
Number of banks	150	150	150	150	150

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 8: Banks Net Funding

netfunds	M1	M2	M3	M4
size	0.195***	0.177***	0.172***	0.147***
	(0.0464)	(0.0432)	(0.0428)	(0.0407)
liquid	0.234***	0.218***	0.210***	0.193***
	(0.0468)	(0.0510)	(0.0492)	(0.0453)
capital	0.334***	0.336***	0.331***	0.299***
	(0.0446)	(0.0444)	(0.0450)	(0.0434)
selic	-0.00234	-0.00117	-0.00162	-0.00130
	(0.00420)	(0.00403)	(0.00387)	(0.00383)
depositcash	0.0488***	0.0452***	0.0401***	0.0376***
	(0.0140)	(0.0132)	(0.0129)	(0.0118)
deposittime		0.0512	0.0492	0.0525*
		(0.0336)	(0.0336)	(0.0315)
interbank			0.0206**	0.0209**
			(0.00956)	(0.00899)
foreign				0.0606***
				(0.0141)
lehman	0.0138	0.0108	0.0263	0.00415
	(0.0285)	(0.0281)	(0.0308)	(0.0302)
lula	0.0390	0.0285	0.0203	0.0114
	(0.0482)	(0.0454)	(0.0455)	(0.0436)
payroll	0.0256	0.0261	0.0323	0.0544
	(0.0529)	(0.0521)	(0.0530)	(0.0498)
investgrade	0.239***	0.219***	0.217***	0.231***
	(0.0630)	(0.0665)	(0.0655)	(0.0650)
Observations	1,394	1,394	1,394	1,394
R-squared	0.749	0.757	0.760	0.779
Number of bank	126	126	126	126

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 9: Loans (Levels)

loanstock	M1	M2	M3	M4	M5
size	0.373***	0.798***	0.798***	0.367***	0.166**
	(0.115)	(0.102)	(0.102)	(0.0790)	(0.0715)
liquid	-0.247***	-0.0814*	-0.0815*	-0.0120	-0.114***
	(0.0434)	(0.0488)	(0.0488)	(0.0300)	(0.0323)
capital	-0.144	0.183**	0.184**	0.0690	-0.107*
	(0.0907)	(0.0854)	(0.0857)	(0.0631)	(0.0611)
selic	-0.000696	-0.00119	0.00126	-0.00209	0.00521
	(0.00580)	(0.00590)	(0.00628)	(0.00309)	(0.00394)
gdp			-0.160		0.237
			(0.240)		(0.264)
indprod			0.298		0.479***
			(0.181)		(0.181)
unemp			-1.983		-1.132
			(1.404)		(1.513)
netfunds	1.108***				0.639***
	(0.149)				(0.0820)
rer		0.146			-0.0241
		(0.125)			(0.142)
npl				-0.0322***	-0.0291***
				(0.00337)	(0.00336)
provisions				0.495***	0.444***
				(0.0624)	(0.0604)
Observations	3,488	3,488	3,488	3,488	3,488
R-squared	0.488	0.366	0.366	0.687	0.724
Number of bank	232	232	232	232	232

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 10: Loans (First Differences)

D.loanstock	M1	M2	M3	M4	M5
D.size	0.236***	0.354***	0.349***	0.239***	0.152***
	(0.0655)	(0.0693)	(0.0702)	(0.0418)	(0.0387)
D.liquid	-0.0831***	-0.0287**	-0.0293**	-0.0102	-0.0521***
	(0.0204)	(0.0144)	(0.0143)	(0.0117)	(0.0163)
D.capital	-0.0337	0.0949	0.0777	0.0665	-0.0454
	(0.0768)	(0.0662)	(0.0667)	(0.0491)	(0.0560)
D.selic	-0.00393	-0.00553	-7.44e-05	-0.00353	0.00875**
	(0.00363)	(0.00353)	(0.00389)	(0.00273)	(0.00355)
D.gdp			0.512**		0.719***
			(0.209)		(0.201)
D.indprod			0.139		0.432***
			(0.110)		(0.128)
D.unemp			-1.466		-1.582*
			(1.257)		(0.949)
D.netfunds	0.546***				0.413***
	(0.0769)				(0.0586)
D.rer		0.00356			-0.277**
		(0.0865)			(0.109)
D.npl				-0.0187***	-0.0181***
				(0.00275)	(0.00281)
D.provisions				0.283***	0.270***
				(0.0429)	(0.0424)
Observations	3,251	3,251	3,251	3,231	3,231
R-squared	0.177	0.102	0.108	0.371	0.426
Number of bank	222	222	222	221	221

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 11: Brazilian Banking System Health Indicators

	2003	2004	2005	2006	2007	2008	2009
Bank Regulatory Capital to RWA	18.8	18.6	17.9	18.9	18.7	18.4	18.5
Bank Capital to Assets	9.6	10.1	9.8	9.9	9.8	9.1	9.2
Bank Nonperforming Loans to Total Loans	4.1	2.9	3.5	3.5	3	3.1	4.3
Bank Provisions to NPL (*)	171.8	214.5	179.8	179.9	181.9	189.8	157.3
Bank Return on Assets	2	2.2	2.9	2.7	2.9	1.5	1.1
Bank Return on Equity	21.1	22.1	29.5	27.3	28.9	15.6	11.6

IMF Global Financial Stability Report 2009
(*) In millions of U.S. dollars
RWA: Risk-Weighted Assets

Table 12: Two stage regressions for Loans

	M1 FE all banks	M2 FE all banks	M3 IV all banks	M4 IV private	M5 IV public
Dependent variable	loanstock	netfunds	loanstock	loanstock	loanstock
size	**0.366*** **		**0.334*** **	**0.323*** **	-0.00758
	(0.0793)		(0.0313)	(0.0328)	(0.0573)
liquid	-0.0116	**0.319*** **			
	(0.0300)	(0.0345)			
capital	0.0685	**0.573*** **			
	(0.0633)	(0.0561)			
selic	0.00583	-0.00352	0.00348	0.00149	0.0148
	(0.00396)	(0.00217)	(0.00627)	(0.00656)	(0.0135)
unemp	-2.537	**-1.369***			
	(1.565)	(0.701)			
rer	-0.0344	0.0933	-0.0514	-0.00680	-0.585
	(0.150)	(0.0676)	(0.253)	(0.264)	(0.543)
gdp	0.143	0.275	0.512	0.425	**2.105** **
	(0.276)	(0.254)	(0.361)	(0.375)	(0.835)
indprod	**0.536*** **		0.387	0.301	0.302
	(0.190)		(0.262)	(0.274)	(0.584)
npl	**-0.0322*** **		**-0.0318*** **	**-0.0322*** **	**-0.0255*** **
	(0.00337)		(0.00100)	(0.00105)	(0.00255)
provisions	**0.496*** **		**0.491*** **	**0.466*** **	**0.750*** **
	(0.0624)		(0.00996)	(0.0103)	(0.0277)
netfunds			0.0861	**0.168*** **	**-0.713*** **
			(0.0565)	(0.0579)	(0.220)
Observations	3,488	4,139	3,488	3,193	295
Number of banks	232	260	232	215	17
Sargan statistic				17.649	12.98

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
FE Fixed Effets and IV Instrument Variable panel regressions (Stata XTIVREG2)

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Public Credit, Monetary Policy and Financial Stability

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Abstract

The supply of public credit in Brazil has successfully served to relaunch the economy after the Lehman-Brothers demise. It was later transformed into a driver for economic growth as well as a regulation device to force private banks to reduce interest rates. We argue that the use of public funds to finance economic growth has three important drawbacks: it generates inflation, induces higher loan rates and may induce financial instability. An additional effect is the prevention of market credit solutions. This study contributes to the understanding of the costs and benefits of credit as a fiscal policy tool.

Keywords: state-owned banks, public credit, monetary policy, financial stability

JEL: G21, H81, E44

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1 Introduction

The roots of the 2007/2009 financial crisis lie in structural economic fractures that existed long before the crisis erupted, namely: the unbalanced growth in the global economy, the rising income inequality in the United States and the populist policies that meant to fix it, the weak safety net, and the reckless credit growth coupled with the increasing risk taking behavior in the financial system (Rajan (2005, 2010)).

Unconventional policies came recently under scrutiny as developed countries face the challenge of reactivating their economies after the crisis. Reinhart and Rogoff (2008) believe that this time will not be different, eight centuries of financial crises experience show that recovery is slow and painful. As an alternative to conventional monetary policy that proved moot in this context lies the Brazilian experience with a strong public banking system that sustained activity when private banks left the credit market.

The public credit alternative gained traction by recent ownership movements in the banking sector. As pointed out by Bertay et al. (2012) "[D]uring the last decades, the share of state ownership in developing countries has tended to decline, from 34.6% in 1999 to 19.4% in 2010. This decrease was especially pronounced during the years from 2007 to 2010. Average state ownership in high income countries, instead, has increased somewhat from 7.9% in 1999 to 9.9% in 2010, with most of the increase occurring after 2007. Overall the state ownership share has been rather stable around 19%, although it declined from 17.5% in 2009 to 13.5% in 2010."

The temptation to reach for public financing rises in crisis periods affecting thinkers across the ideological spectrum. Zakaria (2013) proposes the creation of a public bank to finance investments in infrastructure: "[S]pending on infrastructure is hardly a panacea, however, because without careful planning and oversight, it can be inefficient and ineffective. Congress allocates money to infrastructure projects based on politics, not need or bang for the buck. The elegant solution to the problem would be to have a national infrastructure bank that is funded by a combination of government money and private capital. Such a bank would minimize waste and redundancy by having projects chosen by technocrats on merit rather than by politicians for pork."

The Federal Reserve Bank has so far tried to restart the economy with quantitative easing initiatives with unclear results for the present and the future. An extensive literature[1] presents the risks of interest rates too low for too long. In this context unconventional policies come into debate. The Brazilian response to the economic downturn involved injecting public, subsidized, credit to activate specific sectors of the economy to generate rippling effects to other sectors. This paper argues that if public credit may be a viable alternative in crisis times, in the long run its effectiveness can be questioned as it generates inflation, increases interest rates and fosters financial instability[2].

The working concept of financial stability adopted here follows Houben et al. (2012) as financial stability refers to the ability of the financial system to help the economic system allocate resources, manage risks and absorb shocks. For Silva et al. (2012) "a financial system is stable when it continues performing its functions e.g., maturity transformation, allocation of savings, etc. across a time dimension (e.g., growing in a sustainable way across the financial cycle) without building-up systemic risk measured across its cross-section dimension." The authors also define systemic risk as "the probability of disruption of financial services, when the system is submitted to shocks, related to vulnerabilities such as inadequate leverage and levels of liquidity, and highly correlated co-movements of asset quality in the balance sheet of financial institutions".

We briefly review some reasons for the supply of public credit. One has to keep in mind that the risk-free interest rate in Brazil is high and this would potentially exacerbate a market failure that we shall examine.

1. Public credit may serve as a counter-cyclical tool to compensate for slumps in private credit supply (Mesquita and Torós (2010)). By using a public banking system, it is easier to assure that public funds reach the real economy and are not be hoarded by private banks. The opportunities for this type of intervention in the credit market are temporary and tend to be more the exception than the rule.

[1] See De Nicolò et al. (2010) and Maddaloni and Peydró (2010)

[2] One might question whether the concept of *fragility* as in Bernanke and Gertler (1990) would not be more appropriate than *stability* in this context. We believe that financial fragility characterizes the borrowers situation, in which they have low wealth relative to their investment, while financial stability takes the lenders side and considers the banks vulnerability to shocks in their loan portfolios returns.

2. The provision of public credit to force the private sector to lower loan rates by competing for market share. This makes sense when an oligopolistic market structure prevents competition from lowering rates to the efficient level (Besley (1992)).

3. Public resources may finance key economic sectors within the context of an industrial policy, next to other instruments, such as fiscal stimulus and the creation of special processing zones to facilitate international trade. This credit is focused to specific sectors, like oil & gas, bioengineering and information technology, sectors that the government believes to be strategic.

4. The supply of long-term public credit addresses a void left by private banks (Torres Filho (2007)). The public provision of credit would ideally be a temporary substitute for private credit during the development of long-term sources. There have been some financial innovations to stimulate the private sourcing of these funds but the lack of a clear signal indicating the future reduction of public credit does not help in attracting investors that might fear competing with government funded institutions.

5. Finally, the supply of micro-credit to highly risky borrowers with no collateral. Micro-credit typically targets low-income borrowers that operate in the informal economy. The stimulus allows for small investments that hopefully increase income to the point of bringing the entrepreneur to the formal economy where she gains access to market funding sources.

In all cases, the temporary nature of public credit supply cannot be overstated. The evolution of the financial deepening process in an emerging economy would therefore see an increase in the rate of the population with access to the banking system as well as a reduction in the public supply of credit, notably where it could be more efficiently provided by private banks.

It does not seem realistic to justify the increase in public credit by questioning the institutional setup of the Brazilian banking system. On the contrary, the domestic financial system has been known by its prudence and management capacity. Besides that, authors praise the financial system for not having succumbed to dollarization. Goldfajn et al. (2003) believe that the high development of financial and institutional frameworks explain why there was no

currency substitution in Brazil during the high-inflation period of 1980s and 1990s.

The structure of this paper is this. In section 2 we present the public credit system in Brazil. In section 3 we study public credit as an anti-cyclical tool. In section 4 we discuss the monetary policy implications of credit. In section 5 we discuss the effects of public credit for financial stability. In section 6 we present results from inference from panel and time series data. In section 7 we conclude.

2 The Public Credit System in Brazil

After Plan Real in 1994, the sudden drop in inflation led to a fledgling banking crisis (Moura (1998)) that was fatal to many private banks[3]. Maia (2003) points out that the loss of bank income (inflation rent) exposed bad management practices in some institutions, notably the heavy payrolls. Besides that, the Brazilian Central Bank (BCB) push[4] for the adoption of Basel I regulatory rules was fatal to the smallest institutions. An extensive sanitization process of private institutions took place under the PROER[5] program. At the same time, state governments banks, heavily saddled with bad loans to their controllers, were sanitized under the PROES[6] program to be later sold to private domestic and foreign financial institutions[7].

The privatization period for the banking system went from 1997 to 2001: in 1996 there were 32 state banks while in 2006 only 13 institutions remained, all under federal government control (Lima and Ferreira (2012)). The privatization process reduced the number of public banks as well as the supply of public credit. This tendency was reversed in 2003. The remaining public financial institutions saw their market shares increase in the last decade as a result of policy decisions to supply commercial and personal credit. This policy went further than just compensating for private banks credit rationing in the aftermath of the Lehman crisis in September 2008. Besides complementing the private sector, public banks also supply long-

[3]Banco Economico, Banco Nacional and Bamerindus, three national household brands, perished while other 29 banks were under intervention by the BCB. Moura (1998) blames the early deregulation of the banking system in 1989 for the existence of 23 of these 29 banks that did not survive the stabilization period.

[4]Resolution 2.099 from Conselho Monetario Nacional published in august 17, 1994

[5]Programa de Estímulo à Reestruturação e ao Fortalecimento do Sistema Financeiro Nacional

[6]Further details on "Programa de Incentivo à Redução da Presença do Estado na Atividade Bancária" (PROES) can be found in Salviano Junior (2004)

[7]Banespa, the biggest of these banks, was sold to the Spanish Santander in November 2000 while Banerj, the second biggest state bank, was sold to Banco Itaú, a huge domestic banking conglomerate, in September 1997

term credit to projects in infra-structure and agricultural projects. In this paper we focus on public credit as a whole, but the three most relevant public banks, or SOB[8], are BB (Banco do Brasil), CEF (Caixa Economica Federal) and BDNES (Banco Nacional de Desenvolvimento Economico e Social). They control the major part of public credit. In 2011 direct credit represented 34.6% of total credit stock circulating in the Brazilian economy.

The Brazilian economy experienced a major boost in leverage from 2001 to 2010. Table 1 shows that the total credit in the financial system expanded from 26.3% of GDP in january 2001 to 44.7% in january 2010. This movement is mainly credited to a political decision to increase consumption by extending credit lines to households, a 175% increase in credit to households. This is an impressive figure specially because real GDP per capita grew by 60% in this period. Other factors, such as increased macroeconomic stability and institutional reforms that reduced the cost of credit for both households and companies, allowed this expansion to happen. Among these reforms we underline the importance of the new payroll backed credit legislation ("crédito consignado") and the bankruptcy legislation ("Lei de Falências")[9]. Table 1 also shows that in spite of the rapid expansion of credit to households, with 14.6% of credit in 2010, the biggest borrowers in 2010 are companies, with 21.7% of credit. This paper mainly addresses the allocation of resources to companies.

It is important to clarify the difference between directed (earmarked, channeled) and public credit, yet both constitute manifestations of what McKinnon (1973) and Shaw (1973) called "financial repression", a set of government regulations, laws, and other non-market restrictions to prevent financial intermediaries from functioning at full capacity. Channeled (or directed) credit is the sum of funding mechanisms earmarked to supply resources to companies, rural producers and housing. The majority of resources come from public funding complemented by reserve requirements on cash deposits in private and public banks. Public credit is credit originated by public funding and can be accessed either through public or private banks (in which case they are referred to as transfers). It is relevant to know that private banks retain the responsibility over credit risk in the operations executed with transferred resources.

Reinhart and Sbrancia (2011) list the most frequent forms of financial repression: "[E]xplicit

[8]A State Owned Bank (SOB) is a financial institution in which voting control is in the hands of federal, state or municipal government as stated in regulation (Carta-Circular) n. 2.345 of January 25, 1993

[9]See Barbi (2012) for an extensive discussion.

or indirect caps or ceilings on interest rates, particularly (but not exclusively) those on government debts. (...) Creation and maintenance of a captive domestic audience that facilitated directed credit to the government. (...) Other common measures associated with financial repression aside from the ones discussed above are, direct ownership (China or India) of banks or extensive management of banks and other financial institutions (i.e. Japan). Restrictions of entry to the financial industry and directing credit to certain industries are also features of repressed financial markets (see Beim and Calomiris (2000))." It is clear that the only two measures that do not apply to Brazil are formal ceilings on interest rates[10] and entry restrictions to the financial industry. All the remaining measures are in place, at different grades.

We now briefly summarize the facts presented in detail by Lundberg (2011) to offer a quick overview on public credit channels to explain the present context of public credit. Directed credit in Brazil exists in three formats each tied to a public bank: housing financing is a key business for CEF, rural credit is a relevant part of BB loans while long-term investments are conducted almost exclusively by the national development bank, BNDES.

The major part of directed credit is funded with public resources either originated from forced savings (FAT)[11] or the Treasury[12]. FAT resources come from taxing firms and from a compulsory contribution from workers, FGTS. FGTS constitutes a retirement savings account towards which both employers and employee contribute monthly. An allocation distortion occurs as these funds are poorly remunerated and loose real value. In 2010, FGTS yielded only 4.06% while inflation was 5.9%. A frequently cited explanation relates the low yield of social programs sponsored with the funds[13].

FGTS is a forced savings mechanism that in theory funds housing. As such it presents two problems: the below market remuneration of these funds reduces workers welfare on one hand while on the other hand allows for political influence in resource allocation. As all FGTS funds

[10]Yet, this is quite recent: in 2003 an amendment (EC 40/2003) to the 1988 Brazilian Constitution voided article 192 that imposed limitations to interest rates

[11]Fundo de Amparo ao Trabalhador, the workers support fund

[12]It is relevant to note that while these disbursements do not count towards primary deficit calculation, they only increase federal government total debt. This might have a long-term impact in public finance sustainability if the usual tax-increase channel is closed as indicated by the failure to renew CPMF in Congress on December 2007

[13]In 2010 R$ 4.5 billion were donated to the popular housing program "Minha Casa, Minha Vida". In 2011 this amount rose to R$ 5.5 billion and 2012 some more R$ 4.4 billion are expected to be invested at no return to FGTS funds

are withheld by CEF in a monopolistic setup, workers cannot bargain for better remuneration rates. Federal government opposes changes to this configuration since FGTS provides funding to projects that otherwise would fall under the Treasury responsibility, negatively affecting the generation of fiscal surplus.

As our definition of financial stability goes beyond the traditional risk management and shock resilience capabilities to encompass the allocation of resources it is clear that any institutional arrangement that worsens allocation has a direct negative impact on the stability of the financial system. In addition to the remuneration issue, critics argue that the reduced efficiency in allocation is tied to political mingling as extensively documented in the literature. The inefficiency comes from political interests prevailing over technical criteria when deciding on credit approval: a second-best allocation of public credit reduces efficiency and welfare[14].

To keep it brief our review of the recent literature on state owned banks present two of its most active strands, one relates to economic development while the other relates public banking to political power. La Porta et al. (2002) showed that greater government participation in bank ownership tends to be associated with lower levels of financial development, wider intermediation spreads, slower economic growth and greater financial instability. The authors consider a panel of 92 countries for 35 years (the period between 1960 and 1995 when most privatization process has been completed, but not in Brazil) to reach the disturbing conclusion that "[C]ountries with high government ownership of banks are indeed more backward and more statist: they are poorer, have more interventionist and less efficient governments, as well as less secure property rights." In this light it seems outdated for a developing economy to expand public share in the banking sector.

On the relation between state-owned banks and politics, Sapienza (2004) verified that "[S]tate-owned banks charge lower interest rates than do privately owned banks to similar or identical firms, even if the company is able to borrow more from privately owned banks. State-owned banks mostly favor firms located in depressed areas and large firms. The lending behavior of state-owned banks is affected by the electoral results of the party affiliated with the bank: the stronger the political party in the area where the firm is borrowing, the lower

[14]The same criticism is valid for industrial policy initiatives, as government officials must "pick winners" there is a permanent risk of cronyism and political mingling.

the interest rates charged."

Studying the Brazilian case, Carvalho (2010) supports the view "that government control over banks leads to an economically significant influence of political considerations over the real decisions of firms (...) politicians use control over bank lending decisions to influence the decisions of firms and increase employment in politically attractive regions."

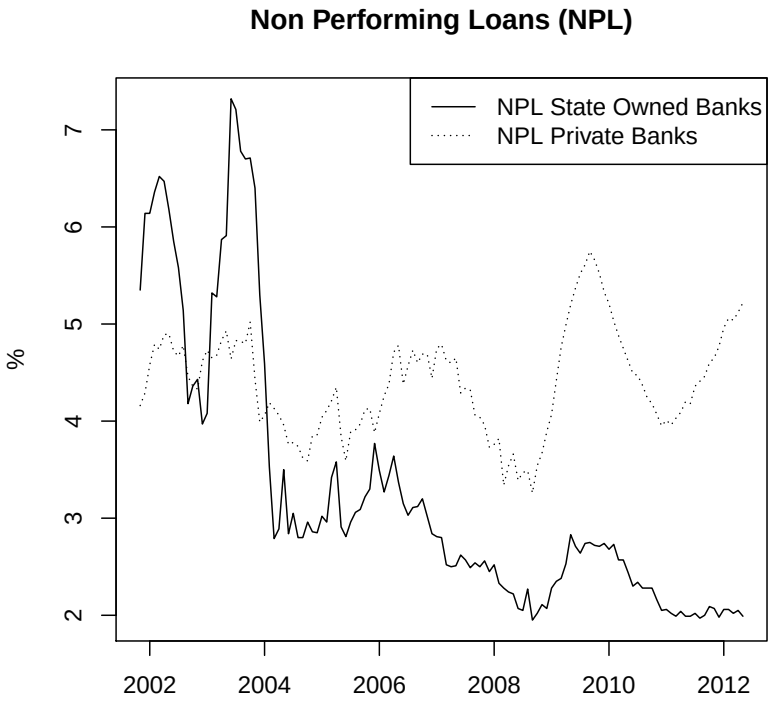
More recently Iannotta et al. (2011) use an extensive sample of large Western European banks between 2000 and 2009 to verify that government owned banks suffer significant political influence as they increase lending more than private banks during election years. They conclude that "government owned banks do not play a counter-cyclical role by increasing their lending activity more than private banks during economic recessions, while they are consistently with the political view more subject to political pressures by expanding their lending more than private banks during election years". This is an interesting result since we will see later, in Cull and Peria (2012) , that Latin America governments are particularly concerned with credit during bad times. Two different sets of emerging economies react differently during crisis but tend to behave similarly under the political pressure of electoral cycles, suggesting that weak political institutions, a common trait between them, may be a key motivator for government bank ownership.

Are public banks less efficient in the credit business than their private counterparts? Figure 1 shows that public banks face lower default rate than private institutions after a shift in 2003/2004. To explain this shift we suggest that either public banks improved credit technology or that public credit is crowding out the worst borrowers to the private banking sector, as discussed in section 4.

3 Public Credit as an Countercyclical Tool

The steady reduction of inflation and short-term interest rates (figure 2) after 2003 allowed for the expansion of the domestic credit market. Total credit went from 26.8% of GDP in 2001 to 48% in 2010. As public banks increase their participation in credit markets in 2002/3 and 2008/9 (figure 3), they tend to complement the supply of private credit as an countercyclical to reduce output fluctuations. According to Mesquita and Torós (2010) the public provision of

Figure 1: Average NPL for Public and Private Domestic Banks

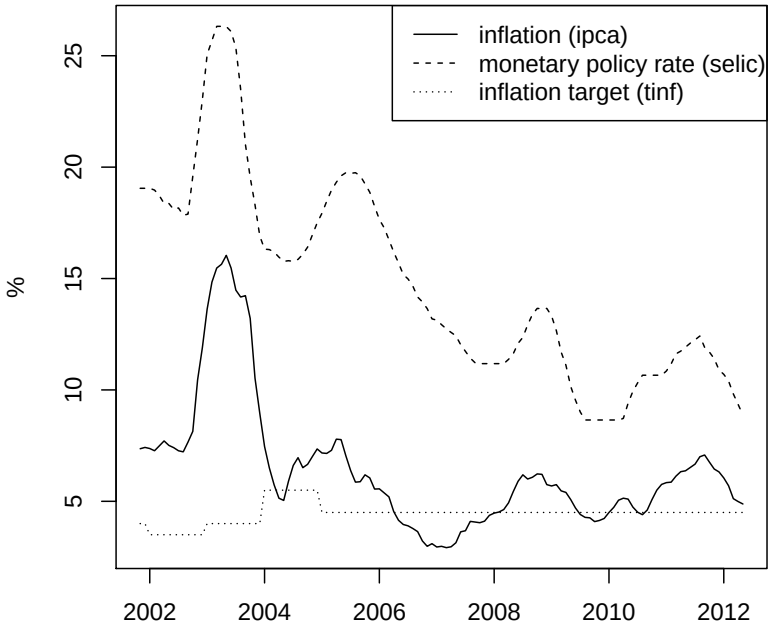


credit proved to be instrumental in revamping Brazilian industrial production after the crisis that followed the credit crunch triggered by the Lehman Brothers demise in September 2008.

During the 2008 crisis the BCB intervention was critical to provide liquidity to financial institutions in particular because of the huge maturity mismatch between banks liabilities (deposits) and assets (loans). At the same time, Mesquita and Torós (2010) observe that public banks quickly gained market share as they supplied liquidity to firms expanding their market-share from 28% in August 2008 to 34% in June 2009. Supporting the thesis that crisis impact the banking system asymmetrically, the authors report that after the collapse of Lehman Brothers, the high level of uncertainty caused the migration of deposits from smaller institutions to bigger ones: between August 2008 and January 2009 deposits in bigger banks rose some 20% while they decayed by 11% (medium) and 23% (small) in smaller institutions.

The counter-cyclical intervention of public banks was not a Brazilian phenomenon. Some authors report the same behavior in other Latin America countries. Cull and Peria (2012) using an extensive Bankscope database verified that in Latin America public banks loan growth

Figure 2: Monetary Policy Rate (selic), Inflation (ipca) and Inflation Target (tinf)



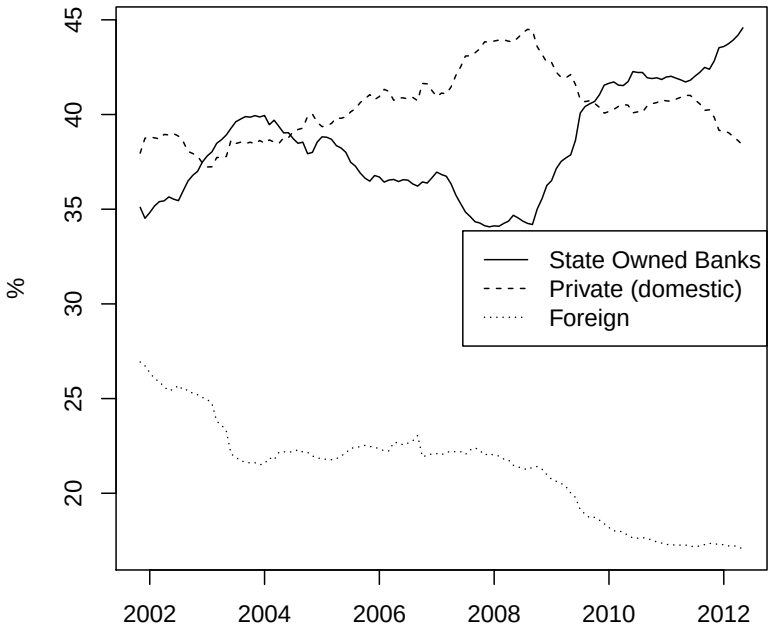
exceeded that of other bank types during the 2008/2009 crisis years. The ownership effect was observed both in corporate and consumer loans, but not in residential mortgage market, indicating a clear and targeted policy decision to sustain economic activity through the crisis. The same behavior was not observed in Eastern European banks, according to Iannotta et al. (2011).

To test the hypothesis of counter-cyclality we build a dynamic model for economic activity (Y) given by

$$\Delta Y_t = \beta \begin{bmatrix} \Delta Y_{t-1} \\ X_{t-1} \\ crisis_t \\ directed_t * crisis_t \\ free_t * crisis_t \end{bmatrix} + \epsilon_t$$

Where X is a set of control regressors composed by: lagged first difference of directed

Figure 3: Credit Market Shares by Bank Ownership



credit, free (non-directed) credit, real exchange rate (rer), short-run interest rate (selic), long run interest rate (tjlp), minimum wage and two interaction variables of the directed and free credit with the crisis dummy ($crisis_t$)to capture specific effects of the forms of credit in a stress context. As the objective is to test the effects of credit in the recent crisis triggered by Lehman the crisis dummy only exists as long as the product is below average in the years 2008 and 2009. No previous crisis events are treated. We expect that both free and direct credit have a positive relation with economic activity but only directed credit bears a counter-cyclical relation with activity as free credit is believed to be pro-cyclical.

Bertay et al. (2012) find similar results: "lending by state banks is less pro-cyclical than the lending by private banks, especially if the bank is located in a country with good governance, as proxied by indicators of government effectiveness.(. . .) State banks also expand their credit relatively more during banking crises, which suggests a stabilizing influence of state banks at a time of financial instability."

The authors add an important observation that will be tested with a panel dataset for

Brazilian banks. They say that "[O]n the liability side, state banks expand their non-deposit liabilities relatively little during booms, especially if these banks are located in countries with good governance. In contrast, the relative increase in non-deposit liabilities of private banks during economic booms puts these banks at some risk, as this type of funding may be less stable than funding through deposits."

4 Public Credit and Monetary Policy

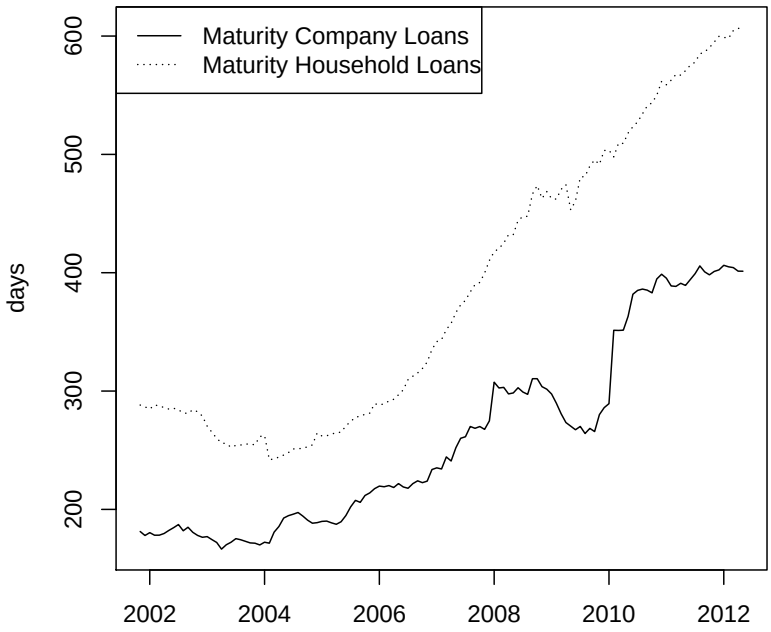
In this section we focus on Silva et al. (2012) definition of financial risk to analyze the changing feature of public credit and its impact in the financial system capacity to manage risks and absorb shocks. We will consider two seemingly unrelated phenomena that are taking place simultaneously. The first phenomenon is the tendency that banks increase risk-taking when the risk-free-rate goes down. The second phenomenon is the growing participation of public credit in a context of rapid credit expansion. We believe that the conjunction of both movements leads to a dangerous situation as the private financial sector grows more vulnerable to shocks.

Schularick and Taylor (2012) show that credit growth is a powerful predictor of financial crises. Using a new dataset on money and credit covering 14 developed countries [15], from 1870 to 2008, the authors verify that financial crises can be seen as "credit booms gone wrong", a credit view argument associated with Minsky and Kindleberger and and others that thought that credit deserved to be watched carefully and incorporated into a broader central bank policy framework.

Our basic working model without government combines monitoring and relaxed lending standards. The central bank considers that inflation is under control and gradually reduces short-term interest rates. A reduction in the basic rate makes more entrepreneurs willing to get credit: demand for bank credit goes up. At the same time, as the amount of non-performing loans (NPL) decreases, because of the increased activity level, banks are willing to offer more credit and credit supply goes up. Banks establish profitability targets that require them to become more aggressive in credit concessions and standards are relaxed. A good indication of

[15]The authors point out the very different definitions of credit, money and banking institutions across countries, which might make cross-country comparisons rather inaccurate.

Figure 4: Credit Maturity for Companies and Households



this is the extension of maturity that takes place in both private and corporate credit markets, as figure 4 indicates. The number of projects financed raises to the point that it exceeds close monitoring capacity by the banks and eventually delinquency rates accrue. Banks provision for their expected losses and renegotiate with delinquents to refinance their debt, extending debt maturity. At the same time, credit spreads go higher to reflect increased risks of default and some moderation is instilled in the supply side of credit.

Now let's add a government that is politically motivated to increase growth by adopting short-term measures. Economic authority increases public credit supply to force competition on private institutions so they have to pass-through the reduction in costs down to credit takers in order to defend their market share. A possible explanation for the large difference between private and public credit spreads in normal (non-crisis) times is that as private banks enjoy market power, they delay reductions in interest rates even though the basic rate (selic) is falling to capture rent from entrepreneurs and households.

Another hypothesis is that as the short term monetary rate declined, private banks take

more risk and the default level increases, raising credit spreads. Economic authority increases the supply of public credit to compensate for the higher private spreads. Without a policy decision to extend credit to small (risky) borrowers, public banks freely offer the limited amount of funds at subsidized rates in the market. The majority of these funds is directed to less risky projects sponsored by big companies that manage to overcome a series of bureaucratic hurdles.

Public banks therefore capture the less risky borrowers leaving the more risky projects to the private banks. Private banks spreads are permanently locked above the level of the public banks. The high spread is used as a justification for public credit supply with no mentioning that this very supply generates the higher private spreads. The lack of an explicit policy to channel public credit to small and medium enterprises (SME) creates a perverse feedback loop that sustains private bank interest rates well above public credit rates.

4.1 Is Inflation a Concern?

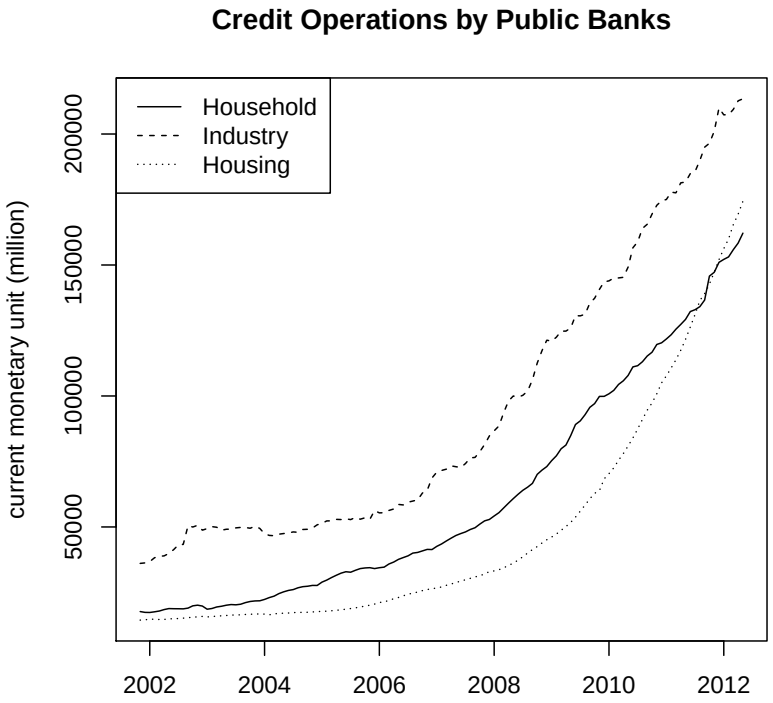
In Brazil the Brazilian Central Bank (BCB) is the guardian of both monetary and financial stability. The institution has repeatedly argued against public credit in Monetary Policy Committee (COPOM) minutes urging for the reduction of this form of fiscal stimulus. Does the allocation of public credit generate inflation in the short and long-terms?

The first question is whether public credit has any effect on inflation. The short-term unbalance between demand and supply, mirrored by an abundance of credit to consumers, suggests that if consumption grows faster than supply-side investments there will be pressure on the price level. Figure 5 shows that public credit to consumers (ex-housing) has increased faster than public credit to companies. In fact, short-term, current, inflation is in fact has become stable well above target level (4.5%) as can be seen in figure 2, suggesting that public credit has indeed some responsability on the current inflation.

But what about future, expected, inflation? Considering that the cornerstone for an inflation target central bank is the ability to manage inflation expectations, we use the Johansen (1995) cointegration framework to separate short and long run effects as in:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \delta X_{t-i} + \epsilon_t$$

Figure 5: Public Credit directed to Industry, Housing and Households



Where X is the set of control variables that include inflation (ipca), the short-term interest rate (selic), the long-term interest rate (tjlp), the stock of free and directed credit, the real effective exchange rate (reer), the inflation expectation rate(focus), the inflation target rate (tinf), GDP and minimum wage.

The short-term interest rate (selic) is included as suggested by the original Taylor rule. The long-term interest rate (tjlp) is included because it is the basis for remuneration of BNDES originated credit. The actual interest rate also depends on the borrower's risk, but the reduced basic rate is the key component to guarantee that the final rate will stay below free market levels. The stock of free credit (free) is also considered as more credit in the economy may lead to higher demand and therefore higher prices. We expect inflation to be negatively related with directed credit as discussed shortly. The real effective exchange rate (reer) is included as to capture the international price level pass-through to domestic prices. We also control for the inflation 1-year expectation rate (focus), the inflation target rate (tinf) and the level of economic activity measured by GDP. A final control for wage inflation is included in the

form of minimum wage (minwage). Recent legislation established that the revisions to the minimum wage must not only account for last year's inflation but also incorporate a real gain corresponding to GDP growth lagged two years . As the minimum wage bears a direct relation with wage costs, we expect a positive long-run relation with inflation.

The volume of public credit may have a negative relation with inflation if more investments in long-term projects create better infra-structure and lead to lower costs. This setup might trigger the reduction of producer prices and finally bring down consumer price levels in competitive markets. But if the long-term relationship between directed credit and inflation is positive one can suppose that directed credit fuels inflation and acts against monetary policy objectives in the long-run. This would be an evidence of the conflict between fiscal and monetary policies that would require a focused approach to long-term financing of social (mostly education) and infra-structure initiatives to reduce production costs.

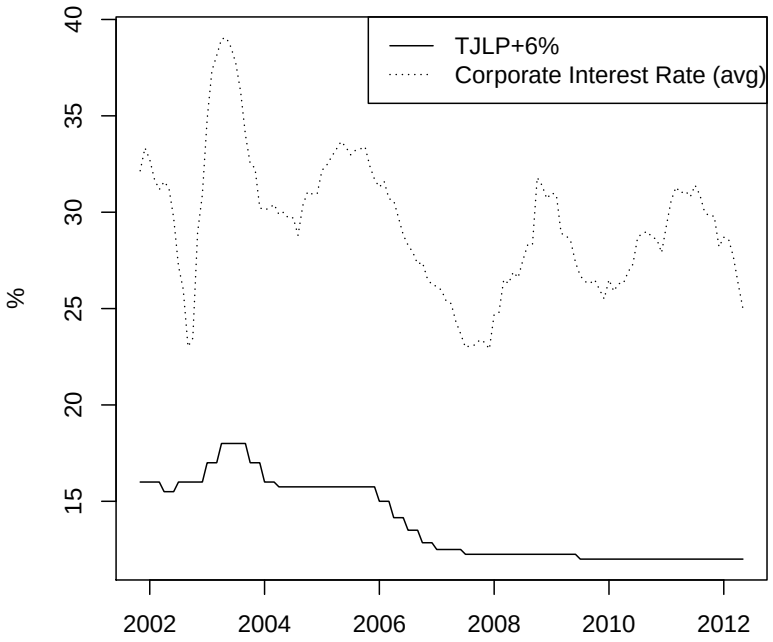
5 Public Credit and Risk Taking

The moral hazard framework suggests that as the public institutions are explicitly backed by the Treasury, they tend to be less diligent when approving credit to private companies. They may be also driven by political objectives, more than technical criteria. If this is the case, they should face higher default rates than their private counterparts. Figure 1 shows that this is was the case until 2003 when a shift occurred and private banks have showed higher non-performing loan rates. As this contradicts our first expectations it is valid to question whether this is the result of the public institutions reducing credit supply, but figure 3 shows that public credit is gaining market share and another hypothesis must be made.

Public banks offer subsidized loan rates to conquer market share. Figure 6 shows that the average interest rates for companies in the free credit market is higher than in the public financial institutions (tjlp+6% per year). This happens because the basic rate is reduced: the long-term interest rate, tjlp, is historically lower than its short-term counterpart, selic; but also because the borrowers present less risk. There is a selection process of borrowers drawing the best ones (those with the less risky projects) to public banks.

The adverse selection theory of credit markets pioneered by Stiglitz and Weiss (1981)

Figure 6: Average Interest Rates in Public and Private Domestic Banks



proposes a discontinuity in credit supply when the borrowers marginal type became so risky that expected returns are actually reduced by a surge in defaults. Arnold and Riley (2009) showed that rationing with a single equilibrium rate is unrealistic (it only happens under very extreme distribution of projects in the pool of loan candidates), so if there is rationing that's because there are at least two interest rates: in their model borrowers enter a lottery for the low rate while the remaining demand for credit is met by banks offering a higher rate.

In Brazil, the majority of public funds destined to financing companies (essencially through BNDES) goes primarily to big companies. That is not a lottery: when firms compete for cheaper public funds only the players that have the technology to approach public banks have access to the lower rates. There is no evidence that credit standards differ between public and private banks. The indication that a systematic self-selection process is underway is the fact that although small and medium enterprises (SME) are more than 80% of the total number of companies in Brazil, they get a disproportionally low share of public resources: according to Lundberg (2011) only 27.1% of BNDES funds went to SME in 2010 (17.5% in 2009 and 24%

in 2008).

Why would companies with access to equity markets access credit markets to finance their projects? There are two different theories to explain preference for debt over equity. The first is the Pecking Order theory (Myers and Majluf (1984)) according to which companies order sources of financing according to the cost: cheapest (internal financing) first. According to this theory, debt is a signalling device to show that the company has confidence in a project (a superior return would bear the higher costs of debt). A second theory, Delegated Monitoring (Diamond (1984)), states that minority shareholders prefer some debt to keep managers under scrutiny by lenders, so they do not have to incur in monitoring costs. This preference is reflected in higher share prices.

The projects that are not selected by public banks come from smaller companies, present higher risks and therefore require higher returns. These risky projects are financed by private banks that face higher default and spread rates. Spread rates are a combination of cost of funds, default rates, administrative costs and operational margins. Not only the supply of public credit does not reduce average rates but, worse, the raising stock of riskier loans in private banks makes these portfolios more vulnerable to liquidity shocks. The burden falls particularly to domestic private banks as the foreign banks tend to cater to the needs of multinational firms that usually present lower risk. In India, for example, Pennathur and Vishwasrao (2013) documented that foreign banks focus on relationships with foreign, listed, and larger firms.

The alleged reason for offering public funds to long-term projects is the lack of long-maturity credit supply by private institutions. To cope with this deficiency, new credit instruments were recently created to fund long-term lending for housing and agricultural activities[16]. Figure 3 shows that public credit has increased its market share since 2008 and is crowding out credit issued by both private domestic and foreign banks. As the supply of public credit is increased to generate and sustain growth in the short-term, the new market-based funding tools do not meet the necessary demand to allow for their full development. So public credit remains the only alternative for financing long-term projects.

According to the credit channel theory the financial sector influences the effectiveness of

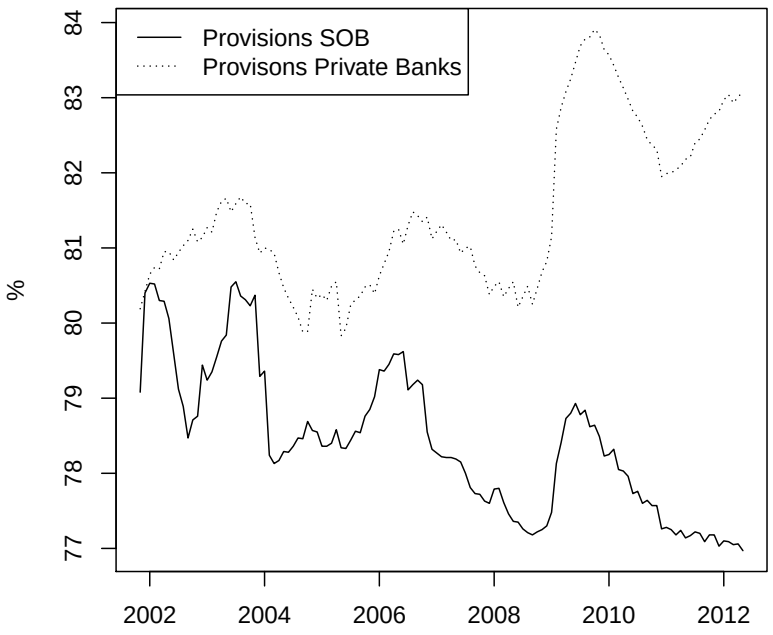
[16]Letra de Crédito Imobiliário (LCI) and Letra de Crédito do Agronegócio (LCA).

monetary policy because firms cannot perfectly substitute between sources of funding, debt and equity. Kashiap and Stein (2000) provide strong evidence towards the existence of a bank lending channel. The authors sustain that banks lending behavior is conditioned by their balance sheets in response to monetary shocks. Size, liquidity and capital are the usual indicators adopted in the literature to control for the bank balance-sheet state. Banks with more liquidity tend to lend more, as do those with more assets (size) and capital. When a negative monetary shock hits the economy, banks with less capital usually reduce the supply of credit in anticipation for a higher default rate. If the state of the economy is severely impacted, there may be a slump in deposits and capital will be vital to guarantee the outstanding stock of loans. Bank assets also indicate the lending capacity of the institution: in monetary restrictive contexts as deposits migrate to big institutions they may not significantly reduce their supply of credit. The relevance of the traditional bank lending channel to monetary policy is questioned by Distayat (2010) for whom financial international markets makes it easier for banks to procure funds even when domestic savings are not enough . According to this point of view a bank lending channel would be relevant in the short-run by affecting the risk perception of the bank balance sheet. If this is true, the empirical framework of this section will complement the long-term approach adopted in the previous section.

This literature considers a contraction in monetary policy but Brazilian economy has experienced in the 2000 decade mostly an expansionary monetary policy. In a expansionary context, banks may adversely influence the transmission of monetary policy if they do not reduce the cost of credit in the same proportion and/or rhythm of the reduction in the basic rate (selic). If this is the case, the supply of public credit is a way to force loan rates down. If risky borrowers would have access to these funds, one would expect public bank spreads to go up as average spread rates are essentially determined by borrower risk level, cost of funds and operational margins (dividends expected by shareholders). In figure 6 it is clear that public spread is well below spreads in the private sector.

In addition to the relation between monetary policy and delinquency, we study the quality credit portfolios in public and private banks by observing two indicators of credit quality: provisions/loans and maturity/provisions. Provisions are reserves made after 90 days past due payment date. Before turning into a default, the bank contacts the credit taker and offers

Figure 7: Provisions/Loans for Public and Private Banks



to refinance: this translates to a debt maturity increase. If after 360 days past due date the credit cannot be collected it is written-off the bank balance sheets.

Regulations define a floor for provisions conditional on the delinquency classification of the credit. Yet, banks are not limited by these rules. Figure 7 shows that the relation Provisions/Loans is not stable for neither class of banks: for public banks there is a clear tendency of reduction while for private banks this ratio is increasing with a hike in both classes around Lehman's demise. This indicator focuses on provisions but controls for the amount of credit issued by each class of bank. The conclusion is that private banks are carrying worse quality portfolios than public banks. Unfortunately there is no data on maturity by bank class. The existing data as showed in figure 4 indicates that maturity is rising for both companies and individuals suggesting that either lending standards are being relaxed and/or that portfolio quality is decreasing (debt renegotiation usually entails a longer repayment schedule).

5.1 Public Credit and the Financial Stability

To illustrate the effects of adverse-selection of borrowers directed to private banks and public banks gaining market-share, we propose a simple model with two banks (public and private) and two types of projects (A and B). We assume that projects A and B have the same average return, $\mu_A = \mu_B$, but projects B are riskier, $\sigma_A < \sigma_B$.

The expected return and variance of the each bank credit portfolio are

$$\begin{aligned} E_t &= \theta_{A,t}\mu_A + \theta_{B,t}\mu_B \\ \sigma_t^2 &= \theta_{A,t}^2\sigma_A^2 + \theta_{B,t}^2\sigma_B^2 + 2\rho_{A,B}\sigma_A^2\sigma_B^2\theta_{A,t}\theta_{B,t} \end{aligned}$$

In a simple two period model, we choose the portfolio risk-adjusted return (RAR) as the relevant indicator[17] for our analysis

$$RAR_t = \left(\frac{E}{\sigma}\right)_t = \frac{\theta_{A,t}\mu_A + \theta_{B,t}\mu_B}{\sqrt{\theta_{A,t}^2\sigma_A^2 + \theta_{B,t}^2\sigma_B^2 + 2\rho_{A,B}\sigma_A^2\sigma_B^2\theta_{A,t}\theta_{B,t}}}$$

This choice is motivated by the observation that imbalances in credit portfolios are early warnings of problems in the credit market. The imbalance may happen due to lower return and/or increased risk of borrowers. At equilibrium, all bank portfolios have the same risk-adjusted return.

We define $\theta_{A,t}^i$ as the relative market-share of A-type borrowers in bank $i = (public, private)$

$$\theta_{A,t}^i \equiv \frac{N_{A,t}^i}{N_{A,t}^{private} + N_{A,t}^{public}} \text{ where } \theta_{A,t}^i \in (0,1)$$

There are only two banks, public and private, so at any moment t

$$\theta_{A,t}^{private} + \theta_{A,t}^{public} = 1$$

At start, $t = 0$, $\theta_{A,0}^{private} = \theta_{A,0}^{public} = \theta_{B,0}^{private} = \theta_{B,0}^{public} = 0.50$.

Assuming, for simplicity, that project outcomes are independent, $\rho_{A,B} = 0$. It is likely that

[17]The market designation for this indicator is RAROC, Risk Adjusted Return on Capital.

projects A and B show positive correlation (as business cycles are the same), in which case the portfolio variance would be even bigger than the one we use to show that an increase in private banks portfolios risk has a negative welfare effect.

Let's suppose that at time $t = 0$ public banks are competitive so that the risk-adjusted return of both banks are equal to the private banks returns:

$$\left(\frac{E}{\sigma}\right)_{t=0}^{private} = \left(\frac{E}{\sigma}\right)_{t=0}^{public}$$

Two phenomena are simultaneously observed. First, State Owned Banks' (SOB) market-share increases in $t = 1$ ("market-share effect")

$$\theta_{A,1}^{private} + \theta_{B,1}^{private} < \theta_{A,1}^{public} + \theta_{B,1}^{public}$$

Second, the distribution of projects among banks is affected ("adverse-selection effect"): a higher proportion of less risky projects (type A) have access to lower rates offered by the SOB (ie. $\theta_{A,0}^{public} < \theta_{A,1}^{public}$) the riskier projects (type B) are driven towards private banks (ie. $\theta_{B,0}^{private} < \theta_{B,1}^{private}$). This condition can be expressed by $0 < \Delta_B < \Delta_A < 1$ if we define Δ_A and Δ_B as

$$\begin{aligned} \Delta_A &= \theta_{A,1}^{public} - \theta_{A,0}^{public} = \theta_{A,0}^{private} - \theta_{A,1}^{private} \\ \Delta_B &= \theta_{B,0}^{public} - \theta_{B,1}^{public} = \theta_{B,1}^{private} - \theta_{B,0}^{private} \end{aligned}$$

We may therefore express the second-term risk adjusted return to private banks as

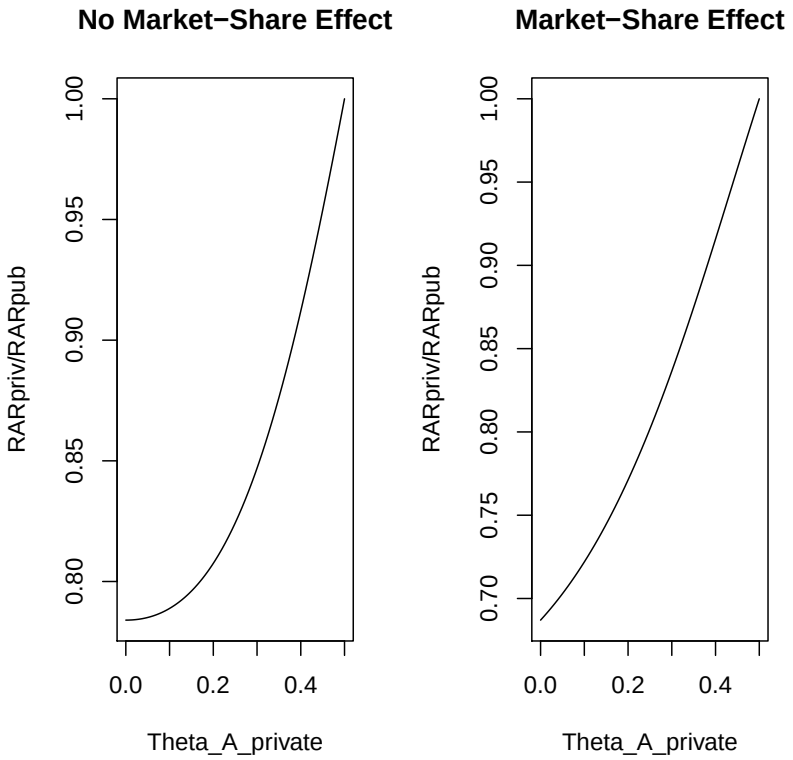
$$\left(\frac{E}{\sigma}\right)_{t=1}^{private} = \frac{(\theta_{A,0} - \Delta_A)\mu_A + (\theta_{B,0} + \Delta_B)\mu_B}{\sqrt{(\theta_{A,0} - \Delta_A)^2\sigma_A^2 + (\theta_{B,0} + \Delta_B)^2\sigma_B^2}}$$

For public banks the new risk adjusted return is given by

$$\left(\frac{E}{\sigma}\right)_{t=1}^{public} = \frac{(\theta_{A,0} + \Delta_A)\mu_A + (\theta_{B,0} - \Delta_B)\mu_B}{\sqrt{(\theta_{A,0} + \Delta_A)^2\sigma_A^2 + (\theta_{B,0} - \Delta_B)^2\sigma_B^2}}$$

With this setup it can be shown that private banks credit portfolios expected return are

Figure 8: Model Simulation



reduced while the public banks' increased so that

$$\left(\frac{E}{\sigma}\right)_{t=1}^{private} < \left(\frac{E}{\sigma}\right)_{t=1}^{public}$$

To illustrate the dynamics of the process, we simulate in figure 8 two cases: RAR with and without market-share effect. We plot in the y-axis the ratio $RAR^{private}/RAR^{public}$. It is clear that the market-share effect makes the ratio goes down deeper (0.687 against 0.784) and more abruptly.

This reduction in the private banks' risk-adjusted expected returns is compatible with a moral hazard behavior with increasing risk-taking by private banks. The point here is to show that by choosing to finance the best projects and gain market-share, public credit expansion actually induces imbalances and vulnerability in the banking system. To compensate for the higher risk, interest rates in the private sector must increase instead of decreasing, as would be expected by the policymaker willing to induce competition in the credit banking market.

In table 2 there is a simulation of three sets of parameter calibrations. The values for projects parameters were chosen under three constraints: $\mu_A = \mu_B = 1.0$, $\sigma_A \leq \sigma_B$ and the outcomes must be statistically significant, therefore (and supposing a normal distribution) this entails $\sigma_A = \mu_A/2.5$ and $\sigma_B = \mu_B/1.96$.

The first panel is simulated with only the market-share effect: private banks reduced A-type projects in their portfolios from 50% to 10% while increased B-type projects from 50% to 70% thus loosing market-share to public banks (note that $\sigma_A = \sigma_B$). The second panel assumes only an adverse-selection effect, $\sigma_A < \sigma_B$. Finally, the last panel considers both effects at once. The portfolios have the same adjusted return at $t = 0$ but they differ in $t = 1$. Private banks always end up with a smaller risk-adjusted return: $2.236 < 2.739$ under pure market-share effect, $2.084 < 2.294$ under pure adverse-selection and $1.797 < 2.546$ when both effects happen at once.

The increased vulnerability can be seen in the stress test cases on the lower panels of the table. The first line corresponds to $RAR_{t=1}$ with no shock. Case 1 corresponds to the credit portfolio return given a one standard-error shock to returns, Case 2 corresponds to a two standard-error shock and so on. It is clear that the adverse selection effect renders private banks portfolios vulnerable to shocks as their return decays more than public banks'. This illustrates that public credit dynamics actually reduces welfare by increasing financial risk.

It may be argued that as the risk of private bank portfolios increases, prudential regulations require higher provisions. This result does not change the central point of our argument because if additional capital must be allocated by the private bank to ensure its credit operation, there is an additional cost of funds that will be included in the spread rate. As spreads go up, the interest rates in private banks increases, instead of decreasing as desired by policymakers, and less projects will be undertaken, reducing welfare.

6 Data and Results

We use two different datasets: a time series dataset to understand the dynamics of credit expansion and a panel dataset to relate bank characteristics to this dynamics. The time series dataset of monthly observations goes from 2001/11 to 2012/08: data sources are presented in

table 3, table 4 brings the descriptive statistics and table 5 presents the unit root tests that indicate that all regressors are I(1).

The panel dataset in table 6 goes from 2000/06 to 2012/06 of semiannual observations (T=25) of bank level accounting data obtained from the COSIF reports. The initial number of banks was 269. We filtered out banks with less than 80% of observations to eliminate uninformative sample attrition and banks that had loans stock below 10% of total assets because they are not in the credit business. The final number of banks dropped to 117, sufficiently large to validate the asymptotic properties of fixed effect estimators.

Data availability determined these choices as the information on non-performing loans, a key indicator for us, is not present in reports before 2001. Data is available at a monthly basis but since banks are only forced to consolidate their balance-sheets in June and December, these reports present the most reliable numbers. Besides, we tentatively used higher frequency data (on a monthly basis) but found out that the noise in the series degraded the quality of the results. A detailed composition of the regressors from COSIF accounts is presented in appendix 1. This level of detail is necessary to avoid double counting but there may still be some mismeasurement as more detailed accounting data is not publicly available.

Table 6 presents basic statistics of the panel dataset: first all sample, then the three subsets of private domestic banks, state owned banks (sob) and foreign banks (fob). At first glance non-performing loans in public banks is higher than in domestic private and foreign banks. The average public bank has more assets (size) and capital than the average bank in the other classes (private and foreign).

Tables 7 and 8 presents models to test the impact of credit in economic activity. In table 7 models M1 and M2 show that the effects of private and public credit (coefficients for D.public and D.private) are positive and significant, while in models 3 and 4 the same is true analyzing free and directed credit (D.free and D.directed). The key difference between the two sets of models is in crisis times: public credit interaction with the crisis dummy has a positive sign while it is negative for the private credit interaction with crisis dummy. This first important result indicates that public credit is counter-cyclical and significant to retake economic activity while private credit is significant but pro-cyclical. The second important result is that the crisis dummy interaction with free and directed credit is not significant

suggesting that it is not the direction of credit but its availability that is relevant during bad times. This is important to contrast with what we argued before: that in normal times, the direction of credit towards smaller credit takers might be welfare improving. Table 9 is an alternative specification for models 1 and 2 if we consider that GDP and the volume of credit are endogenous. We estimate the first stage for the both credit measures in models M1 and M2 to test instruments (minwage, RER, year dummies) for the credit variables, public and private, to run the instrumental variables (IV) regressions on models M3 and M4. The results indicate that the coefficients for private and public credits are robust and even bigger, as are the coefficients for the counter-cyclical interaction of crisis and public credit in models M3 and M4.

Table 10 presents the long run relation between a set of regressors and inflation (measured by the ipca index) using Johansen's (Johansen (1995)) cointegration framework. The cointegration rank test results according to two information criteria indicate that there is at least one long-run relationship between all regressors of each model. The results indicate a strong and robust positive relation between public credit and inflation (in models M1, M3 and M4). This result might surprise a valid rationale for public funding of development projects in infrastructure and housing is to stimulate the supply and hence control prices in the long-run. This result suggests that public credit is inflationary in the long run thus directly conflicting with restrictive monetary policies. The best model is M4 according to the reported information criteria indicated that only GDP has a higher effect on long-term inflation. Inflation target bears a positive and significant relation with inflation suggesting that monetary authority sets realistic goals to the targeted inflation. Finally inflation expectations (focus) are not statistically relevant in the long-run. This can be read as an indication of the efficiency of price controls: once inflation expectations rise, the adequate policy is conducted so inflation is controlled and reduced.

This paper associates bank risk with the non-performing loans (NPL) indicator. A limitation of this indicator as discussed in Gaglianone and Schechtman (2011) is that it does not translate changes in the volume and maturity of new loans. As these changes may not be directly related to financial risk, this indicator may distort our understanding of the underlying phenomena. This is less a problem if we consider that in Brazil credit volume is increasing at

a faster pace than GDP and that maturity is also expanding. Taking all these indicators at once suggest that risk is raising and that our risk measure is adequate. Table 11 presents the determinants of bank risk taking as measured by NPL. The default rate is positively related to the monetary policy rate with a robust coefficient of about 0.0015 so an increase in 1% of the short-term interest rate increases bank loan default by 0.15% in the next period. Bank capital is not significant as it can be understood that the capital rule is not binding and banks operate well below leverage limits. Banks with more assets are more cautious about the quality of their borrowers, probably bigger firms. Provisions is a significant indicator of the level of default bearing a positive relation with the explained variable as a precautionary measure to control bank risk. We recall that funds used for provisioning cannot be neither distributed to shareholders nor lent, working simultaneously as a buffer and a signaling device about the quality of the credit portfolio. Bank size and liquidity are relevant for state owned banks: the bigger the size of the bank, the higher the default rate. This result may appear contradictory but if we consider that the true coefficient for public banks is the sum of coefficients in models M3 and M5, it is clear that the sum is very close to zero, suggesting the irrelevance of this parameter. The last relevant result is the negative sign of the liquidity coefficient of public banks that suggests that they are operating at higher (NPL/liquid assets) ratios then the private banks. The crisis dummy is significant in most models even after controlling for year dummies (coefficients omitted).

7 Conclusions

We argued that public credit crowds-out private funding to the best, biggest borrowers leaving private banks to finance the more risky projects. We believe there is little support for this allocation of subsidized credit, specially considering that most of the big companies have access to other funding sources, as the equity market or the international financial market.

Almeida (2012)[18] argues that "requiring BNDES to finance large private companies risks turning a development bank into a bank whose performance and strategy is increasingly similar

[18] "Economista do Ipea sugere novo foco de investimentos para o BNDES" in http://www.plataformabndes.org.br/site/ accessed on May 2012.

to a private investment bank, which focuses on companies with high potential growth in sectors in which, typically, Brazil already has comparative advantages as is the case of the sectors related to the production of agricultural and mineral commodities".

In the aftermath of the 2008 crisis, as a counter-cyclical tool public credit sustained activity. Bertay et al. (2012) do not agree that the benefits of public banking supersede the costs: "[O]verall our results suggest that state banks can play a useful role in stabilizing credit over the business cycle as well as during periods of financial instability. However, the track record of state banks in credit allocation remains quite poor, questioning the wisdom of using state banks as a short-term countercyclical tool."

If the very existence of public credit is justified by the lack of market solutions for long-term financing at internationally competitive prices, the increasing participation of public banks clashes with the development of the new long-term financing mechanisms. For Goldfajn et al. (2003) "[T]he major impediments to the development of more active medium- and long-term lending operations by the private banking sector are uncertain macroeconomic environment, notably high and volatile real interest rates, and crowding-out by the public sector's financing needs, at both federal and state levels."

Public funds could reduce average loan rates by either supplying collateral to or directly lending to small companies who bear the riskier projects. Technical innovation, a key driver for growth, is low when resources for risky projects are scarce. An opportunity for government intervention, as the venture capital is still infant, would be to provide credit for innovative, high-risk projects.

In spite of all the technical reasons against public credit, it is undeniable that a public banking system extends the government's reach to intervene and direct the economy. Yet the price to pay may be too high. Fiscal credibility is an important asset that can be easily hurt by accounting manipulation aimed at raising fiscal surplus.

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Appendix 1.COSIF accounts

Loans stock is the sum of accounts 14300002, 16100004, 16200007, 16300000, 16400003, 16500006, 16600009, 16700002, 16800005, 16910005, 16995006, 17100003, 17300009, 17500005, 17700001, 17800004, 17910004, 17920001, 17995005, 18100002, 18275009, 18278006, 18820007, 18600007, 18835009, 18875007, 18878004, 18880009, 18910003, 18995004, 23200007, 24180009, 24199801, minus the accounts 14399006, 18880205, 49206009, 49207008, 49214008, 49217005, 49236000, 49248005, 49285006, 49908008, 49909007.

Non Performing Loans (NPL) is the sum of accounts 31600008, 31700001, 31800004, 31900007. These are the credit operations more than 90 days due and classified under levels E, F, G and H.

Loan Loss Provisions (provisions) is the sum of accounts 16900008, 17900007 e 18900006.

Bank Size is Total Assets as reported in account 39999993.

Bank Capital is the account 61100004.

Liquid Assets is the sum of accounts 11000006, 12100008 minus the accounts (12130009 and 42340003), and minus the smallest value of accounts (12120002 and 42220006), 12200001, 12300004, 12500000, 12600003, 12900002, 13100007, 13200000, 13400006, 13500009, 13600002, 13700005, 13800008, 18570003, 18575008, 18580000, 18590007.

Table 1: Total credit operations in the financial system % of GDP

		2001	2010	Δ%
credit to public sector		1.3	1.9	46.2%
credit to private sector		25.0	42.8	71.2%
	households	5.3	14.6	175.5%
	companies	13.1	21.7	65.6%
	rural	2.3	3.6	56.5%
	housing	4.3	2.9	-32.6%

Credit supplied by private and public banks to public and private sectors.
Credit to companies include industry, commerce and service sectors.
Calculated with data from BCB series 11392 to 11399.

Table 2: Simulations of the theoretical model (private banks' perspective)

market-share effect				adverse-selection effect				market-share + adverse-selection			
	t	$x=A$	$x=B$		t	$x=A$	$x=B$		t	A	B
θ_x	0	0.5	0.5	θ_x	0	0.5	0.5	θ_x	0	0.5	0.5
	1	0.1	0.7		1	0.3	0.7		1	0.1	0.7
$E(x)$		1.000	1.000	$E(x)$		1.000	1.000	$E(x)$		1.000	1.100
σ_x		0.400	0.400	σ_x		0.400	0.510	σ_x		0.400	0.510
Portfolio	t	Private	Public	Portfolio	t	Private	Public	Portfolio	t	Private	Public
E/σ	0	2.500	2.500	E/σ	0	2.181	2.181	E/σ	0	2.181	2.181
E/σ	1	2.236	2.739	E/σ	1	2.084	2.294	E/σ	1	1.797	2.546
Stress Test	SE	Private	Public		SE	Private	Public		SE	Private	Public
RAR t=1	0	0.800	1.200		0	1.000	1.000		0	0.800	1.200
RAR Case 1	-1	0.400	0.800		-1	0.600	0.490		-1	0.400	0.690
RAR Case 2	-2	0.000	0.400		-2	0.200	-0.020		-2	0.000	0.180
RAR Case 3	-3	-0.400	0.000		-3	-0.200	-0.531		-3	-0.400	-0.331

θ_x is from the private banks' perspective.

Table 3: Time series data description and sources

Variable	Description	Source
development	Credit operations in the financial system - Chan.res. BNDES-Tot (million)	BCB7522
directed	Credit operations in the financial system - Channeled resources - tot (million)	BCB7524
eai	Economic Activity Index (monthly)	Serasa
focus	Expected Inflation (median) 12 months ahead	BCB FOCUS
foreign	Credit operations in the foreign financial system - total - c.m.u.	BCB12150
free	Credit operations with nonearmarked resources - total - R$ (million)	BCB12130
gdp	GDP monthly - current prices (R$ million) - R$ (million)	BCB4380
ipca	Broad National Consumer Price Index (IPCA) - Monthly % var.	BCB433
minwage	Minimum wage (annual)	BCB1619
nplpriv	Deliquency of credit ops in the national private finl system - total - R$ (million)	BCB12951
nplpub	Deliquency of credit ops in the public financial system - total - R$ (million)	BCB12949
private	Credit operations in the national private financial system - total - c.m.u.	BCB12106
public	Credit operations in the public financial system - total - c.m.u. (million)	BCB2007
reer	Real effective exchange rate index (IPCA) - Jun/1994=101 - Index	BCB11752
rer	Real effective exchange rate index (IPCA) - Jun/1994=100 - US Dollar - Index	BCB11753
selic	Interest rate - Selic accumulated in the month in annual terms - % p.y.	BCB4189
tinf	Target Inflation	BCB13521
tjlp	Interest rate - Long-term interest rate (TJLP) - % p.y.	BCB256

BCB FOCUS is available at https://www3.bcb.gov.br/expectativas/publico/consulta/serieestatisticas
The number after BCB is the series number available at http://www.bcb.gov.br/?TIMESERIESEN

Table 4: Time series descriptive statistics

Variable	Obs	Min	Median	Mean	Max	SE	Skew	E/K
development	129	11.96	12.22	12.39	13.00	0.33	0.65	-1.16
directed	129	12.45	12.75	12.90	13.59	0.35	0.62	-1.10
eai	129	111.90	138.00	137.93	163.00	16.82	0.08	-1.38
focus	129	3.37	5.03	5.32	13.18	1.58	2.72	9.17
foreign	129	11.97	12.41	12.43	12.82	0.26	-0.08	-1.52
free	129	13.01	13.55	13.58	14.16	0.39	0.01	-1.62
ipca	129	2.92	5.76	6.38	16.04	2.88	1.85	3.20
gdp	129	12.40	12.65	12.66	12.90	0.12	0.03	-0.98
minwage	129	6.07	6.29	6.27	6.43	0.11	-0.27	-1.29
private	129	12.55	13.04	13.09	13.65	0.39	0.01	-1.63
public	129	12.46	12.90	13.04	13.83	0.41	0.43	-1.32
reer	129	71.92	97.43	102.51	171.41	24.50	0.76	-0.49
rer	129	61.56	96.43	103.03	206.11	33.92	0.85	-0.17
selic	129	7.85	13.32	14.58	26.32	4.62	0.72	-0.17
tinf	129	3.50	4.50	4.45	5.50	0.46	0.20	1.36
tjlp	129	5.50	6.50	7.84	12.00	2.02	0.52	-1.30

Monthly observations from 2001/11 to 2012/08
E/K is Excess Kurtosis, $K - 3$

Table 5: Tests for the presence of unit root

	ADF		PP	
Variable	Level	First Diff	Level	First Diff
development	0.9862	0.0000	0.9862	0.0000
directed	0.9956	0.0000	0.9965	0.0000
eai	0.8804	0.0000	0.8761	0.0000
focus	0.2939	0.0000	0.0746	0.0000
free	0.9822	0.0000	0.9813	0.0000
gdp	0.8521	0.0000	0.8826	0.0000
ipca	0.7333	0.0002	0.3437	0.0001
minwage	0.7405	0.0000	0.7517	0.0000
private	0.9615	0.0000	0.9609	0.0000
public	0.9965	0.0000	0.9974	0.0000
reer	0.6985	0.0000	0.5712	0.0000
rer	0.7045	0.0000	0.6164	0.0000
selic	0.9293	0.0142	0.7024	0.0033
tinf	0.1891	0.0000	0.1575	0.0000
tjlp	0.8791	0.0000	0.8501	0.0000

ADF is the Dickey-Fuller test for unit root
PP is the Phillips-Perron test for unit root
Values correspond to p-values (H0:series has a unit root)

Table 6: Bank characteristics in panel dataset

All sample	Obs	Mean	Std.Dev.	Min	Max
capital	4693	18.4377	1.7082	14.5075	24.8637
size	4694	21.8505	2.5156	-0.5218	29.5379
liquid	4693	19.0561	2.4832	-0.5218	26.7195
npl	4024	0.0912	0.1651	0.0000	1.0000
provisions	3995	15.9433	2.7971	3.5056	23.6515
Private domestic banks					
capital	3177	18.2345	1.7008	14.5075	24.5299
size	3178	21.5147	2.4338	-0.5218	29.0824
liquid	3177	18.7422	2.4854	-0.5218	26.7195
npl	2690	0.1000	0.1739	0.0000	1.0000
provisions	2708	15.8832	2.5291	5.2801	23.4456
State owned banks (sob)					
capital	327	20.1737	1.8579	16.7495	24.3162
size	327	24.1398	2.4880	18.9114	29.3940
liquid	327	21.5270	2.1417	17.4692	26.3877
npl	322	0.1209	0.1399	0.0000	1.0000
provisions	325	18.4849	2.7815	8.8944	23.6515
Foreign owned banks (fob)					
capital	1189	18.5031	1.3783	15.9189	24.8637
size	1189	22.1184	2.3756	16.8096	29.5379
liquid	1189	19.2152	2.1473	9.2079	25.8318
npl	1012	0.0585	0.1424	0.0000	1.0000
provisions	962	15.2537	3.0364	3.5056	23.2044

Semiannual observations from 2000/06 to 2012/06

Table 7: Impact of credit on economic activity

Dependent variable: D.gdp	M1	M2	M3	M4
D.L.gdp	0.0883	0.0627	0.0415	0.0768
	(0.0668)	(0.0658)	(0.0673)	(0.0707)
D.rer	0.000959	0.000841	0.00136	0.000771
	(0.00215)	(0.00228)	(0.00207)	(0.00229)
D.reer	-0.000823	-0.00170	-0.00256	-0.000800
	(0.00243)	(0.00252)	(0.00231)	(0.00249)
D.selic	0.00175	0.000408	-0.00172	0.00189
	(0.00646)	(0.00697)	(0.00680)	(0.00678)
D.tjlp	0.0149	0.0130	0.0154	0.0153
	(0.0119)	(0.0120)	(0.0125)	(0.0131)
D.minwage	**-0.310***	**-0.428****	**-0.434****	**-0.367***
	(0.182)	(0.193)	(0.217)	(0.192)
crisis	0.00336	-0.0211	-0.0161	0.00232
	(0.0127)	(0.0134)	(0.0146)	(0.0134)
D.private	**1.107*****			
	(0.140)			
D.public		**1.140*****		
		(0.179)		
crisis*D.private	**-1.245***	**-1.924*****		
	(0.704)	(0.716)		
crisis*D.public	**1.221***	**1.888*****		
	(0.692)	(0.703)		
D.directed			**1.052*****	
			(0.193)	
D.free				**1.102*****
				(0.156)
crisis*D.directed			-0.201	0.0607
			(0.320)	(0.137)
crisis*D.free			0.187	-0.0594
			(0.301)	(0.129)
Observations	128	128	128	128
AIC	-478.0259	-477.2970	-467.7386	-478.0259
BIC	-446.6535	-445.9246	-436.3663	-446.6535

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
D is the first difference operator. L is the 1-period lag operator.

Table 8: Impact of credit on economic activity

	AR(1)	AR(1)	IV	IV
	M1	M2	M3	M4
Dependent variable	D.private	D.public	D.gdp	D.gdp
D.L.private	0.00147			
	-0.03970			
D.L.public		0.04370		
		-0.05910		
D.rer	0.00064	0.00109*	-0.00074	
	-0.00052	-0.00056	-0.00103	
D.selic	-0.00337	-0.00059	0.00272	0.00197
	-0.00409	-0.00444	-0.00694	-0.00649
D.tjlp	0.02570	0.02320	0.00264	0.00837
	-0.02620	-0.02310	-0.01200	-0.01320
D.minwage	-1.028***	-0.944***		
	(0.312)	(0.290)		
D.L.gdp			0.0431	0.0639
			(0.0655)	(0.0667)
D.public			**1.442*** **	
			(0.194)	
D.private				**1.415*** **
				(0.186)
crisis*D.private			**-1.908***	**-1.390***
			(1.089)	(0.819)
crisis*D.public			**1.871***	**1.363***
			(1.069)	(0.805)
Observations	128	128	128	128
Overidentification test (p-val)			0.8074	0.8419

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
D is the first difference operator. L is the 1-period lag operator.

Table 9: Long Run (Cointegrated) Relations with inflation (ipca)

	M1	M2	M3	M4
selic	0.1707	-0.6321	0.1960	0.1370
	(0.1513)	(0.5015)	(0.3214)	(0.2185)
tjlp	-0.3779	4.4853***	-3.0918***	-1.8313**
	(0.5131)	(1.6084)	(1.0487)	(0.7634)
priv	2.2294	41.7961***	-15.4398*	-10.1021*
	(3.8639)	(11.9374)	(8.2607)	(5.3798)
public	6.7053***	7.4007	20.1490***	14.9836***
	(2.5746)	(7.8891)	(5.0870)	(3.4941)
reer	0.1721***	0.6839***	-0.1692***	-0.0424
	(0.0264)	(0.0845)	(0.0545)	(0.0363)
focus	-3.3032***	-8.3870***	1.5166**	-0.4037
	0.3165	(0.9990)	(0.6458)	(0.4305)
tinf		-7.4355***	2.5955***	1.6061**
		(1.5189)	(0.9794)	(0.6502)
gdp			-83.5665***	-53.2992***
			(8.1139)	(5.4712)
minwa				8.2422
				(9.0978)
Cointegration rank test				
SBIC	1	1	1	1
Obsservations	128	128	128	128
AIC	-3.3193	-4.0469	-8.2995	-14.6264
HQIC	-2.6946	-3.2592	-7.3308	-13.4586
SBIC	-1.7818	-2.1084	-5.9153	-11.7521

AIC Akaike information criterion
HQIC Hannan and Quinn information criterion
SBIC Schwarz's Bayesian information criterion
In all models the ipca coefficient is normalized to 1

Table 10: Long Run (Cointegrated) Relations with Public Credit

	M1	M2	M3	M4
public_industry	-0.2280***	-0.4091***	-0.2150*	-0.9834**
	0.0490	0.1048	0.1139	0.4821
public_housing	-0.0304	0.1258*	0.0550	0.3653
	0.0380	0.0680	0.0587	0.2443
public_rural	0.2597***	0.6611***	0.5342***	-0.4124
	0.0826	0.1514	0.1292	0.7090
public_commerce	0.7155***	1.5333***	1.3694***	3.6319***
	0.1418	0.2754	0.2412	0.9910
public_households	-0.9528***	-1.3581***	-1.0504***	-2.7991***
	0.1407	0.2493	0.2184	0.9220
public_other svcs	-0.5141***	-0.9965***	-1.1188***	-1.2107*
	0.0801	0.1558	0.1464	0.6501
reer		0.0028	0.0040***	0.0222***
		0.0007	0.0009	0.0039
focus			-0.0330***	-0.2466***
			0.0066	0.0292
tinf			0.0469**	-0.0833
			0.0192	0.0897
gdp				4.7212***
				0.6259
minwage				-0.2788
				1.2300
Cointegration rank test				
SBIC	1	1	1	2
Num of Observations	128	128	128	128
AIC	-38.1525	-32.9231	-32.7148	-43.3824
HQIC	-37.5279	-32.1355	-31.5469	-41.7619
SBIC	-36.6151	-30.9846	-29.8405	-39.3940

AIC Akaike information criterion
HQIC Hannan and Quinn information criterion
SBIC Schwarz's Bayesian information criterion

Table 11: Determinants of Non Performant Loans (NPL)

	M1	M2	M3	M4
npl(t-1)	**0.591*** **	**0.588*** **	**0.588*** **	**0.584*** **
	(0.0395)	(0.0392)	(0.0389)	(0.0385)
selic	**0.00149***	**0.00146***	**0.00147***	0.00143
	(0.000872)	(0.000866)	(0.000876)	(0.000871)
size	**-0.0233*** **	**-0.0253*** **	**-0.0284*** **	**-0.0318*** **
	(0.00666)	(0.00701)	(0.00851)	(0.00902)
capital	0.00133	0.00260	0.00185	0.00363
	(0.00465)	(0.00473)	(0.00525)	(0.00545)
liquid	0.00357	0.00420	0.00567	0.00672*
	(0.00259)	(0.00268)	(0.00347)	(0.00362)
provisions	**0.0181*** **	**0.0181*** **	**0.0186*** **	**0.0187*** **
	(0.00318)	(0.00322)	(0.00307)	(0.00311)
sob*size		**0.0375*** **		**0.0437*** **
		(0.0128)		(0.0140)
sob*capital		-0.0112		-0.0123
		(0.0119)		(0.0122)
sob*liquid		**-0.0171***		**-0.0191** **
		(0.00877)		(0.00909)
fob*size			**0.0166***	**0.0197** **
			(0.00923)	(0.00967)
fob*capital			-0.00155	-0.00327
			(0.00695)	(0.00713)
fob*liquid			-0.00685	-0.00787*
			(0.00430)	(0.00445)
crisis	**0.00656***	0.00609	**0.00664***	0.00610
	(0.00390)	(0.00390)	(0.00391)	(0.00390)
Observations	3691	3691	3691	3691
Number of banks	228	228	228	228

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

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Bayesian Forecasting of Interest Rates: Do Priors Matter?

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Abstract

Central Banks that commit to an Inflation Target monetary regime are bound to respond to inflation expectation spikes and product hiatus widening in a clear and transparent way by abiding to a Taylor rule. There are various reports of central banks being more responsive to inflationary than to deflationary shocks rendering the monetary policy response to be indeed non-linear. Besides that there is no guarantee that coefficients remain stable during time. Central Banks may switch to a dual target regime to consider deviations from inflation and the output gap. An estimation of the a Taylor rule may therefore have to consider a non-linear model with time varying parameters. This paper uses Bayesian forecasting methods to predict short-term interest rates. We take two different approaches: from a theoretic perspective we focus on an augmented version of the Taylor rule and include the Real Exchange Rate, the Credit-to-GDP and the Net Public Debt-to-GDP ratios. We also take an "atheoretic" approach based on the Expectations Theory of the Term Structure to model short-term interest. The selection of priors is particularly relevant for predictive accuracy yet, ideally, forecasting models should require as little *a priori* expert insight as possible. We present recent developments in prior selection, in particular we propose the use of hierarchical hyper-g priors for better forecasting in a framework that can be easily extended to other key macroeconomic indicators.

Keywords: forecasting, Bayesian model averaging, hyper-g prior, monetary policy

JEL: C53, E27, E43, E47

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1 Introduction

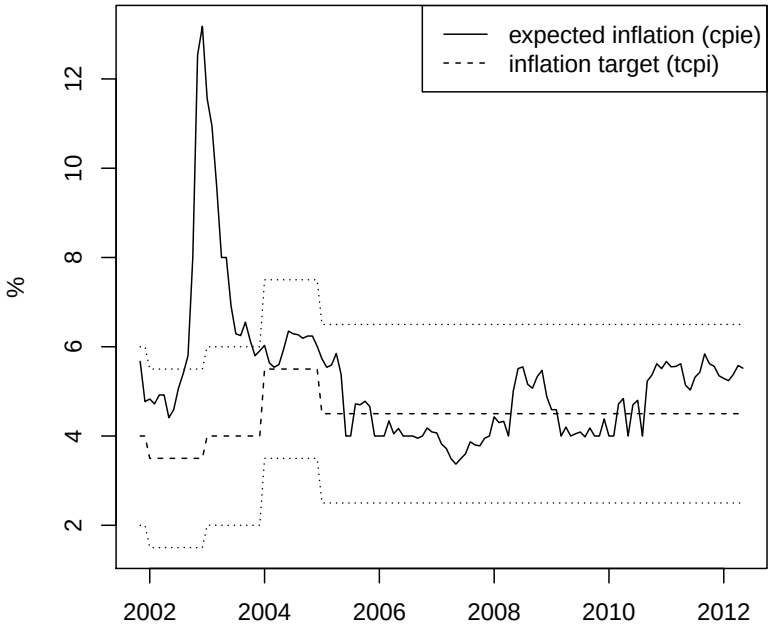
Since Taylor (1993) uncovered the Federal Reserve monetary policy response to inflation and product gaps, the Taylor rule is a central tool in the conduction of monetary policy as it conveys the necessary transparency to the monetary authority reaction to price shocks. Petersen (2007) sums up the essence of the rule: "the Taylor rule corresponds to a guide-post to good monetary policy: a mechanism that constrains monetary policy to be systematic, consistent, and rule-like. Monetary policy that is systematic, consistent, and rule-like characterizes a transparent and credible monetary policy, and therefore alleviates the time-inconsistency problems associated with discretionary monetary policy." Consistent with the rational expectation behavior of agents Clarida et al. (2000) suggest changing the original rule to a forward-looking reaction function.

This paper introduces a new way to estimate the Central Bank decision on monetary policy rate (MPR), selic, by using a Bayesian Model Averaging (BMA) framework based on hyper-g priors. Our first contribution is to test the forecasting accuracy of policy rates using a methodology that handles possible changes in the structure of the rule. The choice for BMA also considered previous interest rates forecasting attempts, notably using multivariate methods as did Lima et al. (2006) whose results suggest that VAR/VEC models perform poorly in terms of forecasting accuracy of interest rates. The motivation for this paper is to empirically test the hyper-g priors proposed by Liang et al. (2008). Our work extends Chua et al. (2011), who got enticing results forecasting interest rates for Australia. We used flexible hyper-g priors and controlled for the "supermodel effect" to reach very accurate forecasts.

Our second contribution is to discuss the best forecasting approach given that there are two clear distinct viewpoints: the "theoretic" approach proposes a causal relation between inflation expectations and the level of interest rates while the "atheoretic" approach is guided by expectations over the policy rate path shaping the yield curve. The forecasting capability of the monetary policy instrument reflects the quality of Central Bank communication: in an ideal monetary policy context agents should be able to correctly anticipate rate movements keeping uncertainty to a minimum to reduce[1] sovereign risk premium, that would otherwise

[1]Other sources of sovereign risk, notably fiscal policy, are not a concern in this work.

Figure 1: Expected Inflation (cpie) x Target Inflation (tcpi)

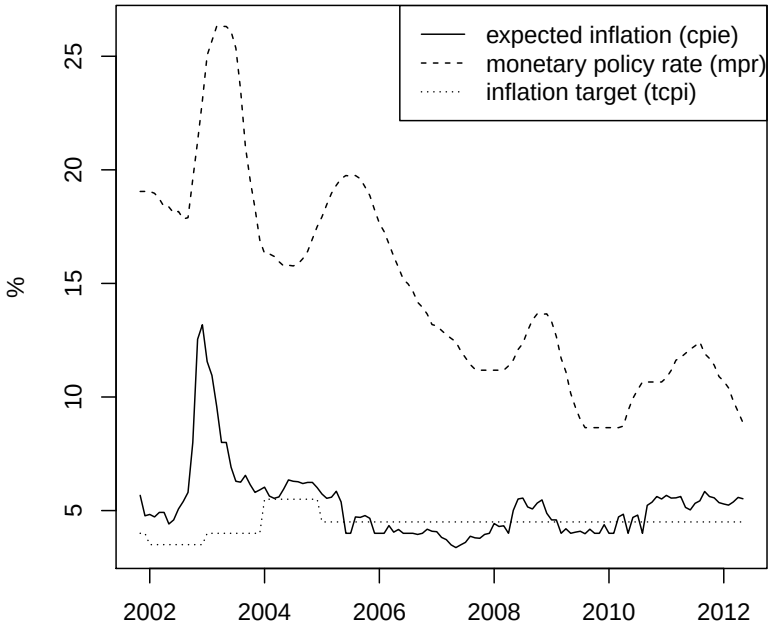


be charged by Brazilian bonds holders.

The very essence of the commitment to a target inflation comes from the Central Bank credibility. According to Minella et al. (2003) "private agents should believe that the central bank will act consistently within the inflation-targeting framework. Gaining credibility, however, takes time. In the context of large shocks, even with a strong response by the monetary authority, expectations will tend to deviate from the targets. In this case, communication with the market public to explain the reasons of the non-fulfillment of the targets becomes crucial. Furthermore, it is important that expectations converge to the target over a certain time horizon." Albeit transparency is paramount to credibility, the Brazilian Central Bank (BCB) does not publish its reaction function (Taylor rule) leaving the market to infer its dynamic structure. This study offers a novel estimation methodology of the reaction function in an effort to improve the market understanding of the evolution of monetary policy.

Figure 1 presents the expected inflation 12 months ahead (cpie) and inflation target (tcpi)to show that inflation was tamed in 2005/2006. Before that some adjustments were made to

Figure 2: Expected inflation (cpie) x Monetary Policy Rate (mpr)

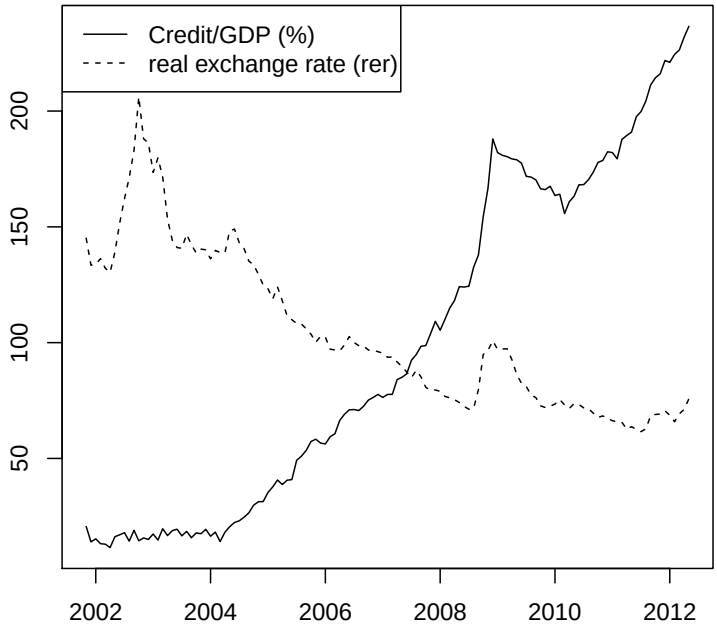


the target and its fluctuation band that later was set to ±2%. Only after 2006 the BCB gained the necessary credibility over inflation control. Figure 2 shows the evolution of inflation expectations (cpie) and the movements in the monetary policy rate.

In Garcia et al. (2011) the authors test the response of an advanced economy and an emerging economy to demand, cost-push and premium risk shocks if the Central Bank adopts a Taylor augmented (or hybrid) rule that incorporates the real exchange rate. Their simulations indicate that the origin of the demand shock matters: if domestic, the deterioration of trade balances induces an undesirable depreciation of the currency but if this positive demand shock originated abroad, a strong balance may induce a currency appreciation. The authors also conclude that emerging markets might gain by adopting hybrid Taylor rules specially when facing risk premium shocks.

Emerging economies bear some common aspects. Access to credit markets is restricted so consumption is more related to current income when compared to developed economies in which agents can smooth consumption through credit. In Brazil credit availability has

Figure 3: Credit/GDP x Real Exchange Rate (rer)



increased significantly as can be seen in figure 3 where the credit/GDP ratio expansion is presented to show how credit has risen fivefold in 2012 over its 2002 level. We can also see that after 2003 the exchange rate tended to appreciate in real terms. Emerging markets present some restrictions to capital mobility that renders foreign exchange interventions effective. Although these macroeconomic variables are relevant, it is not clear if and how the BCB incorporates the exchange rate and the expanded credit base in its monetary policy decisions.

What is generally accepted, though, is that policymakers are unwilling to allow sharp exchange rate movements whenever the pass-through effect is significant and movements in exchange rate might impact domestic inflation. This is particularly relevant in the context of depreciations in which there is a raising risk for domestic inflation that may materialize when the Marshall-Lerner condition[2] is valid. On the other hand, depreciation may expose the economy to balance sheet risks if a significant portion of domestic debt is denominated in

[2]The Marshall-Lerner condition states that exchange rates affect output when the sum of import and export elasticities is above 1 (Obstfeld and Rogoff (1996)).

foreign currencies, thus leading to the *Fear of Floating* syndrome (Calvo and Reinhart (2002)).

The alternative movement towards exchange rate appreciations bears risk for the competitiveness of manufactured goods in the international market. Brazil has undergone a relative reduction in the participation of the industrial sector on output, suggesting a de-industrialization process (Oreiro and Feijó (2010)), caused not only by the long-run appreciation of the Real but also from a fierce competition from China[3].

The mere volatility of exchange rate may also be undesirable as it introduces uncertainty in long-term contracts. Central Banks might be willing to intervene in foreign exchange markets not to set levels but to reduce volatility. Garcia et al. (2011) verify that placing some weight on the exchange rate in an open economy Taylor rule substantially reduces the volatility of output and inflation when facing demand shocks.

It can be expected that since inflation was tamed in 2006 the BCB may have changed its preferences about inflation hiatus and output gap by reweighting the coefficients in the reaction function, the Taylor rule that will be presented in the next section. In the inflation targeting period where inflation expectation data is available, from 2001 to 2012, the BCB has been ruled by three presidents whose mandates coincide with the Presidential mandates: Fernando Henrique Cardoso (from 1999 to 2003), Luiz Inácio Lula da Silva (from 2003 to 2010) and Dilma Rousseff (from 2011 to 2014).

Minella and Souza-Sobrinho (2009) showed that the exchange rate transmission channel is important in Brazil. It might be argued that in this context the BCB might have adopted a Taylor augmented rule to respond to increases in the expected inflation, in spite of the fact that this option was never explicitly communicated to the market[4]. If the appreciation of the Real is relevant for domestic inflation, interest rates might be calibrated to target specific exchange rate levels rather than to set specific inflation targets or output gaps.

The linearity of the Taylor rule might suggest that the monetary authority reacts symmet-

[3]Some other possible causes would be structural shortcomings that increase production costs such as high taxation, infrastructure bottlenecks and restricted exporters access to cheap financing.

[4]Central banks that follow the inflation targeting regime may enhance their credibility by improving communications with the market. Blinder et al. (2008) define central bank communication "as the provision of information by the central bank to the public regarding such matters as the objectives of monetary policy, the monetary policy strategy, the economic outlook, and the outlook for future policy decisions. Nowadays, it is widely accepted that the ability of a central bank to affect the economy depends critically on its ability to influence market expectations about the future path of overnight interest rates, and not merely on their current level."

rically to either positive or negative deviations of inflation from its target. Petersen (2007) uses a Logistic Smooth Transition Regressions (LSTR) to verify that the Fed follows a non-linear Taylor rule even not considering either the smoothing or the forward-looking aspects of the rule. Castro (2008) corrects these omissions and extends the investigation to verify that besides the Fed both the ECB (European Central Bank) and the BoE (Bank of England) adopted non-linear Taylor rules. This later work also uses LSTR technology to model the transitions between monetary policy regimes modeled as endogenous breaks. The author justifies the choice by "allowing for endogenous regime switches – contrary to the Markov-switching models – it also provides economic intuition for the nonlinear policy behavior of the central bank and it is able to explain why and when the central bank changes its policy rule."

We will proceed after this introduction to present two theories for short-term interest rate in section 2, Bayesian inference and forecasting methodologies are introduced in section 3, data and results are presented in section 4 and we propose some conclusions in section 5.

2 Theories for short-term interest rate

2.1 The Taylor rule

Essential to any central bank toolkit the Taylor rule was empirically devised by John Taylor in early 1990. This generated a new strand in monetary policy literature in a time when money supply was losing the prominent place it held since the end of 1960[5]. At a time when most believed that a new instrument of monetary policy should be chosen, the new rule brought much needed light. Agents would be able to predict the future path of the short-term basic rate. The rule simplicity may be an important reason for its choice as the *de facto* instrument of monetary policy and a key macroeconomic indicator for asset prices throughout the economy.

[5]Friedman (1968) stated his option for monetary policy instrument: "The first requirement is that the monetary authority should guide itself by magnitudes that it can control, not by ones that it cannot control. If, as the authority has often done, it takes interest rates or the current unemployment percentage as the immediate criterion of policy, it will be like a space vehicle that has taken a fix on the wrong star. No matter how sensitive and sophisticated its guiding apparatus, the space vehicle will go astray. (...) I believe that a monetary total is the best currently available immediate guide or criterion for monetary policy - and I believe that it matters much less which particular total is chosen than that one be chosen."

Originally the Taylor rule was stated as

$$i_t = \bar{i} + 1.5(\pi_t - \bar{\pi}) + 0.5(y_t - \bar{y}) + \nu_t$$

where i_t is the nominal interest rate, $\bar{i}$ is the natural interest rate, π_t is the inflation rate, $\bar{\pi}$ is the inflation target, y_t is output and $\bar{y}$ is the natural product. The difference between inflation and its target is the "inflation hiatus", $(\pi_t - \bar{\pi})$, and the difference between product and potential output is the "product gap", $(y_t - \bar{y})$.

Yet this apparent simplicity can be quite elusive as this rule proved to be rather difficult to estimate. An important issue to estimate a Taylor rule is that the natural interest rate and the natural product are both non-observed variables. The natural interest rate according to Woodford (2003a) is "the equilibrium rate of return in the case of fully flexible prices" and the natural product is the product that would exist should there not be any frictions such as monopolistic competition or price and wage rigidities. Let's briefly review four issues concerning the estimation of this rule.

The first problem with the Taylor rule specification is that the key parameters of natural interest rate and the natural product are not known by the policymaker at the time when a decision must be made. Orphanides (2001) discusses the relevance of using historical, unrevised data available to the policymaker: "Retrospectively, the "appropriate" policy setting for a particular quarter may appear different with subsequent renditions of the data necessary to evaluate the rule for that quarter. Through a distorted glass, the interpretation of historical episodes may change."

Certain parameters are either not observed or not precisely measurable when a decision is made. The usual way to estimate these non-observed components in the econometric literature is to filter the output time series with a Hodrick-Prescott filter to generate a smoothed series that would represent the long run equilibrium. Another form of eliciting both the natural interest rate and the ouput gap is to impose a structural model as did Laubach and Williams (2003). The key insight of this model is that both unobserved components share a common

factor, g_t, assumed to have a unit root:

$$\bar{i}_t = \gamma_t g_t + z_t \quad \text{and} \quad \bar{y}_t = \bar{y}_{t-1} + g_{t-1} + \epsilon_t$$

The stochastic process z_t may be a stationary auto-regressive process (generally of low order) but it may also have a unit root. The authors postulate that natural output is I(2) and explain that "as Stock and Watson (1998) point out, when the disturbance to the growth rate component has small variance, such a test statistic has a high false-rejection rate."

A second issue in estimating the Taylor rule concerns the forward-looking aspect of the reaction function as discussed by Clarida et al. (2000). There is a delay from 6 to 12 months to transmit unanticipated shocks to the MPR to inflation Walsh (2010). This requires that the Central Bank focuses in the future inflation, generally 12 months ahead. There is also an "expectation channel" that captures the effects of monetary policy shocks through changes in inflation expectations. The Taylor rule can be written as:

$$i_t = \bar{i}_t + \beta_{\pi^e}(\pi^e_{t+k|t} - \bar{\pi}_t) + \beta_\pi(\pi_t - \bar{\pi}_t) + \beta_y(y_t - \bar{y}_t) + \nu_t$$

The expectations provided by the FOCUS bulletin, a survey made weekly next to market participants, is generally accepted as the best indicator of future inflation and frequently cited in the Monetary Policy Committee (COPOM) minutes. Note that in the above equation the current inflation term is preserved: its significance indicates some degree of backward-looking by the Central Bank.

A third issue concerns the inertia of interest rates. The inertia in the interest rate rule is explained by Woodford (2003b) as a way to influence the market about the future path of interest rates: "an effective response by the Fed to inflationary pressures, say, requires that the private sector be able to believe that the entire future path of short rates has changed. A policy that maintains interest rates at a higher level for a period of time once they are raised – or even following initial small interest-rate changes by further changes in the same direction, in the absence of a change in conditions that makes this unnecessary – is one that, if understood by the private sector, will allow a moderate adjustment of current short rates to

have a significant effect on long rates."

Some authors distinguish between the Taylor rule and the central bank response by stating that the response rule incorporates inertia in interest rates while the Taylor rule is just the sum of the original three components. We use these expressions interchangeably, for us the Taylor rule incorporates inertia as in:

$$i_t = \rho i_{t-1} + (1-\rho)\left[\bar{i}_t + \beta_{\pi^e}(\pi^e_{t+k|t} - \bar{\pi}_t) + \beta_y(y_t - \bar{y}_t)\right] + \nu_t$$

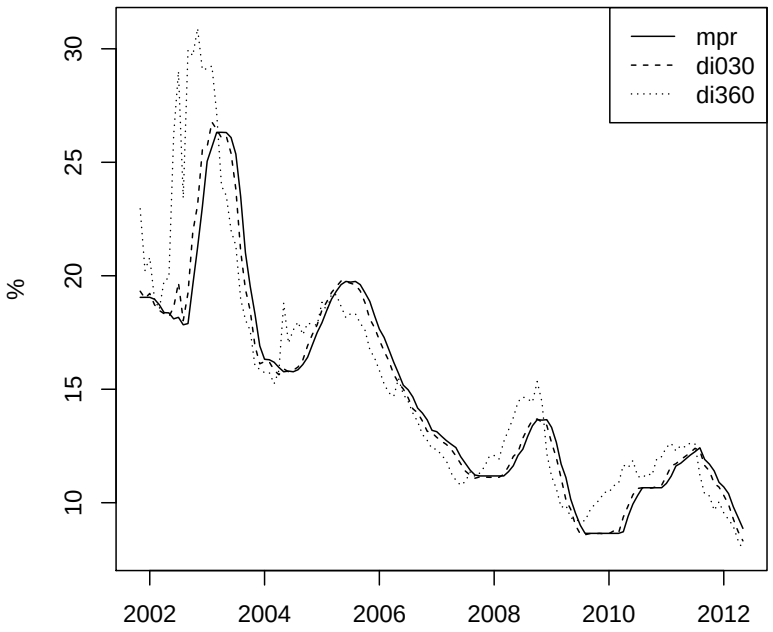
Even if we agree with Lansing (2002) that the interest rate smoothing is an illusion caused by the use of final data, as opposed to real-time data used by the central bank, there is still some degree of auto-correlation in the interest rate series, albeit smaller than the traditionally estimated at 0.8. Rudebush (2002) opposes the concept of inertia on quarterly interest rates by studying the behavior of interest rates at the short-term end of the yield curve. He believes that the illusion of inertia is the result of persistent shocks that cause the central bank to deviate from the policy rule. Yet, he does not deny the existence of smoothing on a monthly basis. More recently Coibion and Gorodnichenko (2012) offer another explanation to the persistence of interest rates: "the higher order auto-regressive process for interest smoothing may have been capturing the central bank's response to the private sector's information set. This suggests a novel potential explanation for deviations of actual interest rates from standard Taylor rule prescriptions." To be practical this study considers an auto-regressive process for the MPR.

A fourth issue to be addressed is the stability of the parameters of the reaction function. A linear model with time varying parameters is:

$$i_t = \rho_t i_{t-1} + \beta_{i,t}\bar{i}_t + \beta_{\pi^e,t}(\pi^e_{t+k|t} - \bar{\pi}_t) + \beta_{y,t}(y_t - \bar{y}_t) + \nu_t$$

Figure 3 suggests that the policy rate increases as the inflation expectation rises towards the inflation target upper bound and that it might be reduced when inflation is under control but output is negatively affected.

Figure 4: Interest rates: MPR, DI030, DI360



2.2 The Expectations Theory of the Term Structure

The Expectations Theory of the Term Structure (Walsh (2010, Chap. 10)) states that monetary policy affects long-term interest rates by directly influencing short-term rates and by altering market expectations of future short-term rates

$$(1 + i_{n,t})^n = \prod_{h=0}^{n-1} (1 + i_{t+h})$$

where $i_{n,t}$ is the nominal yield to maturity at time t on an n period discount bond and i_t the short-term rate. Taking the logs and recalling that $log(1 + x) \approx x$

$$i_{n,t} = \sum_{h=1}^{n-1} i_{t+h}$$

$$(1 + i_{n,t})^n = (1 + i_t)(1 + i_{n-1,t+1})^{n-1}$$

In figure 4 we can compare the short rate (mpr), the 30 days (di030) and one year (di360)

maturities. They exhibit a common behavior in time but with closer horizons, the curves get smoother.

The long-term nominal interest rate depends on current short-rate and market expectations of future short-rates

$$I_t^n = E_t \left[\frac{1}{n} \sum_{h=1}^{n-1} i_{t+h} \right] + E_t \phi_t^n$$

where I_t^n is the long-term nominal interest rate at horizon n and ϕ_t^n is average risk premium.

In the rest of this paper we address this approach as "atheoretic" as it does not involve a causal relation among interest rates and explanatory variables. This is a naming convention and does not imply that the referred theory is not valid. Actually, the Expectations Theory implies a long-term relationship between short-term and long-term rates that was tested for cointegration with an error correction model (Johansen (1995)) as in

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \delta X_{t-i} + \epsilon_t$$

where $X_t = (i_t, i_t^{30}, i_t^{60}, i_t^{90}, i_t^{120}, i_t^{180}, i_t^{360})$ and i_t^{360} is the one-year interbank swap contract. Tests in table 1 suggest a cointegration rank of $r = 5$ with 2 or 3 lags.

3 Bayesian Inference and Forecasting

Bayesian inference allows for pre-existing knowledge about the observed phenomenon to be factored in the model, embedded in a prior distribution of the parameters to be estimated. Generally the prior brings expert insight that will be confronted with observed data. From this observation, a posterior distribution is generated that may confirm the prior insight or contradict it. Either way the outcome is directly influenced by the choice of priors. The need for a prior distribution over unknown parameters may be seen as a limitation of the method. This requirement is usually met with uncompromising, uninformative priors that forsake the opportunity to bring additional previous knowledge to the inference process.

The advantages of adopting Bayesian methods are, on the other hand, significant. First, Bayesian inference supports both linear and non-linear models in the same estimation frame-

work and therefore avoids the need for detecting and treating structural breaks in the data. Second, Bayesian inference is very efficient as it transforms an optimization problem, the cornerstone of the maximum likelihood approach, into an integral calculation that is less computationally intense. Closed form posteriors (like the ones generated from conjugate Normal-Gamma priors) are popular ways to increase computational efficiency even more. Yet, with the average computer power available today, any distribution can be quickly sampled using MCMC (Markov Chain Monte Carlo) algorithms, as we do.

Given the potential upside from the adoption of Bayesian inference a thriving literature tries to elicit an objective process for prior selection. In this paper we present recent prior proposals and test them by forecasting the short-term monetary policy rate in Brazil. To get results that are comparable to those in existing literature we assume a linear relation between $\mathbf{y}$ $(N \times 1)$ and the covariates $\mathbf{X}$ $(N \times K)$ for the model M_s as in

$$\mathbf{y} = \mathbf{X}\beta_s + \epsilon_s \qquad \text{where} \qquad \epsilon_s \sim N(0, \sigma_s^2 \mathbf{I}) \tag{1}$$

When comparing two candidate models, the *posterior odds* ratio combines the marginal posterior probabilities of two competing models M_i and M_j for a direct comparison between them given the observed data y. Posterior odds are written as

$$\frac{p(M_i|y,X)}{p(M_j|y,X)} = \frac{p(M_i|X)}{p(M_j|X)} \frac{p(y|M_i,X)}{p(y|M_j,X)}$$

because by the Bayes theorem: $p(M_i|y,X)p(y|X) = p(y|M_i,X)p(M_i|X)$.

The posterior odds ratio can be decomposed into the product of the *prior odds ratio* and the marginal likelihood ratios, also known as the *Bayes Factor* (Kass and Raftery (1995)) defined as

$$B(M_i, M_j) \equiv \frac{p(y|M_i,X)}{p(y|M_j,X)}$$

A Bayes Factor $B(M_i, M_j)$ higher than one indicates the superiority of model M_i over M_j.

Prior selection affects Bayes Factors. The use of an *improper prior*[6] is not permitted in model selection since posterior model probabilities and Bayes Factors may be indeterminate

[6]i.e. a distribution density probability function that does not integrate to 1, an "infinitely spread-out prior".

as improper priors are determined only up to an arbitrary multiplicative constant (Berger and Pericchi (2001)).

Congdon (2003, Chap. 2) tackles prior selection from an identification perspective: "[T]he major issues in identifying mixture models using parametric densities $f(y|\theta_j)$ are the general question of identifiability in the face of possibly flat likelihoods (Bohning (2000)), and the specification of appropriate priors that are objective, but also effective in estimation. Thus, Wasserman (2000) cites the hindrance in mixture modelling arising from the fact that improper priors yield improper posteriors. More generally, vague priors even if proper, may lead to poorly identified posterior solutions, especially for small samples. Various approaches to prior specification in mixture modelling have been proposed and often mildly informative proper priors based on subject matter knowledge may be employed."

Before discussing model averaging we briefly present the process of model selection to show how models can be sorted conditionally on the observed data. In a model averaging context this ranking translates into a weighting function.

3.1 The Choice of Priors

Zellner (1986) proposes a family of gaussian priors on the coefficients β_s of equation 1 known as the *g-priors*. These priors are considered as fixed because they do not adapt to observed data and only reflect the researcher's perspective and confidence on parameter distributions:

$$p(\sigma_s) = 1/\sigma_s$$
$$\pi(\beta_s|\sigma_s, M_s) \sim N(0, \frac{g}{\sigma_s}(X'X)^{-1})$$

As Liang et al. (2008) we assume a null-based approach[7] to calculate the Bayes factor as

$$BF(M_s, M_N) = (1+g)^{(n-k-1)/2}(1+g(1-R_s^2))^{-(n-1)/2}$$

where R_s is the determination coefficient for model M_s and k is model's size (number of regressors).

[7]In this case, the base model is the null model $M_N : y_t = \epsilon_t$

When setting priors, there are generally two criteria for prior selection: the Bartlett's paradox and the Information paradox (Liang et al. (2008)). The Bartlett's paradox states that uninformative priors tend to favor the parsimonious null model.

The Information paradox states that Bayes Factor may not perform well when faced with information overload. As model's M_s coefficient of determination, R_s^2, goes to 1, the Bayes Factor, when compared to the null model, should go to infinity. Actually for some priors (like the Zellner g-prior) as posterior probability increases the Bayes Factor is bounded and therefore looses its selection capability.

Feldkircher and Zeugner (2009) argue that, beyond Bayes Factors, marginal likelihood characteristics should affect priors choice. They argue that the elicitation of g should be guided by consistency concerns and the use of g as a penalty term to enforce parameter parsimony. Consistency assures that the choice of g is such that posterior model probabilities asymptotically uncover 'the true model' M_T, i.e. $p(M_T|Y) \to 1$ as $N \to \infty$.

Considering the implications of the choice of g to parsimony, Liang et al. (2008) point out that under Uniform prior, the choice of g determines model selection: large values for g tend to concentrate the prior on parsimonious models with a few large coefficients and conversely small g tend to concentrate the prior on saturated models with small coefficients.

The hyperparameter g conveys how much certainty the researcher has about that coefficients are zero. A small g means little prior coefficient variance and implies confidence that the coefficients are indeed zero. In contrast, a large g suggests uncertainty and may not be robust to noise innovations and risks over-fitting by using more terms than necessary to reproduce the data generating process.

Fernandez et al. (2001) lists other automatic prior generation criteria. Some popular priors are (N is the sample size and K the model size):

1. Unit Information Prior (UIP): $g = N$.
2. Risk Inflation Criterion Prior (RIC): $g = K^2$.
3. Benchmark RIC (BRIC): $g = max(N, K^2)$.
4. Empirical Bayes Local (EBL): $g_s = \arg\max_g p(y|M_s, X, g)$.

Liang et al. (2008) show that the UIP, RIC, and BRIC priors do not resolve the Information paradox for fixed N and K since the choices of g are fixed values not depending on the information in the data. Only the EBL approach has the desirable behavior (see Appendix).

3.2 Hyper-g priors

Liang et al. (2008) introduce a family of priors $\pi(g)$ on $g(g > 0)$ as in

$$\pi(g) = \frac{a-2}{2}(1+g)^{-a/2}$$

The authors propose the *hyper-g* priors, a new class of flexible-g hierarchical priors based on the hypergeometric distribution, with a closed form posterior distribution of g given by

$$p(g|X, M_s) = \frac{p_s + a - 2}{2F(\frac{n-1}{2}, 1, \frac{p_s+a}{2}, R_s^2)}(1+g)^{(n-1-p_s-a)/2}\left[1 + (1-R_s^2)g\right]^{-(n-1)/2}$$

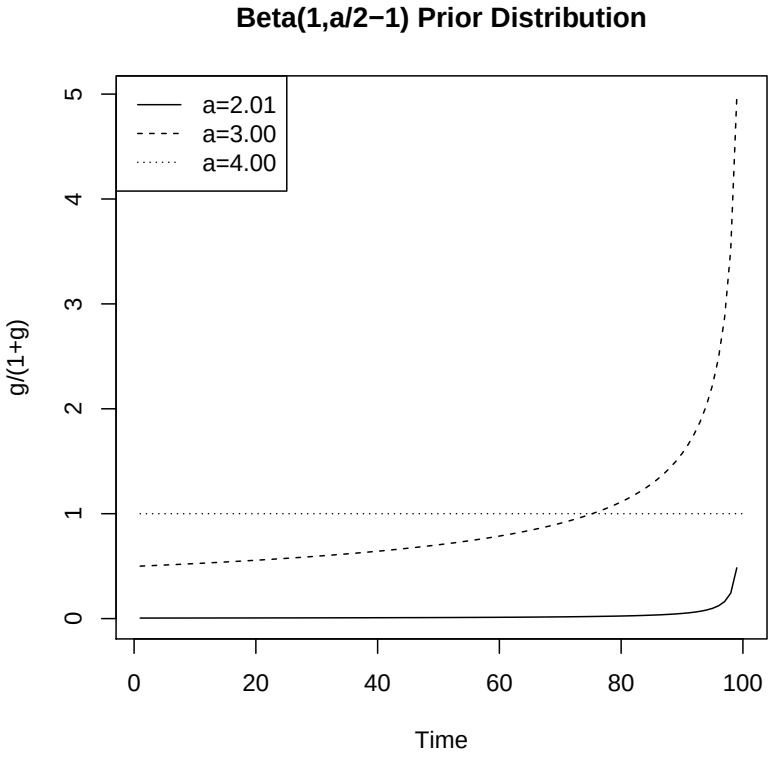
where n is the sample size, p_s is the number of covariates in model M_s and $F()$ is the gaussian hypergeometric distribution as given by

$$F(a, b, c, x) = \frac{\Gamma(c)}{\Gamma(b)\Gamma(b-c)}\int_0^1 y^{b-1}(1-y)^{c-b-1}(1-xy)^{-a}dy$$

The authors show that this prior solves the Information paradox.

The hyper-g priors fare better when compared to fixed-g priors, specially when facing noisy data because hyper-g priors dilute the posterior mass among models while fixed-g priors incorrectly favors one model. This is a symptom of the "supermodel effect". As documented by Feldkircher and Zeugner (2009) the supermodel effect refers to the concentration of posterior mass on a few models as indicated by the choice of g. The hyper-g prior is less exposed to this effect than a fixed-g prior because it adjusts the distribution of posterior mass according to the information provided by the data. The authors empirically showed that: "[S]mall degrees of noise trigger a concentration of posterior mass under the hyper-g prior and the empirical Bayes approach. A surge in noise is reflected in a wider spread of posterior mass among models under flexible priors, whereas fixed priors still concentrate on a small number of models."

Figure 5: Hyper-g Priors for different value of a



Hyper-g priors are shrinkage priors. Shrinkage priors provide a continuous alternative to point mass mixture priors. Komaki (2006) shows that the use of shrinkage priors for Bayesian predictive distributions asymptotically dominates improper priors (such as the Jeffreys' prior). Liang et al. (2008) show that the hyper-g prior translates into a Beta[8]prior on the shrinkage factor[9] $\gamma = \frac{g}{1+g}$ in a hierarchical setup that further simplifies the prior definition:

$$\frac{g}{1+g} \sim Beta\left(1, \frac{a}{2} - 1\right) \qquad \text{therefore} \qquad E(\frac{g}{1+g}) = \frac{2}{a}$$

The researcher's choice now concerns $a \in (2, 4]$ where $\pi(g)$ is always proper. The choice $a = 4$ makes the prior uniform, while as a moves to 2 the prior mass of the shrinkage factor concentrates close to 1 as can be seen in figure 5.

[8]If $X \sim Beta(a, b)$, $f(x) = \Gamma(a+b)/(\Gamma(a)\Gamma(b))x^{a-1}(1-x)^{b-1}$ and $E(X) = a/(a+b)$

[9]The "shrinkage factor" γ affects the distribution of the coefficients since $E(\beta_i|\gamma) = (1-\gamma)\beta_i + \gamma E(\beta_i)$.

3.3 Bayesian Model Averaging

From the previous Taylor rule discussion it is clear that there is a high level of uncertainty about model composition and dynamics. The Central Banker preferences may evolve from a pure inflation target to a dual target (inflation hiatus and output gap) and extend the original rule to include other factors (RER and Credit-to-GDP) that reflect different transmission channels of Monetary Policy. There is a Bayesian tool that is flexible enough to allow for both parameter and model uncertainties.

Bayesian Model Averaging[10] (BMA) is an efficient tool to handle the model uncertainty problem. As parameter uncertainty is intrinsically handled by Bayesian inference and different models are weighted according to their corresponding Bayes Factors the researcher does not have to choose a single model and can work with a set of models, with different structures, weighed according to the observed data. This supersedes the structural model choice as all models are always considered[11]. Ley and Steel (2007) show the influence of prior choice to BMA results.

BMA has been increasingly considered since Raftery et al. (1997) and Fernandez et al. (2001) showed the improved forecasting performance of this class of models. BMA factors in model uncertainty by basing inference on a weighted average of all possible models. In the Bayesian framework weighting comes naturally from posterior model probabilities (PMP). The PMP $p(M_s|y, X, g)$ for model M_s conditional on data (y, X) is proportional to the marginal likelihood $p(y|M_s, X)$ times a model prior $p(M_s)$ as in:

$$p(M_s|y, X) \propto p(y|M_s, X)p(M_s|X)$$

If K_s is the number of covariates in model M_s there are 2^{K_s} possible sampling models, depending on whether we include or exclude each of the regressors. The posterior model probabilities is given by

$$p(M_s|y, X, g) = \frac{p(y|M_s, X, g)p(M_s|X, g)}{p(y|M_s, X, g)} = \frac{p(y|M_s, X, g)p(M_s|X, g)}{\sum_{j=1}^{2^K} p(y|M_j, X, g)p(M_j)}$$

[10] Hoeting et al. (1999) offer a detailed tutorial and software tools.

[11] Weighting with a zero-weight prior permanently excludes a model from the model set.

As shown by Feldkircher and Zeugner (2009) the Bayes Factor for hyper-g priors allows for the comparison of any two models M_s and M_j by assessing their relative weights:

$$B(M_s, M_j) \equiv \frac{p(y|M_s, X, g)}{p(y|M_j, X, g)} = (1+g)^{\frac{K_j - K_s}{2}} \left(\frac{1 - \frac{g}{1+g} R_s^2}{1 - \frac{g}{1+g} R_j^2} \right)^{-\frac{N-1}{2}}$$

Model averaging is the marginal posterior distribution of the parameter set $\theta = (\beta, \alpha, \sigma)$ obtained by mixing posterior model probabilities:

$$p(\theta|y, X) = \sum_{j=1}^{2^K} p(\theta|y, X, M_j) p(M_j|y, X)$$

A common criticism of the BMA methodology is that it is always possible to find a better fitting model than the weighted average model. One may face this situation under two perspectives. The pragmatic researcher may treat BMA results as a benchmark to be beaten while the cautious researcher may prefer to use an encompassing method. As the dynamics of the underlying process may change the optimal model at each point in time BMA seems to be the ideal tool for inference, yet the true quality of a model may stem from its predictive power, this is why we take the proposed models a step further and test their predictive performance.

3.4 Bayesian Forecasting

Geweke and Whiteman (2006) stress the importance of the posterior predictive probability distribution for Bayesian forecasting: "A principal attraction of the Bayesian structure is its internal logical consistency, a useful and sometimes distinguishing property in applied economic forecasting. But the external consistency of the structure is also critical to successful forecasting: a set of bad models, no matter how consistently applied, will produce bad forecasts. (...) One of the most useful tools in the evaluation of external consistency is the posterior predictive distribution".

We recall that $X = (x_1, \ldots, x_N)$ and $y = (y_1, \ldots, y_N)$. If we define the h-step forecasts by

$X_h = (x_{N+1}, \ldots, x_{N+h})$ the predictive posterior probability at $N + h$ is

$$p(M_s|X_h, y, X) = \frac{p(y_h|X_h, y, X)p(X_h|y, X)}{\sum_{j=1}^{2^K} p(y_h|X_h, y, X, M_j)p(M_j|X_h, y, X)}$$

where the predictive likelihood for one-step ahead is

$$p(y_h|X_h, y, X) = \int p(y_h|\theta_j, X_h, y, X)p(\theta_j|X_h, y, X)\, d\theta_j$$

The predictive likelihood can be obtained by simulation from the posterior $N - N_b$ draws (N_b is the size of the burnin sample) of the parameters θ_s^j as in

$$p(y_h|X_h, y, X, M_s) = \frac{1}{N - N_b} \sum_{j=N_b+1}^{N} p(y_h|\theta_s^j, X_h, y, X, M_s)$$

To gauge quality of the out-of-sample forecasting we use the Log Predictive Probability (LPS). LPS is an approximation to the expected loss with a logarithmic rule related to the well-known Kullback-Leibler criterion (see Appendix). It is defined for a h-step ahead predictive likelihood as

$$LPS(X_h, y, X) \equiv -\frac{1}{h} \sum_{i=1}^{h} \ln p(y_{N+i}|X_h, y, X)$$

The smaller the value of LPS the better is the model in terms of forecasting. We use a BMA version of LPS to take into account the predictive likelihood of all the models. When analyzing forecast results, we provide both out-of-sample MAPE and LPS measures. The MAPE shows how the set of models predicted with the existing dataset while LPS indicates the model predictive capabilities and may be considered a better measure of quality as it is not limited by the quality of the dataset used neither in estimation nor forecasting.

4 Data and Results

Table 2 brings data sources while table 3 presents basic descriptive statistics for the full sample, from November 2001 up to May 2012. This sample choice is determined by data availability. In order to conduct out-of-sample forecasting we split the sample in two parts: a training period

from November 2001 up to September 2009 and a forecasting period from October 2009 up to May 2012. The out-of-sample dynamic forecast is performed with a rolling window over forecasting period.

(Place Table 2 about here)

(Place Table 3 about here)

To measure model predictive accuracy four statistics were used: the p-value for the well-known Diebold and Mariano (1995) predictive accuracy test, the in-sample and out-of-sample MAPE[12] (Mean Average Percentage Error) measures and the Log Predictive Score (LPS). All sampling was conducted by a MCMC birth/death algorithm (see Appendix) with $N = 100.000$ draws and $N_b = 50.000$ burnin sample size.

(Place Table 4 about here)

Table 4 is ordered according to posterior inclusion probabilities (PIP). PIP is the sum of the posterior model probabilities (PMP) for all models wherein the covariate was included. The next columns present the estimated coefficient posterior mean and standard deviation. All models are estimated with UIP (Unit Information Priors) as it is the underlying prior for the BIC selection criterion (see Appendix). Model M01 is a simple AR(1) used as a reference. Model M02 is standard Taylor. M03 is an augmented Taylor. Model M04 is a mix between extended Taylor regressors and yield curve components. DI030 stands for the average interbank rate for the 30 day maturity contract and so on until DI360 that covers maturities of one year.

The Diebold Mariano test (see Appendix) is conducted comparing the residuals for each model from an optimum series of zeros (perfect match). The p-values indicate that the null hypothesis (that model residuals are zero) is rejected for all models except M01, what could be expected since this model presents a very low in-sample MAPE of 0.05% that is much lower than the second best of 0.23%. Anyway, this test does not look adequate to sort models in this BMA framework as all models generate the same p-value close to zero.

Of all models, M01 has the best in-sample, with the lowest MAPE, but the lowest out-of-

[12] $MAPE = \sum_{t=1}^{T} |\epsilon_t|/T$ where ϵ_t is the forecast error given by $\epsilon_t = y_t - y_{t|t-1}$ (see Appendix).

sample MAPE is from M04. Model M04 also has the lowest LPS, suggesting a better predictive capacity. The most relevant covariates are the one period lagged MPR, MPR(-1), and the DI030 contract. Both present not only high PIPs but are also statistically significant (we assume their distributions to follow gaussian normal distributions). The other most frequent covariates, DI090 and DI060, should appear in only 25% and 24% of the models (out of $2^{16} = 65536$ possible) but are not statistically significant. Neither are the real exchange rate (RER) or its lead (1 period look-ahead rate), RER(+1). As M04 has the best indicator for predictive performance, next we will test this model with different fixed and flexible priors. Worth mentioning is the fact that even when most covariates are not statistically significant, when they are present the model's predictive capacity increases because their presence reduces the error variance (bias-variance trade-off).

(Place Table 5 about here)

Table 5 compares different fixed priors: RIC, BRIC and EBL. The qualitative choice of covariates is not changed, MPR(-1) and DI030 are omnipresent with roughly the same coefficients: 0.42 for MPR(-1) and 0.79 for DI030. The difference might induce to believe that DI030 is more relevant to predict the MPR but as the standard-error for DI030 is larger than the one for MPR(-1) it is not clear that the coefficients so distant apart so both covariates are equally relevant.

This result can be interpreted as good news: the BCB appears to be conducting communications with the market in an efficient manner because agents are able to predict the monetary policy instrument level and price it in the yield curve. If the MAPE measures are basically the same for all three models, the relevant difference is again in the Log Predictive Score (LPS). The EBL prior generates a significantly lower LPS of -0.800 when compare to the -0.194 from RIC and BRIC. BRIC's LPS is actually a little smaller than RIC's but this is not reported due to the rounding display settings. So far EBL would be the best prior to use. We now estimate with hyper-g priors and expect an even better predictive capacity.

(Place Table 6 about here)

Table 6 presents model M04 with hyper-g priors with $a = 2.01$, $a = 3$ and $a = 4$. The

in-sample and out-of-sample indicators have not changed, suggesting they are not adequate measures of the differences. LPS is basically the same for all three, between -0.58 and -.0.59 suggesting that they offer good forecasting capacity but not as much as the models estimated with EBL priors. A noteworthy result is that the relative importance of the covariates changes. In previous models, DI030 and the lagged MPR had basically the same relevance, now the same qualitative result applies: MPR(-1) has an average coefficient of 0.51 while DI030 has a coefficient circa 0.47 with a somewhat higher standard error. This clearly indicates that both covariates offer the same degree of predictive capacity. DI030 is present on average in 93% of the models, while before it would be present in 100% of the models. The importance of this covariate dropped in terms of PIP from 100% to 93% now, but as the standard error also dropped we understand this to be an important covariate for prediction.

(Place Table 7 about here)

As a final result we test all the priors in a pure yield curve model in table 7. The results were qualitative compatible to the ones with the mixed, Taylor + Yield, M04 model. The EBL prior leads to the lowest LPS but this time the results are coherent: a lower LPS translates into a lower MAPE for both in and out-of-samples. EBL priors generate the lowest in-sample MAPE (0.16%) of all models studied while its out-of-sample (0.39%) is also amongst the lowest ones. This performance is acceptable in a production environment.

We could verify that priors matter: the flexible g priors offer better predictive performance that the fixed-g priors, as expected. The use of flexible priors with different hyper-parameters also allowed for lower in and out-of-sample MAPEs but Log Predictive Score is worse when compared to the EBL prior model.

5 Conclusions

Albeit priors allow for expert insights, forecasting models should require as little previous knowledge as possible. By verifying that prior choice impacts the predictive accuracy this paper offers guidance for a better forecasting framework that might reduce the need for previous knowledge about macroeconomic variable paths.

The empirical results confirm the relevance of the prior choice for improved predictive performance. The key to prior choice seems to be the flexibility of the prior to adapt to different noise levels in data. While we expected the hyper-g priors to dominate both in-sample and out-of-sample predictions, we verified that Local Empirical Bayes (EBL) priors, in which the prior distribution is also estimated from the data, provide superior predictive performance. This result reinforces EBL priors as good alternatives as they are proper, consistent priors and do not suffer from the Information paradox limitations. In terms of performance, hyper-g priors may offer some advantage given their closed form posterior distributions. The collected data on time performance during our experiments does not allow for a definite conclusion on this.

The discussion over the best empirical model to estimate an Taylor rule and the high quality predictions of the short-term interest rates in an emerging market riddled with high volatility, suggest that the lack of a sound theoretic model is not an impediment to construct good forecasting models for macroeconomic indicators. Future research could extend this exploration to forecast other macroeconomic relevant indicators notably economic activity, price and wage inflations, and exchange rate.

Finally we may also conclude in favor of the Brazilian Central Bank communication efforts since the interbank market predicts with great accuracy the level of the monetary policy instrument, selic. Finally, another interesting conclusion is that the best predictive model comes from a combination of a forward-looker Taylor rule based model, with an atheoretic yield curve model. Although the yield curve offers enough information for a good predictive performance our results indicate that the best path is to mix covariates from both models and choose a hyper-g prior.

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Technical Appendix

Bayes factors consistency

Liang et al. (2008) showed that EBL and hyper-g priors have consistent Bayes factors when the true model is not the null one. The null-based Bayes factors for these priors are:

$$BF_{EBL}(M_s, M_N) = \frac{(1+g)^{\frac{(n-p-1)}{2}}}{(1+(1-R_s^2))g^{\frac{(n-1)}{2}}} \leq (1-R_s^2)^{\frac{-(n-1)}{2}}$$

$$BF_{h-g}(M_s, M_N) = \int L(g)\pi(g)\,dg = \int \left(1 - R_s^2 \frac{g}{1+g}\right)^{-\frac{(n-1)}{2}} \frac{\pi(g)}{(1+g)^{p/2}}\,dg$$

Assuming that the true model is not the null one both Bayes factors are consistent, ie. they tend to zero as the sample size increases

$$\underset{n\to\infty}{plim}\, BF(M_s, M_N) = 0$$

Unit Information Prior (UIP)

Under Kass and Raftery (1995) recommendation, we chose UIP as our reference prior: "if one were willing to use this prior as a reference prior, the Schawrz criterion would be a reasonably good approximation of the log to the Bayes factor."

The Unit Information Prior is a multivariate normal prior with mean at the maximum likelihood estimate and variance equal to the expected information matrix for one observation. Roughly speaking, this prior corresponds to assigning the same amount of information to the conditional prior of β as is contained in one observation.

As discussed in Raftery (1998) Unit Information Priors are the implicit priors used in BIC (bayesian information criteria) indicators. "[T]he unit information prior is well spread-out relative to the likelihood, and is relatively flat within the part of parameter space where the likelihood is substantial, without being much larger outside it. (...) In this situation, we can say that the likelihood dominates the prior. The unit information prior usually leads us to be in this (often desirable) situation. (...) Most of the criticisms of the unit information prior on which BIC is based imply that it is too spread out".

Risk Inflation Criterion Prior (RIC)

George and Foster (2000) named their prior proposal as Risk Inflation Criterion (RIC) because it asymptotically minimizes the maximum predictive risk inflation. Let $X = (x_1, \ldots, x_p)$ and the set of models $\gamma = 1, \ldots, 2^p$. The dimensions are X_γ is $(n \times q)$, β_γ is $(p \times 1)$. Let's assume the model

$$Y = X\beta + \epsilon \quad \text{where} \quad \epsilon \sim N_n(0, \sigma^2 I)$$

The sum of squares errors SSE_γ is the regression sum of squares for the γth model.

$$SSE_\gamma = Y'Y - \hat{\beta}'_\gamma X'_\gamma X_\gamma \hat{\beta}_\gamma$$

The penalised sum of squares criterion entails picking the γth model that minimizes $SSE_\gamma/\hat{\sigma}^2 + Fq_\gamma$ where F can be interpreted as a 'dimensionality penalty'. For $F = \log(n)$ we have BIC and for $F = 2\log(p)$ we have RIC.

Empirical Bayes Priors

Empirical Bayes was developed by George and Foster (2000). "To avoid some of the difficulties of a fully Bayes approach, we propose an empirical Bayes approximation that uses the data to estimate c and w. Although such an approximation ignores the uncertainty of the estimates by treating them as known, as opposed to a fully Bayes marginalisation over c and w, it at least avoids using arbitrary choices of c and w which may be at odds with the data." (c and w are hyper-parameters)

Empirical Bayes estimators are flexible and robust. According to Lehmann and Casella (1998) they have "proven to be an effective technique of constructing estimators that perform well under both Bayesian and frequentist criteria. One reason for this is that empirical Bayes estimators tend to be more robust against misspecification of the prior distribution."

In a hierarchical setup the desired model is conditioned on a θ parameter that is distributed

according to a γ hyper-parameter that must be estimated based on the sample data X_i:

$$X_i|\theta \sim f(x|\theta)$$

$$\theta|\gamma \sim \pi(\theta|\gamma)$$

The marginal likelihood of $\mathbf{X}$ has density:

$$m(\mathbf{x}|\gamma) = \int \prod f(x_i|\theta)\pi(\theta|\gamma)\, d\theta$$

We estimate $\hat{\gamma}(\mathbf{x})$ by MLE of γ and determine the estimator $\hat{\theta}$ for θ by minimizing the empirical posterior loss:

$$\hat{\theta} = \underset{\theta}{argmin} \int L(\theta, \delta(\mathbf{x}))\pi(\theta|\mathbf{x}, \hat{\gamma}(\mathbf{x}))\, d\theta$$

The Empirical Bayesian estimator $\hat{\theta}$ is a Bayes estimator when the posterior density $\pi(\theta|\mathbf{x}, \hat{\gamma}(\mathbf{x}))$ is proper.

MCMC birth/death algorithm

Stephens (2010) propose the birth/death MCMC (BDMCMC), an alternative method to the Reversible Jump MCMC (RJMCMC), of constructing an ergodic Markov chain with stationary distribution, when the number of components of mixture model is unknown.

The BDMCMC algorithm view the parameters of the model as a marked (ie.weighed to sum 1) point process, with each point representing a component of the mixture. The scheme allows the number of components to vary by allowing new components to be "born" and existing components to "die". These births and deaths occur in continuous time, and the relative rates at which they occur determine the stationary distribution of the process. BDMCMC is a continuous-time version of RJMCMC, with a limit on the permitted types of moves to simplify implementation.

Algorithm 1.Simulation of a process with appropriate stationary distribution.

Assume $\pi = (\pi_1, \ldots, \pi_k)$ are the mixture proportions and $\phi = (\phi_1, \ldots, \phi_k)$ are the com-

ponent specific parameters. There are k components. Let the likelihood be $L(k, \pi, \phi, \eta) = p(x^n|k, \pi, \phi, \eta)$, $y = (\pi_1, \phi_1), \ldots, (\pi_k, \phi_k)$ and $y \setminus (\pi_i, \phi_i) = y$ less the term (π_i, ϕ_i). To simulate a process with appropriate stationary distribution we iterate:

1. Let the birth rate $\beta(y) = \lambda_b$ (a constant).
2. Calculate the death rate $\delta(y_i)$ for each component, the death rate for component j being given by $\delta_j(y) = \lambda_b \frac{L(y \setminus (\pi_j, \phi_j))}{L(y)} \frac{p(k-1|\omega,\eta)}{kp(k|\omega,\eta)}$ where $j = (1, \ldots, k)$
3. Calculate the total death rate $\delta(y) = \sum_j \delta_j(y)$
4. Simulate time to next jump from an exponential distribution with mean $1/(\beta(y) + \delta(y))$
5. Simulate the type of jump: birth or death with respective probabilities, where $p(birth) = \beta(y)/(\beta(y) + \delta(y))$ and $p(death) = \delta(y)/(\beta(y) + \delta(y))$
6. Adjust y to reflect the birth or death. Birth: Simulate the point (π, ϕ) at which a birth takes place from the density $Beta(y, \pi, \phi) = k(1 - \pi)^{k-1}\tilde{p}(\phi|\omega, \eta)$ by simulating π and ϕ independently from densities $k(1 - \pi)^{k-1}$ and $\tilde{p}(\phi|\omega, \eta)$. Death: Select a component (π_i, ϕ_i) to die with probability $\delta_j(y)/\delta_(y)$. Note: $\phi_1, \ldots, \phi_k$ is independent and identically distributed from $\tilde{p}(\phi|\omega, \eta)$.
7. Return to step 2

Algorithm 2.Simulation of a Markov chain with appropriate stationary distribution.

This algorithm uses Gibbs sampling to simulate a value for $\Theta^{(t+1)} = \theta^{(t+1)}$ given the state $\Theta^{(t)} = \theta^{(t)}$ as time t:

1. Sample $(k^{(t)'}, \pi^{(t)'}, \phi^{(t)'})$ by running the birth-death process for a fixed time t_0 starting from $(k^{(t)}, \pi^{(t)}, \phi^{(t)})$ and fixing (ω, η) to be $(\omega^{(t)}, \eta^{(t)})$. Set $k^{(t+1)} = k^{(t)'}$.
2. Sample $(z^n)^{(t+1)}$ from $p(z^n|k^{(t+1)}, \pi^{(t)'}, \phi^{(t)'}, \eta^{(t)}, \omega^{(t)}, x^n)$.
3. Sample $\eta^{(t+1)}, \omega^{(t+1)}$ from $p(\eta, \omega|k^{(t+1)}, \pi^{(t)'}, \omega^{(t)'}, x^n, z^n)$.
4. Sample $\pi^{(t+1)}, \phi^{(t+1)}$ from $p(\pi, \phi|k^{(t+1)}, \eta^{(t+1)}, \omega^{(t+1)}, x^n, z^n)$.

Diebold Mariano Test for Predictive Accuracy

Assume $y_{t+h|t}$ are the true unknown values of the h-ahead forecast for series y_t. There are two competing forecast models, each generates residuals given by $\epsilon^i_{t+h|t} = y_{t+h|t} - y^i_{t+h|t}$ for $i = 1, 2$.

The Diebold-Mariano test is based on the squared error loss difference $d_t = (\epsilon^1_{t+h|t})^2 - (\epsilon^2_{t+h|t})^2$ and the test statistic is $S = \frac{d_t}{\sqrt{\hat{var}(d_t)}}$.

The null of equal predictive accuracy is $H_o : S \sim N(0, 1)$ implying that $E(d_t) = 0$.

In our implementation, the model residuals were compared to the perfect predictor that generates a series of zeros. By rejecting the null hypothesis, the expected model residual is not zero and the model does not offer a good out-of-sample predictor.

Measures of Forecast Accuracy

Let ϵ_t be the forecast error given by $\epsilon_{t+1} = y_{t+1} - y_{t+1|t}$ where $y_{t+1|t}$ is the forecast of y_{t+1} made at time t. As a way of measuring the quadratic loss criterion, the Root Mean Square Error (RMSE) is a frequent choice.

$$RMSE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(y_{t+1} - y_{t+1|t})^2}$$

Unfortunately, this measure has some flaws: performance may be significantly affected by outliers, and it is inherently scale dependent, in that its magnitude depends not only on forecast accuracy, but also on the level of the underlying series. For example, a forecast 10% in excess of an actual value of $1,000,000$ result in a substantially greater RMSE than one 10% percent above an actual of $1,000$.

The Mean Absolute Percentage Error (MAPE) favored by practitioners, which expresses error as a fraction of the associated actual value, avoids the scale dependency of the RMSE.

$$MAPE = \frac{1}{T}\sum_{t=1}^{T}\left|\frac{y_{t+1} - y_{t+1|t}}{y_{t+1}}\right|$$

MAPE also has disadvantages. Differently than RMSE, summary MAPE measures may be skewed by small actuals; indeed, the MAPE is infinite for an actual value of 0. MAPE also exhibits a counter-intuitive asymmetry: a forecast of 5 units on an actual of 10 produces an absolute percentage error of 50 percent, while a forecast of 10 units on an actual of 5 gives an APE of 100 percent.

LPS and Kullback-Leibler

Fernandez et al. (2001) relates Log Predictive Probability (LPS) to the Kullback-Leibler (KL) divergence. LPS for a h-step ahead predictive likelihood is

$$LPS(X_h, y, X) \equiv -\frac{1}{h}\sum_{i=1}^{h} \ln p(y_{N+i}|X_h, y, X)$$

The Kullback-Leibler divergence between the actual sampling density and the out-of-sample predictive density is given by

$$KL(p(y_h|X_h), p(y_h|X_h, y, X)) =$$
$$\int_{\mathbb{R}} \{\ln p(y_h|X_h)\} p(y_h|X_h)\, dy_h - \int_{\Re} \{\ln p(y_h|X_h, y, X)\} p(y_h|X_h)\, dy_h$$

where the first term is the negative entropy of the sampling density and the second can be seen as a theoretical counterpart of LPS for a given value of y_h. The entropy has a constant value regardless of the choice of M_s so that LPS is the variable associated the KL measure.

Table 1: Cointegration tests of interest rates

lag order=2	eigen test				trace test			
	test	10%	5%	1%	test	10%	5%	1%
$r \leq 6$	7.58	10.49	12.25	16.26	7.58	10.49	12.25	16.26
$r \leq 5$	20.84	16.85	18.96	23.65	28.42	22.76	25.32	30.45
$r \leq 4$	53.63	23.11	25.54	30.34	82.05	39.06	42.44	48.45
$r \leq 3$	68.83	29.12	31.46	36.65	150.88	59.14	62.99	70.05
$r \leq 2$	103.08	34.75	37.52	42.36	253.96	83.2	87.31	96.58
$r \leq 1$	126.28	40.91	43.97	49.51	380.23	110.42	114.9	124.75
$r \leq 0$	162.64	46.32	49.42	54.71	542.88	141.01	146.76	158.49
lag order=3	eigen test				trace test			
	test	10%	5%	1%	test	10%	5%	1%
$r \leq 6$	6.12	10.49	12.25	16.26	6.12	10.49	12.25	16.26
$r \leq 5$	18.33	16.85	18.96	23.65	24.46	22.76	25.32	30.45
$r \leq 4$	41.44	23.11	25.54	30.34	65.90	39.06	42.44	48.45
$r \leq 3$	47.72	29.12	31.46	36.65	113.61	59.14	62.99	70.05
$r \leq 2$	53.87	34.75	37.52	42.36	167.49	83.2	87.31	96.58
$r \leq 1$	73.47	40.91	43.97	49.51	240.95	110.42	114.9	124.75
$r \leq 0$	120.2	46.32	49.42	54.71	361.16	141.01	146.76	158.49

Tested with linear trend in cointegration with Pfaff (2008) routines.

Table 2: Data description and sources

Data	Description	Source
mpr	Monetary Policy annual rate (selic)	BCB (series 1178)
cpi	Current Consumer Price Inflation (ipca)	BCB (series 433)
cpie	Expected Inflation median 12 months ahead	BCB [1]
tcpi	Target Consumer Price Inflation	BCB [2]
eai	Economic Activity Index (seasonally adj.)	Serasa-Experian
credit/gdp	Tot credit non-earmarked funds/GDP	BCB (12127,12128)
debt/gdp	Net Public Debt/GDP (%)	BCB (series 4513)
rer	Real effective exchange rate index	BCB (11753)
comm	Commodity Index - Brazil - Index	BCB (series 20048)
cci	Consumer confidence index	BCB (series 4393)
ffr	Federal Funds Rate	FRED
di030	Swap reference rate 30-day (end period)	BCB (series 7816)
di060	Swap reference rate 60-day (end period)	BCB (series 7817)
di090	Swap reference rate 90-day (end period)	BCB (series 7818)
di120	Swap reference rate 120-day (end period)	BCB (series 7819)
di180	Swap reference rate 180-day (end period)	BCB (series 7820)
di360	Swap reference rate 360-day (end period)	BCB (series 7821)

Annualized data (constructed as a rolling window of the last 12 months)
[1] daily data was averaged to a monthly basis
[2] http://www.bcb.gov.br/Pec/metas/TabelaMetaseResultados.pdf

Table 3: Descriptive Statistics (full sample)

	Obs	Min	Median	Mean	Max	SE	Skew	E/K
mpr	126	8.65	13.52	14.73	26.32	4.57	0.73	-0.16
mprhp	126	9.80	14.06	14.71	21.40	3.86	0.28	-1.41
cpi	126	2.92	5.85	6.38	16.04	2.92	1.81	3.02
cpie	126	3.37	4.97	5.23	13.18	1.62	2.63	8.82
tcpi	126	3.50	4.50	4.45	5.50	0.46	0.20	1.26
hiatus	126	-1.13	0.53	0.78	9.68	1.78	2.78	9.42
eai	126	111.90	137.00	137.22	163.00	16.50	0.12	-1.35
gap	126	-6.75	0.38	0.00	5.58	2.43	-0.43	0.37
credit/gdp	126	11.50	77.66	98.50	236.61	71.76	0.29	-1.41
debt/gdp	126	35.04	46.67	46.50	62.86	6.77	0.34	-0.79
rer	126	61.56	96.73	103.64	206.11	34.09	0.81	-0.22
comm	126	57.30	101.53	102.27	138.00	15.19	-0.52	1.54
cci	126	84.40	133.74	132.94	170.18	21.31	-0.41	-0.69
ffr	126	0.25	1.25	1.95	5.25	1.77	0.78	-0.82
di030	126	8.32	13.35	14.66	26.77	4.64	0.76	-0.12
di060	126	8.18	13.33	14.69	27.17	4.71	0.78	-0.11
di090	126	8.08	13.31	14.73	27.49	4.77	0.80	-0.07
di120	126	8.01	13.39	14.78	27.75	4.83	0.83	-0.03
di180	126	7.94	13.46	14.86	28.20	4.93	0.91	0.15
di360	126	7.93	13.85	15.18	30.90	5.27	1.20	1.02

hiatus=cpie-tcpi, gap=eai-HPfilter(eai,λ), mprhp=HPfilter(mpr,λ)
SE = standard error, Skew = skewness, E/Kurt = Excess Kurtosis ($K-3$)
Ravn and Uhlig (2002) recommend $\lambda = 129600$ for monthly data

Table 4: BMA Models with Unit Information Priors

Model M01 (UIP)				Model M02 (UIP)				Model M03 (UIP)				Model M04 (UIP)			
	PIP	Mean	S.E.		PIP	Mean	S.E.		PIP	Mean	S.E.		PIP	Mean	S.E.
mpr(-1)	100%	0.986	0.014	mpr(-1)	100%	0.948	0.019	mpr(-1)	100%	0.928	0.031	mpr(-1)	100%	0.436	0.061
				hiatus	100%	0.201	0.037	hiatus	100%	0.226	0.059	di030	95%	0.722	0.287
				gap	99%	0.096	0.028	gap	87%	0.078	0.041	di090	25%	-0.038	0.255
				mprhp	12%	0.003	0.014	credit/gdp	26%	-0.001	0.003	di060	24%	-0.042	0.305
								ffr	23%	0.013	0.031	di120	23%	-0.049	0.172
								debt/gdp	18%	-0.008	0.026	di180	23%	-0.024	0.087
								rer	16%	0.001	0.004	di360	18%	-0.008	0.030
								mprhp	12%	-0.001	0.026	rer	11%	0.000	0.001
								rer(+1)	12%	0.000	0.003	debt/gdp	10%	-0.001	0.006
								comm	12%	0.000	0.002	rer(+1)	10%	0.000	0.001
												mprhp	9%	-0.001	0.011
												comm	9%	0.000	0.001
												credit/gdp	9%	0.000	0.000
												gap	9%	0.000	0.007
												ffr	8%	0.000	0.007
												hiatus	8%	0.000	0.010
in-sample MAPE			0.05%	in-sample MAPE			0.24%	in-sample MAPE			0.23%	in-sample MAPE			0.29%
Diebold-Mariano			0.789	Diebold-Mariano			0.000	Diebold-Mariano			0.000	Diebold-Mariano			0.000
out-of-sample MAPE			0.56%	out-of-sample MAPE			0.75%	out-of-sample MAPE			0.97%	out-of-sample MAPE			0.54%
Log Predictive Score			0.770	Log Predictive Score			0.708	Log Predictive Score			0.681	Log Predictive Score			0.218

Table 5: BMA with fixed g priors

Model M04 (RIC)				Model M04 (BRIC)				Model M04 (EBL)			
	PIP	Mean	S.E.		PIP	Mean	S.E.		PIP	Mean	S.E.
mpr(-1)	100%	0.426	0.042	mpr(-1)	100%	0.425	0.042	mpr(-1)	100%	0.421	0.018
di030	100%	0.794	0.203	di030	100%	0.797	0.202	di030	100%	0.795	0.119
di120	26%	-0.043	0.104	di090	26%	-0.060	0.149	di120	47%	-0.080	0.087
di060	24%	-0.096	0.223	di120	25%	-0.042	0.100	di090	24%	-0.064	0.117
di180	23%	-0.022	0.061	di060	24%	-0.091	0.226	di180	19%	-0.020	0.043
di090	22%	-0.050	0.147	di180	23%	-0.022	0.059	di060	11%	-0.049	0.145
di360	18%	-0.008	0.025	di360	16%	-0.007	0.024	di360	3%	-0.001	0.008
mprhp	8%	-0.001	0.007	mprhp	8%	-0.001	0.007	mprhp	2%	0.000	0.002
debt/gdp	7%	0.000	0.004	debt/gdp	8%	0.000	0.004	rer	2%	0.000	0.000
rer	7%	0.000	0.001	rer(+1)	7%	0.000	0.001	debt/gdp	1%	0.000	0.001
rer(+1)	7%	0.000	0.001	credit/gdp	6%	0.000	0.000	comm	1%	0.000	0.000
ffr	7%	0.000	0.005	rer	6%	0.000	0.001	gap	1%	0.000	0.001
hiatuse	7%	0.000	0.007	ffr	6%	0.000	0.004	credit/gdp	1%	0.000	0.000
gap	7%	0.000	0.004	gap	6%	0.000	0.004	rer(+1)	1%	0.000	0.000
comm	6%	0.000	0.001	hiatuse	6%	0.000	0.006	ffr	0%	0.000	0.001
credit/gdp	6%	0.000	0.000	comm	6%	0.000	0.001	hiatuse	0%	0.000	0.001
in-sample MAPE			0.29%	in-sample MAPE			0.29%	in-sample MAPE			0.29%
Diebold-Mariano			0.000	Diebold-Mariano			0.000	Diebold-Mariano			0.000
out-of-sample MAPE			0.54%	out-of-sample MAPE			0.54%	out-of-sample MAPE			0.54%
Log Predictive Score			-0.194	Log Predictive Score			-0.194	Log Predictive Score			-0.800

Table 6: BMA with hyper-g priors

Model M04 (hyper h=2.01)				Model M04 (hyper h=3.0)				Model M04 (hyper h=4.0)			
	PIP	Mean	S.E.		PIP	Mean	S.E.		PIP	Mean	S.E.
mpr(-1)	100%	0.516	0.038	mpr(-1)	100%	0.512	0.039	mpr(-1)	100%	0.512	0.040
di030	93%	0.475	0.168	di030	94%	0.487	0.167	di030	92%	0.478	0.184
di060	8%	0.024	0.173	di060	7%	0.019	0.169	di060	8%	0.027	0.192
di090	3%	0.003	0.144	di090	4%	0.001	0.130	di090	5%	0.010	0.181
di120	3%	-0.010	0.095	di120	3%	-0.009	0.071	di180	4%	-0.009	0.054
di180	2%	-0.005	0.038	di180	3%	-0.006	0.039	di120	3%	-0.013	0.096
di360	2%	-0.002	0.014	di360	3%	-0.002	0.015	di360	3%	-0.003	0.017
mprhp	1%	0.000	0.004	rer(+1)	1%	0.000	0.000	rer(+1)	1%	0.000	0.001
rer	1%	0.000	0.000	debt/gdp	1%	0.000	0.002	rer	1%	0.000	0.000
debt/gdp	1%	0.000	0.002	rer	1%	0.000	0.000	debt/gdp	1%	0.000	0.002
rer(+1)	1%	0.000	0.000	mprhp	1%	0.000	0.003	mprhp	1%	0.000	0.004
credit/gdp	1%	0.000	0.000	hiatuse	1%	0.000	0.001	credit/gdp	1%	0.000	0.000
gap	0%	0.000	0.001	gap	1%	0.000	0.001	hiatuse	1%	0.000	0.001
hiatuse	0%	0.000	0.001	credit/gdp	1%	0.000	0.000	ffr	1%	0.000	0.001
comm	0%	0.000	0.000	ffr	0%	0.000	0.001	gap	1%	0.000	0.001
ffr	0%	0.000	0.001	comm	0%	0.000	0.000	comm	0%	0.000	0.000
in-sample MAPE			0.29%	in-sample MAPE			0.29%	in-sample MAPE			0.29%
Diebold-Mariano			0.000	Diebold-Mariano			0.000	Diebold-Mariano			0.000
out-of-sample MAPE			0.54%	out-of-sample MAPE			0.54%	out-of-sample MAPE			0.54%
Log Predictive Score			-0.586	Log Predictive Score			-0.587	Log Predictive Score			-0.592

Table 7: BMA with mixture priors

Model M05 (UIP)				Model M03 (RIC)				Model M03 (EBL)			
di030	100%	2.372	0.294	di030	100%	2.232	0.483	di030	100%	2.454	0.150
di090	93%	-2.071	1.025	di090	68%	-1.228	1.294	di090	100%	-2.458	0.559
di120	46%	0.546	0.728	di060	35%	-0.350	0.953	di120	65%	0.820	0.640
di180	38%	0.180	0.285	di120	32%	0.184	0.780	di180	34%	0.170	0.249
di060	17%	-0.046	0.583	di180	28%	0.114	0.328	di060	3%	0.015	0.179
di360	16%	0.014	0.057	di360	21%	0.020	0.084	di360	2%	0.002	0.020
in-sample MAPE			0.17%	in-sample MAPE			0.19%	in-sample MAPE			0.16%
Diebold-Mariano			0.001	Diebold-Mariano			0.000	Diebold-Mariano			0.001
out-sample MAPE			0.46%	out-sample MAPE			0.60%	out-sample MAPE			0.39%
Log Predictive Score			0.462	Log Predictive Score			0.800	Log Predictive Score			0.050
Model M04 - hyper h=2.01				Model M04 - hyper h=3.0				Model M04 - hyper h=4.0			
di030	100%	2.231	0.368	di030	100%	2.221	0.365	di030	100%	2.238	0.364
di090	54%	-0.659	0.786	di090	59%	-0.753	0.839	di090	58%	-0.762	0.865
di060	43%	-0.668	0.788	di060	39%	-0.594	0.776	di060	40%	-0.611	0.784
di120	10%	0.061	0.352	di120	12%	0.078	0.392	di120	13%	0.082	0.409
di180	6%	0.028	0.127	di180	9%	0.039	0.150	di180	10%	0.044	0.158
di360	4%	0.005	0.028	di360	5%	0.006	0.032	di360	5%	0.006	0.033
in-sample MAPE			0.17%	in-sample MAPE			0.17%	in-sample MAPE			0.17%
Diebold-Mariano			0.001	Diebold-Mariano			0.001	Diebold-Mariano			0.001
out-sample MAPE			0.39%	out-sample MAPE			0.39%	out-sample MAPE			0.39%
Log Predictive Score			0.113	Log Predictive Score			0.111	Log Predictive Score			0.109