CENTER FOR LATIN AMERICAN MONETARY STUDIES

**Joint Research Program**
XIX Meeting of the Central Bank Researchers Network

# Monetary Policy and Financial Stability in Latin America and the Caribbean

Editor:
Alberto Ortiz Bolaños

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CENTRAL BANKS RESEARCHERS NETWORK

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**Editor**

*Alberto Ortiz Bolaños*
Manager, Economic Research Department,
Center of Latin American Monetary Studies
<ortiz@cemla.org>

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# PREFACE

Since 2005 CEMLA's central banks have conducted joint research activities to bolster economic research on topics of mutual interest. Annual or multiannual joint research activities have been developed in the following topics: *1)* Estimation and use of nonobservable variables in the region; *2)* The development of dynamic stochastic general equilibrium models; *3)* The transmission mechanism of monetary policy; *4)* Economic policy responses to the financial crisis; *5)* Inflationary dynamics, persistence and price and wage formation; *6*) Capital flows and its macroeconomic impact; *7)* Asset pricing, global economic conditions and financial stability; *8)* Monetary policy and financial stability in small open economies; *9)* Monetary policy and financial stability; *10*) International spillovers of monetary policy; *11)* Monetary policy and financial conditions; *12)* Households' financial decisions; and *13)* Inflation expectations: Their measurement and degree of anchoring.

In 2014, CEMLA's central banks decided that they would conduct a joint research on Monetary policy and financial stability. The joint research group organized their discussion around three general questions: *1)* How does monetary policy affect financial stability?; *2)* How should the monetary authority incorporate financial stability considerations?; and *3)* How does international financial integration constrain monetary policy and prudential regulatory policies? The documents collected in this book provide answers to some aspects of these questions.

CEMLA coordinated this joint research with participation of researchers from the central banks of

Bolivia, Brazil, Dominican Republic, Guatemala, and Mexico. Research work was supported by webinars of academic specialists, virtual meetings where research progress was presented, a workshop at CEMLA, and presentations at the XIX Meeting of the Central Bank Researchers Network of the Americas. The documents that integrate this book represent a memoir of the work done by this group of researchers and it gives an analysis of different aspects of the interactions of monetary and financial stability. This book, in line with CEMLA's objectives, promotes a better understanding of monetary and banking matters in Latin America and the Caribbean.

**Alberto Ortiz Bolaños**
Economic Research Manager
Center for Latin American Monetary Studies

# ABOUT THE EDITOR

## Alberto Ortiz Bolaños

Manager of Economic Research at the Center for Latin American Monetary Studies (CEMLA) and Research Professor at EGADE Business School of Tecnológico de Monterrey.

His main research areas are *1)* the study of macrofinancial linkages; *2)* the measurement of the sources of economic fluctuations in emerging markets; and *3)* the analysis of macroeconomic and financial regulation policies. Among others phenomena, he has analyzed the economic consequences of credit market imperfections and the role of monetary policy and credit contract indexation in economic stabilization; has compared the relative importance of domestic and foreign factors in emerging market economic fluctuations and the role and interaction of monetary and fiscal policies for economic outcomes; and has also studied the determinants of capital buffers in a panel of more than 7,000 banks across 143 countries and he has analyzed the role of banks' net stable funding ratio in explaining future financial instability.

At CEMLA, Dr. Ortiz conducts research in the above mentioned areas, coordinates conferences, seminars, coursesand research related activities. A big part of his efforts are aimed at supporting the coordination of research activities among central bank researchers from CEMLA's membership, including: the Joint Research program, the internship program and the on-line research seminars.

Regarding his academic activies, Dr. Ortiz has taught courses on Microeconomics of Banking, Market Failure in Financial Markets, Macroeconomic Theory, Money and Banking, Open Macroeconomics, Economic Development, Mathematical Methods for Economists, Economic Environment of the Organization, Fundamentals of Global Business, Fundamentals of Economics and International Financial Policy at Boston University, Oberlin College and Harvard University.

He earned his PhD in Economics from Boston University in 2009, having previously acquired a Master Degree in Political Economy at the same institution and a Bachelor Degree in Economics from the Centro de Investigación y Docencia Económicas (CIDE) in 2002.

# Introduction

*Alberto Ortiz Bolaños*

Financial instability can have devastating consequences on economic activity, price stabilityand the monetary policy transmission mechanisms. This is hardly news for Latin America and the Caribbean that have an unfortunate history of financial struggles that has led to a widespread inclusion of an explicit financial stability mandate in many central banks. Given the prevalence of this financial stability mandate, policy making could benefit from a better understanding of the monetary policy-financial stability nexus. This book presents efforts made through joint research among central banks' economists of the Americas to advance in this front.

According to Ingves et al.,[1] there are three main reasons why central banks should have a prominent role in the design and implementation of financial stability policy: *1)* financial instability affects the macroeconomic environment; *2)* central banks, in their role of lenders of last resort, provide liquidity that could be important for financial stability; and *3)* central banks have a comprehensive understanding of the financial system required to design and implement

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[1] Stefan Ingves et al., *Central Bank Governance and Financial Stability*, Study Group Report, BIS, May, 2011.

macroprudential policies. Although there is an agreement of this relevant role that monetary authorities should have, we still need to advance on the determination of how central banks should contribute to financial stability.

During the last decade, an increasing number of countries have strengthened prudential policies in response to financial stability concerns. Those prudential policies aim to *1)* reinforce the solvency and control the leverage of financial intermediaries; *2)* contain liquidity risks; *3)* limit risk associated with unexpected changes in interest and exchange rates; and *4)* reduce negative externalities that could be magnified by the interconnectedness of financial intermediaries. Despite their increasing use, analysis of the efficiency of these risk-containing prudential policies and their interaction with monetary policy is an understudied area. Also, there is a need to better understand the country-level specifics of the monetary policy-financial stability interactions in order to explore the potential benefits of regional policy coordination.

This book has seven chapters that give insights on different issues related to monetary policy and financial stability. The first two look at the effect of changes in monetary policy on the credit supply in Bolivia and Guatemala, respectively, and the differentiated effect depending on the banks' characteristics. The third one studies the relation between credit and economic activity in Costa Rica, the Dominican Republic, El Salvador, Honduras, Guatemala, and Nicaragua, finding a positive relation. The fourth research analyzes the determinants of banks' capital buffers in a sample of 456 Latin American and Caribbean banks. The fifth describes mechanisms on how financial conditions interact with monetary policy to determine macroeconomic outcomes within a DSGE model estimated for the USA. The last two papers analyze the effects of foreign exchange (FX) interventions in Brazil and Mexico. The sixth paper compares the effectiveness of the different types of interventions that those two countries have, while the seventh paper uses realized volatility as an instrument to measure the average effect of a dollar sell or buy on the Brazilian exchange rate.

Below we pose three organizing questions on the relation between monetary policy and financial stability that guided the joint research work and describe each chapter in more detail.

## 1. How Does Monetary Policy Affect Financial Stability?

Monetary policy impacts financial stability through its effect on asset prices and on financial markets' risk taking and lending decisions. The asset price channel refers to how monetary policy stance affects prices in the stock, bond, derivative, real estate, and exchange rate markets. The risk-taking channel refers to how relatively low levels of interest rates may induce financial imbalances as a result of reductions in risk aversion and a more intensive search for yield by banks and other investors. The lending channel refers to how the monetary policy stance could impact credit supply by modifying financial intermediaries' sources of funding.

The first and second chapters advance our understanding on these transmission mechanisms including the quantification of their importance.

The first paper, titled "Does Monetary Policy Affect Bank Lending?: Evidence for Bolivia," was written by Óscar A. Díaz Quevedo and C. Tatiana Rocabado Palomeque from Banco Central de Bolivia. In this chapter they use panel data with generalized methods of moments (GMM) and fixed effects to show that changes in monetary policy, measured by the net balance of monetary regulation bonds, have direct effects over credit supply. In addition, they show that smaller and undercapitalized banks reduce relatively more their lending in response to an increase of monetary bonds.

The second paper, titled "What Microeconomic Banks Data Tell Us about Monetary Policy Transmission and Financial Stability in Guatemala?," was written by José Alfredo Blanco Valdés from the Superintendencia de Bancos de Guatemala and Héctor Augusto Valle from Banco de Guatemala. In this chapter they use a panel data of the 18 banks operating in the financial system to show that there is transmission of monetary policy, which is heterogeneous depending on the liquidity, capitalization and size of banks. The transmission mechanism is weakened by the excess liquidity, the portfolio dollarization, the size of the banks, and the way the reserve requirement is computed.

In addition, there is a need to better understand the interdependence between credit cycles and business cycles and the long-term relation among credit, financial stability, and economic growth. The third paper, titled "The Relation between Credit and Business Cycles in Central America and the Dominican Republic," was written by Francisco A. Ramírez from the Banco Central de la República Dominicana. In this chapter he uses Granger causality tests and spectral analysis to identify a positive relation between credit and economic activity in Costa Rica, the Dominican Republic, El Salvador, Honduras, Guatemala, and Nicaragua. Except for Guatemala, the author finds that credit precedes the business cycle in all countries, with eight-year cycles for Costa Rica, the Dominican Republic, El Salvador, and Honduras.

Also, understanding the financial intermediaries' leverage cycles and the procyclicality of credit is key to comprehend the dynamics of aggregate credit. The fourth paper, titled "Bank Capital Buffers and Procyclicality in Latin America," was written by Óscar A. Carvallo from CEMLA and Leslie A. Jiménez, while she was also at CEMLA. In this chapter they use information of 456 Latin American and Caribbean banks from 18 countries and a two-step system GMM estimator to analyze the determinants of banks' capital buffers. GDP growth is negatively related to capital buffers giving evidence that banks reduce their capital buffers during economic expansions. Bank's size is also negatively related to capital buffers, while profitability, expected losses, and market power are positively related.

## 2. How Should the Monetary Authority Incorporate Financial Stability Considerations?

With the global financial crisis, a consensus emerged among world's central bankers about the importance of including financial stability considerations when making monetary policy decisions. This led to a lively discussion on how central banks should contribute to control systemic risk. There were positions that suggest monetary policy should focus on inflation stability, while macroprudential policy addresses financial stability. Others claimed that monetary policy should take into account its broad effects on financial stability. In addition, monetary policy should consider that its effectiveness is affected by the financial cycle. This debate also includes the question of which are the benefits and costs of an integrated framework where the central bank is in charge of implementing macroprudential regulation along with monetary policy, versus an alternative structure where policies are executed by separate institutions.

There are many standing questions on how monetary policy should incorporate financial stability considerations as: *1)* how macroprudential regulation effectiveness can be altered by the stance of monetary policy; *2)* how price control credibility could be jeopardized by a central bank's commitment to financial stability; *3)* which tools should accompany a financial stability mandate; *4)* which are the arbitrage opportunities generated by the joint implementation of different prudential policies; *5)* how can macroprudential regulation modify the monetary policy transmission mechanisms; and *6)* how both types of policies interact in normal times and in times of financial stress.

The fifth chapter of this book, titled "Targeting Long-Term Rates in a Model with Financial Frictions and Regime Switching", a collaborative work by Alberto Ortiz Bolaños and Sebastián Cadavid Sánchez from CEMLA and Gerardo Kattan Rodríguez from Tecnológico de Monterrey, try to provide some answers to these questions. The authors use measures of the term premium calculated by Adrian, Crump, and Moench[2] to perform Bayesian estimations of a Markov-switching vector autoregression (MS-VAR) model and a Markov-switching dynamic stochastic general equilibrium (MS-DSGE) macroeconomic model with financial frictions in long-term debt instruments developed by Carlstrom, Fuerst, and Paustian (2017)[3] to provide evidence on how financial conditions have evolved in the USA since 1962 and how the Federal Reserve has responded to the evolution of term premiums. Using the estimated model, they perform counterfactual analysis of the potential evolution of macroeconomic and financial variables under alternative financial conditions and monetary policy responses. They analyze six episodes with presence of high financial frictions and/or medium and high shocks volatility. In three of them there was a high monetary policy response to financial factors: 1978Q4-1983Q4 which helped to mitigate inflation at the cost of economic activity, and the 1990Q2-1993Q4 and 2010Q1-2011Q4 episodes in which the high response served to mitigate economic contractions. Meanwhile, in the three

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2 Tobias Adrian, Richard K. Crump, and Emanuel Moench, "Pricing the Term Structure with Linear Regressions," *Journal of Financial Economics*, Vol. 110, Issue 1, October, pp. 110-138, 2013, <https://doi.org/10.1016/j.jfineco.2013.04.009>.

3 Charles T. Carlstrom, Timothy S. Fuerst, and Matthias Paustia, "Targeting Long Rates in a Model with Segmented Markets," *American Economic Journal: Macroeconomics*, Vol. 9, No. 1, January, 2017, pp. 205-242.

episodes where low response to financial factors is observed, if the monetary authority had responded more aggressively, from 1971Q1-1978Q3 it could have attained lower inflation at the cost of lower GDP, from 2000Q4-2004Q4 it could have delayed the GDP contraction to 2002Q3, but this would have been deeper and inflation larger, and in 2006Q1-2009Q4 it might had precipitated the GDP contraction. The presence of high financial frictions and high shock volatility makes recessions deeper and recoveries more sluggish showing the importance of the financial-macroeconomic nexus.

## 3. How Does International Financial Integration Constrain Monetary Policy and Prudential Regulatory Policies?

The process of financial integration has been speeding up and creating interlinkages within Latin America and the Caribbean and between the region and the rest of the world. One goal of this joint research was to understand and measure the mechanisms through which these interlinkages impact domestic financial variables.

The sixth paper, titled "Two Models of FX Interventions: The Cases of Brazil and Mexico," was written by Martín Tobal and Renato Yslas from Banco de México. In this chapter they use a VAR with short-run restrictions to empirically compare the effectiveness of FX interventions in Brazil and Mexico under inflation targeting regime. Brazil has a model of regular discretionary interventions with a net dollar purchase bias, while Mexico has a model of sporadic rule-base interventions with a net dollar sell bias. The authors show that: *1)* FX interventions have had a short-lived effect in both countries; *2)* the Brazilian model entails higher inflationary costs; and *3)* in response to a FX intervention shock, Banco de México raises the interest rate immediately, while the Banco Central do Brasil response appears with a four-month lag.

The seventh paper, titled "Realized Volatility as an Instrument to Official Intervention," was written by João Barata R. B. Barroso from Banco Central do Brasil. In this chapter he proposes a novel orthogonality condition based on realized volatility to perform parametric and nonparametric instrumental variable estimations of the effects of FX interventions. By exploiting the information of full records of BRL/USD spot transactions intermediated by the financial institutions and the actual spot intervention policy of the Banco Central do Brasil, he shows that the average effect of a one billion dollars sell (buy) intervention is close to 0.51% depreciation (appreciation). In addition, he shows that the estimates are robust to nonlinear interactions, with 0.48% depreciation for dollar buy intervention and 0.57% appreciation for dollar sell intervention. Also, he presents evidence in the 0.31% to 0.38% range when controlling for derivative operations.

There are many remaining topics to be understood in the relation between monetary policy and financial stability. We hope that these initial studies focused on Latin America will contribute to advance our understanding and will help central banks to fulfill their price stability mandate while they continue to include financial stability considerations.

# Does Monetary Policy Affect Bank Lending? Evidence for Bolivia

***Óscar A. Díaz Quevedo***
***C. Tatiana Rocabado Palomeque***

**Abstract**

*This paper explores the existence of a bank lending channel for Bolivia. The estimates used panel data through GMM and fixed effects model. The results show that changes in monetary policy have direct effects on the banks' loans supply, because increases in the securities' supply lead to reductions in loan growth. Moreover, interactions size and capital of entities with variable monetary policy would reflect the existence of different bank's reactions.*

*Keywords: monetary policy, lending channel, GMM.*
*JEL classification: E5, G21.*

## 1. INTRODUCTION

Analysis of monetary policy transmission mechanism is one of the major areas of research in macroeconomic literature and is of particular interest to central banks. A proper assessment of such mechanisms allows for understanding and anticipating the impact of monetary conditions on the real economy.

The bank lending channel recognizes the existence of imperfect information in financial markets and assigns an active role to bank

The authors are both officials of the Banco Central de Bolivia. The opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the Banco Central de Bolivia. For all correspondence: <odiaz@bcb.gob.bo> and <trocabado@bcb.gob.bo>.

loan supply in the transmission of monetary policy. In this context, a restrictive monetary policy reduces lendable funds, the supply of loans from the banking sector, and forces agents that depend on this type of funding to decrease their investment spending. The effectiveness of this mechanism can vary amongst banks according to the level of access they have to other sources of funding. As Bernanke and Gertler (1995) and Hubbard (1995) point out, the credit channel is complementary and not a substitute for the traditional channel (interest rates channel) of monetary policy.

Analyzing and testing the existence of a bank lending channel in Bolivia is important given the dependence on bank credit of certain segments of the population and the large share of deposits in the structure of bank liabilities. Moreover, the significant process of de-dollarization of the economy allowed for enhancing the effectiveness of monetary policy. Nevertheless, the literature is still scarce, which is why this paper aims to offer empirical evidence on the topic.

Kashyap and Stein (1995, 2000) and Ehrmann (2003) exploit the cross-sectional heterogeneity and behavior of time series to identify the effects of a monetary policy shock on the loan supply of the Bolivian banking system for the period 2005-2013. This type of calculation offers differentiated responses according to the characteristics of banks, identifying those that are most affected. The findings show that monetary policy has the capacity to directly affect bank loan supply (direct lending channel). Moreover, interactions of the banks' size and capital variables with the monetary policy variable would reflect different reactions; that is, smaller, less capitalized banks would reduce their loans to a larger degree in response to a tightening of monetary policy.

The paper consists of seven sections. Section 1 contains the introduction. Section 2 gives a brief summary of the theory of monetary policy transmission mechanisms and, in particular, the bank lending channel. Section 3 presents some stylized facts on the monetary policy regime and the main characteristics of the banking sector in Bolivia. Section 4 summarizes the most important results of the empirical research. Section 5 describes the model used in the paper and presents the econometric methodology. Section 6 contains the results of the model for the case of Bolivia. Finally, Section 7 contains the conclusions.

## 2. CONCEPTUAL FRAMEWORK

One of the functions of central banks is monetary policy management with the principal objective of maintaining price stability. In recent years, they have also conducted actions toward financial activity and preserving financial stability. It is therefore important for a central bank to identify whether the monetary policy tools it employs can influence the activity of the real sector, affecting aggregate demand and inflation through so-called transmission channels.

Mishkin (1996) identified four transmission channels of monetary policy: The interest rate channel, the credit channel (composed of the broad credit channel and the bank lending channel), the exchange rate channel and assets price channel.[1]

The interest rate channel (money channel) represents the traditional approach of monetary policy and suggests that when the central bank implements a contractive monetary policy the money supply decreases (exchanging securities for bank reserves) with the resulting increase in nominal and real long-term interest rates (the impact of monetary policy on interest rates is produced under the assumption that prices are sticky in the short-term). Higher interest rates lead to a reduction in current investment and consumption, causing a contraction of aggregate demand, which affects output and prices.

Bean et al. (2002) establish the existence of the following components in the interest rates channel: *a)* high rates, and therefore high capital costs, lead to higher required rates of return for an investment project and reduced investment spending, *b)* an increase in interest rates changes the pattern of consumption, that is, the impact of restrictive monetary policy can be broken down into a substitution effect and an income effect, the former is negative given that the increase in interest rates reduces the price of future consumption, while the latter depends on consumers' net asset positions, and *c)* in the case of a floating exchange rate regime, movements in interest rates cause exchange rate volatility, affecting price competitiveness and, therefore, net exports.

The interest rates channel assumes that financial intermediaries do not play any special role in the economy. Aggregate demand

[1] A broad discussion of monetary policy transmission channels can be found in Mies et al. (2004). Only the first two are addressed below.

models usually downplay the importance of the role played by financial intermediaries given that bank loans are grouped together with other debt instruments in a bond market. Money on the other hand is given a special role in the determination of aggregate demand. Bernanke and Blinder (1988) show that the traditional interest rates channel rests on at least one of the following three assumptions: *a)* loans and bonds are perfect substitutes to borrowers, *b)* loans and bonds are perfect substitutes to lenders, or *c)* commodity demand is insensitive to the loan rate.

However, Bernanke and Gertler (1995) show empirical evidence that the interest rates channel was not successful in explaining large changes in output and aggregate demand, giving rise to the production of a large body of literature that attempted to identify and quantify other transmission mechanisms.

At the end of the eighties, the link between credit and output began to become important because it was observed that given the existence of asymmetric information, financial intermediaries played an important role in supplying credit, considerably affecting aggregate demand. Since then a series of studies has emerged explicitly analyzing how the effects of monetary policy could be amplified and propagated in the face of changes in the different agents' financial conditions. This type of model belongs to the so-called credit channel theory, which starts by rejecting the hypothesis that bonds and bank loans are perfect substitutes. Nevertheless, this should not be understood as an independent or parallel transmission channel to the traditional one, but rather as a set of factors that amplify and propagate conventional effects of changes in interest rates (Bernanke and Gertler, 1995).

In particular, there are two mechanisms through which the credit channel can operate: The broad credit channel (the balance sheet channel) and the bank lending or narrow channel (Bernanke and Gertler, 1995). The main idea of the balance sheet channel is that, in the presence of imperfect capital markets, asymmetric information between lenders and borrowers creates a gap between the cost of internal and external financing for borrowers. A restrictive monetary policy that raises real interest rates reduces borrowers' net cash flow, thereby weakening their financial position. Raising interest rates also lowers the value of assets that act as guarantees and, consequently, reduces the ability of borrowers to obtain financing. In both cases the net value of a firm decreases, and being inversely related to the cost (premium) of external financing, for a certain amount of required funding, the firm's spending and activity decline (limiting its borrowing possibilities).

The second mechanism focuses on bank loan supply: Changes in monetary policy do not just affect the interest rates on loans granted by banks, but also on their ability to supply new loans. In particular, a restrictive monetary policy that implies an increase in reserves requirement for banks generates a fall in available bank deposits and creates a need for obtaining alternative sources of funding in order to maintain the volume of loans. If such funding is scarce or unavailable, banks are forced to reduce their supply of loans, having a negative impact on the planned consumption and investment of borrowers that depend on this type of financing (small businesses and consumers). Thus, competition for the reduced supply of bank loans might lead to an increase in interest rates with adverse effects on investment and consumption. The bank lending channel therefore amplifies the impact of monetary policy tightening on aggregate demand, giving a special role to banks.

Unlike the traditional credit channel, the impact of monetary policy on the real economy through the balance sheet channel and the bank lending channel has significant distributive consequences. Banks with different dependency on deposits and businesses with different financial positions and dependence on bank loans are not affected in the same way by monetary policy shocks.

The monetary policy transmission mechanism through the bank lending channel rests on two pillars: The capacity of central banks to affect the bank loan supply and the dependence of businesses and households on bank loans.

a) *Monetary policy actions must affect the bank loan supply.* Banks cannot have perfect substitutes for loans nor significant sources of funding other than deposits (external loans and securities, among others), that is, deposits are one of the least costly sources of financing and, consequently, for some banks it would be expensive and sometimes impossible to replace lost deposits with other sources of funds in order to maintain the same supply of loans. Under such conditions, a restrictive monetary policy reduces the aggregate volume of deposits and affects bank loan supply. Thus, deposits and bonds must be imperfect substitutes for banks.

The fact that the impact of monetary policy on loan supply also depends on the characteristics of the banking sector should be taken into account. In general terms, the stronger a country's banking sector, the weaker the expected impact of changes in monetary policy. Larger and healthier banks are less sensitive to policy changes because their reserves can be replaced quickly with alternative types of financing. Thus, bank size, market concentration, level of capitalization and liquidity are the most commonly studied factors: A relatively small size, weak market concentration and lower levels of liquidity and capitalization suggest existence of a stronger credit channel given that banks are more exposed to market imperfections and would face more difficulties to obtain funding other than from deposits.[2]

Another important factor is ownership structure, given that State influence, exercised through either direct public ownership of banks, State control or public guarantees, provides additional funding possibilities and reduces asymmetric information. Foreign participation in the domestic banking system also weakens the credit channel, as subsidiaries of foreign banks can face lesser funding restrictions due to the possibility of obtaining additional financing from their parent banks.

Kashyap and Stein (1993) argue that the impact on bank loan supply also depends on the regulatory framework, given that risk based regulatory capital requirements can tie up the capacity of a bank to grant loans up to the amount of its own funds and restrict credit. Moreover, the behavior of loan supply can also be affected by deposit insurance requirements –the higher the insurance, the lower customers' risk. A low level of risk reduces the cost of deposits for banks and, therefore, increases dependence on this type of liabilities.

Finally, the speed of monetary policy transmission depends on loan maturity and the type of interest rate. The larger are short-term variable rate loans, the faster loan supply responds to changes in monetary policy.

b) *There must not be any other alternative source of funding that is a perfect substitute for bank lending*. Faced with a reduction in the supply of loans, borrowers (businesses, households) cannot turn to other sources of financing without incurring some costs, for

2 Financial solvency can also be characterized by loan loss provisions, operating costs and returns on assets, as well as the number of past bankruptcies.

instance, issuing bonds, stocks or turning to other financial intermediaries. There is evidence that firms, particularly small ones, depend on banks for financing. They generally lack access to bond markets, an effect that is even more important for countries with less developed capital markets such as Bolivia. With respect to capital, lower capitalization as compared to total assets or loans implies a high bank dependence on lenders and, therefore, a stronger credit channel.

## 3. STYLIZED FACTS

### 3.1 Monetary Policy in Bolivia

In accordance with Law 1670 of the Banco Central de Bolivia (BCB), its objective is to ensure the stability of the domestic currency's purchasing power. To this end, the BCB regulates the liquidity of the financial system, mainly through open market operations (OMO) that affect the volume of credit and amount of money in the economy. The BCB also establishes mandatory reserve requirements for financial intermediaries and grants liquidity loans guaranteed by the Fondo RAL[3] to the institutions. Furthermore, repo operations are an additional source of liquidity.

According to Cossio et al. (2007) the BCB conducts its monetary policy through an intermediate targeting scheme, fixing limits for its net domestic credit and a floor for the variation in net international reserves (NIR).[4] Given that it is not possible to directly control the intermediate target, monetary policy actions are implemented through an operating target, defined as excess financial system liquidity, that is, the amount above legal reserve requirements.

Precisely because of the deepening bolivianization process that began in the middle of the past decade, the current monetary policy regime is more effective. In the period prior to 2005, when financial dollarization levels were above 90% and OMO were carried out in US

3 Fund of required liquid assets.

4 Targets for NIR allow for anchoring net domestic credit (NDC), providing the flexibility necessary in the growth of monetary emission, which in recent years has been explained by economic expansion and the process of dedollarization (bolivianization) in the economy.

dollars, decisions to inject liquidity implied losing the scarce NIR available at that time, limiting their use for offsetting the adverse effects of economic cycles. This capacity has now recovered and the BCB is able to inject large amounts of resources when the economy requires them, such as at the end of 2008 and during 2009, inducing a sharp decline in interest rates, an increase in credit and a strenghtening of economic activity. The mechanism is also effective under environments where it is necessary to withdraw liquidity and, supported by reserve requirements, commissions on external capital flows, exchange position, provisions, direct securities placement[5] and other tools, has allowed for drawing in liquidity and reducing inflationary pressures without substantially affecting interest rates, while preserving the strength of economic activity (Figure 1).

### 3.2 The Bolivian Banking Sector

The banking system performs an important role in the Bolivian economy. As of June 2014 it accounted for over 50% of the financial system's assets[6] and in recent years has recorded significant growth in its loan portfolio. The strength of banking system intermediation activities was reflected in higher financial deepening indicators, the portfolio to GDP ratio shifted from 21% in September 2008 to 32% at the end of 2013. As of June 2014, 31% of the banking portfolio corresponded to loans granted to households (consumer and mortgage credit) and the remaining 69% to business loans. The 49% of the latter percentage funded micro, small and medium-sized firms.

As for the destination of credit, the banking system constitutes the main source of financing for labor intensive firms, while large capital intensive firms obtain funding via external debt. Foreign direct investment is also concentrated in those sectors. Despite the development of the stock market in recent years, financing of non-financial firms through this mechanism is still limited. There are

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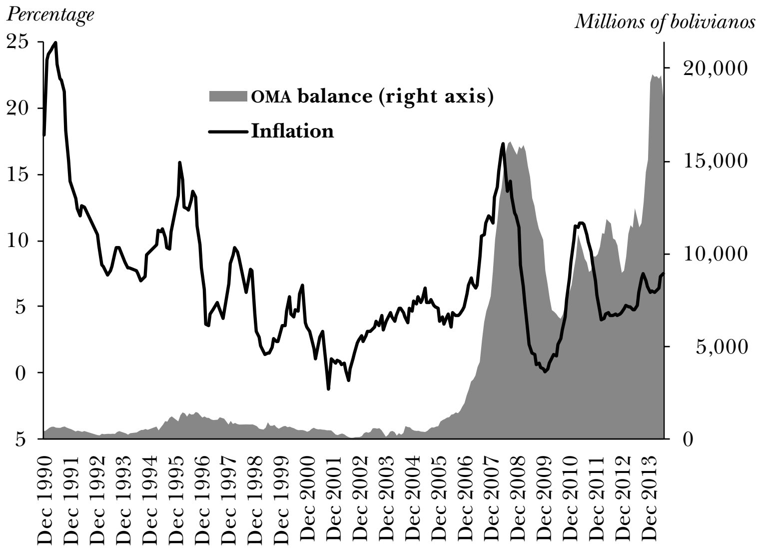
5 In October 2007, through Directory Resolution No. 108/2007, the BCB introduced the direct sale of securities to individuals and legal entities.

6 The Bolivian financial system is composed of financial intermediaries (commercial banks, MSME banks, savings and credit cooperatives, housing finance institutions), managers that administer the Integrated Pensions System, investment fund management associations and insurance companies. Only commercial banks and MSME banks are considered in this study.

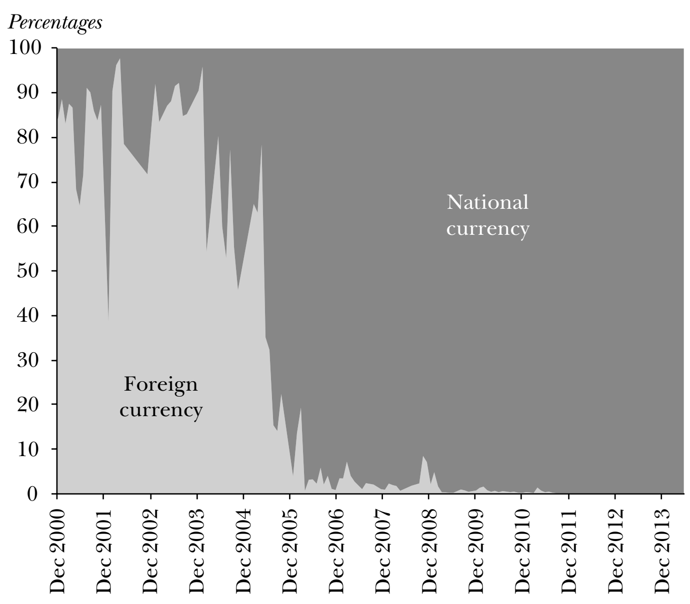
## Figure 1

**EVOLUTION OF OMO**

A. OMO BALANCE AND INFLATION




B. OMO COMPOSITION BY TYPE OF CURRENCY




Sources: INE y BCB.

therefore segments of the population (households and small, medium and micro firms) that depend significantly on bank financing.

Over the last few years the number of banking institutions has remained relatively unchanged. As of June 2014, 13 institutions were operating in the market, two of which were subsidiaries of foreign banks (with a less than 1% share of total banking system assets). Foreign ownership in the sector is limited and there is only one large foreign bank, whose capital is raised in the country, which accounts for 11% of total banking system assets. As of December 2013, there was just one first tier public bank with a 13.4% share of total assets (third largest bank). The small participation of foreign and public banks strengthens the credit channel as said institutions face less funding restrictions due to the potential supply of additional resources they are able to obtain from their parent banks and the State, respectively.

A significant market concentration can generate rigidities in the transmission of monetary policy. A Hirschmann-Herfindhal index[7] of 1,121 for assets indicates medium concentration, which has declined in recent years and has favored the credit channel in Bolivia. Moreover, the five largest banks' share of assets, portfolio and deposits in the financial intermediation system (institutions that capture deposits and grant loans) has exhibited a downward trend from values close to 75% at the start of the decade to values slightly above 65% at the end of 2013 (Table 1).

Since 2010 the banking system has recorded average portfolio growth of over 20% driven by loans in domestic currency that, thanks to bolivianization measures implemented by the BCB in coordination with the Executive Body and the Financial System Supervision Authority (ASFI), represented around 90% of banks' total portfolios in 2013 as compared to 7.5% at the end of 2005. The growing share of loans in domestic currency strengthens the credit channel.

The growth of credit was not accompanied by a reduction in the quality of the banks' assets. On the contrary, the delinquency indicator (default portfolio/gross portfolio) registered historically low

[7] The Hirschmann-Herfindhal index is a measure for estimating market concentration through the relative share of its participants. The index is calculated as the sum of the squares of the relative sizes of the variables used for measuring market structure. An index of above 1,800 classifies the market as highly concentrated, between 1,000 and 1,800 moderately concentrated and below 1,000 unconcentrated.

**Table 1**

**BANKS: FINANCIAL INDICATORS**
Percentages

| | *2005* | *2007* | *2009* | *2011* | *2013* |
|---|---|---|---|---|---|
| *Concentration (assets)* | | | | | |
| Hirschmann-Herfindhal index | 1,416 | 1,293 | 1,230 | 1,155 | 1,121 |
| Share of the five largest banks | 75.2 | 71.9 | 70.0 | 68.6 | 67.3 |
| *Liquidity* | | | | | |
| Liquidity/assets | 33.5 | 39.0 | 48.9 | 39.1 | 37.5 |
| Liquidity/short-term obligations | 85.6 | 84.3 | 98.2 | 79.4 | 79.4 |
| *Solvency* | | | | | |
| CAP | 14.6 | 12.5 | 13.2 | 12.2 | 12.7 |
| *Profitability* | | | | | |
| ROA | 1.0 | 2.2 | 2.3 | 2.1 | 1.7 |
| ROE | 9.9 | 24.4 | 27.0 | 25.4 | 20.7 |
| *Quality of assets* | | | | | |
| Delinquency ratio | 11.0 | 5.3 | 3.3 | 1.7 | 1.5 |
| *Bolivianization* | | | | | |
| Portfolio | 7.5 | 19.1 | 38.7 | 69.5 | 87.6 |
| Deposits | 15.6 | 35.7 | 47.2 | 63.5 | 77.3 |

Source: ASFI.

levels, below 2% since the beginning of the second half of 2011. The portfolio is mostly backed with real guarantees and delinquency is covered by appropriate levels of provisions, which shows that the strength of the banking sector is not associated with a financial weakening or a reduction in asset quality.

As pointed out in the conceptual framework section, besides the two conditions necessary for the existence of a credit channel, it is also important to take into account that the impact of monetary policy on loan supply depends on the characteristics of the banking sector. Liquidity measured in relation to assets and short-term obligations increased between 2005 and 2009, but has registered a downward trend since then. Meanwhile, hedging of short-term obligations remains at high levels.

Public deposits, mostly in bolivianos, have also exhibited considerable strength in recent years and constitute the main source of bank lending. Between 2005 and 2013 on average they represented around 90% of bank liabilities (Table 2). The large share of obligations with the public in bank liabilities significantly increases their sensitivity to monetary shocks and the potential strength of the credit channel. Thus, banks do not possess or employ sources of financing other than deposits, which is one of the conditions for the existence and efficiency of a credit channel.

Some of the characteristics of the banking system mentioned above (the bolivianization achieved, the large share of public deposits in bank lending, the significant dependence of some sectors on bank funding, the majority share of private national banks) would indicate that the credit channel could be important in the case of Bolivia. Meanwhile, banking institutions have different levels of liquidity, capitalization and size that could mean monetary policy has different effects depending on such characteristics.

Table 2

**MAIN BANKING SYSTEM BALANCE SHEET ACCOUNTS**
Millions of bolivianos

| | *2005* | *2007* | *2009* | *2011* | *2013* |
|---|---|---|---|---|---|
| *Asset* | 32,726 | 42,851 | 62,376 | 78,026 | 108,829 |
| Liquid assets | 3,269 | 4,937 | 12,097 | 15,902 | 17,314 |
| Financial investments | 7,687 | 11,796 | 18,375 | 14,590 | 23,513 |
| Gross portfolio | 21,571 | 25,758 | 31,365 | 46,547 | 66,621 |
| Default portfolio | 2,371 | 1,378 | 1,047 | 773 | 1,010 |
| Other assets | 200 | 360 | 539 | 987 | 1,382 |
| *Liability* | 29,046 | 38,729 | 56,914 | 71,413 | 99,927 |
| Obligations with the public | 23,488 | 33,122 | 49,710 | 61,898 | 84,991 |
| Other liabilities | 5,558 | 5,608 | 7,204 | 9,515 | 14,936 |
| *Equity* | 3,681 | 4,122 | 5,462 | 6,613 | 8,902 |

Source: ASFI.

## 4. LITERATURE REVIEW

Analysis of the credit channel has gained special attention from researchers over the last 25 years. One of the first theoretical and empirical studies was carried out by Bernanke and Blinder (1988, 1992), who in their theoretical analysis incorporated banks into the IS-LM model and then in their empirical research estimated a reduced-form loan supply equation using aggregate data. They found evidence for the existence of a credit channel when banks are not able to replace deposits with alternative sources of financing in times of contractionary monetary policy.

Stein (1998) proposed theoretical microfoundations for the model of Bernanke and Blinder, taking into account situations where the structure of bank assets and liabilities is potentially subject to adverse selection problems.

The first authors to find evidence for the existence of a bank lending channel in the microeconomic sphere were Kashyap and Stein (1995 and 2000). They used the central bank intervention interest rate as the monetary policy tool and demonstrated that monetary policy in the United States has heterogeneous effects on the growth of bank lending depending on bank size (1995) and liquidity (2000), that is, that small banks with less liquidity might have problems for maintaining their loan portfolio during a monetary tightening.

Based on the abovementioned result, Kishan and Opiela (2000) found that the impact differs according to the level of bank capitalization, that is, undercapitalized banks have less access to funds other than deposits and are therefore forced to reduce the supply of loans to a greater degree than well-capitalized banks.

Walsh (2003) also extended the analysis of Bernanke and Blinder. He studied the conditions under which loan supply could be perfectly elastic. His results showed that if loans and deposits are complimentary in the costs function of a bank, a change in reserve requirements that reduces deposits can increase the cost of loans, which leads to a displacement in the credit supply function (bank lending channel) causing a reduction in loans.

Along the same lines, Ehrmann et al. (2003) modelled a loan market also inspired by Bernanke and Blinder. They obtained from the solution of their model an equation for bank loans that relates to monetary policy, both directly (via the money channel) and through the characteristics of each bank (the credit channel). The authors used an explicit demand function for bank loans (that introduce aggregate variables of output and prices), taking into account that banks are perceived as risky, leading banks' funding sources to demand an external finance premium. The results of their model showed that a bank lending channel has operated in Germany, France, Italy and Spain, and that less liquid banks have a greater reaction to changes in the monetary policy stance, while size and capitalization are not important.

Worms (2003) reported that the average response of banks in Germany to changes in monetary policy depends on the share of short-term interbank deposits in total assets. Gambacorta (2005) employed data for Italy and showed that bank size is not related to the impact of monetary policy and that monetary shocks are weaker for banks with more liquid assets.

The existence of a credit channel has also been examined in Eastern European countries. Pruteanu (2004) detected the existence of a credit channel for the Czech Republic between 1996-1998, where capitalization influences the impact of monetary policy. Liquidity also seems to make a difference with respect to monetary policy, but only in banks with mostly domestic ownership. Benkovskis (2008) also studied the existence of a credit channel for Latvia. His results showed that some banks react significantly to a domestic monetary shock. Nevertheless, the reaction of total lending from all the banks was not found to be statistically significant. A domestic monetary shock has a solely distributional impact, only affecting smaller domestically owned banks with less liquidity and capitalization.

In Latin America, the credit channel was studied by Takeda et al. (2005). The study was based on a dynamic panel data model for Brazil; the results of which suggest evidence for a bank lending channel because reserve requirements affect bank loans. Said impact is larger for smaller banks, meaning monetary transmission is therefore greater as well.

Alfaro et al. (2003) also analyzed evidence on the bank lending channel in Chile for the period 1990-2002. The authors estimated an econometric data panel of banks in order to identify shifts in bank loan supply in response to monetary policy changes. For this purpose, they constructed an aggregate variable aimed at capturing the main mechanisms behind the bank lending channel. Said variable is used to estimate a VAR to test whether this transmission channel amplifies the impact of a change in the monetary policy interest rate on economic activity. The results showed how the bank lending channel operated as a monetary policy transmission mechanism in Chile during the period analyzed, and had an independent and significant impact on economic activity.

Gómez-González and Grosz (2006) attempted to find evidence for a credit channel in Colombia and Argentina between 1995-2005. Their results showed that while in Argentina it was not possible to prove that bank lending represents a factor amplifying the effects of a monetary policy shock, in Colombia there was evidence for a bank lending channel and the heterogeneous impact of monetary policy on credit intermediaries according to capitalization and liquidity levels.

Carrera (2011) also studied the existence of a bank lending channel for Peru using bank level data. The results showed that a credit channel has been operating in Peru, but it is not important for identifying the monetary policy transmission process toward economic activity.

In the case of Bolivia, there are only few studies done focusing on the theory and effectiveness of the lending channel. Orellana et al. (2000) analyzed three monetary policy transmission channels: Interest rates, exchange rate and credit channel, with VAR models, variance analysis and impulse-response functions for the period 1990-1999. The results established that the credit channel is the most appropriate in the case of Bolivia, given that through it monetary policy could temporarily and partially change the path of GDP growth. Furthermore, economic agents' expectations, the public's preference for cash over deposits, prudential standards of financial regulation and banks' own corporate policy can affect the credit channel.

Rocabado and Gutiérrez (2009) examined the credit channel as a mechanism of monetary policy transmission in Bolivia. The data used included banks' monthly information and other macroeconomic variables for the period 2001-2009. Panel data was employed and the generalized method of moments (GMM) was used, taking into account two monetary policy variables. The results demonstrated empirical evidence for the bank lending channel when the monetary policy indicator is the Treasury bill rate in foreign currency or the Treasury bill rate in housing promotion units. In the first case, the findings are supported through interactions between bank capitalization and liquidity, while in the second bank size and capitalization play an important role. Moreover, when the effective reserve rate is used as an indicator of monetary policy, there is no direct credit channel in any of the periods analyzed, although there is evidence of an indirect channel through the interaction between reserve requirements effective rate and liquidity.

## 5. THEORETICAL MODEL AND ECONOMETRIC SPECIFICATION

The model most used for explaining a bank lending channel in the economy is that developed by Kashyap and Stein (1995 and 2000) and Ehrmann et al. (2003). The authors propose a simple aggregate demand model, where the market for deposits is determined by the equilibrium between deposits ($D$) and the amount of money ($M$), both in relation to the interest rate ($z$) set by the central bank.

$$M = D = -\psi z + \chi, , \tag{1}$$

where $\chi$ is a constant and $\psi$ is the coefficient of the interest rate set by the central bank.

The bank $i$ faces a demand for loans $\left(L_i^d\right)$ which depends positively on economic activity $(y)$, inversely on the nominal interest rate of loans $\left(i_L\right)$ and the inflation rate $(\pi)$. A priori there is no expected sign for the inflation coefficient:[8]

$$L_i^d = \phi_1 y + \phi_2 \pi - \phi_3 i_L . \tag{2}$$

The supply of bank loans $i\left(L_i^s\right)$ is a function of the amount of money (or deposits) available, the nominal interest rate of loans and the central bank intervention rate ($z$). When a bank uses the interbank market to obtain resources, the central bank interest rate is the variable that determines the opportunity cost of such funds. The loan supply is therefore expressed as follows:

$$L_s^i = \mu_i D_i + \phi_4 i_L - \phi_5 z. \tag{3}$$

[8] The theoretical models indicate any sign is possible.

This model also takes into account that banks have different levels of dependence on deposits, that is, the larger the variable characterizing banks ($x_i$) (size, liquidity or degree of capitalization), the smaller the impact of a change in deposits. Said heterogeneity is captured with coefficient $\mu_i$, which measures the effect of asymmetric information according to the following:

4 $$\mu_i = \mu_0 - \mu_1 x_i \,.$$

Equalizing equations of demand 2 and supply 3, and replacing 1 and 4 within the model gives the equilibrium condition:

5 $$L_i = \frac{\phi_1\phi_4 y + \phi_2\phi_4\pi - (\phi_5 + \mu_0\psi)\phi_3 z + \mu_1\psi\phi_3 z x_i + \mu_0\phi_3\chi - \mu_1\phi_3\chi x_i}{\phi_3 + \phi_4}.$$

Equation 5 can be expressed as follows:

6 $$L_i = ay + b\pi - c_o z + c_1 z x_i - d x_i + \text{constant}.$$

Coefficient $c_1 = \dfrac{\mu_1\psi\phi_3}{\phi_3 + \phi_4}$ captures the reaction of bank lending in response to monetary policy, given the characteristics of the financial institutions. Considering the assumptions of the model, a significant $c_1$ coefficient implies that monetary policy affects loan supply. One identification assumption implicit in the model is that interest rate elasticity of loan demand does not depend on bank characteristics ($x_i$); coefficient $\phi_3$ is therefore the same for all banks.

The assumption of a homogeneous reaction of loan demand is instrumental for identifying the effects of monetary policy on loan supply. This assumption does not take into account cases where, for instance, customers of large or small banks are more sensitive to interest rate changes. Furthermore, this assumption seems to be reasonable for Bolivia given that bank loans are the principal source of funding for businesses.

For a better understanding of the sign of the end interaction coefficient, the logarithm is applied to both sides of Equation 6:

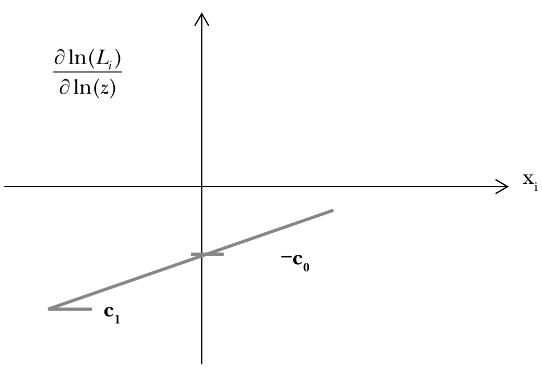
$$\ln(L_i) = \ldots + c_0 \ln(z) + c_1 x_i \ln(z) + \ldots$$

where $L_i$ is the amount of loans of bank $i$; $z$ is the central bank controlled short-term interest rate (corresponds to the monetary policy indicator measured by the net balance of monetary regulation bonds in the case of this paper); $c_0$ is the coefficient of the direct impact of monetary policy; $x_i$ is characteristic $x$ of bank $i$; and $c_1$ is the interaction coefficient between characteristic $x$ of bank $i$ and $\ln(z)$.

It seems reasonable to assume that $\partial \ln\left(L_i\right) / \partial \ln(z) = c_0 + c_1 x_i < 0$, which implies that the amount of loans of bank $i$ decreases in the face of interest rate hikes. If the bank characteristics variable $x_i$ represents liquidity, size or capitalization, it would be expected that $c_0 < 0$ y $c_1 > 0$. Assuming that $x_i$ represents the liquidity position of bank $i$, a positive $c_1$ coefficient would imply that more liquid banks respond to a lesser degree to monetary tightening represented by an interest rate hike.

Figure 2

**SIGN OF THE INTERACTION COEFFICIENT BETWEEN BANK CHARACTERISTICS AND MONETARY POLICY TOOL**




## 5.1 Specification of the Econometric Model

Based on a reduced form of the model presented in Equation 6, it is possible to widen the empirical specification in a way that the growth of the bank loan supply is explained by its lags, the monetary policy variable, the interaction of bank characteristics with monetary policy (key term of the analysis), GDP growth, inflation and banks' own characteristics.

$$\Delta\log(L_{it}) = \sum_{j=1}^{m} a_j \Delta\log\left(L_{it-j}\right) + \sum_{j=0}^{m} b_j \Delta\log\left(OMA\right)_{t-j} + \sum_{j=0}^{m} c_j \Delta\log\left(y_{t-j}\right)$$
$$+ \sum_{j=0}^{m} d_j \pi_{t-j} + ex_{it-1} + \sum_{j=0}^{m} f_j x_{it-1} \Delta\log\left(OMA\right)_{t-j} + \varepsilon_{it}, \quad (7)$$

where, $i$ is the bank $i$, $i$=1, ..., $N$; $t$ represents time, $t$=1, ..., $T$; $\Delta$ is the first difference operator; $m$, the number of lags; $L_{it}$, the loans balalance of bank $i$ in period $t$; $OMA_t$, the monetary policy indicator measured by the net balance of monetary regulation bonds; $y_t$, the economic activity indicator; $\pi_t$, the inflation rate; $x_{it}$, the individual characteristics of the banks, such as size, liquidity and capitalization; $\eta_i$, the specific bank error (individual effects); $\mu_{it}$,the residual error; and $\varepsilon_{it}$, the total error $\varepsilon_{it} = \eta_i + \mu_{it}$.

Dynamic specification of the equation (loan growth rate) takes into account the fact that banks react to changes in monetary policy by adjusting the concession of new loans.

The coefficients of interest are those that capture the effects of the monetary shock ($b_j$) and the coefficients of the interaction between monetary policy and bank characteristics ($f_j$) that attempt to capture whether bank characteristics make any difference in the way banks react to changes in monetary policy.[9] The asymmetric effects of monetary policy are captured by significant terms of interaction coefficients ($f$). Studies carried out found that banks which are smaller (Kashyap and Stein, 1995 and 2000), less liquid (Kashyap and Stein, 2000) or with lower levels of capital (Peek and Rosengren, 1995) react more to changes in monetary policy.[10] These results imply positive coefficients for the terms of interaction.

### *5.1.1 Variables*

The dependent variable is represented by the balance of banking institutions' gross portfolio.

[9] The bank characteristics coefficient ($e$) has an illustrative function, only showing whether there is a linear relation between a change in the supply of bank loans and bank characteristics.

[10] Size, level of capitalization, and liquidity are compared relative to the average for banking institutions analyzed in each of the studies mentioned.

The net balance of monetary regulation bonds was used as an indicator of monetary policy due to the fact that BCB adopts a strategy of quantity intermediate targets for the growth of net domestic credit.

Bank characteristics are represented by variables that correspond to the lending channel theory: size *(size)*, liquidity *(liq)* and capitalization *(cap)*. These variables are compared to the average of the total for banking institutions.

- Bank size is important: larger banks face less asymmetric information problems than smaller banks, therefore, making it easier for them to find sources of funding other than deposits in response to a monetary shock.

8 $$size_{it} = \log A_{it} - \frac{1}{N_t}\sum_{i=1}^{N_t} \log A_{it},$$

where $size_{it}$ is the relative size of a bank; $A_{it}$ is the total assets of the bank; and $N_t$ is the number of banks in period $t$.

- Another important characteristic is liquidity. Liquid banks are able to use their assets to protect their loan portfolios, while this is more difficult for relatively less liquid banks. The argument is that a reduction in banks' lendable funds (deposits), caused by a monetary tightening, does not imply a reduction in loans if the bank has the option to sell its bonds or other liquid assets.

9 $$liq_{it} = \frac{Lq_{it}}{A_{it}} - \frac{1}{T}\sum_{t=1}^{T}\left(\frac{1}{N_t}\sum_{i=1}^{N_t}\frac{L_{it}}{A_{it}}\right),$$

where $liq_{it}$ is the relative liquidity of a bank; $Lq_{it}$ is the liquid assets of a determined bank: The sum of assets and temporary investments, excluding liquid asset reserve requirements and permanent investments; and $A_{it}$ is the total assets of the bank.

- Banks with above average capitalization levels can more easily access alternative sources of financing, meaning they do not have to reduce their loan supply as much as less capitalized banks in times of monetary tightening.

10 $$cap_{it} = \frac{C_{it}}{A_{it}} - \frac{1}{T}\sum_{t=1}^{T}\left(\frac{1}{N_t}\sum_{i=1}^{N_t}\frac{C_{it}}{A_{it}}\right),$$

where $cap_{it}$ is the relative capitalization of a bank; $C_{it}$, the capital and reserves of a bank; and $A_{it}$, the total assets of the bank.

Equations 9 and 10 establish that the global average of liquidity and capitalization is equal to zero across time and among banks, meaning said bank characteristics are zero for all the observations, but not necessarily in every period $t$. This allows the degree of global liquidity and capitalization to vary across the periods. Thus, for the analysis, temporary changes are not removed from the average of these variables.

The definition of size in Equation 8 excludes the rapid growth of the banking sector, adjusting average bank size to equal zero for each time period. This procedure gets rid of unwanted nominal changes in this variable, with which the size of a bank as compared to the size of all the banks in a given period is a relevant measure.

The three bank characteristics are standardized with respect to the average for the group of banks in order to obtain indicators that add up to zero across all the observations. Therefore, the average of the interaction term in Equation 7 is zero, meaning coefficients $b_j$ can be directly interpreted as a measure of the total impact of monetary policy on bank loans.

GDP growth rate and inflation are employed as macroeconomic variables to control for demand shocks.

### *5.1.2 Data Sources*

The period analyzed runs from March 2005 to December 2013. Bank data is taken from the quarterly balance sheets that financial institutions report to the ASFI <www.asfi.gob.bo> and only consider banks currently operating and whose capital is based in the country. The balance sheets published by the ASFI contain the information required for constructing the dependent variable (annual growth of banks' loan portfolio) and the size, liquidity and capitalization coefficients defined in Equations 8 to 10, respectively.

The macroeconomic variables employed are taken from the National Statistics Institute (INE, <www.ine.gob.bo>) and those of monetary regulation are sourced from the BCB (<www.bcb.gob.bo>). The 12-month growth rate for the three macroeconomic variables was considered.

Table 3 shows descriptive statistics for the variables employed in the model for the estimation period.

Table 3

**DESCRIPTIVE STATISTICS FOR THE VARIABLES IN THE MODEL**

Millions of bolivianos and percentages

| | *Mean* | *Standard deviation* | *Minimum* | *Maximum* |
|---|---|---|---|---|
| Loan portfolio growth | 16.9 | 12.7 | −16.0 | 54.7 |
| Net balance of OMO growth | 83.0 | 115.3 | −52.1 | 361.8 |
| GDP growth | 4.7 | 1.3 | 2.5 | 6.9 |
| 12-month inflation rate | 6.5 | 4.0 | 0.3 | 17.3 |
| Capital to assets ratio | 7.5 | 2.0 | 3.7 | 17.0 |
| Liquidity to assets ratio | 33.3 | 12.6 | 10.0 | 63.2 |
| Size (assets) | 5,312 | 3,815 | 266 | 18,153 |

Sources: ASFI, BCB and INE.

## 5.2 Estimation Method

The simplest way to estimate the model is by using ordinary least squares method (OLS). One difficulty with this approach is probably the unobserved importance of heterogeneity in the conditional mean across financial institutions. A simple alternative for estimating the model would therefore be to use static panel data with fixed effects applied within transformation, given that the sample considers all the banking institutions in the system.

However, Equation 7 shows that the dependent variable is modelled through a dynamic specification, given that there might be lagged dependent variables as explanatory variables for the model.

Dynamic specification of a model with fixed effects or least squares dummy variables (LSDV) model is estimated by applying OLS to the model expressed in deviations from the mean of each unit in the panel with respect to time. However, Nickell (1981) showed that the LSDV estimator is biased and inconsistent, particularly when $N$ is large and $T$ is small, a bias which is not reduced by increasing $N$, or by adding explanatory variables. However, as $T$ grows, the fixed effects estimators become consistent.

There have been attempts to correct the bias of the fixed effects LSDV estimator, among which are the instrumental variables (IV) method and the generalized method of moments (GMM). Due to the dynamic nature of the model, the GMM proposed by Arellano and Bond (1991) was employed. To solve possible problems of endogeneity in the procedure based on Arellano and Bond, lagged values of the variables of Equation 7 are employed as GMM type instruments.[11]

The AR test is important when estimating dynamic models in order to analyze the autocorrelation of residuals. By construction, the residuals of the difference equation show first-order autocorrelation, but if the series independence assumption of the original errors is guaranteed, the residual differences should not show a significant *AR(2)* (there should not be any second-order autocorrelation in the residuals of the first-difference equation), which is verified with the *AR(1)* and *AR(2)* tests. The Hansen test was employed to validate the use of chosen instruments.

## 6. RESULTS

Equation 7 was estimated based on the methodology described in the previous section. It is important to mention that the coefficients reported in Table 4 are the long-term ones,[12] while the short-term coefficients are presented in the Annex. Long-term coefficients of the interaction terms were used to test whether there is a monetary policy impact on loan supply, assuming that the other variables included in Equation 7 capture the movements of credit caused by loan demand and supply factors other than changes in monetary policy.

The estimates[13] show that monetary policy has the capacity to directly affect bank loan supply because it presents the expected sign (negative) and is statistically significant in both models. This would

[11] The fact that bank characteristic variables are based on balance sheet data leads to the problem of endogeneity: If bank loans and bank characteristics are closely correlated, a priori it would not be clear which variable drives the other.

[12] The long-term coefficient of a variable is calculated as the sum of its contemporaneous coefficient and its (their) lag(s), divided by one minus the sum of the lagged dependent variable coefficients. The significance of long-term coefficients is tested using the Wald test.

[13] Due to the dynamic character of Equation 7, the preferred model is the one estimated by GMM. Nevertheless, Table 4 presents the results estimated by LSDV in order to test their robustness.

**Table 4**

**LONG-TERM COEFFICIENTS OF THE REGRESSION OF MONETARY POLICY IMPACT ON BANK LOANS**

Dependent variable: $\Delta \log\left(L_{it}\right)$

| | *Fixed effects* | *A&B* |
|---|---|---|
| $\Delta \log(OMA)$ | −0.0474 | −0.0478 |
| | (0.07) | (0.06) |
| $size * \Delta \log(OMA)$ | 0.0380 | 0.0383 |
| | (0.01) | (0.01) |
| $liq * \Delta \log(OMA)$ | −0.5911 | −0.5895 |
| | (0.00) | (0.00) |
| $cap * \Delta \log(OMA)$ | 1.3303 | 1.3284 |
| | (0.04) | (0.04) |

Note: Probabilities are in parenthesis.

imply that a monetary policy tightening (increase in the supply of securities) leads to reductions in loan growth and would signal the existence of a direct lending channel [coefficient of the variable $\Delta \log(OMA)$].

According to the findings, the coefficients for size and capital interactions were statistically insignificant, which reflects the existence of different reactions among the banks to changes in monetary policy through such variables, meaning the proposed methodology would prove the existence of a bank lending channel. The evidence therefore suggests that smaller banks with below average capitalization levels would reduce their loans to a greater degree in the face of a monetary tightening.

The results also imply that in times of monetary policy tightening borrowers of smaller less-capitalized banks on average experience a larger reduction in financing than borrowers of larger more capitalized banks.

Size is the indicator most used in the existing literature to reflect the capacity of banks to obtain sources of funding other than deposits. Small banks would tend to have greater difficulties in obtaining sources of funding given that they face higher information costs or a greater external financing premium, or both, than larger banks do. They are therefore less able to offset the impact of a monetary tightening and are forced to reduce their loan supply to a greater degree than large banks.

High capitalization levels also mean that banks are less likely to experience asymmetric information and moral risk problems. Thus, the external finance premium for a bank with high levels of capitalization should be lower than that for a less capitalized bank, implying that the latter are forced to reduce their loans to a greater degree than the former.

In the case of liquidity, although the interaction variable was statistically significant, it does not present the expected sign. There is therefore no evidence for a bank lending channel with this indicator. According to Worms (2003) liquidity could be endogenous: Banks facing problems of imperfect information would probably decide to maintain a higher amount of liquid assets. The possibility that more liquid banks have greater risk aversion, meaning they would have higher standards for granting loans, cannot be excluded either. If this were the case, in response to monetary policy, there would be differences in the demand for loans between risky and less risky borrowers, meaning liquidity would not be a variable that allowed for discriminating the effects of monetary policy on loan supply.

Finally, autocorrelation tests *AR(1)* and *AR(2)* show that, as would be expected, there is a first-order correlation in the residuals, while there is no second-order correlation. The Hansen test shows that the instruments used are valid.[14]

## 7. CONCLUSIONS

Unlike the traditional interest rates channel, the bank lending channel assigns a significant role to banks in the transmission of monetary policy. The two necessary conditions for the existence of a bank lending channel are the capacity of monetary policy to affect loan supply and the dependence of certain economic agents on bank lending.

There are characteristics of the Bolivian banking system, such as the degree of bolivianization achieved, the large share of public deposits in bank funding, the significant dependence of some sectors on bank funding and the majority share of private domestic

[14] The results of the tests are reported in the Annex.

banks, which indicate that the lending channel could be important in Bolivia's case.

The estimates show that monetary policy has the capacity to directly affect bank loan supply, which would imply that increases in the securities' supply lead to reductions in loan growth. Moreover, interactions of size and capital with the monetary policy variable reflect the existence of different bank reactions, validating the existence of a bank lending channel. The findings would suggest that smaller less capitalized banks reduce their loans to a greater degree in times of monetary tightening.

## ANNEX

Table A.1

**SHORT-TERM COEFFICIENTS OF THE REGRESSION OF THE IMPACT OF MONETARY POLICY ON BANK LOANS WITH THE FIXED EFFECTS METHOD**

Dependent variable: $\Delta \log\left(L_{it}\right)$

| | *Coefficient* | *Standard error* | *Probability* |
|---|---|---|---|
| $\Delta \log(L)[-1]$ | 0.8727 | 0.0312 | 0.0000 |
| $\Delta \log(OMA)$ | −0.0016 | 0.0034 | 0.6540 |
| $\Delta \log(OMA)[-1]$ | −0.0045 | 0.0033 | 0.2110 |
| $\Delta \log(PIB)$ | 0.2011 | 0.1595 | 0.2360 |
| $\Delta \log(PIB)[-1]$ | −0.1555 | 0.2972 | 0.6120 |
| $\pi$ | 0.2636 | 0.1149 | 0.0450 |
| $\pi[-1]$ | −0.1223 | 0.1200 | 0.3320 |
| $size[-1]$ | −0.0240 | 0.0110 | 0.0540 |
| $liq[-1]$ | 0.1402 | 0.0347 | 0.0020 |
| $cap[-1]$ | 0.0705 | 0.2635 | 0.7950 |
| $size[-1] * \Delta \log(OMA)$ | 0.0008 | 0.0021 | 0.7000 |
| $size[-1] * \Delta \log(OMA)[-1]$ | 0.0040 | 0.0021 | 0.0820 |
| $liq[-1] * \Delta \log(OMA)$ | −0.0266 | 0.0344 | 0.4570 |
| $liq[-1] * \Delta \log(OMA)[-1]$ | −0.0487 | 0.0358 | 0.2030 |
| $cap[-1] * \Delta \log(OMA)$ | 0.1074 | 0.0414 | 0.0270 |
| $cap[-1] * \Delta \log(OMA)[-1]$ | 0.0620 | 0.0515 | 0.2560 |
| Constant | 0.0161 | 0.0149 | 0.3060 |

Table A.2

**SHORT-TERM COEFFICIENTS OF THE REGRESSION OF THE IMPACT OF MONETARY POLICY ON BANK LOANS WITH THE GMM**

Dependent variable: $\Delta \log\left(L_{it}\right)$

| | *Coefficient* | *Standard Error* | *Probability* |
|---|---|---|---|
| $\Delta \log(L)[-1]$ | 0.8724 | 0.0310 | 0.0000 |
| $\Delta \log(OMA)$ | −0.0016 | 0.0034 | 0.6440 |
| $\Delta \log(OMA)[-1]$ | −0.0045 | 0.0033 | 0.2050 |
| $\Delta \log(PIB)$ | 0.1963 | 0.1593 | 0.2440 |
| $\Delta \log(PIB)[-1]$ | −0.1576 | 0.2968 | 0.6060 |
| $\pi$ | 0.2640 | 0.1151 | 0.0430 |
| $\pi[-1]$ | −0.1217 | 0.1195 | 0.3300 |
| $size[-1]$ | −0.0248 | 0.0108 | 0.0430 |
| $liq[-1]$ | 0.1365 | 0.0325 | 0.0010 |
| $cap[-1]$ | 0.0570 | 0.2574 | 0.8290 |
| $size[-1] * \Delta \log(OMA)$ | 0.0009 | 0.0021 | 0.6910 |
| $size[-1] * \Delta \log(OMA)[-1]$ | 0.0040 | 0.0021 | 0.0770 |
| $liq[-1] * \Delta \log(OMA)$ | −0.0268 | 0.0345 | 0.4540 |
| $liq[-1] * \Delta \log(OMA)[-1]$ | −0.0484 | 0.0358 | 0.2040 |
| $cap[-1] * \Delta \log(OMA)$ | 0.1083 | 0.0414 | 0.0240 |
| $cap[-1] * \Delta \log(OMA)[-1]$ | 0.0611 | 0.0512 | 0.2580 |
| AR(1) | | | 0.0320 |
| AR(2) | | | 0.6940 |
| Hansen | | | 1.0000 |

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# What Microeconomic Banks Data Tell Us about Monetary Policy Transmission and Financial Stability in Guatemala

***José Alfredo Blanco Valdés***
***Héctor Augusto Valle***

**Abstract**

*This paper aims to research the credit channel in Guatemala in a microeconomic context. The country currently conducts its monetary policy through an explicit inflation targeting regime, and previous studies have concluded that the monetary policy transmission mechanism is rather weak. However, the empirical evidence of those studies is based on aggregate data. This paper contributes by performing detailed analysis of individual data for each bank, classified by bank size and loan type. The hypothesis is that policy transmission is heterogeneous by these characteristics. First, a descriptive analysis of the response of interest rates and lending to policy rate variations is carried out. Second, econometric panel data techniques are applied to estimate the lending channel. We find that there is a transmission of monetary policy, but it is heterogeneous, and liquidity, capitalization and bank size play an important role in it. The factors contributing to weakening the mechanism are excess liquidity in the banking system, portfolio dollarization, bank size and the method for calculating reserve requirement.*

*Keywords: monetary transmission mechanisms, credit channel, financial stability.*

*JEL classification: E52, C23.*

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J. A. Blanco Valdés <jblanco@sib.gob.gt>, economics adviser at the Superintendencia de Bancos de Guatemala, and H. A. Valle <havs@banguat.gob.gt>, researcher in the Economics Research Department of the Banco de Guatemala.

# 1. INTRODUCTION

The aim of this paper is to research the credit channel in Guatemala as a basis for assessing the impact of monetary policy on the banking system and the financial stability. Different studies, by the Economic Research Department of the Banco de Guatemala and the International Monetary Fund (Medina Cas et al., 2011), have concluded that monetary policy transmission mechanisms in the country are weak. Nevertheless, all those papers have one thing in common: They are based on aggregate data, mainly employing autoregressive vector models.

This paper contributes to study of the credit channel in Guatemala by using a microeconomic bank database. It is hoped this research will provide answers to "why the transmission mechanism is weak." Banks are the first link in the transmission of monetary policy to consumption and investment. This paper, therefore, analyzes the transmission of the policy rate to market rates, which is the origin of the credit demand channel. However, the main focus of the work is to identify and estimate the lending channel, which reveals the impact of monetary policy on the supply of bank loans.

The particular interest in performing a detailed study of the lending channel stems from the fact that it may help to reveal the interaction between monetary policy and banks, and, therefore, to discover the factors that influence the effectiveness of the Banco de Guatemala's monetary policy actions.

First, we conduct an event study. Identifying and estimating monetary policy transmission mechanisms is complicated in small economies with underdeveloped financial markets, frequent structural breaks, and relatively short data sets. Hence, as a first step in studying the monetary policy transmission, this paper takes an event narrative approach as in Bergm, Charry, Portillo, and Vlcek (2013). However, unlike the referred paper, event analysis is performed with microeconomic data instead of aggregate data. This approach is used to analyze policy rate movement events and banks' response to them, classified by bank size and loan type. The approach not only helps to assess the effects on financial institutions in accordance with their characteristics but also helps to guide later econometric work.

Micro economic data of 18 banks in Guatemala's banking system for the period from January 2010 to April 2014 was used to build a data panel for the econometric study of this research. The lending channel is estimated for the data group as a whole, and for subgroups organized by bank size and loan type.

The outcomes confirm the hypotheses on the factors weakening the transmission channel. In particular, it was found that partial dollarization of the financial system, excess bank liquidity, and bank concentration influence the rigidity of monetary policy transmission (RMPT). Also, the microeconomic study of the Guatemalan banking system provides other explanations that can help identify concrete measures that financial supervisory and monetary authorities can adopt over the medium-term to improve the transmission of monetary policy signals, while at the same time increasing the soundness of the financial system. In specific, we found that improving the method for calculating reserve requirement can lead to more efficient bank liquidity management, which is an important variable that determines RMPT. De-dollarization of bank balances –especially large banks–, as well as greater bank internationalization and de-concentration, are all macroprudential policy directions that can also improve RMPT, among other issues that can be addressed gradually over the medium term.

Other significant rigidities found are the predomination of so-called *large corporate loans* at preferential interest rates that do not obey policy rate movements, the post-crisis attraction of investing in central government securities and capital restrictions faced by a specific banking segment. In general, it seems that monetary policy transmits better through medium and small-size banks.

The Guatemalan economy has been characterized by a long tradition of macroeconomic and financial stability. In the context of financial stability, this research contributes with a macroeconomic study of the lending channel, which is a fundamental precondition for linking the impact of monetary policy with financial stability. Said link, however, is not directly addressed in this paper, although it does lay the groundwork for doing so in later studies. Notwithstanding, it can be seen that there are no significant monetary policy implications for financial stability through the lending channel.

The first part of this paper characterizes the Guatemalan banking system based on the event narrative and other indicators. The second part includes an econometric study of the lending channel, using panel data techniques. A brief analysis of the financial system in Guatemala is presented in the third part, and the fourth gives the conclusions.

## 2. CHARACTERIZATION OF THE TRANSMISSION CHANNEL: EVENT NARRATIVE APPROACH

This section presents the event narrative approach. In particular, based on the microeconomic data collected from each of the 18 banks making up the Guatemalan financial system, stylized facts for monetary policy transmission mechanisms in Guatemala are profiled, specifically the bank lending channel. Said facts are inferred in the graphical analysis by particularly studying the period from September 2011 to December 2013. This period was chosen for two main reasons. First, the policy rate of Banco de Guatemala recorded three increases in 2011 after having remained unchanged at 4.5% from September 17, 2009. In specific, on March 31, 2011, it was raised to 4.75%, on July 28 to 5% and on September 29 to 5.5% (see Figure). These events represent an appropriate period for assessing the transmission of monetary policy, considering that they were successive hikes after an extended period of having kept the rate fixed and that the inflation targeting scheme in Guatemala, after being implemented six years previously, was by that time more mature.

Second (and this is connected with the *greater maturity* of the scheme), in 2011 the term for Banco de Guatemala's certificates of deposit, which constitute its policy instrument, was reduced from seven days to one day (overnight operations). The inflation targeting scheme was formally adopted on January 1, 2005. The 2005-2010 period is ruled out because it is influenced by several changes in the definition of the monetary policy rate, assigning that property to central bank certificates at different terms, decreasing from 91 to seven days and, finally, overnight operations in 2011.

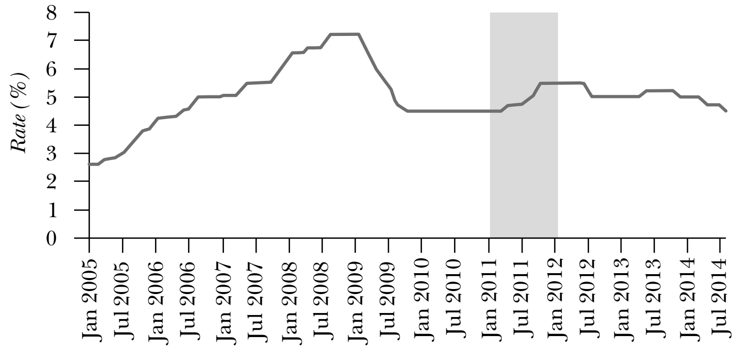
### 2.1 Transmission of Policy Rates to Market Rates

#### *2.1.1 Transmission of Policy Rates to Short-term Rates*

As of September 1, 2011, when the overnight rate for central bank certificates was adopted as the monetary policy instrument–within a monetary regime of explicit inflation targets–, there has been a significant improvement in monetary policy transmission (MPT) to the money market. In fact, as can be seen in Figures A.2 and A.3 in Annexes, in the three periods of policy rate hikes between 2011 and 2013, repo rates in the national stock market and interbank market rates increased in line with said adjustments, converging towards

Figure 1

**POLICY INTEREST RATE**




the monetary policy rate. Figure A.2 shows the evolution of the total interest rate (weighted average for all terms), the rate for terms of one to seven days and the overnight rate. The transmission is clearly shown in the figures, and it is fairly comprehensive in very short-term operations (overnight) but is not as strong at slightly longer terms (from one to seven days and total), although the transmission is still evident. The graphical event analysis makes it possible to infer that there is a clear transmission from the policy rate to short-term market rates.

Also, the Banco de Guatemala implemented an organizational change in its structure that has allowed it to improve bank liquidity management. In specific, the central bank established a front, middle, and back office system. As part of the front office functions, the central bank communicates with all banks in the system on a daily basis to establish their liquidity requirements, which serves as a reference for fixing the size of central bank participation in the daily auctions of its certificates in the money market. This is complemented by establishing an interest rate corridor to guide banks participation in the money market towards the monetary policy rate.

### *2.1.2 Transmission of the Policy Interest Rate to Bank Lending Rates*

The reaction of bank lending rates to adjustments in monetary policy rate has been varied, differing in nature according to bank group (large, medium or small-sized) and the type of market they target their operations on (large corporate loans, small business loans, consumer loans, and mortgages). In accordance with the hypotheses set forth by this paper, a detailed disaggregated study is performed by bank size and loan type. In specific, an event analysis is carried out using the same policy rate increases employed in previous sections, comparing them with the path of interest rates by bank size (large, small and medium) and loan type: large corporations, small business, consumer, microcredit, and mortgage.

The figures of the event analysis are presented in Annexes (Figure A.3). The figures show how, in response to the 2011 policy interest rate hikes, the sensitivity of interest rates for large corporate loans by large banks is null; they do not even affect the overall trajectory observed in the opposite direction –decline–. Very similar behavior is observed for medium-sized banks. Small banks are the exception, where behavior in the same direction as policy rate changes is identified. Nevertheless, large banks, unlike the majority of other banks, generally concentrate their loans on this type of customers and it can be seen how the interest rate fixed for such loans have a significant component that does not necessarily respond to market conditions that can be influenced by monetary policy. These specific conditions of the financial market in Guatemala are feasible under a context of high bank liquidity and a few large firms with strong bargaining power that agree on interest rates on very large loans with the banks. Given that large and medium-sized banks make up almost 90% of the country's banking system, and that large corporate loans constitute almost 60% of the total bank portfolio, the effect policy rate might have on large corporate loan interest rates must be very small. It, therefore, becomes more important to understand the transmission mechanisms to identify their rigidities and, consequently, suggest measures for improving them.

The same occurs with small business loans (Figure A.3), where it is observed that the market rates of large and medium-sized banks do not react to policy rate increases either. In a similar way to large corporate loans, small bank interest rates seem to react with some lags and only temporarily, without affecting their long-term trajectory.

In the case of consumer loans, there is a better adjustment in the market interest rates of medium-sized banks and, probably, of small sized ones, but not of large banks. The overall result improves after the overnight rate was adopted as the monetary policy instrument in September 2011. In any case, this is not the type of loan with the most significant influence on the economy's aggregate demand, meaning its importance for improving monetary policy transmission mechanisms is not so decisive.

Mortgage loans do not exhibit sensitivity to monetary policy rate adjustments either in the graphical analysis. Microloans and mortgages are not very important in the portfolio. As regards mortgages, this result could be because they require a guarantee from the Instituto de Hipotecas Aseguradas and include specific conditions in the financial characteristics of the loans.

## 2.2 Impact of the Policy Rate on Lending

To typify and obtain a first approximation of the impact of the monetary policy rate on lending, this section analyzes in graphic form the effects of the policy rate increase events during 2011 by different loan types and bank size. In the same way, as in the previous section, bank size is classified into large, medium, and small, and loan type into large corporations, small business, microcredit, and consumer.

The results are shown in Figure A.4. The figures for the total lending show there is a contraction in lending, which operates with lags, in response to the policy rate increases for all three bank sizes.

In the same way, lagged contractions in lending are observed in response to policy rate increases in large and small business loans for large, medium and small-sized banks (Figure A.4).

In the case of consumer credit, microloans, and mortgages, the graphical evidence is less clear (Figure A.4).

In general, a stronger contraction can be seen after the last policy rate increase which took place at the end of September 2011. This could be attributable to the change made that same month by the Banco de Guatemala to shorten the term of its policy instrument (central bank certificates of deposit) from seven days to one. However, this is an assumption that cannot be proven with graphical analysis.

Graphical event analysis is not conclusive regarding the contraction of lending in response to policy rate hikes. The decreases that occurred after the rate increase could be due to many other reasons. On the other hand, the graphical analysis is extremely useful for making a first approximation in the study of monetary policy transmission, form some initial ideas and characterize the behavior of the banking sector in Guatemala.

The above observations mean positive expectations can be made regarding the presence of a lending channel, that it operates with lags, that not all episodes are the same and that the use of shorter-term instruments could have helped to boost transmission. Nevertheless, at this point, all these statements are only assumptions.

## 2.3 Dollarization of Bank Balances

Dollarization of bank balances, indicated by a 43% share of the portfolio in foreign currency, as a proportion of the total portfolio, and around 18% of deposit liabilities (Figure A.5), could be having a major influence on the above results, mainly because the group of large banks is the most dollarized. In general, those banks mainly grant large corporate loans to major firms in foreign currency due to the nature of their business and because there is a market for supplying funds in foreign currency at lower interest rates –in the current global financial environment–. This implies that a considerable amount of bank funding is not tied to local market conditions.

Although the process of dedollarizing bank assets is important for enhancing monetary policy transmission mechanisms, it should be taken into account that the observed postcrisis increase is a tendency to recover precrisis levels, meaning we should expect to be at a time when dollarization is beginning to recede. In fact, the portfolio in foreign currency is now growing slower than that in domestic currency. Nonetheless, financial dollarization is relatively high, meaning it could be considered as a macroprudential instrument in the future, not without considering the dedollarizing effect the start of hikes of monetary policy reference rate by the Federal Reserve System of the United States might have.

## 2.4 The Composition of Bank Assets

It is worth asking whether the composition of bank assets tells us anything about the behavior of bank lending, particularly because in recent years banks have been investing large amounts of their available resources into treasury bonds issued by the central government. This was seen above all after the recent international financial crisis that led to an easing of countercyclical fiscal policy in different countries, including Guatemala (see Figure A.6). In fact, after observing fiscal deficits of 2% or less, the latter have reached between 2% and 3% (although with a downward trend). This led to higher funding requirements and the resulting increase in issues destined for the domestic market, where the banking system is the main purchaser.

Consequently, large banks have increased their investments in government bonds, pursuing less risk and greater yields. It is important to mention this because there has supposedly been a minor breach of the portfolio theory, which states that the higher the risk, the higher the interest rate. However, investments in government bonds offer better interest rates than portfolio placement in the large corporate loans segment, for instance, along with lower risk. Increased investments in government securities could be affecting monetary policy transmission. This cannot be seen in the graphical analysis, and if said investments have indeed been growing, it has not significantly affected the ascending behavior of the loan portfolio. Intuitively the latter portfolio, particularly that of large corporate loans, is insured for its customers. This is based on the fact that several periods of decline or slowing in the growth rate of lending observed recently are due to private firms finding external sources of funding at lower costs than those offered by banks operating in the domestic market.

## 2.5 Banking System Liquidity

Guatemala's banking system suffers from chronic excess liquidity. This is demonstrated by the fact that the Banco de Guatemala conducts open market operations to withdraw excess liquidity on a daily basis with its certificates of deposit at overnight term. Historically there have only been two events where the Bank has had to inject liquidity. This chronic excess liquidity is a significant constraint for the lending channel given that, according to theory, in order for the channel to exist, banks should always be at the limit of their liquid assets and reserves.

Figure A.7 shows available liquid resources (excess reserves plus overnight investments in the Banco de Guatemala) along with policy interest rate increase and decrease events. It can be seen that bank liquidity follows an upward trend and in the case of large and medium-sized banks it is immune to policy rate movements. In particular, it shows graphically how small banks exhibit slight variations around the points where rate changes occur.

### *2.5.1 Method for Calculating Reserve Requirements*

The current methodology requires banks to maintain reservable assets on a monthly basis, being able to be without required reserves for up to 14 days during a month. This causes bank treasurers to make significant liquidity forecasting efforts to satisfy the requirement by the end of the month, under a context where the increase in financial transactions could put this compliance at risk (above all when there might be unexpected movements beyond the control of the treasury strategy). For this reason, banks continue to be very cautious in how they must hold resources in excess of the reserve requirement in anticipation of such contingencies. Thus, although the implementation of overnight operations has improved bank liquidity management, the method for calculating reserve requirements continues to constrain it. Changing to some type of daily requirement with a two-day settlement term could improve the system's liquidity management, while strengthening monetary transmission.

### *2.5.2 Banking System Liquidity*

The graphical analysis shows, according to the balance of the liquid assets available to the banking system, that there is space to continue improving liquidity management, above all in small banks, where it can be seen how the buildup of liquid assets is very sensitive to expansive monetary policy (Figure A.7). In the case of all three bank groups, the buildup of liquidity has moderated slightly during periods of restrictive monetary policy. Thus, an improvement in the methodology for calculating reserve requirements would support the financial activity of small banks more.

In addition, short-term interbank interest rates have also converged towards the monetary policy reference rate, which is further evidence of improvements in bank liquidity management (Annex A.8).

# 3. THE LENDING CHANNEL

## 3.1 Literature Review

The broad credit channel comprises the balance-sheet channel, net flows channel, and bank lending channel. We specifically analyze the bank lending channel in this paper. The latter is the relevant channel for researching the role of banks in monetary policy transmission and, particularly, how this can affect banks' financial stability.

The impact of the lending channel is through bank assets and not their liabilities, which is the traditional money channel approach. In general, the channel operates as so: in response to a policy rate increase the central bank carries out open market operations (selling bonds to commercial banks), banks' reserves decrease, banks must reduce reservable deposits and, consequently, these lost reservable deposits must be replaced with nonreservable liabilities or, alternatively, they can reduce assets such as loans and securities. In Guatemala, all deposits are subject to reserve requirements, meaning banks would have to reduce their assets (reduce lending) in response to a policy rate increase.

For the bank lending channel to be operational, prices must not adjust fully and instantaneously in the face of a change in the demand for money. Moreover, the central bank's open market operations must affect the supply of bank loans, and loans and bonds must not be perfect substitutes (as a source of credit for borrowers). This ensures that at least part of the adjustment will fall on loans.

The empirical challenge is to identify if a change in monetary policy affects bank lending. However, a decrease in lending might reflect a reduction in demand and not supply. It is therefore important to control for demand factors that can alter lending.

Performing a study from the point of view of liquidity and portfolio size, Kashyap and Stein (2000) show in their work how banks with small loan portfolios and more liquid banks are the most sensitive to monetary policy shocks.

Meanwhile, Kishian and Opiela (2000) argue that the loan portfolios of the most capitalized banks are less sensitive to monetary policy shocks, with the opposite being true for badly capitalized banks.

With respect to banks with capital restrictions, Peek and Rosengren (1995) find evidence that the portfolios of banks without capital restrictions (in England) have a greater capacity to respond to monetary policy shocks than banks with restrictions.

In the area of investment, the work of Gertler and Gilchrist (1994) stands out. They show that, at an aggregate level, the investment of a group of small firms is more sensitive to changes in monetary policy as compared to the investment of a group of large firms.

Meanwhile, Driscoll (2004) employs an aggregate-level panel data model to investigate to what degree changes in bank loan supply affect output. Using specific shocks to money demand as an instrumental variable for addressing the problem of endogeneity, he did not find any significant impact of loan supply shocks on state-level economic activity.

Holod and Peek (2007) distinguish between two types of banks: publicly traded on the stock exchange and non-publicly traded. They find that the portfolios of publicly traded banks are less affected by monetary policy than non-publicly traded banks.

Finally, Maddaloni and Peydró (2011) adopt an alternative approach to address identification challenges based on surveys of bank lending standards (for the Eurozone and the United States). They find that low short-term interest rates soften standards for household and corporate loans, which reinforces the lending channel that operates through banks.

## 3.2 Econometric Model

The econometric model for researching the lending channel in Guatemala is based on the work of Kashyap and Stein (1994), and of Kishan and Opiela (2000). In particular, the econometric approach in this research is based on Carrera (2011), and Joyce and Spaltro (2014), which in turn are based on the theoretical model of Ehrmann et al. (2003).

The following equation expresses the econometric model:

$$C_{it} = \sum_{j=0}^{n} \rho_i C_{it-j} + \sum_{j=0}^{n} \sigma'_j a_{it-j} + \tau'_j b_{it-1} + \sum_{j=0}^{n} w'_j b_{it-1} a_{3it-j} + \varepsilon_{it}, \tag{1}$$

where $C_{it}$ is the annual growth of loans (total, commercial and consumption), $a_{it}$ is the vector of macroeconomic variables ( $a_{3it}$ is the bank interest rate), $b_{it}$ is the vector that contains the characteristics of each bank's variables (liquidity, size and capitalization), $\varepsilon_{it}$ is a vector that contains the error terms and $n$ is the number of lags.

Taking into account that it is a dynamic panel, the most widely used estimation methodology is that of Arellano and Bond, which allows for obtaining consistent estimators, a property that is not observed when using ordinary least squares.

The model is estimated with four lags, using a maximum of four lags as instrumental variables as well.

### 3.3 Data

This section describes the data used in this investigation for the empirical study of the lending channel transmission mechanism and its impact on microfinancial stability.

Total banking system loans in domestic currency, commercial loans, and consumer loans, are used as the lending variable. Each of these items is divided into bank size, grouped into large, medium, and small. This classification is based on the ratio of each bank's deposits to total deposits in the domestic banking system. If the ratio is greater than 10% it is defined as a large bank, if it is between 2% and 10% it is a medium-sized bank, and if it is below 2% it is considered a small bank.

The interest rate, liquidity, a size variable and a capitalization variable are employed as independent variables. Four definitions are used for interest rates, which are very closely related to the monetary policy rate. These interest rates are: *1)* the interbank rate; *2)* the interest rate of stock market repo operations; *3)* the interest rate on certificates of deposit of the Banco de Guatemala at one and seven days terms, and *4)* the monetary policy rate. Four interest rate definitions are used in pursuit of sound results and to identify the interest rate through which policy operates directly.

Liquidity is defined as the ratio of cash assets to deposits plus financial liabilities, where cash assets are bank reserves plus deposits. The size is the ratio of each bank's total assets to total system assets (sum of all banks' assets).

The capitalization variable is equity as a proportion of each bank's total assets. The monthly economic activity indicator (MEAI) adjusted by season and real exchange rate is employed as a control variable to capture lending variations deriving from changes in demand. The MEAI is an indicator of monthly output that is compatible with the quarterly gross domestic product (GDP).

## 3.4 Results

This section presents the results from estimating the model of the lending channel in Guatemala. Equation 1 was estimated for the period from January 2010 to April 2014 for 18 banks in the system. The banks were also grouped into small, medium, and large. Estimates were made for total lending, commercial credit, and consumer credit in order to distinguish how the lending channel can vary according to bank size and the type of market in which it operates. The hypothesis is that large banks can better shield themselves against policy rate shocks, in such way that movements in policy interest rates do not affect the sum of the loans they offer. Moreover, medium and small banks have fewer sources of funding available and are therefore more vulnerable to policy shocks, which affect their capacity to grant loans.

It is also expected that the commercial credit of large banks would be less affected by policy changes. This stems from the fact that this type of lending obeys the investment projects of large firms, mainly industrial, the disbursements and interest rates are agreed in advance with disbursements programmed according to a contract.

### *3.4.1 Total Lending*

*Banking system:* the results are presented in Table B.1. There is evidence of a lending channel operating directly through the interest rate on the certificates of the Banco de Guatemala and the policy interest rate with lags of between two and three months. All the interest rates seem to act through bank size and equity, although the latter effects are very small. There is also evidence of effects through liquidity, but they appear to be very weak.

*Large banks:* the evidence of direct effects of interest rates on large banks is practically inexistent (Table B.2). As for indirect effects, there appears to be a minimal impact on capital operating with a lag of between three and four months.

*Medium-sized banks:* there is evidence for the direct effects of interest rates, mainly the policy rate and, to a lesser degree, repo and Banco de Guatemala interest rates (Table B.3). There is also evidence of indirect effects through liquidity, size, and capital. The effects of liquidity and capital are very small, and those of capital have a negative sign. The size effect is bigger but presents inverse signs. In the aggregate, a stronger effect than that for large banks can be seen.

*Small banks:* the direct effects of interest rates on small banks' total lending is significant, although it has the opposite sign than that expected (Table B.4). Concerning indirect effects through liquidity, size and capital, they are not significant.

### 3.4.2 Commercial Credit

*Banking system:* there is evidence of the direct influence of interbank interest rates, certificates of the Banco de Guatemala and the policy rate, although the aggregate impact appears to be small (Table B.5). There is also evidence of indirect effects through capital and interest rates, but they are very small. There is no solid evidence of effects through liquidity.

*Large banks:* the results only show negative effects on the loans of large banks and the interbank interest rate (Table B.6). There are also indirect effects of the interbank interest rate and repos through liquidity and size. All the interest rates impact the lending of large banks through capital, although these effects are extremely small in the aggregate.

*Small banks:* the outcomes reveal that there are direct effects of four interest rates (interbank, repos, certificates of the Banco de Guatemala, and policy). There are also significant indirect effects through liquidity, size, and capital, although they are substantially smaller. In general, the lending channel operates stronger in small banks than in large ones (Table B.7).

*Small banks:* contrary to what might be expected, the lending channel for the commercial loans of small banks is not very strong (Table B.8). The evidence of direct effects is weak and is only observed for certificates of the Banco de Guatemala and repo rates, although their net impact is positive. The evidence of indirect effects is extremely weak and seems to be present only through the capital.

### 3.4.3 Consumer Credit

*Banking system:* the direct effect of interest rates on the lending channel is present and significant with all rates, although the effect of interest rates on the certificates of the Banco de Guatemala has the opposite sign to that expected (Table B.9). There is also evidence of indirect effects through liquidity, size, and capital.

*Medium-sized banks:* there is evidence of direct effects mainly from interbank interest rates and repo and policy rates (Table B.10). There is also evidence that the channel operates through liquidity, size, and capital. Nevertheless, the net impact of direct and indirect effects is very small.

*Small banks:* the results show direct effects of interest rates on the supply of loans, mainly through the interbank rate and, to a lesser degree, repo rates (Table B.11). There is also evidence of indirect effects through liquidity, size, and capital. The aggregate effect is, however, small in all cases.

According to the results, in general terms, the lending channel can be seen in the whole banking system, for both total lending and commercial and consumer credit. It can be seen how its effects are stronger in total lending and consumer credit than in commercial credit.

The lending channel has a little direct impact on the commercial credit of large banks; its indirect effects seem to be more significant. The commercial and consumer credit of medium-sized banks is affected by the lending channel in a very similar way, although with greater influence on commercial credit. The lending channel has a significant effect on the consumer credit of small banks, while its impact on commercial credit is almost nonexistent.

## 4. FINANCIAL STABILITY

This is a topic of recent discussion and is difficult to identify. The literature with the models that allow for understanding the macroprudential themes is still being developed. In the case of this paper, it was hoped that if it proved the lending channel operates on the supply-side, that is, if reference interest rate movements generate changes in the composition of bank liabilities that cause movements from core liabilities to non-core liabilities, which in turn adjust the supply of loans, then there might be some impact on financial stability. However, it is the opposite case: it has been found that the phenomenon is more on the demand than the supply side.

Notwithstanding, a study by bank group of the behavior of indicators such as: *1)* capital adequacy; *2)* leverage; *3)* return on assets (ROA), and *4)* return on equity (ROE), suggest that financial stability has not been at risk during the period of study. In fact, with respect to Basel I and II capital adequacy, all bank groups show levels above 8% and even up to 10% (see Figure C.1). Data for small banks is exceptionally large because they specialize more in investments than granting loans. In the case of leverage, banks do not pass a ratio of 12 as suggested by the literature (Figure C.2). As for ROE, banks obtain higher returns than on 10-year Treasury bonds (approximately 7%) except in the case of small banks during a short period in 2013 that is substantially influenced by a bank that was implementing a planned expansion (Figure C.3). The returns for that group of banks then go back to normality. Finally, ROA – an indicator of efficiency– is above 1% for all banks as is also suggested by the studies (Figure C.4).

## 5. CONCLUSIONS

The investigation on the lending channel in Guatemala contains two core components: a characterization of the lending channel using an event narrative approach and an econometric study based on microeconomic panel data for 18 banks in the system. This section presents the main findings of the study.

The event narrative analysis reveals that the interest rate for business loans, both small and large, does not react to policy rate changes. Meanwhile, the interest rate on consumer loans does appear to be affected by the policy rate, particularly after the Banco de Guatemala reduced the term of its policy instrument from seven days to overnight operations. Finally, the interest rate on mortgage loans and microloans do not seem to be affected by the policy rate either.

The graphical examination of the impact of policy interest rate hikes on lending suggests that there is a contraction in total lending that operates with lags for all three bank sizes. The reduction in lending is mainly observed in business loans, both large and small, while the evidence is less clear for consumer loans, microloans and mortgage loans.

This research also shows that the banking system in Guatemala has been characterized by an increase in investment in government securities, growing loan portfolio dollarization, and chronic excess liquidity. This is due to the upward trend of the country's fiscal deficit, which has prompted the government of Guatemala to issue bonds with very attractive yields. Moreover, the predominantly low-interest rates worldwide along with excess liquidity have led domestic banks (mostly the large ones) to take advantage of the credit lines offered by international banks at very low-interest rates, which has led to a significant supply of loans in US dollars.

Finally, for many years there has been chronic excess liquidity in the national financial system, leading the Banco de Guatemala to carry out open market operations on a daily basis to mop up liquidity.

Historically there have only been two exceptional cases where said central bank has needed to inject liquid resources into the financial market instead of withdrawing them. All the factors above (high investment in government bonds, growing credit dollarization, and chronic excess liquidity) weaken the monetary policy transmission mechanism.

Another factor that contributes to weakening the transmission mechanism is the method for calculating the reserve requirements of banks in Guatemala. In accordance with current legislation, banks must maintain a monthly average of reserve requirements but may default on these requirements up to 14 days within a month. This implies that banks have relatively wide room for maneuver when managing their treasury. Thus, in response to policy rate increases banks can reduce reserves without urgently needing to recompose their reservable liabilities or decrease lending and, therefore, avoid or diminish the impact of monetary policy.

With respect to econometric estimates, these reveal that, in general terms, the lending channel operates in Guatemala with lags and is relatively small. Evidence was found that for commercial credit the lending channel mainly operates through medium-sized banks, while for consumer credit the channel operates significantly through both medium-sized and small banks. With respect to large banks, the lending channel is extremely small and, in some cases, inexistent. There is also clear evidence that bank liquidity, capitalization and size variables play a very important role in the presence and strength of said channel.

Finally, financial stability indicators reveal that the financial system in Guatemala does not show any signs of fragility. Taking into account that there is a lending channel, although small, it is possible to believe that monetary policy does not currently represent a risk for financial stability. Thus, this paper lays the foundation for further studies that formally and meticulously link the relationship between these two variables.

In sum, the transmission of monetary policy to market rates and lending is weak. This can be explained by the chronic excess liquidity of the financial system, high investment in government bonds, portfolio dollarization, and the method for calculating bank reserve requirements. The lending channel is present in Guatemala, but its impact is very small and determined by type of loan, bank size, capitalization, and liquidity.

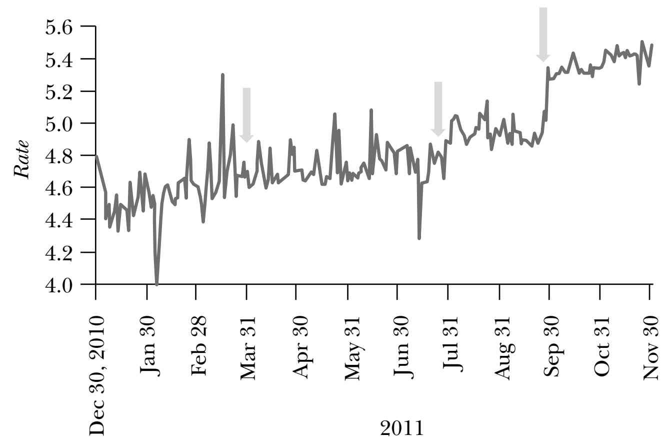
# ANNEXES

## Annex A. Figures

Figure A.1

**REPO OPERATIONS INTEREST RATE**

REPO OPERATIONS IN STOCK EXCHANGE
(GENERAL TOTAL)




REPO OPERATIONS IN STOCK EXCHANGE
(OVERNIGHT)

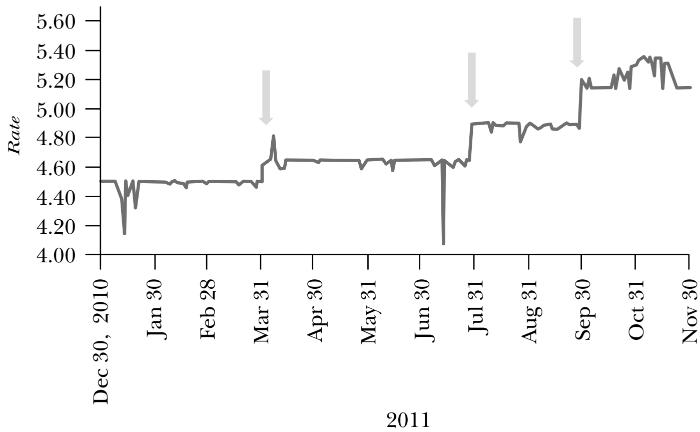
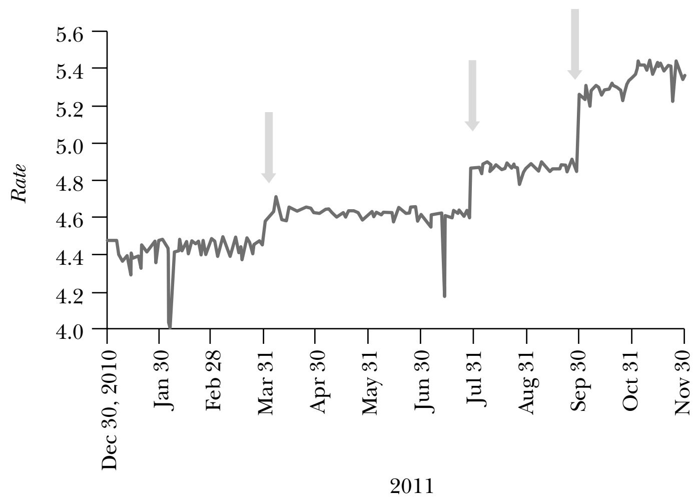


Figure A.1 (cont.)

**REPO OPERATIONS INTEREST RATE**

REPO TRANSACTIONS
IN THE STOCK EXCHANGES (TERM OF 1 TO 7 DAYS)




LEADING INTEREST RATE OF MONETARY POLICY

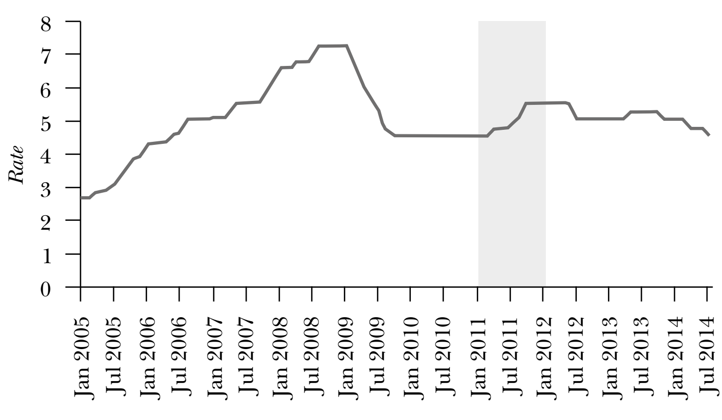
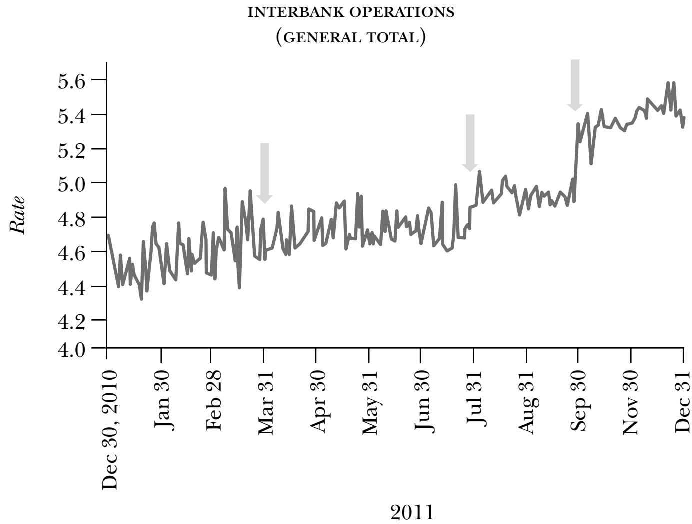


Figure A.2

**INTERBANK INTEREST RATES**



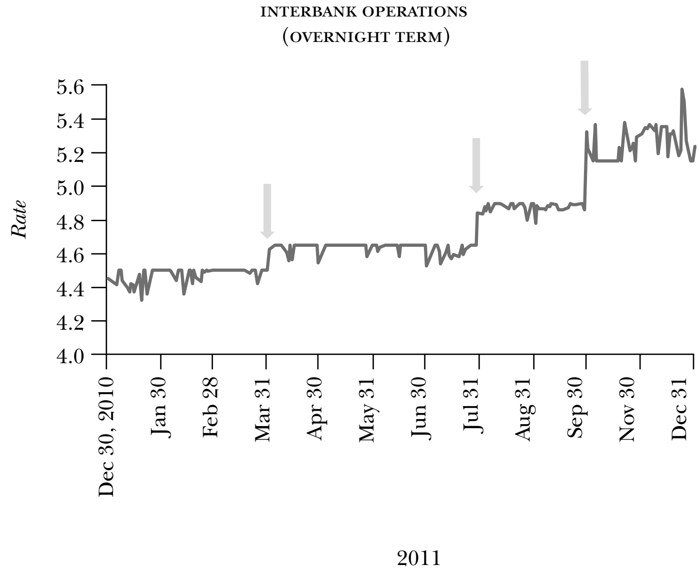
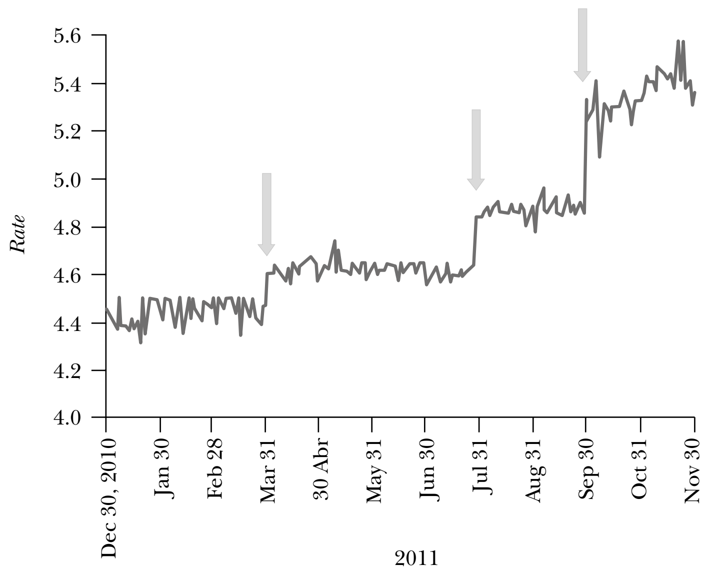



**Figure A.2 ( cont.)**

**INTERBANK INTEREST RATES**

INTERBANK OPERATIONS
(TERM OF 1 TO 7 DAYS)




LEADING INTEREST RATE OF MONETARY POLICY

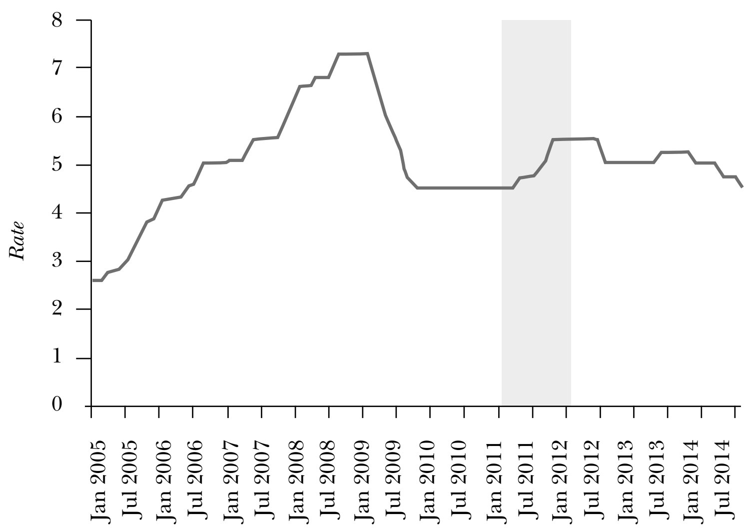
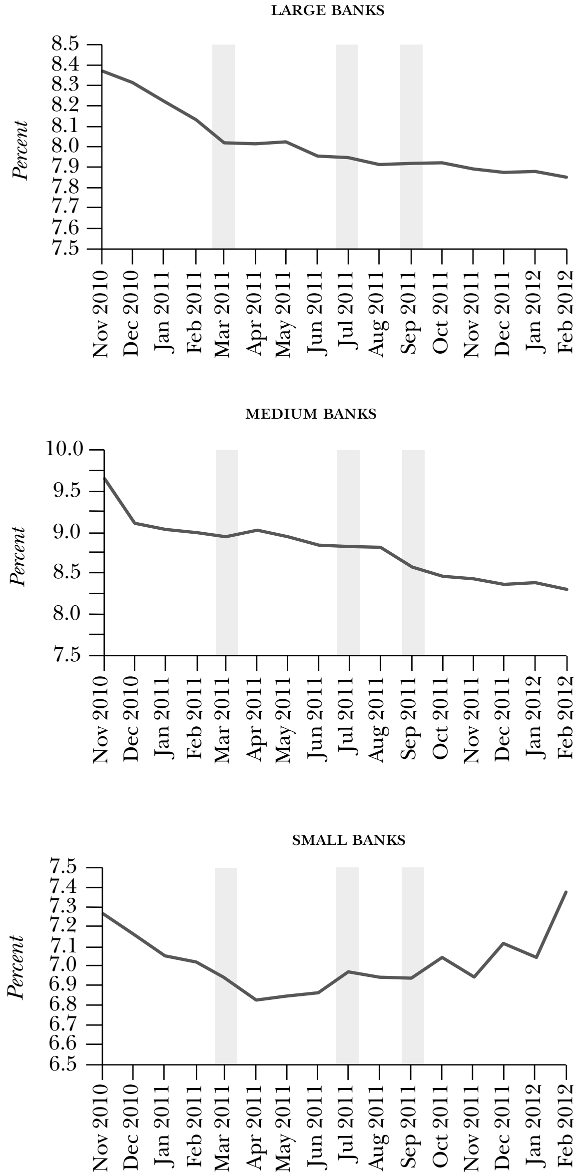


**Figure A.3**

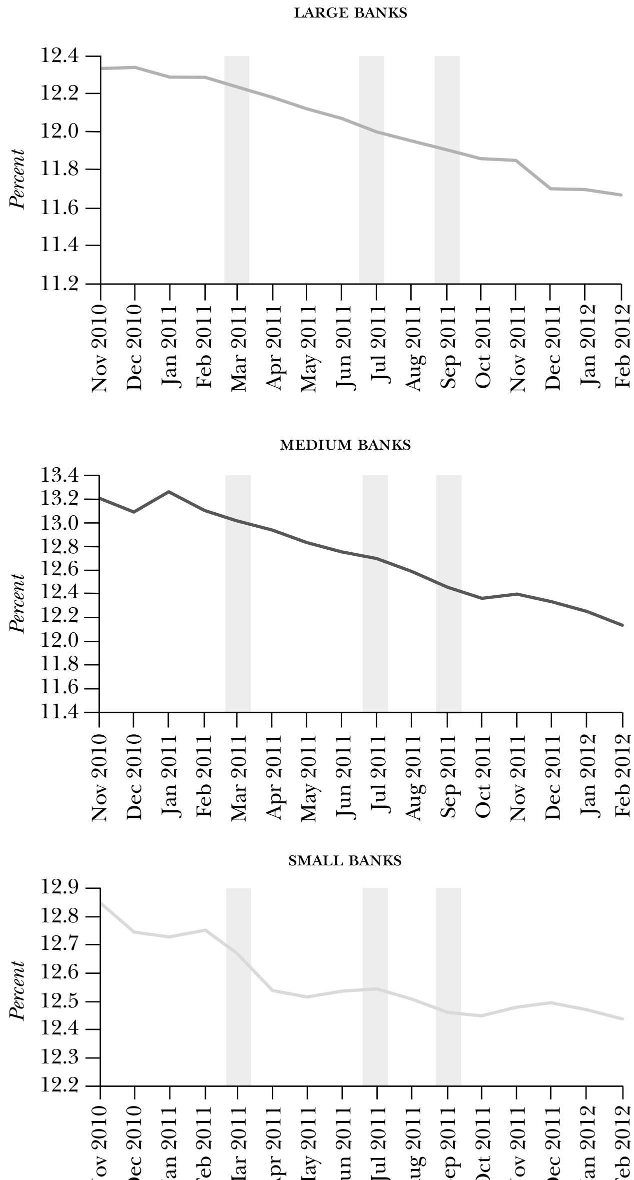
**BEHAVIOR OF INTEREST RATES OF CREDIT TO MAJOR BUSINESS SECTOR**[1]




[1] The shaded area indicates episodes of contractive monetary policy (increase in the monetary policy rate).

Figure A.3 (cont.)

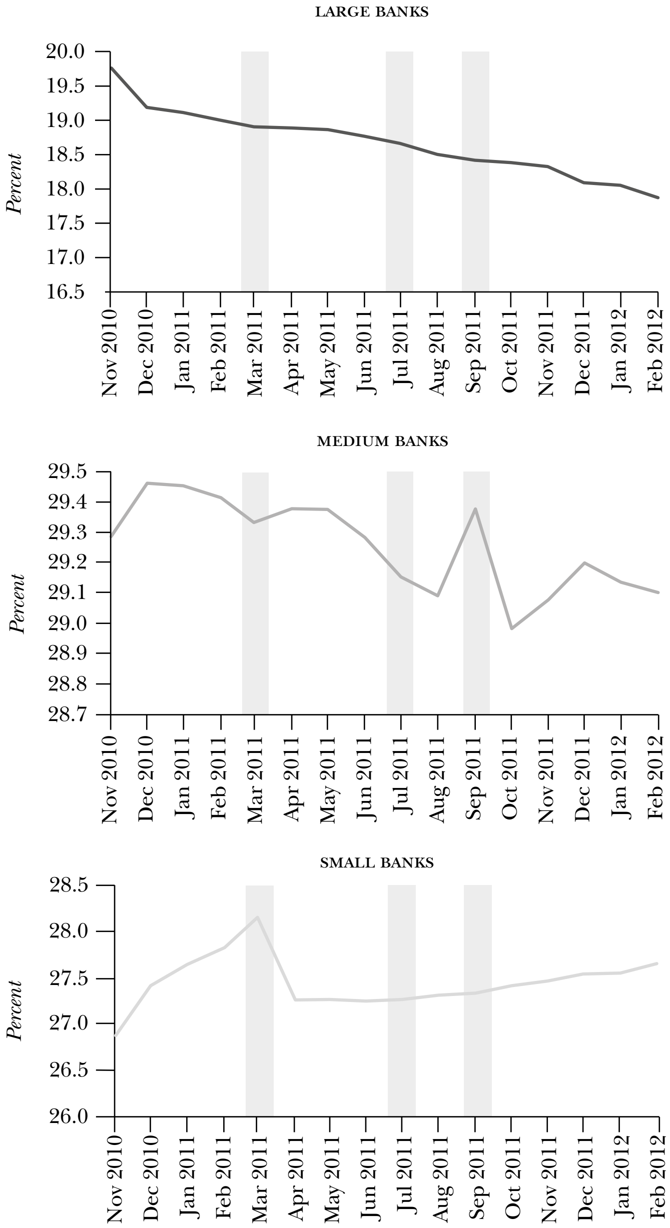
**BEHAVIOR OF CREDIT INTEREST RATES TO THE LESSER BUSINESS SECTOR**[1]




[1] The shaded area indicates episodes of contractive monetary policy (increase in the monetary policy rate).

**Figure A.3 (cont.)**

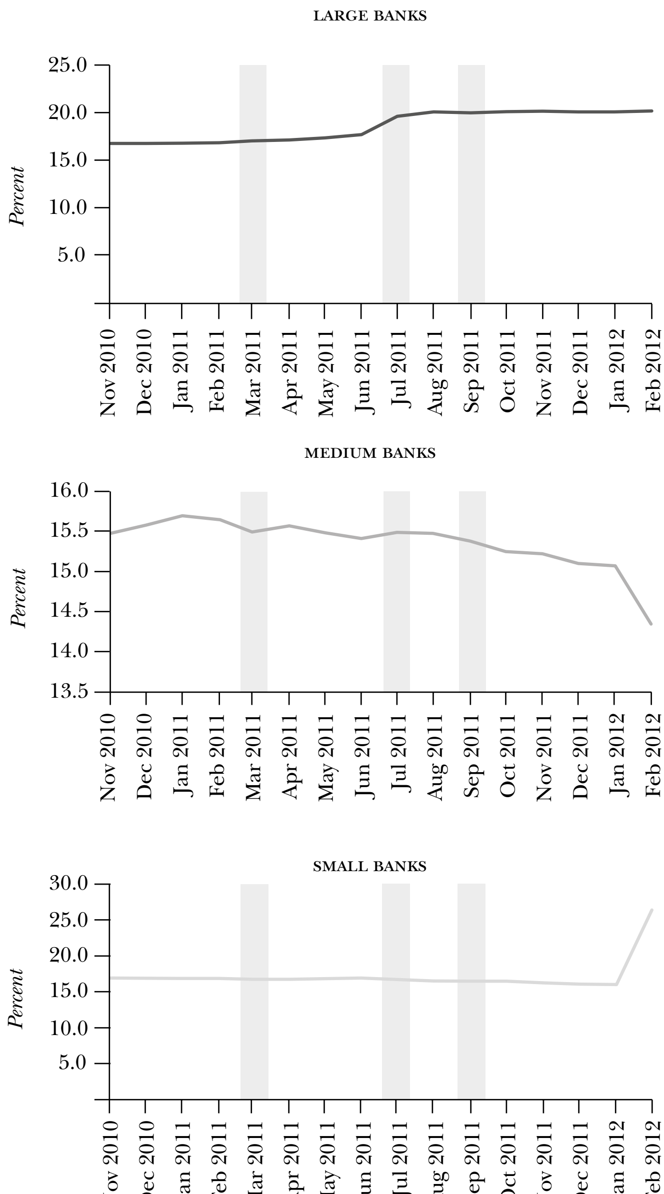
**BEHAVIOR OF INTEREST RATES OF CONSUMER CREDIT[1]**




[1] The shaded area indicates episodes of contractive monetary policy (increase in the monetary policy rate).

**Figure A.3 (cont.)**

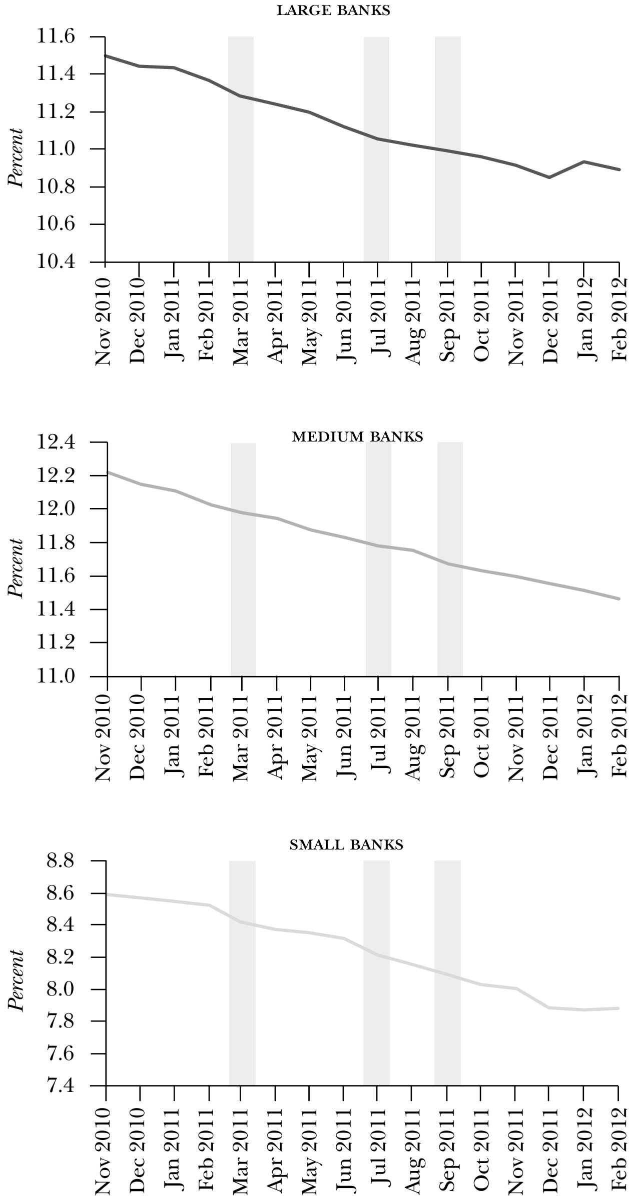
**BEHAVIOR OF INTEREST RATES OF CREDIT TO THE MICROCREDIT SECTOR**[1]




[1] The shaded area indicates episodes of contractive monetary policy (increase in the monetary policy rate).

Figure A.3 (cont.)

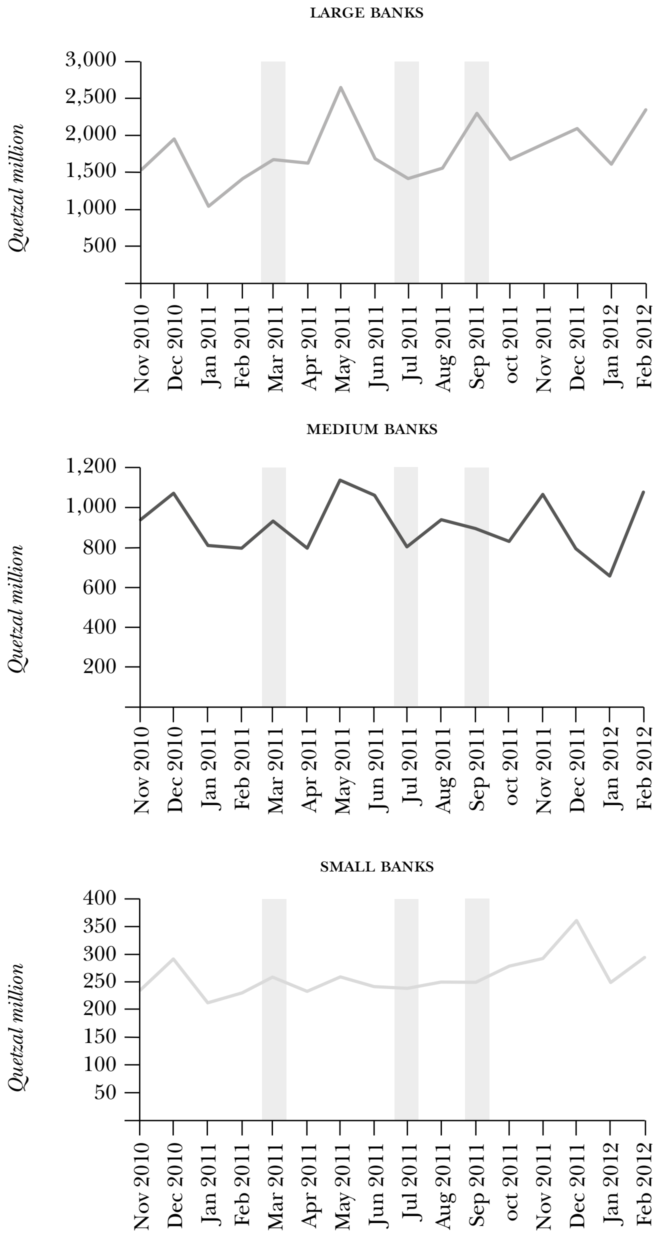
**BEHAVIOR OF INTEREST RATES OF MORTGAGE CREDIT FOR HOUSING**[1]




[1] The shaded area indicates episodes of contractive monetary policy (increase in the monetary policy rate).

Figure A.4

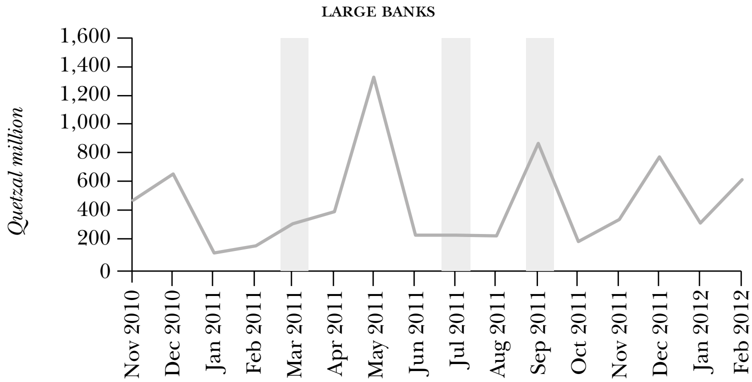
**BEHAVIOR OF CREDIT IN NATIONAL CURRENCY[1]**

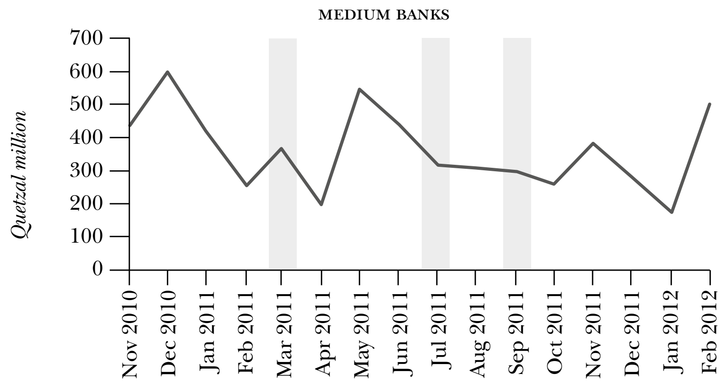


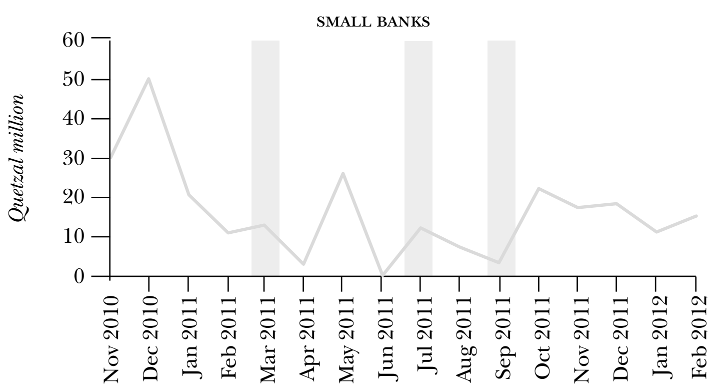

[1] The shaded area indicates episodes of contractive monetary policy (increase in the monetary policy rate).

**Figure A.4 (cont.)**

**BEHAVIOR OF CREDIT IN NATIONAL CURRENCY TO THE MAJOR BUSINESS SECTOR**[1]



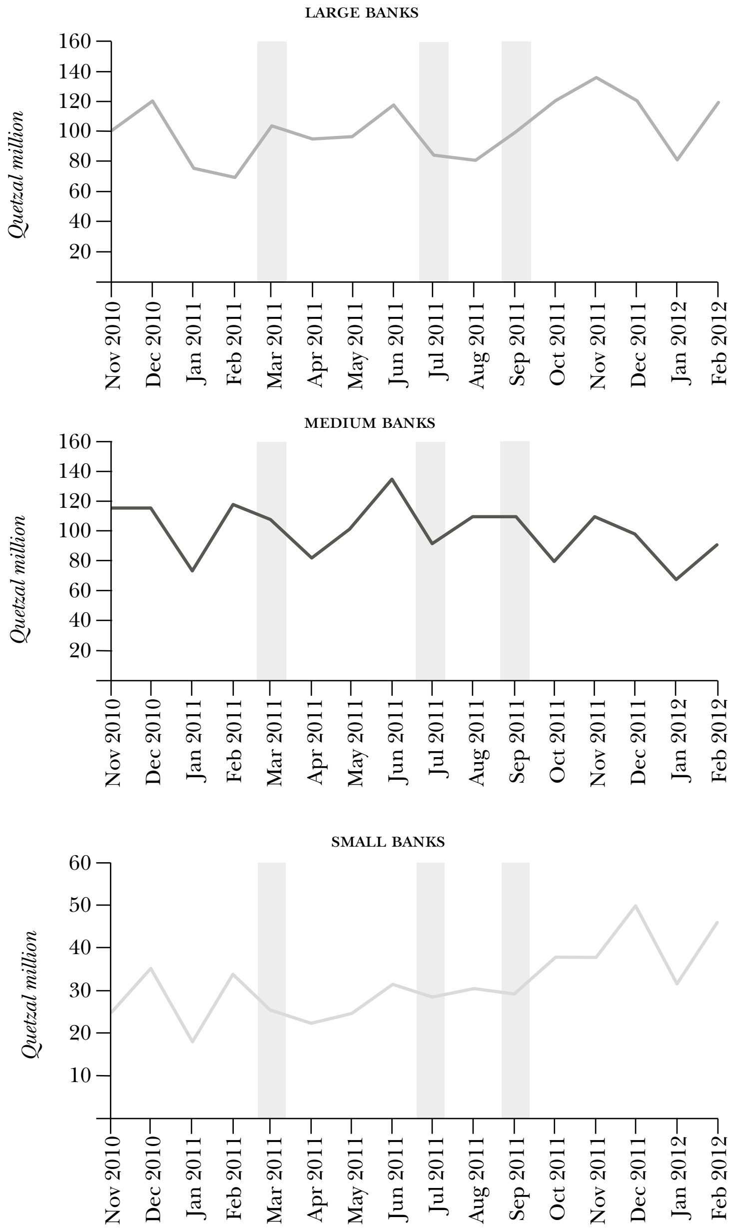




[1] The shaded area indicates episodes of contractive monetary policy (increase in the monetary policy rate).

Figure A.4 (cont.)

**CREDIT BEHAVIOR IN NATIONAL CURRENCY TO THE LESSER BUSINESS SECTOR**[1]

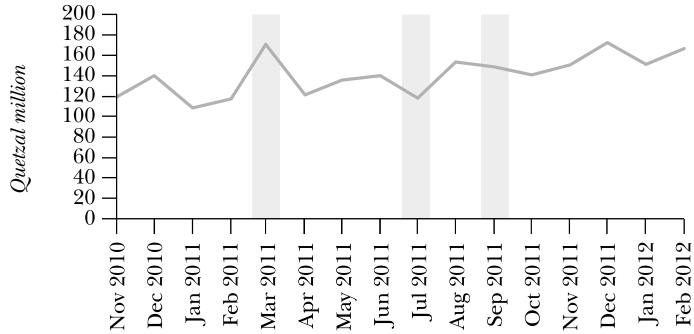



[1] The shaded area indicates episodes of contractive monetary policy (increase in monetary policy rate).

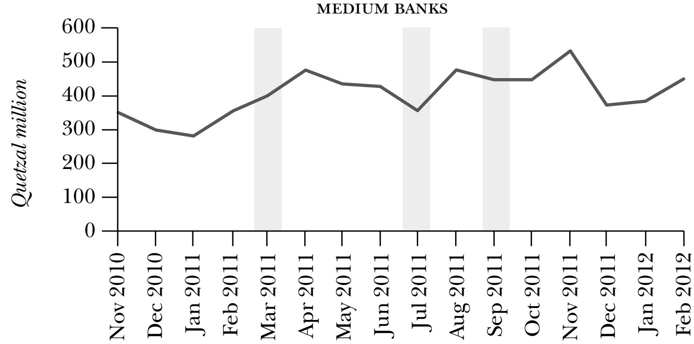
Figure A.4 (cont.)

**BEHAVIOR OF CREDIT IN NATIONAL CURRENCY TO THE CONSUMER SECTOR**[1]

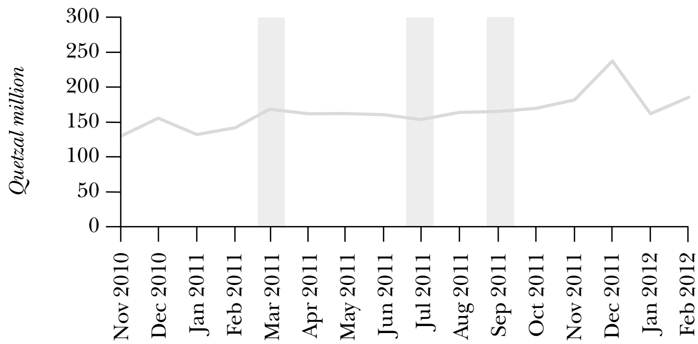
LARGE BANKS




MEDIUM BANKS



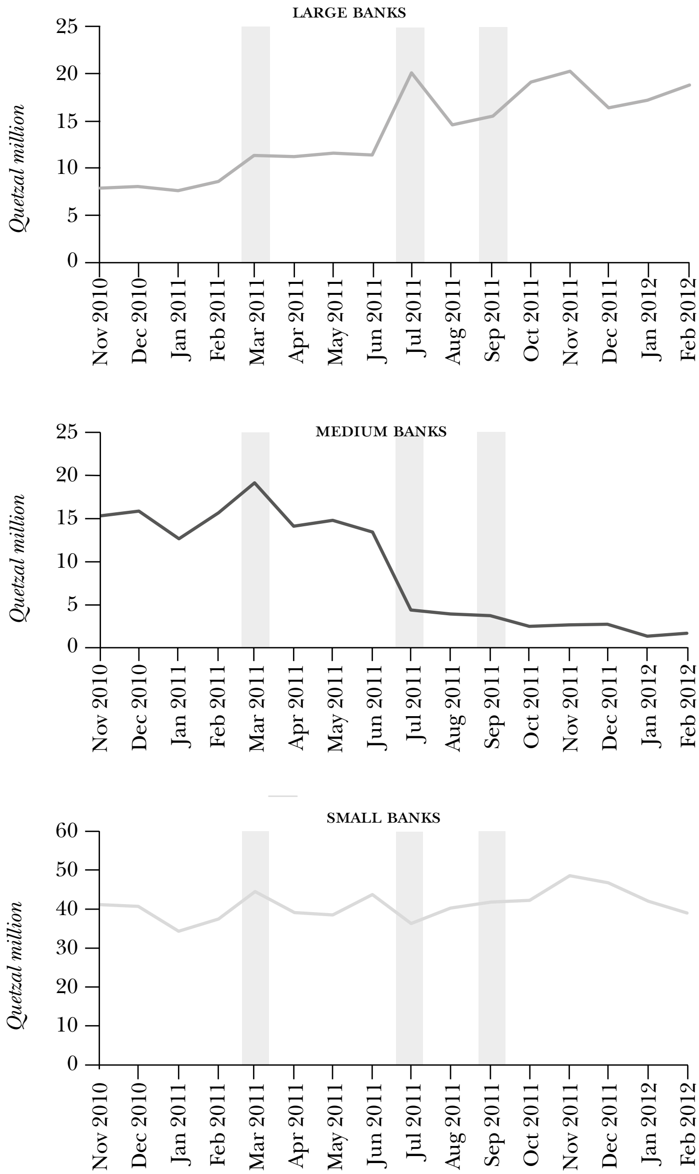

SMALL BANKS




[1] The shaded area indicates episodes of contractive monetary policy (increase in monetary policy rate).

Figure A.4 (cont.)

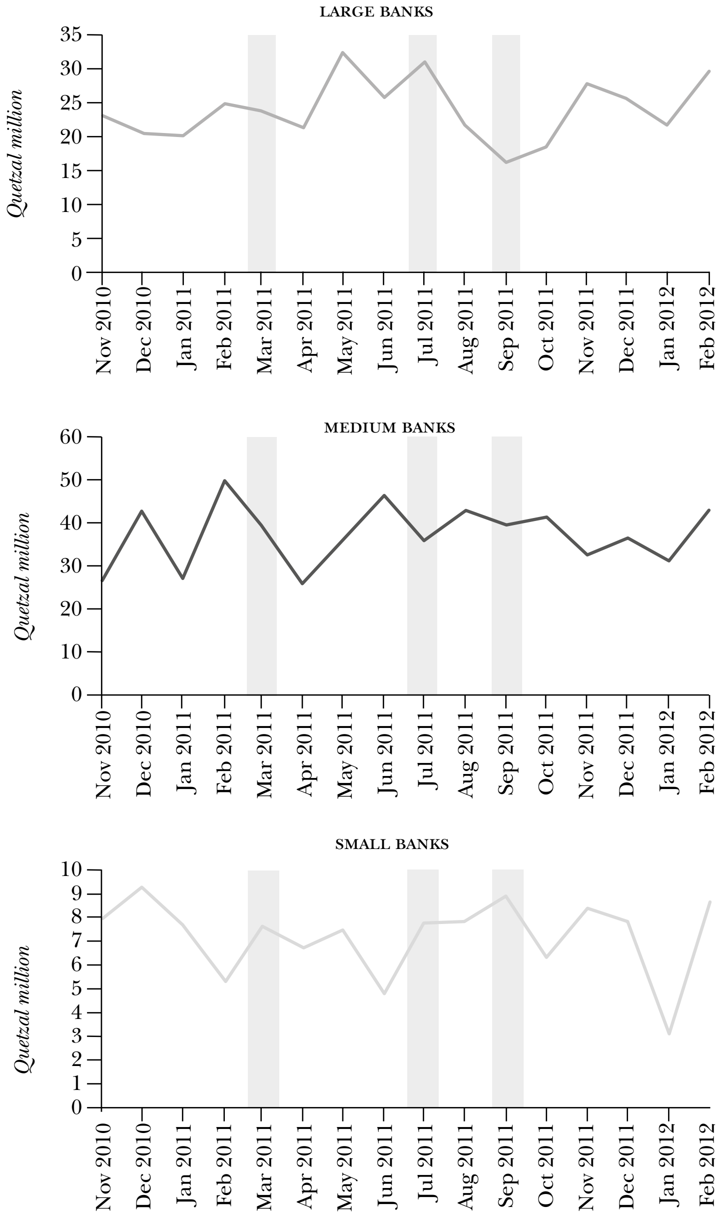
**BEHAVIOR OF CREDIT IN NATIONAL CURRENCY TO THE MICROCREDIT SECTOR** [1]




[1] The shaded area indicates episodes of contractive monetary policy (increase in the monetary policy rate).

Figure A.4 (cont.)

**BEHAVIOR OF MORTGAGE CREDIT IN NATIONAL CURRENCY FOR HOUSING[1]**

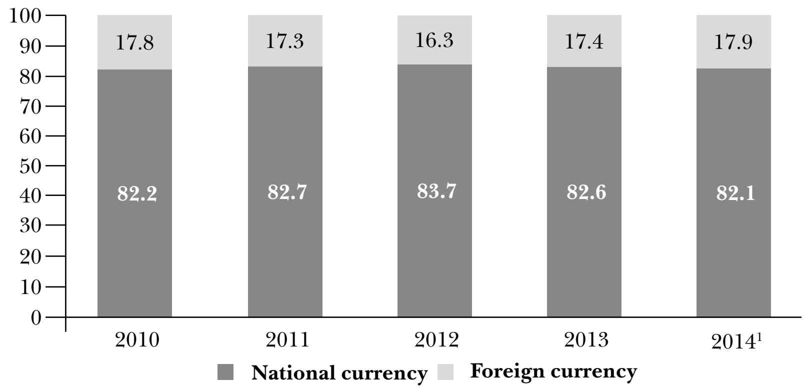



[1] The shaded area indicates episodes of contractive monetary policy (increase in the monetary policy rate).

Figure A.5

**DOLLARIZATION OF THE BANKING SYSTEM**

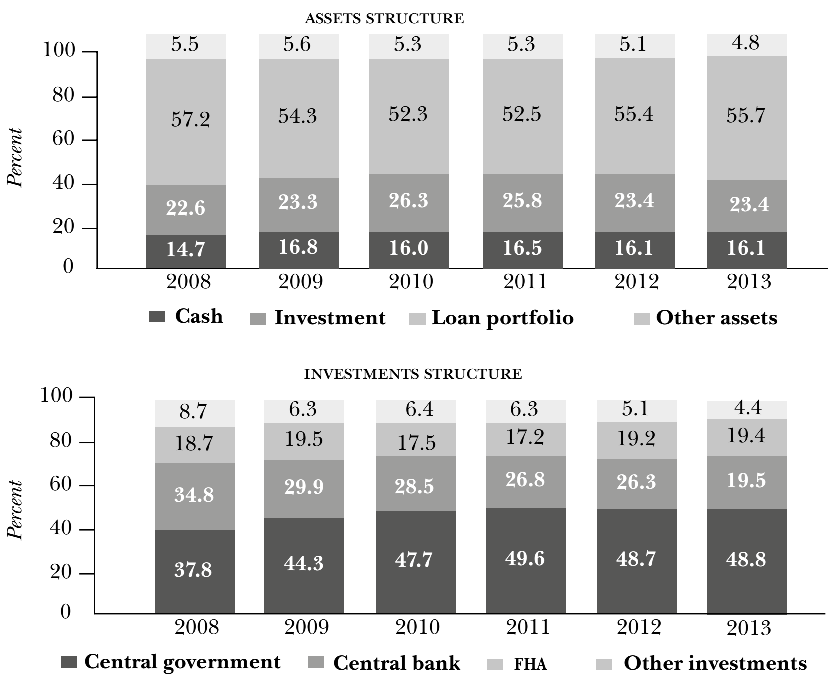
Depositary bonds
Structure by type of currency




[1] September.

Figure A.6

**STRUCTURE OF ASSETS AND INVESTMENTS OF THE BANKING SYSTEM[1]**

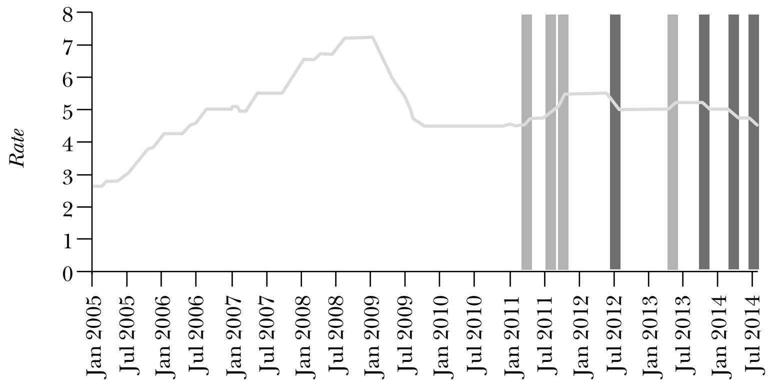



[1] The figures are as of December of each year.

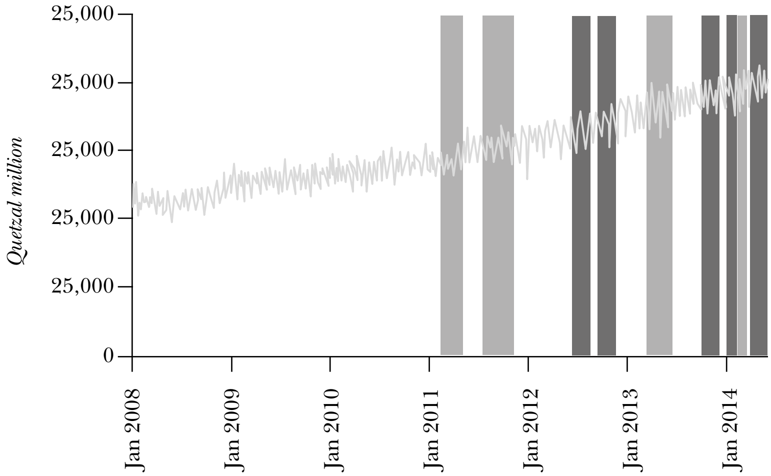
Figure A.7

**LIQUIDITY OF THE BANKING SYSTEM**[1]

LEADING MONETARY POLICY RATE




LIQUID RESOURCES AVAILABLE
Large banks

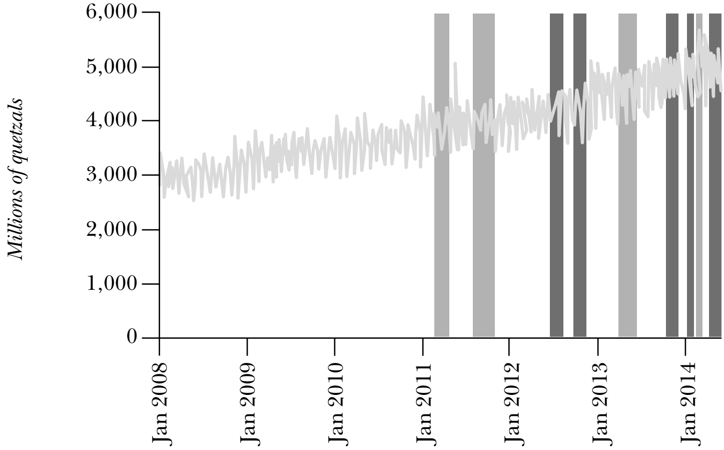



[1] The areas in light gray indicate an episode of contractive monetary policy (increase in the monetary policy rate). The dark gray areas indicate an episode of expansive monetary policy (decrease in the monetary policy rate).

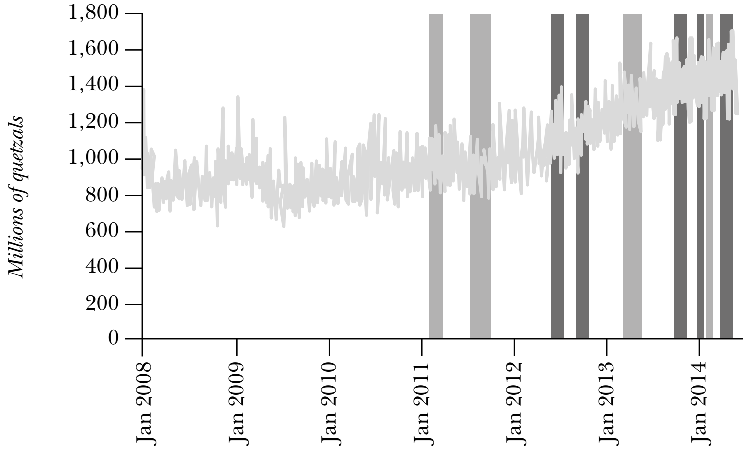
Figure A.7

**LIQUIDITY OF THE BANKING SYSTEM[1]**

LIQUID RESOURCES AVAILABLE



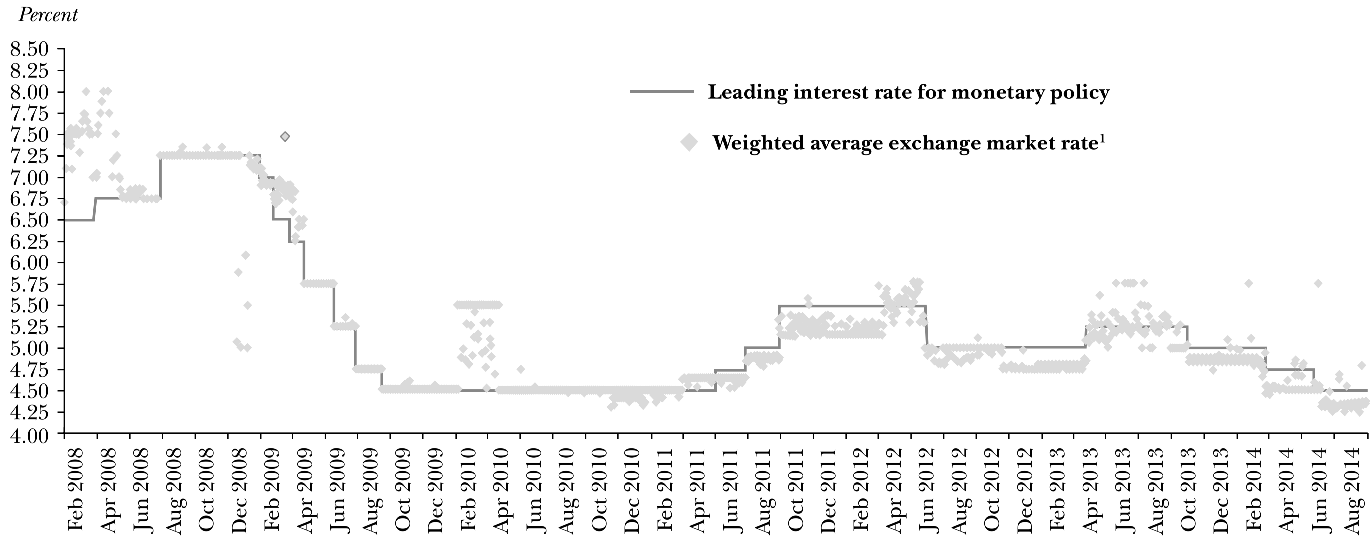

LIQUID RESOURCES AVAILABLE
Small banks




[1] The areas in light gray indicate an episode of contractive monetary policy (increase in the monetary policy rate). The dark gray areas indicate an episode of expansive monetary policy (decrease in the monetary policy rate).

Figure A.8

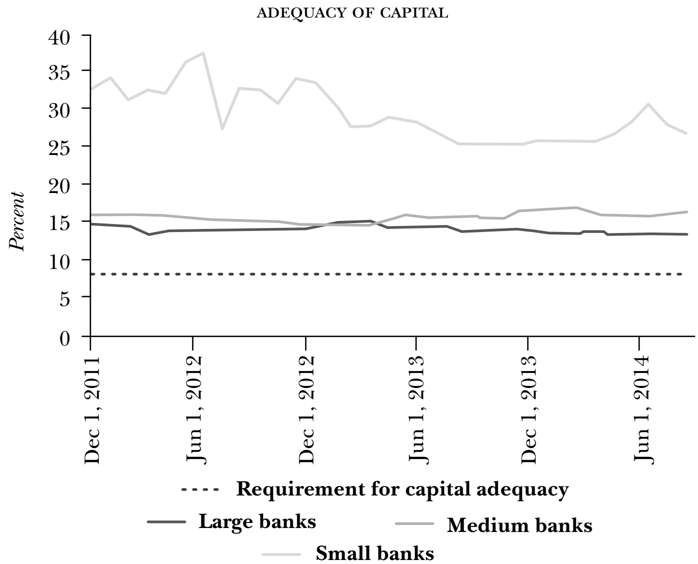
**INTEREST RATE OF MONETARY POLICY AND OVERNIGHT INTEREST RATE, WEIGHTED AVERAGE OF REPO OPERATIONS IN THE STOCK MARKET AND OVER-THE COUNTER INTER-BANK MARKET**




[1] As of June 1, 2011, the Execution Committee established that the term of operations would be one day. Previously, operations were carried out within seven days.

Figure C.1

**INDICATORS OF THE BANKING SYSTEM**



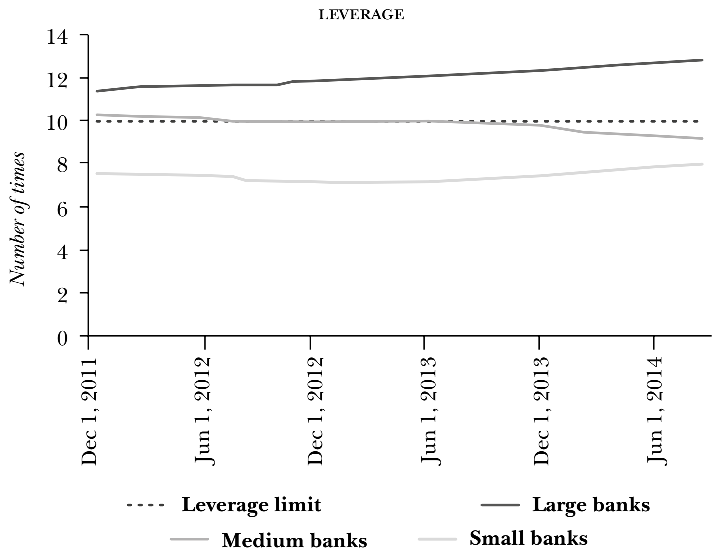
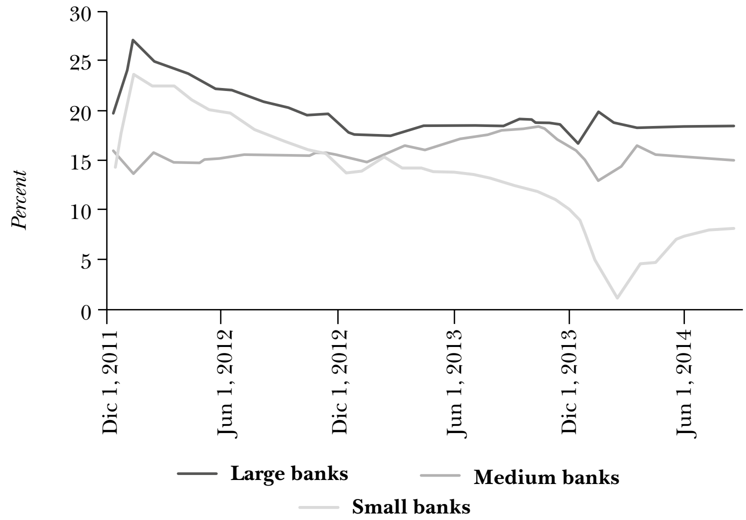



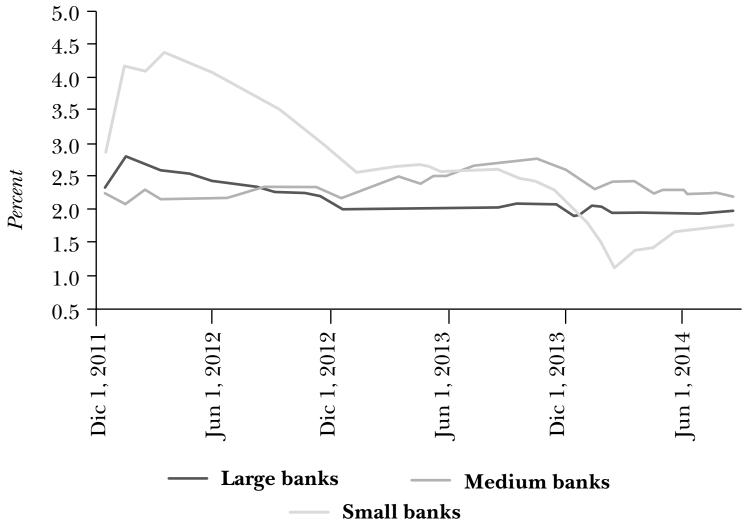
Figure C.1 (cont.)

**INDICATORS OF THE BANKING SYSTEM**

RETURN OVER EQUITY




RETURN ON ASSETS



## Annex B. Lending Channel Regressions

Table B.1

**TOTAL CREDIT OF THE BANKING SYSTEM**
Dependent variable: Log(total credit)
Banks: 18

| | *Interbank interest rate* | | *Repo interest rate* | | *1-to-7-days interest rate* | | *Policy interest rate* | |
|---|---|---|---|---|---|---|---|---|
| *Variable* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* |
| **Interest rate** | | | | | | | | |
| T | −0.4909377 | 0.074 | −0.4619099 | 0.184 | −0.1252282 | 0.614 | −0.1957404 | 0.314 |
| L1 | 0.7237534 | 0.025 | 0.8482868 | 0.004 | −0.1167119 | 0.523 | 0.2445011 | 0.271 |
| L2 | −0.2069681 | 0.456 | −0.2925259 | 0.113 | −0.2851544 | 0.056 | −0.1789511 | 0.380 |
| L3 | −0.3976827 | 0.160 | −0.2208082 | 0.338 | −0.083836 | 0.633 | −0.4947765 | 0.033 |
| L4 | 0.3203206 | 0.068 | 0.182936 | 0.248 | 0.3596766 | 0.104 | 0.651466 | 0 |
| **Log(MEAI)** | | | | | | | | |
| T | 3.407028 | 0.052 | 3.388981 | 0.047 | 3.00124 | 0.091 | 3.232304 | 0.079 |
| L1 | −3.721268 | 0.216 | −5.902379 | 0.091 | −3.936543 | 0.202 | −4.97924 | 0.095 |
| L2 | 2.540394 | 0.442 | 4.682591 | 0.189 | 1.7337 | 0.560 | 2.15809 | 0.478 |
| L3 | 5.10627 | 0.038 | 3.398524 | 0.142 | 2.436927 | 0.256 | 2.43657 | 0.234 |
| L4 | −1.39544 | 0.707 | 0.0504513 | 0.988 | 1.836709 | 0.541 | 0.5192603 | 0.867 |
| **Log(real exchange rate)** | | | | | | | | |
| T | 2.606976 | 0.430 | −0.7785922 | 0.802 | −1.046257 | 0.730 | 1.152934 | 0.688 |
| L1 | −6.57062 | 0.044 | −1.205755 | 0.673 | −1.550082 | 0.525 | −7.646531 | 0.013 |
| L2 | 14.90129 | 0 | 11.70891 | 0 | 10.0457 | 0 | 13.2232 | 0 |
| L3 | −7.145291 | 0 | −6.411225 | 0 | −3.260583 | 0.048 | −4.622826 | 0.007 |
| L4 | −0.7924288 | 0.735 | −0.8922811 | 0.727 | −2.191903 | 0.362 | −1.273638 | 0.573 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log(liquidity)*interest rate** | | | | | | | | |
| T | 0.008451 | 0.488 | −0.0032606 | 0.827 | −0.001048 | 0.457 | 0.0004433 | 0.762 |
| L1 | 0.0006872 | 0.638 | 0.001013 | 0.546 | −0.0015982 | 0.097 | −0.0000719 | 0.941 |
| L2 | 0.0017263 | 0.289 | 0.0015726 | 0.315 | 0.0006815 | 0.588 | 0.0017803 | 0.183 |
| L3 | −0.0022305 | 0.219 | −0.0022291 | 0.216 | −0.0035304 | 0.160 | −0.0025581 | 0.251 |
| L4 | −0.0015592 | 0.14 | −0.0018777 | 0.091 | −0.0027257 | 0.025 | −0.0019493 | 0.020 |
| **Size*interest rate** | | | | | | | | |
| T | −10.73332 | 0.003 | −6.50576 | 0.069 | −1.784911 | 0.670 | −1.594393 | 0.357 |
| L1 | 0.5247567 | 0.645 | −1.904766 | 0.192 | −0.6648962 | 0.276 | 2.265303 | 0.030 |
| L2 | 1.646029 | 0.411 | 2.374594 | 0.064 | 3.212196 | 0.002 | 1.532912 | 0.282 |
| L3 | 0.8998345 | 0.41 | 0.5498481 | 0.589 | −1.51582 | 0.042 | 0.078065 | 0.954 |
| L4 | −0.1431472 | 0.894 | 0.5454194 | 0.592 | 0.076216 | 0.945 | −1.194204 | 0.493 |
| **Capital*interest rate** | | | | | | | | |
| T | 0.0005574 | 0.014 | 0.0004543 | 0.092 | 0.0002517 | 0.487 | 0.0000186 | 0.792 |
| L1 | −0.0000464 | 0.263 | −0.0000487 | 0.159 | 0.0000307 | 0.444 | 0.0000163 | 0.682 |
| L2 | −0.0000518 | 0.148 | −0.0000425 | 0.382 | −0.0000375 | 0.417 | −0.0000482 | 0.070 |
| L3 | 0.000132 | 0.008 | 0.0001124 | 0.026 | 0.0001194 | 0.007 | 0.000098 | 0.005 |
| L4 | −0.0001159 | 0.187 | −0.0001064 | 0.222 | −0.000101 | 0.217 | −0.0001001 | 0.211 |
| **Liquidity** | −0.038205 | 0.562 | 0.0202396 | 0.793 | | | | |
| **Size** | 80.66147 | 0.009 | 61.48712 | 0.047 | 16.3114 | 0.597 | | |
| **Capital** | −0.0027225 | 0.018 | −0.0021448 | 0.088 | −0.0013637 | 0.400 | | |
| **Constant** | −30.11688 | 0.325 | −27.69959 | 0.348 | −20.87977 | 0.517 | −11.85381 | 0.697 |
| Observations | 823 | | 823 | | 759 | | 823 | |

Table B.2

**TOTAL CREDIT OF LARGE BANKS**

Dependent variable: Log(total credit)

Banks: 3

| | *Interbank interest rate* | | *Repo interest rate* | | *Interest rate from 1 to 7 days.* | | *Policy interes rate* | |
|---|---|---|---|---|---|---|---|---|
| *Variable* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* |
| **Interest rate** | | | | | | | | |
| T | −2.060481 | 0.032 | −1.186908 | 0.257 | −2.147539 | 0.169 | −0.5126384 | 0.449 |
| L1 | 0.3371757 | 0.344 | −0.3101836 | 0.602 | −1.022698 | 0.008 | 0.6399861 | 0.428 |
| L2 | −0.383901 | 0.446 | −0.0632279 | 0.631 | 1.128346 | 0.031 | 0.0477821 | 0.720 |
| L3 | 0.0461861 | 0.959 | 0.0046602 | 0.994 | −1.397854 | 0.127 | −0.6950076 | 0.343 |
| L4 | 0.3352813 | 0.464 | 0.2856284 | 0.443 | 1.063632 | 0.199 | 0.5519077 | 0.132 |
| **Log(MEAI)** | | | | | | | | |
| T | −1.299923 | 0.704 | −0.9589005 | 0.606 | 3.632756 | 0.002 | 3.455825 | 0.147 |
| L1 | −5.087289 | 0.134 | −5.237427 | 0 | −11.48038 | 0 | −3.295123 | 0.099 |
| L2 | −4.612838 | 0.397 | −5.424773 | 0.218 | −4.163673 | 0.210 | −1.673104 | 0.762 |
| L3 | 6.527088 | 0.063 | 1.371275 | 0.681 | −0.7807842 | 0.710 | 0.9770222 | 0.753 |
| L4 | 2.9324 | 0.242 | 7.618708 | 0.049 | 9.384027 | 0.055 | 1.15092 | 0.235 |
| **Log(real exchange rate)** | | | | | | | | |
| T | −7.940776 | 0 | −9.321351 | 0 | −10.38663 | 0.005 | −1.316862 | 0.508 |
| L1 | 0.151278 | 0.873 | 1.965378 | 0.153 | 1.121857 | 0.685 | −5.553732 | 0.008 |
| L2 | 14.02251 | 0.009 | 9.396626 | 0.018 | 9.654653 | 0.003 | 13.29795 | 0.008 |
| L3 | −8.593314 | 0 | −3.129221 | 0.220 | −4.38664 | 0.008 | −11.10065 | 0.001 |
| L4 | −2.268397 | 0.444 | −5.112575 | 0.175 | −1.833766 | 0.44 | 3.301395 | 0.058 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log(liquidity)*interest rate** | | | | | | | | |
| T | −0.0002191 | 0.994 | 0.0113629 | 0.788 | 0.082329 | 0.264 | 0.0040051 | 0.328 |
| L1 | 0.0008443 | 0.868 | −0.0013144 | 0.773 | −0.0002662 | 0.954 | 0.0017196 | 0.796 |
| L2 | 0.0083131 | 0 | 0.0089024 | 0.033 | 0.0043831 | 0.460 | 0.0054896 | 0.105 |
| L3 | 0.0028068 | 0.529 | 0.0020123 | 0.518 | 0.0030621 | 0.400 | 0.0007159 | 0.876 |
| L4 | −0.0008173 | 0.748 | −0.0013641 | 0.510 | −0.0075363 | 0.058 | −0.007266 | 0.051 |
| **Size*interest rate** | | | | | | | | |
| T | −0.6558221 | 0.679 | −1.830743 | 0.287 | −1.270686 | 0.636 | 0.0978354 | 0.877 |
| L1 | 1.228524 | 0.553 | 2.536272 | 0.142 | 0.6294615 | 0.712 | 1.221393 | 0.567 |
| L2 | 0.9397125 | 0.254 | −1.107058 | 0 | −0.6767586 | 0.523 | −0.6205081 | 0.453 |
| L3 | −1.03512 | 0.333 | 1.112346 | 0.513 | 0.54892 | 0.741 | −0.7801117 | 0.591 |
| L4 | −1.858068 | 0.142 | −2.492131 | 0.075 | −1.699907 | 0.470 | −0.5478345 | 0.711 |
| **Capital*interest rate** | | | | | | | | |
| T | 0.0004557 | 0.001 | 0.0002904 | 0.054 | 0.0003502 | 0.048 | −0.0000129 | 0.795 |
| L1 | 0.0000379 | 0.396 | 0.0000568 | 0.122 | 0.000087 | 0.003 | 0.0000364 | 0.413 |
| L2 | −0.0000258 | 0.508 | −0.000067 | 0.217 | −0.0000732 | 0.142 | −0.0000579 | 0.157 |
| L3 | 0.000129 | 0.091 | 0.0001573 | 0.026 | 0.0001494 | 0.080 | 0.000146 | 0.020 |
| L4 | −0.0001232 | 0.001 | −0.0001266 | 0 | −0.0001116 | 0.011 | −0.0001051 | 0.001 |
| **Liquidity** | 0.0268869 | 0.862 | −0.030047 | 0.889 | −0.3739555 | 0.309 | | |
| **Size** | 0.9073731 | 0.827 | 4.567614 | 0.358 | 6.711039 | 0.513 | | |
| **Capital** | −0.0024622 | 0 | −0.0015957 | 0.040 | −0.0018112 | 0.078 | | |
| **Constant** | 29.42842 | 0.141 | 34.91201 | 0.004 | 44.01609 | 0 | 4.523113 | 0.826 |
| Observations | | 153 | | 153 | | 141 | | 153 |

Table B.3

**TOTAL CREDIT OF MEDIUM BANKS**

Dependent variable: Log(total credit)

Banks: 6

| | *Interbank interest rate* | | *Repo interest rate* | | *1-to-7-days interest rate* | | *Policy interest rate* | |
|---|---|---|---|---|---|---|---|---|
| *Variable* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* |
| **Interest rate** | | | | | | | | |
| T | −0.8448465 | 0.242 | −0.8355787 | 0.156 | 0.2691549 | 0.544 | −0.3673222 | 0.088 |
| L1 | 0.4018894 | 0.102 | 0.2927494 | 0.424 | 0.1349061 | 0.346 | 0.8125943 | 0.043 |
| L2 | −0.3817442 | 0.240 | −0.0699238 | 0.842 | −0.4128702 | 0.079 | −0.5704682 | 0.070 |
| L3 | −0.4877373 | 0.187 | −0.7859304 | 0.005 | 0.0384806 | 0.788 | −0.6700826 | 0.075 |
| L4 | 0.2460712 | 0.435 | 0.2963538 | 0.197 | −0.3357417 | 0.175 | 0.3313726 | 0.209 |
| **Log(MEAI)** | | | | | | | | |
| T | 4.507404 | 0.210 | 5.381941 | 0.113 | 4.463939 | 0.126 | 1.67906 | 0.612 |
| L1 | −3.009558 | 0.174 | −5.376489 | 0.029 | −0.765239 | 0.536 | −3.646972 | 0.049 |
| L2 | 3.224714 | 0.130 | 4.714926 | 0.073 | 1.503945 | 0.458 | 4.744049 | 0.002 |
| L3 | 3.125566 | 0.370 | 3.596832 | 0.232 | 2.198652 | 0.426 | 3.21037 | 0.271 |
| L4 | 2.541359 | 0.457 | 2.064539 | 0.428 | 3.373703 | 0.344 | 2.754518 | 0.483 |
| **Log(real exchange rate)** | | | | | | | | |
| T | −0.5788985 | 0.795 | −2.619259 | 0.272 | −2.944582 | 0.344 | −0.8053176 | 0.798 |
| L1 | 3.689941 | 0.125 | 6.463213 | 0.094 | 6.133376 | 0.143 | 0.8906468 | 0.792 |
| L2 | 9.338449 | 0 | 8.459793 | 0.001 | 6.95547 | 0.001 | 11.3831 | 0 |
| L3 | −7.316414 | 0 | −7.351132 | 0.003 | −5.569923 | 0.038 | −8.543409 | 0.001 |
| L4 | −0.2102113 | 0.937 | −0.3123799 | 0.919 | −0.2371758 | 0.935 | −1.003442 | 0.669 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log(liquidity)*interest rate** | | | | | | | | |
| T | 0.0195852 | 0.441 | 0.0165286 | 0.38 | −0.0064214 | 0.633 | −0.005224 | 0.004 |
| L1 | 0.0006105 | 0.514 | 0.0011883 | 0.235 | −0.0009489 | 0.326 | −0.0003612 | 0.712 |
| L2 | 0.0031276 | 0.097 | 0.0024918 | 0.192 | 0.0020457 | 0.425 | 0.0036351 | 0.054 |
| L3 | −0.0008138 | 0.654 | −0.0004847 | 0.753 | −0.0005651 | 0.716 | −0.0012166 | 0.463 |
| L4 | −0.0019539 | 0.259 | −0.0021357 | 0.298 | −0.0036145 | 0.129 | −0.0034501 | 0.102 |
| **Size*interest rate** | | | | | | | | |
| T | −0.433405 | 0.972 | −1.920377 | 0.872 | −2.541695 | 0.705 | −1.836952 | 0.624 |
| L1 | −3.406611 | 0.016 | −3.531004 | 0.077 | −5.063878 | 0.083 | −3.204646 | 0.253 |
| L2 | 5.804696 | 0.251 | 4.932536 | 0.277 | 4.55189 | 0.189 | 4.847404 | 0.342 |
| L3 | 6.023309 | 0.059 | 6.925737 | 0.016 | −1.973405 | 0.061 | 3.004937 | 0.241 |
| L4 | 1.863036 | 0.571 | 2.919205 | 0.329 | 8.456508 | 0 | 5.814996 | 0.021 |
| **Capital*interest rate** | | | | | | | | |
| T | 0.0002074 | 0.572 | 0.0003376 | 0.417 | −0.0001268 | 0.792 | −0.0000456 | 0.580 |
| L1 | −0.0000176 | 0.835 | 0.00000434 | 0.957 | 0.0000219 | 0.720 | 0.0000293 | 0.749 |
| L2 | −0.000014 | 0.389 | −0.0000426 | 0.125 | −0.0001322 | 0.312 | −0.0000189 | 0.180 |
| L3 | 0.0000267 | 0.577 | 0.0000447 | 0.374 | 0.0002281 | 0.343 | 0.00000527 | 0.935 |
| L4 | −0.0001118 | 0.005 | −0.0001119 | 0.005 | −0.0001153 | 0.175 | −0.0001187 | 0 |
| **Liquidity** | −0.1161879 | 0.329 | −0.0991972 | 0.252 | 0.0040568 | 0.948 | | |
| **Size** | −4.743059 | 0.940 | −0.9659825 | 0.988 | 24.87261 | 0.193 | | |
| **Capital** | −0.0011253 | 0.619 | −0.0018386 | 0.464 | 0.0001721 | 0.936 | | |
| **Constant** | −47.2888 | 0 | −46.52654 | 0.002 | −50.49184 | 0.003 | −36.52279 | 0.006 |
| Observations | | 306 | | 306 | | 282 | | 306 |

**Table B.4**

**TOTAL CREDIT OF SMALL BANKS**

Dependent variable: Log(total credit)

Banks: 9

| | *Interbank interest rate* | | *Repo interest rate* | | *1-to-7-days interest rate* | | *Policy interest rate* | |
|---|---|---|---|---|---|---|---|---|
| *Variable* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* |
| **Interest rate** | | | | | | | | |
| T | −0.5413136 | 0.398 | −0.7210839 | 0.232 | 2.115953 | 0.068 | −0.1712745 | 0.621 |
| L1 | 1.338554 | 0.052 | 1.350212 | 0.020 | −0.2075881 | 0.450 | 0.0410789 | 0.939 |
| L2 | −0.7575616 | 0.200 | −0.6945605 | 0.021 | −0.3154399 | 0.308 | −0.3683911 | 0.558 |
| L3 | −0.4407134 | 0.329 | −0.1647669 | 0.582 | −0.2523904 | 0.412 | −0.4146268 | 0.466 |
| L4 | 0.2151312 | 0.490 | −0.0102199 | 0.948 | 0.6231161 | 0.069 | 0.7971114 | 0.004 |
| **Log(MEAI)** | | | | | | | | |
| T | 4.402802 | 0.139 | 2.914529 | 0.325 | 1.812233 | 0.614 | 6.903398 | 0.015 |
| L1 | −4.956174 | 0.407 | −9.157553 | 0.264 | −6.177943 | 0.233 | −9.81595 | 0.100 |
| L2 | 1.849494 | 0.793 | 5.399663 | 0.472 | 4.566799 | 0.53 | −0.5150726 | 0.947 |
| L3 | 3.4549 | 0.501 | 1.730122 | 0.772 | 3.362041 | 0.468 | 0.2544303 | 0.954 |
| L4 | −11.04304 | 0.129 | −8.028912 | 0.228 | 0.2236906 | 0.968 | −2.718774 | 0.669 |
| **Log(real exchange rate)** | | | | | | | | |
| T | 2.849307 | 0.680 | −2.368695 | 0.750 | −3.189563 | 0.643 | −0.7417765 | 0.921 |
| L1 | −14.33659 | 0.023 | −5.761743 | 0.230 | −4.290599 | 0.227 | −13.46916 | 0.026 |
| L2 | 20.13806 | 0.022 | 15.4437 | 0.071 | 14.6427 | 0.024 | 16.65633 | 0.022 |
| L3 | −12.45281 | 0.004 | −11.50043 | 0.005 | −4.422712 | 0.160 | −3.596682 | 0.322 |
| L4 | 0.9123698 | 0.822 | 0.7302012 | 0.874 | −4.659553 | 0.392 | −1.670999 | 0.718 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log(liquidity)*interest rate** | | | | | | | | |
| T | 0.0039437 | 0.709 | −0.00229 | 0.821 | | | 0.0025841 | 0.147 |
| L1 | 0.0022334 | 0.448 | 0.0026576 | 0.404 | 0.0011955 | 0.666 | 0.000627 | 0.782 |
| L2 | 0.0017698 | 0.379 | 0.002001 | 0.324 | 0.002435 | 0.274 | 0.0012469 | 0.469 |
| L3 | −0.0031611 | 0.233 | −0.0031154 | 0.248 | −0.0022425 | 0.129 | −0.0041326 | 0.164 |
| L4 | −0.0015504 | 0.418 | −0.0021585 | 0.25 | −0.0001199 | 0.955 | −0.0017335 | 0.277 |
| **Size*interest rate** | | | | | | | | |
| T | 39.23574 | 0.484 | 104.129 | 0.089 | −71.59759 | 0.233 | 22.60016 | 0.531 |
| L1 | −17.43401 | 0.733 | −39.51217 | 0.457 | −7.405139 | 0.872 | −1.021446 | 0.980 |
| L2 | 58.99465 | 0.189 | 75.80798 | 0.092 | 33.26888 | 0.314 | 49.66126 | 0.210 |
| L3 | −10.92922 | 0.706 | −27.85802 | 0.367 | −36.661 | 0.290 | −23.4312 | 0.326 |
| L4 | 17.59433 | 0.458 | 33.06268 | 0.174 | 2.232245 | 0.898 | 12.1443 | 0.635 |
| **Capital*interest rate** | | | | | | | | |
| T | −0.0019595 | 0.515 | −0.0040948 | 0.167 | 0.0019244 | 0.562 | −0.0001449 | 0.884 |
| L1 | −0.0000313 | 0.956 | 0.0001302 | 0.732 | −0.0003049 | 0.564 | −0.0000463 | 0.904 |
| L2 | −0.0006008 | 0.532 | −0.0004903 | 0.654 | −0.0003967 | 0.725 | −0.0001849 | 0.821 |
| L3 | 0.0007631 | 0.334 | 0.0003678 | 0.631 | 0.0010778 | 0.267 | 0.0008977 | 0.252 |
| L4 | 0.0001287 | 0.862 | 0.0002938 | 0.724 | −0.0005383 | 0.257 | −0.0002886 | 0.740 |
| **Liquidity** | 0.0039437 | 0.709 | 0.027898 | 0.596 | 0.3994744 | 0.006 | | |
| **Size** | −115.9692 | 0.718 | −388.4445 | 0.127 | 649.4785 | 0.116 | | |
| **Capital** | 0.01168 | 0.494 | 0.0220077 | 0.156 | −0.0101861 | 0.592 | | |
| **Constant** | 37.42318 | 0.557 | 42.85562 | 0.517 | −23.22178 | 0.706 | 35.95073 | 0.601 |
| Observations | | 364 | | 364 | | 336 | | 364 |

Table B.5

**COMMERCIAL CREDIT FROM BANK SYSTEM**

Dependent variable: Log(commercial credit)

Banks: 18

| | *Interbank interest rate* | | *Repo interest rate* | | *1-to-7-days interest rate* | | *Policy interest rate* | |
|---|---|---|---|---|---|---|---|---|
| *Variable* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* |
| **Interest rate** | | | | | | | | |
| T | −0.1952672 | 0.739 | −0.4657869 | 0.529 | 0.5308674 | 0.517 | −0.1168049 | 0.708 |
| L1 | 0.5888104 | 0.004 | 1.082555 | 0 | 0.2206208 | 0.463 | 0.4667097 | 0.094 |
| L2 | −0.1810883 | 0.387 | −0.8716866 | 0.013 | −0.7316877 | 0.003 | −0.4383737 | 0.123 |
| L3 | −0.5218952 | 0.09 | 0.1396752 | 0.657 | 0.0922854 | 0.717 | −0.6496786 | 0.006 |
| L4 | 0.4529672 | 0.04 | 0.0779143 | 0.713 | −0.141577 | 0.652 | 0.5816782 | 0.003 |
| **Log(MEAI)** | | | | | | | | |
| T | 2.413952 | 0.43 | 1.110489 | 0.736 | 6.056361 | 0.005 | 3.965276 | 0.151 |
| L1 | −2.254114 | 0.581 | −2.344005 | 0.610 | 1.122593 | 0.802 | −0.6300461 | 0.870 |
| L2 | −3.882751 | 0.183 | −1.020404 | 0.750 | −6.777204 | 0.015 | −3.241335 | 0.285 |
| L3 | 10.89977 | 0.01 | 6.839705 | 0.070 | 5.860846 | 0.097 | 6.023036 | 0.063 |
| L4 | 2.630294 | 0.482 | 4.260845 | 0.281 | 2.202356 | 0.591 | 0.4122242 | 0.907 |
| **Log(real exchange rate)** | | | | | | | | |
| T | 0.8435724 | 0.782 | −3.43049 | 0.205 | −1.286432 | 0.68 | 1.207124 | 0.631 |
| L1 | −4.510552 | 0.096 | 2.976957 | 0.351 | −1.803012 | 0.574 | −6.049659 | 0.019 |
| L2 | 16.24715 | 0 | 10.71674 | 0.001 | 9.316857 | 0.001 | 13.75906 | 0 |
| L3 | −7.561572 | 0.004 | −6.024797 | 0.008 | −2.431373 | 0.163 | −7.23363 | 0 |
| L4 | 1.76508 | 0.635 | 0.9735073 | 0.792 | 0.9507437 | 0.761 | 1.404284 | 0.674 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log(liquidity)*interest rate** | | | | | | | | |
| T | −0.0166932 | 0.546 | −0.017863 | 0.566 | −0.0234378 | 0.56 | −0.0057465 | 0.019 |
| L1 | −0.0003318 | 0.764 | 0.0000588 | 0.961 | 0.0000812 | 0.963 | −0.0004977 | 0.701 |
| L2 | 0.0010873 | 0.489 | 0.0006748 | 0.668 | −0.000219 | 0.897 | 0.0009505 | 0.535 |
| L3 | 0.0019161 | 0.256 | 0.0021985 | 0.217 | 0.0009208 | 0.535 | 0.001739 | 0.329 |
| L4 | −0.0003338 | 0.855 | −0.0010641 | 0.569 | −0.0018845 | 0.343 | −0.0013926 | 0.499 |
| **Size*interest rate** | | | | | | | | |
| T | −7.300077 | 0.184 | −1.072763 | 0.837 | −1.503694 | 0.79 | −2.456129 | 0.398 |
| L1 | 1.420129 | 0.215 | −1.648875 | 0.325 | −1.737466 | 0.178 | 1.379605 | 0.352 |
| L2 | 1.562335 | 0.509 | 3.065453 | 0.01 | 4.774158 | 0 | 3.218865 | 0.091 |
| L3 | 0.8476729 | 0.511 | 0.1236167 | 0.933 | −2.63547 | 0.019 | 0.1161459 | 0.941 |
| L4 | 0.573178 | 0.711 | 1.658812 | 0.29 | 3.516021 | 0.068 | 0.1412326 | 0.954 |
| **Capital*interest rate** | | | | | | | | |
| T | 0.0002849 | 0.47 | 0.000072 | 0.849 | −0.0000437 | 0.898 | −0.0000431 | 0.576 |
| L1 | −0.0000203 | 0.686 | −0.0000182 | 0.648 | 0.0000424 | 0.41 | 8.08E−06 | 0.891 |
| L2 | −0.0000251 | 0.573 | −0.0000211 | 0.735 | −2.55E−06 | 0.965 | −0.000017 | 0.65 |
| L3 | 0.0001483 | 0.014 | 0.0001334 | 0.02 | 0.0001063 | 0.001 | 0.0001251 | 0.001 |
| L4 | −0.0002819 | 0 | −0.0002804 | 0 | −0.0002178 | 0.004 | −0.0002702 | 0 |
| **Liquidity** | 0.0570598 | 0.683 | 0.0607674 | 0.694 | 0.0817978 | 0.669 | | |
| **Size** | 47.22299 | 0.301 | 17.57713 | 0.682 | 22.32312 | 0.209 | | |
| **Capital** | −0.0016723 | 0.438 | −0.000553 | 0.786 | −0.0003297 | 0.86 | | |
| **Constant** | −56.02469 | 0.059 | −47.29661 | 0.093 | −44.76053 | 0.164 | −30.43354 | 0.255 |
| Observations | | 734 | | 734 | | 674 | | 734 |

**Table B.6**

**COMMERCIAL CREDIT OF LARGE BANKS**

Dependent variable: Log(comercial credit)

Banks: 3

| | *Interbank interest rate* | | *Repo interest rate* | | *1-to-7-days interest rate* | | *Policy interest rate* | |
|---|---|---|---|---|---|---|---|---|
| *Variable* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* |
| **Interest rate** | | | | | | | | |
| T | −2.746482 | 0.003 | −1.137441 | 0.311 | −2.717861 | 0.118 | −0.7760462 | 0.352 |
| L1 | 0.518873 | 0.030 | −0.2597881 | 0.677 | −1.279654 | 0 | 0.7668683 | 0.367 |
| L2 | −0.5526882 | 0.536 | −0.2943018 | 0.467 | 1.329904 | 0.064 | 0.1922495 | 0.667 |
| L3 | 0.0374358 | 0.975 | 0.2241838 | 0.746 | −1.762833 | 0.143 | −0.9904491 | 0.321 |
| L4 | 0.4670497 | 0.353 | 0.2755625 | 0.418 | 1.184378 | 0.227 | 0.6267173 | 0.167 |
| **Log(MEAI)** | | | | | | | | |
| T | −1.735387 | 0.689 | −2.556433 | 0.299 | 5.774162 | 0.004 | 4.873107 | 0.137 |
| L1 | −6.990026 | 0.095 | −5.755376 | 0 | −12.82058 | 0.002 | −4.169698 | 0.035 |
| L2 | −6.611359 | 0.352 | −7.315641 | 0.218 | −6.389268 | 0.180 | −3.040581 | 0.667 |
| L3 | 6.581078 | 0.176 | −0.4042687 | 0.926 | −4.996485 | 0.022 | −1.00207 | 0.778 |
| L4 | 4.955312 | 0.137 | 11.04053 | 0.016 | 11.09481 | 0.130 | 2.151317 | 0.186 |
| **Log(real exchange rate)** | | | | | | | | |
| T | −11.18208 | 0 | −13.1494 | 0 | −13.68244 | 0 | −2.174917 | 0.494 |
| L1 | 0.6354872 | 0.681 | 4.194613 | 0.001 | 2.365351 | 0.485 | −5.905318 | 0.051 |
| L2 | 17.12262 | 0.014 | 10.25472 | 0.050 | 9.063164 | 0.056 | 14.38041 | 0.029 |
| L3 | −9.012654 | 0 | −2.317428 | 0.489 | −4.262575 | 0.200 | −11.57745 | 0.031 |
| L4 | −3.872277 | 0.297 | −7.164972 | 0.034 | −1.328558 | 0.68 | 3.413233 | 0.130 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log(liquidity)*interest rate** | | | | | | | | |
| T | 0.0003048 | 0.991 | −0.0014781 | 0.974 | 0.1047907 | 0.19 | 0.0089379 | 0.045 |
| L1 | 0.0018335 | 0.818 | −0.0013851 | 0.841 | 0.0002499 | 0.969 | 0.0029882 | 0.768 |
| L2 | 0.0105145 | 0.002 | 0.0119759 | 0.047 | 0.0063183 | 0.466 | 0.0073571 | 0.176 |
| L3 | 0.0054724 | 0.422 | 0.0035033 | 0.478 | 0.0052676 | 0.33 | 0.0024423 | 0.717 |
| L4 | 0.0003224 | 0.912 | −0.0001545 | 0.956 | −0.0094942 | 0.033 | −0.0083253 | 0.028 |
| **Size*interest rate** | | | | | | | | |
| T | −1.508297 | 0.382 | −2.676631 | 0.219 | 0.9576013 | 0.816 | 0.4024897 | 0.659 |
| L1 | 1.115259 | 0.641 | 3.324261 | 0.073 | 0.1029022 | 0.953 | 1.107877 | 0.639 |
| L2 | 2.001821 | 0.08 | −1.224608 | 0.186 | −0.3744608 | 0.822 | −0.343352 | 0.649 |
| L3 | −1.816777 | 0.155 | 1.197361 | 0.567 | 0.9557564 | 0.684 | −1.14359 | 0.535 |
| L4 | −2.515497 | 0.073 | −3.438104 | 0.046 | −1.98364 | 0.468 | −0.8276232 | 0.627 |
| **Capital*interest rate** | | | | | | | | |
| T | 0.0006411 | 0 | 0.0003414 | 0.033 | 0.0002822 | 0.287 | −2.72E−06 | 0.964 |
| L1 | 0.0000428 | 0.358 | 0.0000728 | 0.042 | 0.0001286 | 0 | 0.0000456 | 0.293 |
| L2 | −0.0000273 | 0.669 | −0.0000876 | 0.288 | −0.0000834 | 0.266 | −0.0000725 | 0.318 |
| L3 | 0.0001658 | 0.089 | 0.000205 | 0.018 | 0.0001838 | 0.065 | 0.000187 | 0.026 |
| L4 | −0.000149 | 0.001 | −0.0001526 | 0 | −0.0001037 | 0.029 | −0.0001145 | 0.004 |
| **Liquidity** | 0.0511299 | 0.714 | 0.0613922 | 0.798 | −0.4530979 | 0.269 | | |
| **Size** | 7.721098 | 0.047 | 10.23538 | 0.142 | −6.949472 | 0.727 | | |
| **Capital** | −0.0033931 | 0 | −0.0018498 | 0.034 | −0.001464 | 0.326 | | |
| **Constant** | 44.60479 | 0.192 | 47.91921 | 0.033 | 69.76511 | 0.002 | 13.97103 | 0.640 |
| Observations | | 153 | | 153 | | 141 | | 153 |

Table B.7

**COMMERCIAL CREDIT OF MEDIUM BANKS**

Dependent variable: Log(commercial credit)

Banks: 6

| Variable | *Interbank interest rate* | | *Repo interest rate* | | *1-to-7-days interest rate* | | *Policy interest rate* | |
|---|---|---|---|---|---|---|---|---|
| | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* |
| **Interest rate** | | | | | | | | |
| T | 0.0124608 | 0.99 | −0.4375447 | 0.731 | −0.4956476 | 0.749 | −0.3119854 | 0.560 |
| L1 | 0.7335517 | 0.054 | 1.017053 | 0.001 | 0.4990262 | 0.12 | 0.852573 | 0.166 |
| L2 | −0.878847 | 0.014 | −1.002772 | 0.066 | −0.9171677 | 0.009 | −0.9015741 | 0.025 |
| L3 | −0.9174303 | 0.033 | −0.8145425 | 0.074 | 0.2167642 | 0.638 | −1.030245 | 0.023 |
| L4 | 0.7689661 | 0.058 | 0.6203104 | 0.150 | −0.8685804 | 0.034 | 0.662068 | 0.049 |
| **Log(MEAI)** | | | | | | | | |
| T | 1.949191 | 0.721 | 2.833494 | 0.650 | 3.851696 | 0.304 | 1.941213 | 0.605 |
| L1 | 2.190835 | 0.661 | 0.0346542 | 0.996 | 3.501251 | 0.553 | 1.67811 | 0.800 |
| L2 | 0.1825088 | 0.934 | 4.070513 | 0.233 | −6.108447 | 0.149 | 0.1025886 | 0.962 |
| L3 | 6.022093 | 0.166 | 2.938023 | 0.333 | 1.990034 | 0.265 | 3.185463 | 0.176 |
| L4 | −3.015551 | 0.295 | −1.733416 | 0.201 | −1.051339 | 0.809 | −1.901406 | 0.526 |
| **Log(real exchange rate)** | | | | | | | | |
| T | 7.513458 | 0.043 | 2.451508 | 0.477 | 2.195322 | 0.680 | 6.38855 | 0.138 |
| L1 | −4.812092 | 0.222 | 4.832029 | 0.223 | −1.485344 | 0.797 | −7.954879 | 0.009 |
| L2 | 12.06689 | 0.002 | 5.948958 | 0.068 | 6.807236 | 0.001 | 12.82469 | 0.001 |
| L3 | −10.30706 | 0.026 | −8.762593 | 0.010 | −1.578002 | 0.565 | −7.856664 | 0.094 |
| L4 | 2.278327 | 0.611 | 2.075186 | 0.641 | −1.609332 | 0.584 | −0.7187891 | 0.871 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log(liquidity)*interest rate** | | | | | | | | |
| T | 0.0012942 | 0.969 | −0.0017748 | 0.966 | 0.0086592 | 0.851 | −0.007621 | 0 |
| L1 | 0.002074 | 0.182 | 0.0033987 | 0.015 | 0.0025264 | 0.013 | 0.00224 | 0.193 |
| L2 | 0.0023084 | 0.119 | 0.0008646 | 0.627 | 0.001227 | 0.695 | 0.0036538 | 0.095 |
| L3 | 0.0024167 | 0.388 | 0.003597 | 0.198 | 0.0033104 | 0.046 | 0.0029959 | 0.260 |
| L4 | 0.0010212 | 0.705 | 0.0009511 | 0.722 | 0.001633 | 0.628 | 0.0008993 | 0.801 |
| **Size*interest rate** | | | | | | | | |
| T | 1.9032 | 0.913 | 4.063233 | 0.819 | −15.05949 | 0.565 | −6.111284 | 0.527 |
| L1 | 3.030703 | 0.685 | −0.2990812 | 0.978 | 0.1848929 | 0.988 | 2.387488 | 0.763 |
| L2 | 10.58401 | 0.048 | 11.18339 | 0.010 | 9.64897 | 0.05 | 7.151587 | 0.387 |
| L3 | 5.754053 | 0.179 | 7.208232 | 0.139 | −8.05 | 0.176 | 1.234019 | 0.746 |
| L4 | −1.803765 | 0.668 | −1.927377 | 0.685 | 11.88569 | 0 | 4.264168 | 0.111 |
| **Capital*interest rate** | | | | | | | | |
| T | −0.0012571 | 0.015 | −0.0007931 | 0.077 | 0.0008332 | 0.462 | −0.0000155 | 0.917 |
| L1 | −0.000075 | 0.712 | −0.0000991 | 0.592 | 0.0000451 | 0.738 | −0.0000736 | 0.743 |
| L2 | 0.0000796 | 0.253 | 0.0000346 | 0.471 | −0.000183 | 0.409 | 0.0000491 | 0.475 |
| L3 | 0.00000211 | 0.933 | 0.0000412 | 0.358 | 0.0001882 | 0.15 | 0.00000165 | 0.976 |
| L4 | −0.0002798 | 0 | −0.0002823 | 0 | 0.0001966 | 0.552 | −0.0001585 | 0.060 |
| **Liquidity** | −0.0352769 | 0.828 | −0.0242741 | 0.904 | −0.0866666 | 0.687 | | |
| **Size** | −59.50757 | 0.216 | −50.90979 | 0.181 | 40.24076 | 0.663 | | |
| **Capital** | 0.0066779 | 0.005 | 0.0043059 | 0.053 | −0.0043098 | 0.404 | | |
| **Constant** | −43.15354 | 0.063 | −45.66382 | 0.069 | −8.332783 | 0.575 | −22.73011 | 0.293 |
| Observations | | 300 | | 300 | | 276 | | 300 |

Table B.8

**COMMERCIAL CREDIT OF SMALL BANKS**

Dependent variable: Log(commercial credit)

Banks: 9

| | *Interbank interest rate* | | *Repo interest rate* | | *1-to-7-days interest rate* | | *Policy interest rate* | |
|---|---|---|---|---|---|---|---|---|
| *Variable* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* |
| **Interest rate** | | | | | | | | |
| T | 0.5181065 | 0.719 | −1.34532 | 0.327 | 1.470955 | 0.057 | 0.5683128 | 0.243 |
| L1 | 0.1043881 | 0.718 | 1.218945 | 0.021 | 0.1182979 | 0.847 | −0.1056033 | 0.868 |
| L2 | 0.204834 | 0.502 | −1.073738 | 0.065 | −0.6762621 | 0.094 | −0.1346671 | 0.852 |
| L3 | −0.5404779 | 0.144 | 0.5525608 | 0.168 | 0.2209939 | 0.554 | −0.2381973 | 0.605 |
| L4 | 0.016434 | 0.929 | −0.4017794 | 0.277 | −0.0732487 | 0.859 | 0.1580966 | 0.686 |
| **Log(MEAI)** | | | | | | | | |
| T | 5.976343 | 0.246 | 2.085996 | 0.742 | 5.928652 | 0.327 | 6.805235 | 0.127 |
| L1 | −4.188342 | 0.711 | −2.243686 | 0.864 | 0.3409801 | 0.965 | −3.983015 | 0.655 |
| L2 | −5.940211 | 0.294 | −1.650497 | 0.776 | −9.139661 | 0.187 | −7.024099 | 0.223 |
| L3 | 12.88644 | 0.108 | 10.71028 | 0.218 | 12.36065 | 0.176 | 10.36036 | 0.107 |
| L4 | −4.619261 | 0.502 | −2.33971 | 0.706 | 0.1977204 | 0.97 | −4.423334 | 0.587 |
| **Log(real exchange rate)** | | | | | | | | |
| T | 0.5883475 | 0.84 | −0.8838548 | 0.781 | −1.567794 | 0.585 | 0.6700556 | 0.841 |
| L1 | −4.674338 | 0.409 | 1.340651 | 0.817 | −0.3710512 | 0.944 | −4.917068 | 0.389 |
| L2 | 14.40596 | 0.032 | 10.83902 | 0.126 | 9.21181 | 0.163 | 13.45374 | 0.001 |
| L3 | −8.064161 | 0.229 | −8.372164 | 0.125 | −4.002546 | 0.318 | −7.265279 | 0.071 |
| L4 | 4.94087 | 0.436 | 5.223512 | 0.366 | 4.102706 | 0.363 | 5.87753 | 0.289 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log(liquidity)*interest rate** | | | | | | | | |
| T | −0.0240081 | 0.601 | 0.0081448 | 0.832 | −0.0435454 | 0.196 | −0.0020396 | 0.388 |
| L1 | −0.0030471 | 0.242 | −0.0023363 | 0.4 | −0.0000645 | 0.988 | −0.0036219 | 0.15 |
| L2 | −0.0001353 | 0.963 | −0.000304 | 0.922 | 0.0007632 | 0.813 | −0.0011193 | 0.702 |
| L3 | −0.0015179 | 0.249 | −0.0009169 | 0.293 | −0.0006074 | 0.637 | −0.0022942 | 0.006 |
| L4 | 0.0023654 | 0.352 | 0.0019765 | 0.459 | 0.0003056 | 0.893 | 0.0008956 | 0.673 |
| **Size*interest rate** | | | | | | | | |
| T | | | | | −31.6423 | 0.601 | −17.12293 | 0.571 |
| L1 | 26.77212 | 0.414 | −1.306842 | 0.976 | −6.204653 | 0.883 | 20.98064 | 0.54 |
| L2 | −4.84202 | 0.729 | 24.42041 | 0.117 | −17.29096 | 0.481 | 0.2020334 | 0.991 |
| L3 | 6.432083 | 0.692 | −11.64778 | 0.121 | 8.532964 | 0.682 | −4.433993 | 0.764 |
| L4 | 18.65982 | 0.428 | 28.44896 | 0.123 | 18.72083 | 0.38 | 15.52189 | 0.599 |
| **Capital*interest rate** | | | | | | | | |
| T | 0.0011121 | 0.653 | 0.0018113 | 0.444 | −0.0014825 | 0.803 | −0.0010785 | 0.031 |
| L1 | 0.0012515 | 0.004 | 0.0007989 | 0.218 | −0.000241 | 0.723 | 0.0012589 | 0.066 |
| L2 | −0.0004159 | 0.772 | 0.0001012 | 0.952 | 0.0007149 | 0.645 | 0.0001022 | 0.943 |
| L3 | 0.0012254 | 0.037 | 0.0007986 | 0.307 | 0.0005399 | 0.375 | 0.0011261 | 0.008 |
| L4 | −0.0006103 | 0.358 | −0.0006268 | 0.408 | −0.0003554 | 0.748 | −0.0008428 | 0.174 |
| **Liquidity** | 0.1130941 | 0.638 | −0.0517698 | 0.793 | 0.2026051 | 0.195 | | |
| **Size** | 79.32864 | 0.809 | −205.6554 | 0.396 | 229.5736 | 0.536 | | |
| **Capital** | −0.0117136 | 0.43 | −0.0163471 | 0.247 | 0.0039388 | 0.903 | | |
| **Constant** | −32.91442 | 0.157 | −39.66989 | 0.051 | −64.08103 | 0.011 | −21.12529 | 0.455 |
| Observations | | 281 | | 281 | | 257 | | 281 |

Table B.9

**CONSUMER CREDIT OF THE BANKING SYSTEM**

Dependent variable: Log(consumer credit)

Banks: 18

| | *Interbank interest rate* | | *Repo interest rate* | | *1-to-7-days interest rate* | | *Policy interest rate* | |
|---|---|---|---|---|---|---|---|---|
| *Variable* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* |
| **Interest rate** | | | | | | | | |
| T | −0.508486 | 0.124 | −0.4559609 | 0.132 | −0.4987562 | 0.353 | −0.1814174 | 0.415 |
| L1 | 0.3817457 | 0.008 | 0.184955 | 0.319 | 0.0410404 | 0.864 | 0.491845 | 0.047 |
| L2 | −0.2456633 | 0.006 | 0.2816057 | 0.173 | −0.2653019 | 0.102 | −0.2602982 | 0.042 |
| L3 | −0.264208 | 0.029 | −0.7273989 | 0.004 | 0.1183518 | 0.344 | −0.3048213 | 0.006 |
| L4 | 0.3063568 | 0.046 | 0.4736485 | 0.008 | 0.2543522 | 0.030 | 0.4832584 | 0 |
| **Log(MEAI)** | | | | | | | | |
| T | 3.678627 | 0.018 | 4.327084 | 0.005 | 1.244175 | 0.549 | 1.666999 | 0.320 |
| L1 | −0.8951289 | 0.742 | −3.172934 | 0.255 | −1.543023 | 0.638 | −3.634583 | 0.185 |
| L2 | 4.276038 | 0.114 | 5.608634 | 0.034 | 4.353367 | 0.162 | 4.263249 | 0.121 |
| L3 | 2.650963 | 0.327 | 4.066075 | 0.108 | 4.6854 | 0.066 | 4.53865 | 0.103 |
| L4 | −2.455379 | 0.263 | −2.993435 | 0.195 | 0.8508831 | 0.760 | 0.8246218 | 0.703 |
| **Log(real exchange rate)** | | | | | | | | |
| T | −0.7935599 | 0.593 | −1.407786 | 0.290 | −3.247731 | 0.027 | −2.396276 | 0.060 |
| L1 | −0.8619887 | 0.725 | 0.6822708 | 0.754 | 2.436969 | 0.468 | −1.943461 | 0.445 |
| L2 | 5.636247 | 0.025 | 5.305556 | 0.002 | 5.856303 | 0.002 | 8.351389 | 0.001 |
| L3 | −4.816378 | 0.001 | −5.362725 | 0 | −4.098013 | 0.003 | −4.080075 | 0.005 |
| L4 | −2.023701 | 0.291 | −1.356471 | 0.472 | −3.650795 | 0.075 | −2.369832 | 0.160 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log(liquidity)*interest rate** | | | | | | | | |
| T | 0.0326708 | 0.029 | 0.0269111 | 0.060 | 0.0193 | 0.240 | 0.0007505 | 0.501 |
| L1 | −0.0006089 | 0.585 | −0.0006957 | 0.540 | −0.0005402 | 0.708 | −0.00004 | 0.973 |
| L2 | 0.0020022 | 0.034 | 0.0021548 | 0.032 | 0.0029133 | 0.016 | 0.0025676 | 0.007 |
| L3 | 0.0014762 | 0.181 | 0.0014476 | 0.204 | 0.0018806 | 0.184 | 0.0016954 | 0.198 |
| L4 | 0.0001961 | 0.698 | 0.0003296 | 0.543 | −0.0003408 | 0.653 | −0.000289 | 0.686 |
| **Size*interest rate** | | | | | | | | |
| T | 2.242759 | 0.362 | 0.7171308 | 0.754 | −1.965476 | 0.522 | 1.643149 | 0.204 |
| L1 | −1.149859 | 0.046 | −0.4531029 | 0.522 | −0.8503253 | 0.358 | −1.80682 | 0.021 |
| L2 | 1.008525 | 0.031 | 0.0852247 | 0.905 | 0.3446335 | 0.611 | 1.252448 | 0.174 |
| L3 | 0.8743333 | 0.329 | 1.24825 | 0.259 | −0.8324535 | 0.256 | 0.6195622 | 0.494 |
| L4 | −1.634419 | 0.146 | −1.146926 | 0.335 | −0.5188997 | 0.513 | −1.458757 | 0.220 |
| **Capital*interest rate** | | | | | | | | |
| T | −0.0002026 | 0.363 | −0.0001145 | 0.575 | 0.0002338 | 0.255 | −0.0000708 | 0.002 |
| L1 | −7.24E−07 | 0.968 | 9.99E−06 | 0.520 | 0.0000148 | 0.450 | 5.55E−06 | 0.755 |
| L2 | −0.00004 | 0.013 | −0.0000516 | 0.002 | −0.0000483 | 0.139 | −0.0000402 | 0.007 |
| L3 | 0.0000357 | 0.058 | 0.0000442 | 0.015 | 0.0000124 | 0.654 | 0.0000274 | 0.240 |
| L4 | −0.0000494 | 0.174 | −0.0000655 | 0.091 | −0.0000473 | 0.097 | −0.0000753 | 0.053 |
| **Liquidity** | −0.162668 | 0.028 | −0.1300654 | 0.063 | −0.090523 | 0.263 | | |
| **Size** | −7.191554 | 0.708 | 4.235661 | 0.799 | 13.84144 | 0.486 | | |
| **Capital** | 0.0006785 | 0.555 | 0.0001708 | 0.866 | −0.0017987 | 0.088 | | |
| **Constant** | −25.17243 | 0.261 | −30.14078 | 0.210 | −36.28096 | 0.110 | −30.91736 | 0.142 |
| Observations | | 793 | | 793 | | 729 | | 793 |

Table B.10

**CONSUMER CREDIT OF MEDIUM BANKS**

Dependient variable: Log(consumer credit)

Banks: 6

| | *Interbank interest rate* | | *Repo interest rate* | | *1-to-7-days interest rate* | | *Policy interest rate* | |
|---|---|---|---|---|---|---|---|---|
| *Variable* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* |
| **Interest rate** | | | | | | | | |
| T | −1.678186 | 0.082 | −1.184656 | 0.121 | −0.508465 | 0.278 | −0.1440416 | 0.326 |
| L1 | 0.3325247 | 0.005 | −0.3169102 | 0.293 | −0.0974718 | 0.756 | 0.9099204 | 0.012 |
| L2 | −0.3223165 | 0.059 | 0.6295952 | 0.119 | −0.2148955 | 0.365 | −0.7985492 | 0.005 |
| L3 | −0.5724017 | 0.090 | −1.297863 | 0.009 | 0.2147636 | 0.132 | −0.6087405 | 0.046 |
| L4 | 0.7645619 | 0.124 | 0.9758033 | 0.035 | 0.2984903 | 0.202 | 0.8322986 | 0.051 |
| **Log(MEAI)** | | | | | | | | |
| T | 7.390604 | 0.073 | 9.176843 | 0.039 | 0.5354771 | 0.876 | 1.546356 | 0.556 |
| L1 | −7.942219 | 0.001 | −10.42584 | 0 | −7.386049 | 0.028 | −10.8876 | 0.001 |
| L2 | 9.258991 | 0.042 | 8.803011 | 0.033 | 10.16421 | 0.009 | 10.49764 | 0.022 |
| L3 | −4.554498 | 0.019 | −1.266963 | 0.653 | −0.7045347 | 0.733 | −0.6529453 | 0.720 |
| L4 | 1.746347 | 0.647 | −0.2435631 | 0.952 | 5.412033 | 0.144 | 5.022261 | 0.093 |
| **Log(real exchange rate)** | | | | | | | | |
| T | −2.582821 | 0.265 | −2.343108 | 0.244 | −6.118255 | 0.004 | −4.079473 | 0.034 |
| L1 | 2.62105 | 0.595 | 1.629523 | 0.681 | 8.969606 | 0.178 | 2.316299 | 0.629 |
| L2 | 5.016026 | 0.077 | 6.727463 | 0.003 | 4.798638 | 0.126 | 8.942561 | 0 |
| L3 | −7.061614 | 0 | −8.778237 | 0 | −8.22987 | 0 | −8.476565 | 0 |
| L4 | 0.8267003 | 0.728 | 2.306947 | 0.291 | 0.3774674 | 0.886 | 0.6475282 | 0.836 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log(liquidity)*interest rate** | | | | | | | | |
| T | 0.0699889 | 0.033 | 0.0640837 | 0.013 | −0.0025223 | 0.931 | −0.000666 | 0.644 |
| L1 | −0.0004322 | 0.758 | −0.0003291 | 0.800 | −0.001521 | 0.428 | −0.0004444 | 0.744 |
| L2 | 0.0023312 | 0 | 0.0020642 | 0 | 0.0029411 | 0.009 | 0.0031305 | 0.006 |
| L3 | −0.0005342 | 0.737 | −0.0010047 | 0.467 | −0.001089 | 0.588 | −0.0014983 | 0.237 |
| L4 | −0.0006634 | 0.567 | −0.0006266 | 0.600 | −0.0044718 | 0.105 | −0.0030497 | 0.099 |
| **Size*interest rate** | | | | | | | | |
| T | 0.9581948 | 0.862 | −5.754769 | 0.128 | 5.550391 | 0.081 | 1.086911 | 0.662 |
| L1 | −5.862591 | 0.069 | −2.327119 | 0.551 | −5.402918 | 0.304 | −8.115613 | 0.056 |
| L2 | 5.895959 | 0.032 | 3.326273 | 0.121 | 6.213572 | 0.073 | 9.706246 | 0.005 |
| L3 | 7.0428 | 0.102 | 7.424869 | 0.127 | 0.6943676 | 0.867 | 6.114332 | 0.191 |
| L4 | −10.8494 | 0.198 | −9.597725 | 0.206 | −5.066277 | 0.317 | −10.85165 | 0.165 |
| **Capital*interest rate** | | | | | | | | |
| T | 0.0005308 | 0.079 | 0.0005467 | 0.121 | 0.0004215 | 0.349 | −0.000037 | 0.250 |
| L1 | −7.76E−06 | 0.908 | 0.0000437 | 0.386 | 0.000054 | 0.248 | 0.0000191 | 0.657 |
| L2 | −0.000052 | 0.082 | −0.0000733 | 0 | −0.0002783 | 0.128 | −0.0000682 | 0.091 |
| L3 | 0.0000272 | 0.620 | 0.000037 | 0.495 | −0.000062 | 0.851 | 0.00000674 | 0.902 |
| L4 | 0.0000382 | 0.286 | 0.0000489 | 0.131 | 0.0001509 | 0.309 | 0.0000483 | 0.309 |
| **Liquidity** | −0.3476285 | 0.028 | −0.3124355 | 0.011 | 0.0063333 | 0.965 | | |
| **Size** | 8.72808 | 0.759 | 30.67346 | 0.043 | −15.50523 | 0.531 | | |
| **Capital** | −0.0029303 | 0.060 | −0.0031844 | 0.080 | −0.0023618 | 0.274 | | |
| **Constant** | −15.94507 | 0.536 | −19.51749 | 0.433 | −33.28763 | 0.185 | −23.32263 | 0.261 |
| Observations | | 306 | | 306 | | 282 | | 306 |

Table B.11

**CONSUMMER CREDIT OF SMALL BANKS**

Dependent variable: Log(consumer credit)

Banks: 9

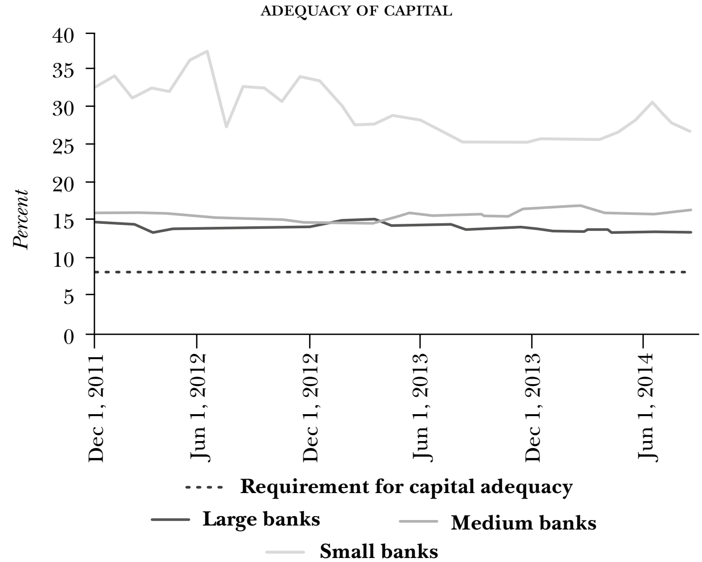
| Variable | *Interbank interest rate* | | *Repo interest rate* | | *1-to-7-days interest rate* | | *Policy interest rate* | |
|---|---|---|---|---|---|---|---|---|
| | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* | *Coefficient* | p *value* |
| **Interest rate** | | | | | | | | |
| T | 0.7816919 | 0.413 | 0.3393521 | 0.678 | −0.7269764 | 0.302 | −0.2950523 | 0.413 |
| L1 | 0.4382741 | 0.033 | 0.3773966 | 0.146 | 0.3427675 | 0.452 | 0.3643891 | 0.382 |
| L2 | −0.313859 | 0.002 | 0.0821507 | 0.797 | −0.5543495 | 0.172 | −0.2436027 | 0.277 |
| L3 | −0.3089103 | 0.018 | −0.6947387 | 0.042 | 0.2369871 | 0.395 | −0.2415755 | 0.083 |
| L4 | 0.5201907 | 0.014 | 0.6559587 | 0.013 | 0.1894788 | 0.276 | 0.5889466 | 0 |
| **Log(MEAI)** | | | | | | | | |
| T | 4.468997 | 0.046 | 5.222764 | 0.001 | 4.387605 | 0.171 | 2.469467 | 0.368 |
| L1 | 2.275046 | 0.612 | −0.6395372 | 0.886 | 4.784449 | 0.460 | 0.6492252 | 0.875 |
| L2 | 2.02785 | 0.284 | 5.156365 | 0.015 | 0.7656722 | 0.798 | 1.780561 | 0.476 |
| L3 | 8.047917 | 0.060 | 8.31077 | 0.050 | 9.472557 | 0.045 | 7.963802 | 0.064 |
| L4 | −6.212098 | 0 | −5.960052 | 0.008 | −3.590953 | 0.292 | −3.699575 | 0.009 |
| **Log(real exchange rate)** | | | | | | | | |
| T | 1.594697 | 0.402 | 0.5157135 | 0.787 | 1.080689 | 0.671 | 0.3191855 | 0.897 |
| L1 | −4.072873 | 0.230 | 0.1440071 | 0.960 | −1.314857 | 0.710 | −4.628037 | 0.246 |
| L2 | 9.563759 | 0.025 | 7.086135 | 0.062 | 6.28869 | 0.053 | 9.997692 | 0.051 |
| L3 | −5.232969 | 0.088 | −5.881816 | 0.050 | −4.367015 | 0.123 | −4.235891 | 0.205 |
| L4 | −3.023942 | 0.366 | −1.767256 | 0.518 | −3.367153 | 0.297 | −3.184467 | 0.131 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log(liquidity)*interest rate** | | | | | | | | |
| T | −0.0166895 | 0.494 | −0.006431 | 0.717 | −0.0025163 | 0.837 | 0.0000511 | 0.964 |
| L1 | −0.0006605 | 0.706 | −0.0009045 | 0.633 | 0.0008936 | 0.581 | −0.0000253 | 0.987 |
| L2 | 0.0015914 | 0.082 | 0.0017794 | 0.096 | 0.002933 | 0.027 | 0.0018756 | 0.072 |
| L3 | 0.001713 | 0.010 | 0.0016546 | 0.036 | 0.0023096 | 0.001 | 0.0018586 | 0.018 |
| L4 | 0.0007254 | 0.300 | 0.0008786 | 0.124 | 0.0015363 | 0.105 | 0.0004984 | 0.622 |
| **Size*interest rate** | | | | | | | | |
| T | −63.12185 | 0.244 | −42.1234 | 0.297 | 5.686298 | 0.889 | 3.038467 | 0.649 |
| L1 | 27.55232 | 0.008 | 19.57125 | 0.085 | 14.72873 | 0.198 | 15.04851 | 0.044 |
| L2 | −0.7645215 | 0.855 | 3.500985 | 0.609 | 2.253779 | 0.775 | 3.921724 | 0.589 |
| L3 | 5.247083 | 0.597 | 2.591425 | 0.786 | 7.88746 | 0.469 | 3.103132 | 0.744 |
| L4 | −14.72979 | 0.018 | −9.730482 | 0.090 | −9.219955 | 0.376 | −6.947952 | 0.291 |
| **Capital*interest rate** | | | | | | | | |
| T | 0.00000703 | 0.983 | −0.0001011 | 0.771 | 0.0028393 | 0.261 | −0.0000876 | 0.822 |
| L1 | −0.0002544 | 0.620 | −0.0002592 | 0.597 | −0.0004599 | 0.307 | −0.0002385 | 0.606 |
| L2 | −0.0002724 | 0.352 | −0.000248 | 0.340 | −0.0001821 | 0.511 | 0.00000814 | 0.974 |
| L3 | 0.0000981 | 0.844 | 0.0000818 | 0.865 | −0.0000351 | 0.943 | −0.0000263 | 0.957 |
| L4 | −0.0005092 | 0.093 | −0.0005532 | 0.029 | −0.0006707 | 0.092 | −0.0004149 | 0.022 |
| **Liquidity** | | | | | 0.017592 | 0.769 | | |
| **Size** | 0.0814375 | 0.500 | 0.0298319 | 0.725 | −20.10115 | 0.937 | | |
| **Capital** | 338.2408 | 0.278 | 237.8141 | 0.294 | −0.0131308 | 0.309 | | |
| **Constant** | −54.40616 | 0.082 | −62.01305 | 0.045 | −71.49521 | 0.008 | −41.56582 | 0.108 |
| Observations | | 334 | | 334 | | 306 | | 334 |

## Annex C. Banking System Indicators

Figure C.1

**INDICATORS OF THE BANKING SYSTEM**



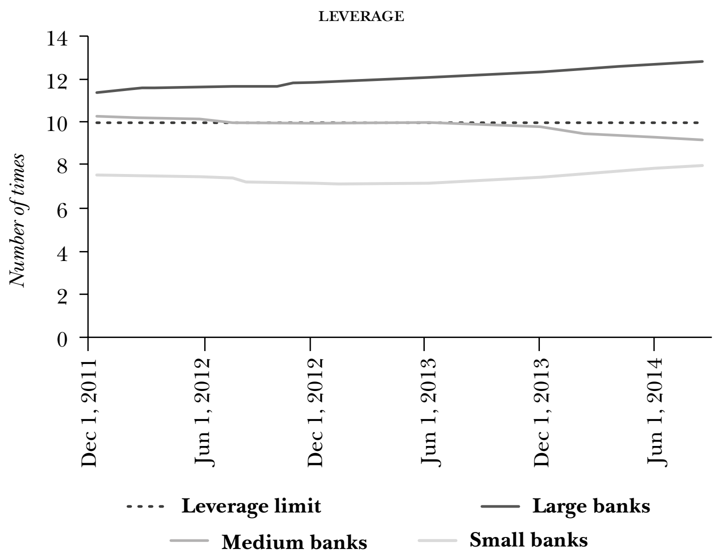
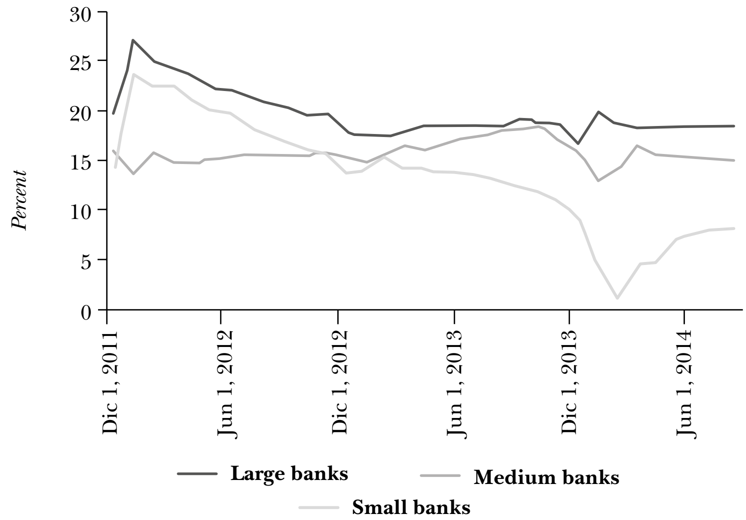



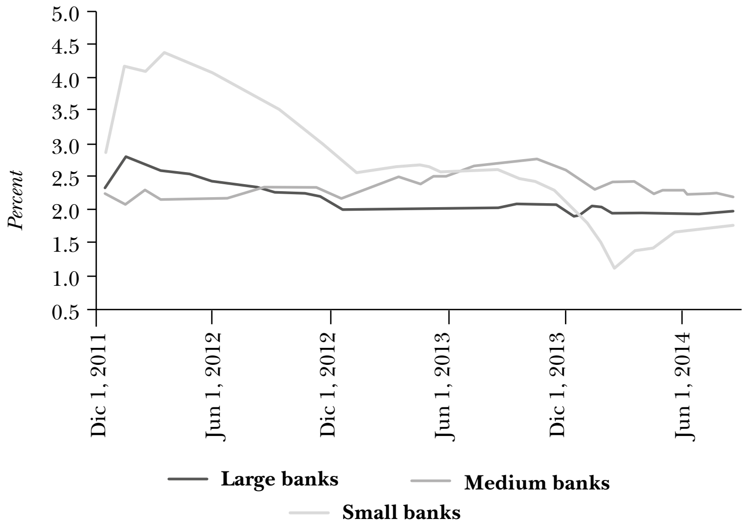
Figure C.1 (cont.)

**INDICATORS OF THE BANKING SYSTEM**

RETURN OVER EQUITY




RETURN ON ASSETS



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# The Relation Between Credit and Business Cycles in Central America and the Dominican Republic

***Francisco Ramírez***

**Abstract**

*This study provides evidence of the relation between credit and real activity in Central America and the Dominican Republic (DR). The link between credit and real activity is addressed for the case of a group of developing countries with limited financial markets where bank credit is the main source of external finance for the private sector. We compile information of credit to the private sector and the aggregate economic activity for Costa Rica, El Salvador, Honduras, Guatemala, Nicaragua and the DR. The data is analyzed using simple statistical tools (Granger causality tests and spectral analysis) to identify stylized facts on the credit-activity relation. We find a positive relation between credit and real activity in frequencies associated to business cycles for all countries. The credit-economic relation in cycles lasting 10 or more years seems relevant in Costa Rica and the DR. There is evidence suggesting that credit precedes economic activity at business cycles frequencies in Costa Rica, El Salvador, Honduras, Nicaragua and the DR. Excluding Nicaragua, this pattern is observed also in cycles over eight years for mentioned economies. In case of Guatemala there is no evidence of statistical precedence of credit to economic activity.*

*Keywords: credit cycle, banking credit, business cycle, developing countries, Central America, Dominican Republic.*

*JEL classification: C32; E32; E51.*

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F. Ramírez <f.ramirez@bancentral.gov.do>, Banco Central de la República Dominicana. I thank the excellent assistance and suggestions of Fernando Casanova. The views expressed in this chapter are my own, and do not reflect the view of the Banco Central de la República Dominicana.

## 1. INTRODUCTION

Since the beginning of the international financial crisis in 2007-2009 there has been a renewed interest on the linkages of financial markets and the real economy, as well as its implications towards the design of monetary policy. In particular, there is a surge in macroeconomic literature relating credit and business cycles and the role of credit shocks on economic dynamics, both theoretical and empirical.

On the empirical side, new evidence has been collected on the role of the credit in different periods of expansion and recession generally associated to business cycle frequencies in advanced economies (Helbling et al., 2010; Zhu, 2011; Busch, 2012; Chen et al., 2012; and Claessens et al., 2011), emerging economies, and recently in Latin America (Gómez-González et al., 2013).

The purpose of this study is to provide evidence of the relation between credit and real activity in Central America and the Dominican Republic (hereafter DR). We address the empirics of the link between credit and real activity for the case of a group of developing countries with limited financial markets where bank credit is the main source of external finance for the private sector. There has been a rise on empirical literature analizing this phenomena in developed and emerging countries, but with little attention to small developing economies. This paper seeks to fill that void in the literature.

To reach that goal, I compile information on credit to private sector and from aggregate economic activity for Costa Rica, El Salvador, Honduras, Guatemala, Nicaragua and the DR. The data is analyzed using simple statistical tools to identify stylized facts on the credit-activity relation. First, I rely on cross correlations and Granger causality tests to learn about the statistical relation between these time series and how the facts fit with conventional theories of credit-ouput linkages. In a second stage, spectral analysis decomposition techniques are used to explore the link between credit and activity in different frequencies. That is, I estimate and classify by the order of importance the type of cycles that best characterize each time series and inquire on which frequency the relation is verified. This is relevant because, according to macroeconomic theory, credit has an important role on real fluctuations at business cycles frequencies (Kiyotaky and Moore, 1997; Bernanke et al., 1999; among others), meaning that credit and economic activity data must show a high covariance in these frequencies.

In terms of the results, the study has mixed findings for the countries under analysis. First, I find a positive relation between credit and real activity in frequencies associated to business cycles (that is, cycles between 1.5 and 8 years) for all countries. Second, the credit and economic relation in cycles lasting 10 or more years seems relevant in Costa Rica and the DR. Third, there is evidence suggesting that credit precedes economic activity at business cycles frequencies in Costa Rica, El Salvador, Honduras, Nicaragua and the DR. Excluding Nicaragua, this pattern is observed also in cycles over eight years for mentioned economies. In case of Guatemala there is no evidence of statistical precedence of credit to economic activity.

The rest of the document is organized as follows. Section 2 resumes the main theories of credit cycles and its implications for real economic activity; it also discusses related empirical literature. Section 3 provides a description of data and the empirical analysis. Section 4 states concluding remarks.

## 2. LITERATURE REVIEW

### 2.1 Theory

The research's interest on the role of credit cycles on economic fluctuations is long-standing. Different theories compete on what kind of relation exists and if credit plays a passive or active role in the generation of real cycles. For example, Hayek (1929) stated that recessions are the result of credit cycles. A credit boom reduces interest rates and increases investment relative to savings. The increase in aggregate demand, given the higher levels of consumption and investment pushes up consumer prices, making consumer goods more profitable than producer goods, and in consequence, shifts investment from producer goods to consumer goods, and eventually leading to recession.

Another author who places credit in the core of economic fluctuations is Minsky (1982). He has a theory associated with large business cycles (more than five years) and relates financial innovation to periods of steady growth that encourage risk taking. In other words, changes in financial markets are responsible for the economic conditions in the medium term. The mechanism implies that an overheating economy will induce a tightening of monetary policy and will eventually cause a recession.

Recent research highlights the relevance of the linkages between credit and assets prices. Brunner and Meztler (1990) incorporate the credit market to the IS-LM model, and show that credit and asset price shocks are relevant sources of business cycle fluctuations.

Contemporary macroeconomic theories of credit address the relation between financial markets and the real economy at business cycle frequencies, highlighting market imperfections such as asymmetric information between agents as well as other financial frictions. According to this approach, the credit market play the role of a propagation mechanism of business cycles when the economy is affected by shocks (Kiyotaki,1998; Kocherlakota, 2000). In other words, in this literature the credit and financial markets have a peripherally role that, given financial frictions, they are amplifying mechanisms of macroeconomic fluctuations. The most popular mechanism of this type is the financial accelerator developed by Bernanke et al. (1999) who establish that, due to imperfect information in credit markets, fluctuations in asset prices affect agent's net worth and therefore influences on its borrowing, investing and consuming capacities, bringing more volatility to the economy. This mechanism has been applied to open economies and emerging markets by Céspedes et al. (2004), and Caballero and Krishnamurthy (1998).

## 2.2 Empirical Literature

Recent empirical literature on the relation between credit and economic activity focuses on the role and weight that financial shocks have played on the Great Recession for developed countries, their importance explaining global business cycles and lessons from emerging markets experience dealing with real effects from financial crisis.

Helbling et al. (2010) analyze the role of credit shocks on global business cycles for the G7 economies. Using a VAR methodology they conclude that in business cycle frequencies, credit has much impact as productivity in explaining economic activity for this specific group of economies, that put together, account for almost 40% of the global economy.

Claessens et al. (2011) study in detail the interaction between business and financial cycles using a database of 44 countries for a period that spans 50 years. They enumerate several interesting findings about recessions. First, financial cycles are often more pronounced than business cycles, with deeper and more intense downturns than recessions. Second, recessions accompanied with financial disruptions tend to be longer and deeper than other recessions. In particular, recessions associated with house price busts last significantly longer than recessions without such disruptions, especifically by some 1.5 quarters on average. Third, recessions with credit crunches and house price busts result in significantly larger drops in output and correspondingly greater cumulative output losses (more than four percentage points in case of house price busts) relative to those without such episodes. Recessions accompanied with equity busts are also associated with significantly larger output declines than recessions without the busts, although the typical cumulative loss in such a recession is somewhat smaller than in those recessions accompanied with a credit crunch or a house price bust.

Similar to how financial disruptions are associated with longer and deeper recessions, so are recoveries associated with credit or house price booms shorter and associated with stronger output growth. The speed of recovery is also faster for those episodes associated with financial booms. Recoveries with financial booms are not necessarily accompanied with rapid growth on financial variables, reflecting the persistance of financial downturns during recoveries. These results indicate that changes in asset prices tend to play a critical role in determining the duration and the cost of recessions as well as on the strength of recoveries.

The study of credit-output relation distinguishing types of frequency cycles has been explored for the United States and euro area economies. Chen et al. (2012) use a multivariate unobserved components model with phase shifts to analyze the interactions of financial variables and output. They find that longer-run and business output cycles are correlated with assets prices, interest rates and credit. However, Zhu (2011), using time and frequency-domain methods, examines the credit-output link and concludes that the cyclical relation between the two variables is weak in the United States, relatively weak in Japan, and strong in the euro area. For Latin America, Reyes et al. (2013) analyze the problem of interest and find that credit and activity cycles with duration between 1.25 to less eight years are more volatile than medium size cycles (8 to 20 years) in Colombia, Chile and Peru. In terms of causation, they document that credit precedes activity, being negative in the case of short term cycles and positive in medium term GDP fluctuations.

## 3. DATA AND EMPIRICAL ANALYSIS

### 3.1 Data

This study uses monthly data to loans to the private sector by the banking system as a measure of aggregate credit, and uses production and economic activity indexes as an indicator of GDP or real economic activity. Data sources include the central banks of Central America and the Dominican Republic as well as the macroeconomic database of the Consejo Monetario Centroamericano.

The choice of these datasets is based on two reasons. First, since the financial sector in these countries is basically the banking system, and there is no data available on internal finance or corporate bond markets, the analysis restricts the definition of credit solely to loans to the private sector. Second, monthly data is used because GDP time series in some of the countries are not available with enough observations (Nicaragua) or exist only on an annual basis (Honduras); but for each of these countries there is a monthly measure of production or economic activity that I use for convenience. However, despite our gains from using this data, the sample sizes are not the same for all countries.

Finally, all series are seasonally adjusted and deflated by the CPI of each country. Figure 1 displays the evolution of logs of real private sector loans and real economic activity.The first prominent feature is the substantial covariation between real loans and economic activity for all countries despite the differences in variability around trend behavior. Except for the DR and Nicaragua, where loan series show sharp trend movements relative to real activity, all other countries show a loan trend behavior similar to the trend of the real activity.

Table 1 analyzes more closely the statistic regularities between both series. It provides some statistics for the series of annual growth of real loans and economic activity indexes.

Overall, real loans tend to grow at higher average annual rates and displays more volatility than economic activity, with the exception of El Salvador. Real loans grow at rates that double the growth of economic activity in Costa Rica, Guatemala and the Dominican Republic; are nearly 1.3 times in the case of Honduras; and are relatively equivalent in Nicaragua and El Salvador.

**Figure 1**

**REAL LOANS AND ECONOMIC ACTIVITY INDEX**
In logs

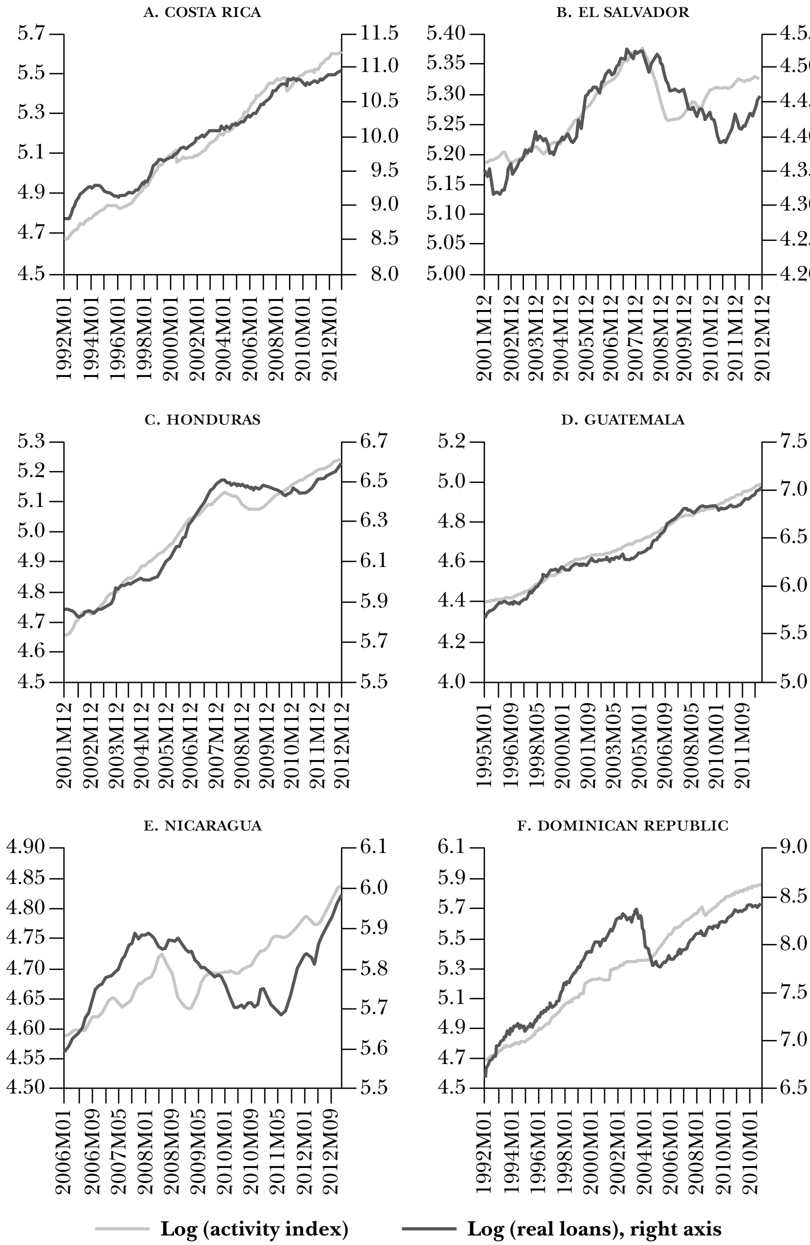


**Table 1**

**DESCRIPTIVE STATISTICS OF ANNUAL GROWTH RATES**
Percentages

| Countries | *Economic activity index* | | *Real loans* | | Sample |
|---|---|---|---|---|---|
| | *Average* | *Standard deviation* | *Average* | *Standard deviation* | |
| Costa Rica | 4.7 | 3.8 | 9.7 | 10.5 | Jan. 1992 – Dec. 2012 |
| El Salvador | 1.3 | 4.3 | 1.0 | 3.7 | Dec. 2002 – Dec. 2012 |
| Honduras | 5.2 | 4.4 | 6.9 | 7.8 | Dec. 2002 – Dec. 2012 |
| Guatemala | 3.3 | 3.1 | 7.1 | 6.5 | Jan. 1996 – Dec. 2012 |
| Nicaragua | 3.2 | 4.4 | 3.5 | 10.1 | Jan. 2007 – Dec. 2012 |
| Dominican Republic | 5.9 | 3.9 | 9.2 | 14.7 | Jan. 1992 – Dec. 2012 |

When I examine a common sample, 2007-2012, the period including the international financial turmoil, excluding Guatemala and the DR, there are no substantial changes in the behavior of observed series. In the case of Guatemala, real loans become more volatile relative to activity and the DR shows the opposite behavior.

## 3.2 Empirical Analysis

### *3.2.1 Cross Correlation in the Time Domain*

In this section I analize the relation between real loans and economic activity using cross correlation analysis. Cross correlation is a common tool of empirical analysis in macroeconomics, and consists of estimating the correlation coefficients of an $X$ variable with leads and lags of a $Y$ variable. That is, the sample cross correlation coefficient of order $k$ between $X$ and $Y$ is:

1
$$\rho(k)=\frac{\gamma_{xy}(k)}{\sqrt{\gamma_{xx}(0)}\sqrt{\gamma_{yy}(0)}},$$

2 $$\gamma_{xy}(k)=\begin{cases}\sum_{t=1}^{T-k}\left((x_t-\bar{x})(y_{t+k}-\bar{y})\right)/T & k=0,1,2,\ldots\\ \sum_{t=1}^{T-k}\left((y_t-\bar{y})(x_{t+k}-\bar{x})\right)/T & k=0,-1,-2,\ldots\end{cases},$$

where $\gamma_{xy}(k)$ is the cross covariance between $X$ and $Y$, and $\gamma_{xx}(0)$ $(\gamma_{yy}(0))$ is the variance of $X(Y)$.

If the coefficient of cross correlation is positive, it is said that $X$ and $Y$ are procyclical, and if it is negative they are countercyclical. Also, if a large correlation is observed with the $k$-th lag of $X$, that is $\mathrm{corr}(x_{t-k}, y_t)$, then it is said that $X$ leads $Y$, or that the past values of $X$ give information of present values of $Y$. On the other hand, if the maximum correlation is verified with the $k$-th lead of $X$, I conclude that $X$ lags $Y$.

The computation of cross-correlation coefficients assumes that the series are stationary, so I compute the coefficients using the annual rates of growth of real loans and economic activity. In addition, I report the results when the cross correlations are computed using Hodrick-Prescott filtered series. Table 2 shows the results for each country specifying how sample sizes vary between them.

**Table 2**

**CROSS CORRELATIONS**
Maximum correlation, number of months leading(+) or lagging(−) real loans

| *Country* | *Growth rate* | *HP filtered* | *Sample* |
|---|---|---|---|
| Costa Rica | 0.33(+11) | 0.31(−3) | Jan. 1992 – Dec. 2012 |
| El Salvador | 0.56(+5) | 0.39(+5) | Dec. 2002 – Dec. 2012 |
| Honduras | 0.52(+2) | 0.36(+5) | Dec. 2002 – Dec. 2012 |
| Guatemala | 0.26(0) | 0.17(0) | Jan. 1996 – Dec. 2012 |
| Nicaragua | 0.45(+10) | 0.30(0) | Jan. 2007 – Dec. 2012 |
| Dominican Republic | 0.44(+6) | 0.45(+2) | Jan. 1992 – Dec. 2012 |

According to Table 2, real loans evolve procyclically with economic activity; however, it does not seem to be a variable that leads the economic activity. When correlations are calculated using the rates of growth, loans lags economic activity almost one year in the case of Costa Rica and Nicaragua, and between two to six months in El Salvador, Honduras, and the DR. On the other hand, in Guatemala it seems to be a coincident variable, but with a low coefficient.

Results do not change when filtered variables are used instead of the rates of growth. Only in Costa Rica past values of loans give information on present values of real activity, it does so with a three month lag. In other countries loans lag economic activity by five months, and they are coincidental in Guatemala and Nicaragua.

In conclusion, cross correlation analysis suggests a relation between the variables, but evidence indicates that real loans is a variable driven by economic activity. Nevertheless, one characteristic of our loan data is that it is composed of both new loans and also amortization, implying that the growth does not reflect exclusively the granting of new loans.

To further clarify the relation between real credit and activity, I perform an analysis of statistical precedence. Table 3 shows Granger causality tests among real loans and activity annual growth rates with different lags. Granger test points out that real loans *precede* the behavior of activity in the DR, Guatemala and Nicaragua, and shows mixed results in the case of Honduras. No evidence of Granger causality is found in Costa Rica and El Salvador.

### *3.2.2 Credit and Activity in the Frequency Domain*

In this section I analyze the Relation using spectral analysis. There are different theories regarding the relation of credit and economic activity depending of the horizon on which the relation is analyzed. For example, as mentioned in the section 2, Misky (1982) establishes that financial innovations lead to relative large cycles of steady growth and induce risk taking, delivering a spiral of credit that ends in a recession. In this case, one must expect that credit and economic activity are tightly correlated in frequencies associated to cycles with a duration of 5 to 10 years.

Frequency or spectral analysis consist in the decomposition of variability (in case of one variable) or covariability (in case of two or more variables) in different frequencies. This approach would shed

Table 3

**GRANGER CAUSALITY TEST**

| Countries | $H_0$ | Lags 2 | 4 | 8 | 12 | 24 |
|---|---|---|---|---|---|---|
| Costa Rica | Cr $\nrightarrow$ $Y$ | 0.66 | 0.38 | 1.17 | 1.23 | 1.18 |
| | $Y \nrightarrow$ Cr | 0.07 | 0.85 | 1.49 | 1.31 | 1.12 |
| El Salvador | Cr $\nrightarrow$ $Y$ | 0.48 | 0.34 | 0.89 | 0.91 | 1.39 |
| | $Y \nrightarrow$ Cr | 2.12 | 1.12 | 1.23 | 1.26 | 1.66[a] |
| Honduras | Cr $\nrightarrow$ $Y$ | 2.05 | 3.00[b] | 1.99[b] | 2.08[b] | 1.64[a] |
| | $Y \nrightarrow$ Cr | 4.50[b] | 2.20[a] | 1.50 | 1.62[a] | 1.81[b] |
| Guatemala | Cr $\nrightarrow$ $Y$ | 2.04 | 0.81 | 0.69 | 1.77[a] | 1.15 |
| | $Y \nrightarrow$ Cr | 0.09 | 0.39 | 0.86 | 0.82 | 1.33 |
| Nicaragua | Cr $\nrightarrow$ $Y$ | 0.54 | 1.02 | 1.70 | 1.82[a] | |
| | $Y \nrightarrow$ Cr | 0.48 | 0.39 | 0.93 | 1.38 | |
| Dominican Republic | Cr $\nrightarrow$ $Y$ | 14.10[c] | 10.45[c] | 5.95[a] | 5.13[c] | 2.25[c] |
| | $Y \nrightarrow$ Cr | 4.09[b] | 1.80 | 1.63 | 1.67[a] | 1.16 |

Note: $\nrightarrow$ does not Granger cause. $H_0$ is rejected at [a] 1%, [b] 5%, and [c] 10 percent.

light on the idea of whether the evidence of correlation between the two variables happens solely because of the duration of the cycle that it is analyzed on.

We first proceed showing an univariate analysis through the estimation of the periodogram, which is a tool that describes how much variation of the series is accounted by the frequencies related with each cycle. With this information, I visually explore if the distribution of variance across frequencies of each series shows any type of correspondency. Next, I formaly analyze the covariability of both series using bivariate analysis in frequency domain, through the computing of the coespectrum, the quadrature and the coherence, each one gives an idea of the comovement of both series by frequency. Finally, Granger causality test in frequency domain is done by the test proposed in Breitung and Candelon (2006).

### *3.2.3 Univariate Analysis*

Following Hamilton (1994), the sample periodogram or estimated spectral density can be expressed as:

$$\hat{s}_y(\omega_j) = \frac{1}{2\pi T}\left\{\left[\sum_{t=1}^{T} y_t \cos\left[\omega_j(t-1)\right]\right]^2 \left[\sum_{t=1}^{T} y_t \sin\left[\omega_j(t-1)\right]\right]^2\right\}, \tag{3}$$

where $T$ is the sample size, and $\omega_j = 2\pi j/T$ denotes the frequency $j$, and each frequency is associated to a specific period $2\pi j/\omega_j = T/j$. The number of cycle components *(j)* is bounded by cero and $T/2$. Figure 2 shows the periodogram of the annual rate of growth real loans and economic for each country. The number of cycles is limited by the sample available. For Costa Rica and the Dominican Republic the longer cycle last almost 21 years, while in Guatemala, El Salvador and Honduras last 17 and around 10 years, respectively. Finally, Nicaragua has the shortest sample (2007-2012), then its longer cycle last six years.

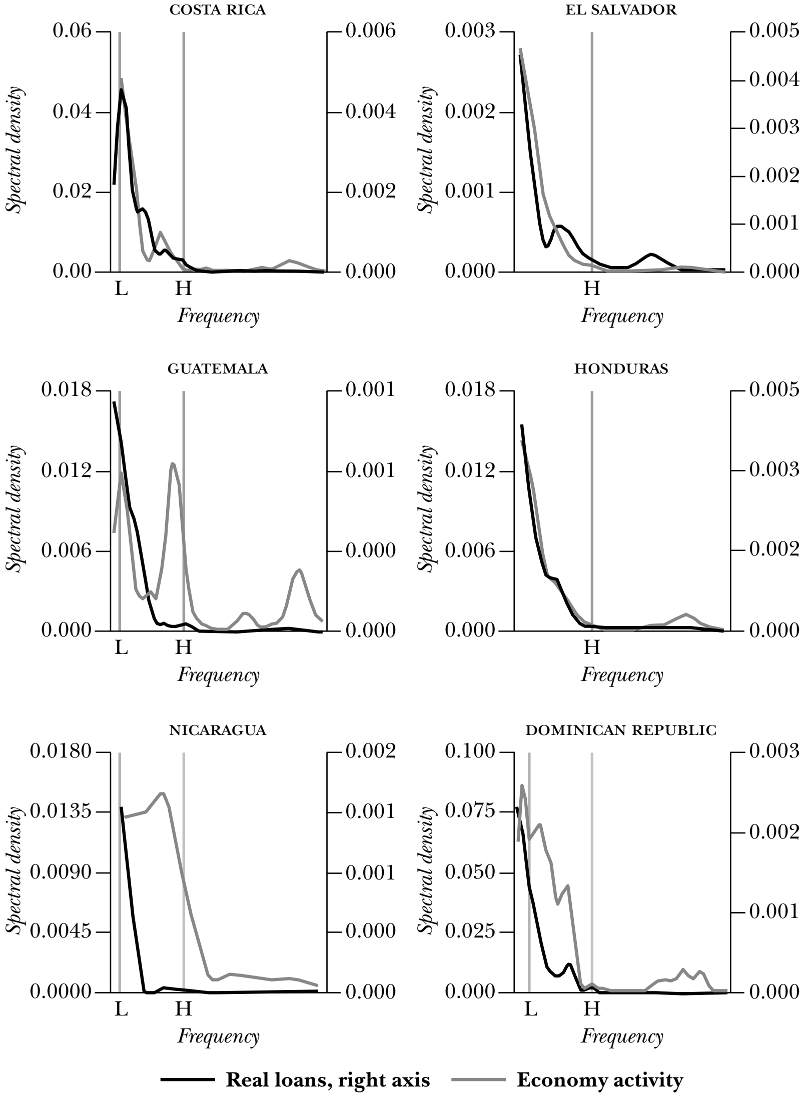
For all countries, most part of the variance of both series is concentrated at frequencies of 18-month cycles or more. Neglecting Nicaragua, no negligible proportions of the variance of real loans and activity is verified to be in frequencies over 96 months. Another regularity for these countries is that the distribution of cycles inside the range classified as business cycle frequencies is far from symetric. In fact, relative large business cycles with at least 3.5 years of duration dominate the distribution. This pattern is present on all countries, except in Guatemala, where a great part of the variance of economic activity growth is in frequencies of two-year cycles.

Judging for the amplitude of periodograms, credit cycles are more volatile and persistent than economic activity cycles, a pattern that is observed mainly at very low frequencies. Finally, credit cycles do not show important cycles at frequencies higher than business cycles, that means cycles in frequencies below 18 months.

Summarizing, the analysis of individual periodograms suggest that both series concentrate high levels of variability in frequencies associated to business cycles, and the distribution of the variability inside this type of cycles varies significantly across frequencies.

Figure 2

**PERIODGRAMS OF REAL LOAN AND ECONOMIC ACTIVITY INDEX, BY COUNTRY**




Notes: Periodgrams are computed using the annual rates of growth of both variables and conditional to the sample available for each country. The area between bars shows frequencies asociated with business cycles (cycles of 18 to 96 months or 1.5 to 8 years), where the upper limit is given by L (cycles of 96 months) and the lower limit is given by H (cycles of 18 months).

### *3.2.4 Bivariate Analysis*

Similar to cross correlation analysis, I can compute a measure of the bivariate relation between real loans and economic activity rates of growth by frequency, and identify the cycles where these variables are most related to each other, if they indeed are. Following Hamilton (1994), the equivalent in spectral analysis of cross correlation is the cross spectrum which, in the case of two variables, can be defined by:

4 $$s_{xy}\left(\omega_j\right)=\frac{1}{2\pi}\sum_{k=-T+1}^{T-1}\hat{\gamma}_{xy}^{(k)}e^{-iwk},$$

where $i=\sqrt{-1}$ and $\hat{\gamma}_{xy}^{(k)}$ is the covariance function at lag $k$, which is given by:

5 $$\hat{\gamma}_{xy}^{(k)}=\hat{\gamma}_{xy}^{(-k)}=E\left(x_{t+h}-E(x)\right)\left(y_t-E(y)\right).$$

The cross spectrum can be rewritten in terms of two important measures: the co-spectrum and the quadrature that are expressed in equations 7 and 8 as:

6 $$s_{xy}(\omega)=c_{xy}(\omega)+i.q_{xy}(\omega),$$

7 $$c_{xy}(\omega)=\frac{1}{2\pi}\sum_{k=-T+1}^{T-1}\hat{\gamma}_{xy}^{(k)}\cos(\omega k),$$

8 $$q_{xy}(\omega)=\frac{1}{2\pi}\sum_{k=-T+1}^{T-1}\hat{\gamma}_{xy}^{(k)}\sin(\omega k).$$

The cospectrum gives an idea of the relation of $x$ and $y$ in a phase, that is, the covariation in a determined type of cycle. Quadrature, meanwhile, provides information on the linkages out of phase. With these measures, I can construct the coherence that summarizes the strength of correlation between two time series at selected frequencies. In other words, coherence indicates the percentage share of the variance between two time series at a particular frequency. Equation 9 shows how to compute this indicator:

$$h_{xy}(\omega)=\frac{\left[c_{xy}(\omega)\right]^2+\left[q_{xy}(\omega)\right]^2}{s_{yy}(\omega)s_{xx}(\omega)}. \tag{9}$$

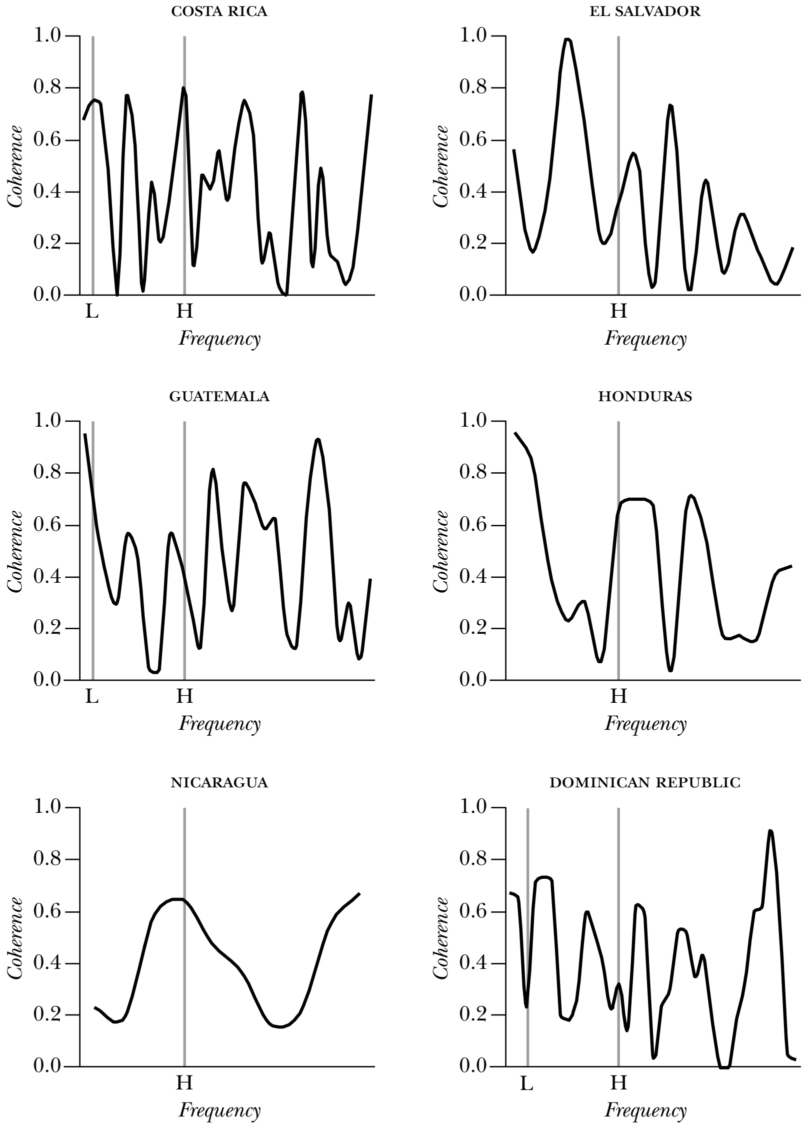
Asuming that $s_{yy}$ and $s_{xx}$ are different from zero, and the series under analysis are stationary, the coherence is bounded by zero and one.

Figure 3 shows the estimated coherence for each countries. According to the coherence, the correlation varies significantly across frequency. In business cycle frequencies (between 1.5 to 8 years) the credit-economic activity relation is high (over 0.5) for El Salvador, the Dominican Republic, and Costa Rica in less degree in Guatemala and Honduras, and not relevant in the case of Nicaragua. For Guatemala and Honduras, credit-activity relation seems to be important in cycles over 10 years, a pattern also observed in the DR and Costa Rica; however, it is not different from business cycles frequencies. Finally, although the series were seasonally adjusted, correlation on frequencies below 1.5 years was found to be important.

Particular attention is given to what coherence is shown in frequencies associated to business cycles, for its implication in terms of monetary and macroprudencial policy issues. We can identify that correlations are important in cycles between 1.5 to 3 years of length, linked to what is known as a monetary policy horizon, for Costa Rica, Honduras, Guatemala, Nicaragua, and the DR. On the other hand, Costa Rica and El Salvador display high covariability of the mentioned variables for cycles lasting four to five years, while for Guatemala, the DR, and Honduras, for business cycles lasting nearly 10 years.

## Figure 3

**COHERENCE**




Notes: The coherence is computed using the annual rates of growth of both variables and conditional to the sample available for each country. The area between bars shows frequencies asociated with business cycles (cycles of 18 to 96 months or 1.5 to 8 years), where the upper limit is given by L (cycles of 96 months) and the lower limit is given by H (cycles of 18 months).

### *3.2.5 Granger Causality Test in Frequency Domain*

In section 2 I showed the results of the statistical precedence test between credit and activity, finding evidence for the DR, Guatemala, and Nicaragua and in lesser extent for Honduras. Now, I analyze the statistical precedence by frequency through the Granger test version of Breitung and Candelon (2006). The methodology consists in estimate a bivariate VAR using credit and economic activity index, where the order of the lag is obtained by the AIC criteria. That is,

10 $$\Theta(L)Y_t = \varepsilon_t,$$

where $Y_t$= [*activity*$_t$, *credit*$_t$] is a two dimensional vector with credit and economic activity; $\Theta(L) = I - \Theta_1 L - \ldots - \Theta_p L^p$ is a lag polinominal of order 2×2, and $\varepsilon_t$ is a vector of structural innovations with $E(\varepsilon_t) = 0$ and $E(\varepsilon_t \varepsilon_t') = \Sigma$ as the positive definite variance-covariance matrix. Assuming the stationarity of the bivariate process, the moving-average representation is given by:

11 $$Y_t = \Phi(L)\eta_t,$$

where $\eta_t = B\varepsilon_t$ is the vector of reduced form residuals and B is a lower diagonal matrix of the Cholesky decomposition $B'B = \Sigma^{-1}$. $\Phi(L) = \Theta(L)^{-1} B^{-1}$ represents the reduce form coefficients that can be partitioned as:

12 $$\begin{bmatrix} \Phi_{11}(L) & \Phi_{12}(L) \\ \Phi_{21}(L) & \Phi_{22}(L) \end{bmatrix}.$$

Based on 12, the spectral density of activity is:

13 $$f_{activity} = \frac{1}{2\pi}\left\{ \left|\Phi_{11}\left(e^{-i\omega}\right)\right|^2 + \left|\Phi_{12}\left(e^{-i\omega}\right)\right|^2 \right\}.$$

From 13, Breitung and Candelon (2006) proposed the following measure of Granger causality:

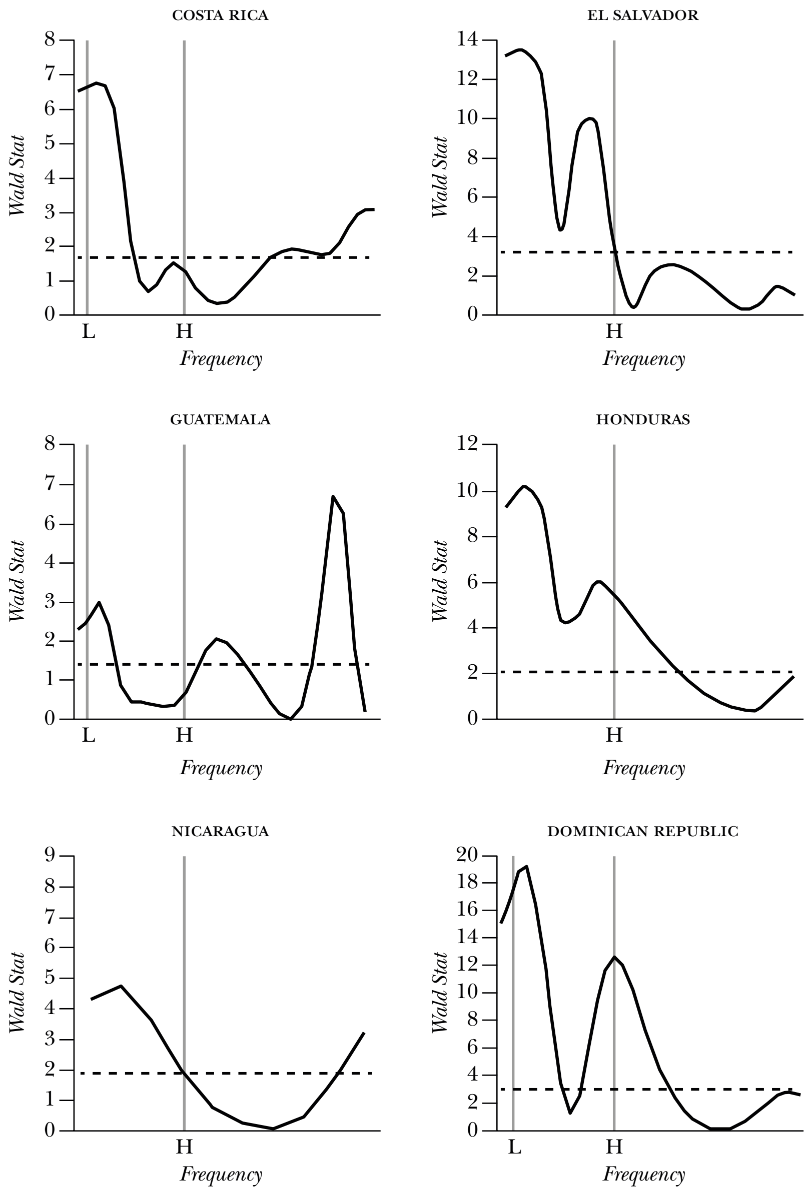
14 $$M_{credit \rightarrow activity}(\omega) = \log\left[1 + \frac{\left|\Phi_{12}\left(e^{-i\omega}\right)\right|}{\left|\Phi_{11}\left(e^{-i\omega}\right)\right|}\right],$$

where the null hypotesis is that $\Phi_{12}\left(e^{-i\omega}\right) = 0,$ meaning that credit does not cause activity at frequency $\omega.$ The evaluation of the proposed hypotesis is based on a Wald test for each frequency. Figure 4 display the results with the Wald statistic critical value for each frequency represented by the dotted horizontal line.

Granger test results suggest that the relation of causation from credit to activity is restricted to certain types of cycles. For Costa Rica, El Salvador, Honduras, Guatemala and the DR there is evidence that credit granger causes activity in cycles over eight years. Also, this pattern is observed in business cycle frequencies for the previously mentioned countries and Nicaragua. In the case of Guatemala, I do not find evidence of granger causation in frequencies associated with cycles between 1 and 4 years. In Honduras and El Salvador credit is relevant to explain future values of activity, both in short cycles between 1.5 to 3 years and relatively large cycles of 6 to 8 years. Finally, in the DR and Nicaragua credit seems to precede activity across frequencies linked to business cycles.

## Figure 4

**GRANGER CAUSALITY TEST**



# 4. CONCLUSION

This study addresses the relation between credit and economic activity in Central America and the Dominican Republic. Using time and frequency domain techniques, it explores the linkages between the credit cycles and economic activity cycles. As a proxy of credit, this paper uses aggregate loans to the private sector in real terms and as a proxy of economic activity the economic activity index, both variables in monthly frequency.

I found that real loans and economic activity display different types of cycles, standing out those known as business cycles (1.5 to 8 years) and low frequency cycles. There is evidence of a positive relation between credit and real activity growth in frequencies associated to business cycles for all countries with the exception of Nicaragua with correlation coefficients below 0.5.

According to the coherence, which measures the correlation by frequency among credit and activity, I foundthat for Costa Rica and the DR this correlation is important in frequencies with cycles lasting 10 or more years.

Using a frequency version of Granger test, I identified evidence suggesting that credit precedes economic activity business cycles frequencies in Costa Rica, El Salvador, Honduras, Nicaragua and the DR. Excluding Nicaragua, this pattern is observed also in cycles lasting over eight years for these mentioned economies. In case of Guatemala there is no evidence of statistical precedence of credit to activity.

# ANNEX

## Replication Codes

### *Matlab Procedure to Compute Periodograms and Coherence based on Hamilton (1994) Chapters 6 and 10.*

```
clear all; close all; clc;
DATOS;
x=x−mean(x);
y=y−mean(y);
T=length(x);
t=(1:T)';
```

```
j = (1:T/2);
w = 2*pi*j/T;
alpha = zeros(1,length(j));
delta = zeros(1,length(j));
a = zeros(1,length(j));
d = zeros(1,length(j));
for j = 1:length(j)
    alpha(j) = (2/T)*(sum(y.*cos(w(j)*(t−1))));
    delta(j) = (2/T)*(sum(y.*sin(w(j)*(t−1))));
    a(j) = (2/T)*(sum(x.*cos(w(j)*(t−1))));
    d(j) = (2/T)*(sum(x.*sin(w(j)*(t−1))));
%Periodogramas
    sy(j) = (T/(8*pi))*(alpha(j)^2 + delta(j)^2);
    sx(j) = (T/(8*pi))*(a(j)^2 + d(j)^2);
%Coespectro
    cxy(j) = (T/(8*pi))*(a(j)*alpha(j) + d(j)*delta(j));
%Cuadratura
    qxy(j) = (T/(8*pi))*(d(j)*alpha(j) + a(j)*delta(j));
end
h = 1;
m = (−h:h);
k = ((h + 1−abs(m))/(h + 1)^2);
sy = sy'; sx = sx'; cxy = cxy'; qxy = qxy';
syr = zeros(1,length(w));
sxr = zeros(1,length(w));
cxyr = zeros(1,length(w));
qxyr = zeros(1,length(w));
for r = h:length(w)−(h + 1);
    syr(r) = k*sy(r−(h−1):r + (h + 1),1);
    sxr(r) = k*sx(r−(h−1):r + (h + 1),1);
    cxyr(r) = k*cxy(r−(h−1):r + (h + 1),1);
    qxyr(r) = k*qxy(r−(h−1):r + (h + 1),1); end
for j = 1:length(w)
%Coherencia
    hxy(j) = (cxyr(j)^2 + qxyr(j)^2)/(syr(j)*sxr(j));
%Gain
    R(j) = (cxyr(j)^2 + qxyr(j)^2)^0.5;
%Phase
    Q(j) = (−atan(qxyr(j)/cxyr(j)))/w(j);
end
```

```
result = [sxr' syr' cxyr' qxyr' hxy' R' Q' w'];
figure
    subplot(2,2,1), plot(w,sxr);
    title('Spectrum X')
    subplot(2,2,2), plot(w,syr);
    title('Spectrum Y') subplot(2,2,3),
    plot(w,cxyr);
    title('Co−spectrum XY')
    subplot(2,2,4), plot(w,qxyr);
    title('Cudrature XY')
figure
    subplot(3,1,1),
    plot(w,hxy);
    title('Coherence XY')
    subplot(3,1,2), plot(w,R);
title('Gain XY')
subplot(3,1,3), plot(w,Q);
title('Phase XY')
```

***Matlab Functions for Granger Causality Test by Frequency based on Breitung and Candelon (2006)'s Gauss codes (Modified to consider specific types of cycles according to sample size)***

Important: This function is a Matlab version of Breitung and Candelon (2006) 's Gauss codes availables on their websites. Copyright J. Breitung and B. Candelon.

```
%INPUT: Y Txk matrix of data.
%1st column: Target variable
%2nd column: Causing variable
%p number of lags
%OUTPUT: G 314 x 2 matrix where the 1st column contains
%frequencies and 2nd column: Wald test statistics
%This function compute the test function [wald] = granger(y,p,w)
    [n,k] = size(y);
    xstar = y(3:n,2)−2*cos(w)*y(2:n−1,2) + y(1:n−2,2);
    x = horzcat(y(p:n−1,:),y(p−1:n−2,:));
    if p>2;
          i = 1;
```

```
            while i<p−2;
                x = horzcat(x,y(p−1−i:n−2−i,1));
                if k>2;
                x = horzcat(x,y(p−1−i:n−2−i,3:k));
                end
                i = i + 1;
            end
        end
    i = 1;
    while i< = p−2;
        x = horzcat(x,xstar(p−1−i:n−2−i));
        i = i + 1;
    end
    x = horzcat(x,ones(n−p,1));
    [e1,e2] = size(x);
    depvar = y(p + 1:n,1);
    b = inv(x'*x)*x'*depvar; u = depvar-x*b; sig2 = u'*u; sig2 = sig2/
(n-p-e2); varb = sig2*inv(x'*x); ind = vertcat(2,(k + 2));
    wald = b(ind)'*inv(varb(ind,ind))*b(ind);
end
%This function uses the previous function
%to calculate the test for multiple frequencies.
function [wald,wstar] = tfreq(y,p)
T = length(y); t = (1:T)';
j = (1:T/2);
wstar = 2*pi*j/T;
    wald = zeros(314,2);
        wstar = 0.01;
        j = 1;
            while wstar<3.14;
                wald(j,1) = wstar;
                wald(j,2) = granger(y,p,wstar);
                wstar = wstar + 0.01;
                j = j + 1;
            end
end
```

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# Bank Capital Buffers and Procyclicality in Latin America

***Óscar A. Carvallo***
***Leslie A. Jiménez***

**Abstract**

*In this chapter, we conduct an empirical study of fluctuation patters of regulatory capital buffers with respect to the business cycle for the 2001 to 2003 period with data of 18 countries and 456 Latin American and Caribbean banks. We also present results for Argentina, Brazil, Mexico, Panama and Venezuela. Our results show that, although the general intuition sustaining the countercyclical approach of Basel III capital buffers agrees with the data, patterns vary across countries, being determining variables bank size, their forms of organization and levels of competition in the region's banking systems.*

*Keywords: capital buffers, procyclicality, business cycle, Basel III, Latin America.*

*JEL classification: G21, G28, E32.*

## 1. INTRODUCTION

The financial crisis experienced by the world economy since 2007 was confronted with combined efforts on several fronts. On the one hand, restructuring and strengthening of the financial regulatory system were undertaken on a global scale. Capital was also injected and most of the major banks were partly nationalized, a process that has now been completely reversed. Massive fiscal

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Ó. Carvallo <ocarvallo@cemla.org>, Deputy Manager of Financial Research, and L. Jiménez, Director of Planning, CONSAR (this chapter was developed while she was affiliated with CEMLA).

stimulus programs were introduced simultaneously, while demand was boosted through extremely loose monetary policy around the world.

Reforms that have been implemented in financial regulation include the new proposal for regulatory capital requirements (Basel III), as well as the deep regulatory reforms implemented in the United States (Dodd-Frank Wall Street reform and Consumer Protection Act, July 2010) and the European Union (New European Regulatory Framework approved by the European Commission in September 2010).[1]

Led by the G20, the Basel Committee generated a series of proposals in 2008 that served as a basis, after a long and arduous process of international negotiations, for the new rules announced on September 12, 2010. These regulations, known as Basel III, form part of the international reform package and are aimed at achieving two general goals: *1)* strengthen banks' capital bases, demanding stricter risk assessment, and *2)* contribute to the global economic recovery by introducing standards that reduce the likelihood of a future crisis and increase confidence in the financial system.

It combined both objectives by allowing for a relatively long transition period, placing an upper limit on bank leverage and including countercyclical measures in the proposal. The phase-in equity strengthening arrangement that started on January 1, 2013, and will end on January 1, 2019, aims to contribute to financial stability over the long term, ensuring that banks can accommodate the new requirements while underpinning the economic recovery through bank credit. Although the adjustment in regulatory capital can initially be described as a restrictionary measure that could compromise the recovery phase of the business cycle, it should not in principal affect economic growth given its transitory nature.

The original consultative documents, *Strengthening the Resilience of the Banking Sector* and *International Framework for Liquidity Risk Measurement, Standards and Monitoring* (BCBS, 2009a and 2009b),

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1 Bill H.R. 4173: "To promote the financial stability of the United States by improving accountability and transparency in the financial system, to end 'too big to fail,' to protect the American taxpayer by ending bailouts, to protect consumers from abusive financial services practices, and for other purposes," United States Congress, July 2010. Jacques de Larosière (2009), *The High-level Group on Financial Supervision in the EU- Report*, Brussels, February 25, 2009.

introduce far-reaching reforms in the following areas: Raising the quality, transparency and consistency of the capital base; enhancing risk coverage and increasing minimum standards; introducing a maximum leverage ratio; reducing procyclicality of capital requirements; establishing a new global liquidity standard, and increasing the supervision of systemically important institutions and markets.

A common vision in all the initiatives is that financial system regulation should take into account the systemic risks deriving from the increasing interconnectedness among financial markets and the greater complexity arising from rapid technological innovation. This new vision, announced as *macrofinancial* regulation, aims to complement traditional *microfinancial* regulation, which, by itself, will be insufficient to address the growing interconnectedness between financial institutions and markets, and between nonfinancial institutions and markets and the financial sector, as well as the presence of shadow financial systems fueled by financial innovation and the evasion of microfinancial regulation. The emphasis on systemic risk and macrofinancial regulation, coupled with associated comprehensive early warning systems, will be an enduring general characteristic of bank and central bank regulation over the coming years.

## 1.1 Regarding Financial Procyclicality

It is important to ask exactly what is meant by procyclicality. Reinhart et al. (2011), who study the graduation of countries from episodes of external debt default, inflation and banking crises, developed the concept of *graduation from procyclicality*. In the same way, Frankel et al. (2013) study graduation with respect to fiscal procyclicality, while Shin and Shin (2011) analyze the procyclicality of monetary aggregates, particularly, as regards noncore funding. Graduation from procyclicality can be understood as the acquisition by agents (be they countries, banks, or governments) of the capacity to reduce the risk of recurring episodes of crisis, with either monetary, fiscal, financial or external aggregates.

The financial cycle has also become more widely accepted in the literature, understood as "self-reinforcing interactions between perceptions of value, attitudes towards risk and financing constraints" (Borio, 2014), which occurs in cycles that have a lower frequency than the business cycle, as well as the decoupling of money, saving and credit. Likewise, theoretical models such as those of Kiyotaki and

Moore (1997), and Adrian and Boyarchenko (2012) generate credit and leverage cycles. Schularick and Taylor (2009) examine the behavior of credit, money, leverage and the balance sheets of advanced economies' banking systems, in both the period before and after the World War II. They find a structural change in leverage during the latter period, accompanied by an acceleration of credit with respect to GDP and money growth.

The literature reviewed on the graduation from procyclicality and its determinants converges towards two factors: The importance of institutions (contracts and how to make them valid) and the level of financial integration of the economies. For instance, Gavin, Hausmann et al. (1996), as well as Gavin and Perotti (1997), argue that limited access to international capital markets determines the likelihood of countries implementing countercyclical policies. In the case of monetary cyclicity, works such as Shin and Shin (2011) and Adrian and Shin (2010) highlight the role of financial integration in the rise of noncore funding, which ends up being related to credit booms and systemic risk. Cetorelli and Goldberg (2012) find that international banks manage liquidity on a global scale, moving resources across borders in response to local shocks, thereby contributing to the propagation of such shocks. Bruno and Shin (2014) formulate a banking and global liquidity model where global banks interact with their local peers. Leverage cycles arise determined by the transmission of international financial conditions through bank capital flows.

## 1.2 Basel III and the Regulatory Response to Procyclicality

The precrisis regulatory framework, known as Basel II, was approved only in 2004, and a majority of global banks were still in the process of implementing it when the international financial crisis broke out in 2007. Basel II was never able to legitimately test its regulatory potential. However, the severity of the crisis led to the conviction that this framework was still insufficient to serve as a support for the current international financial system. Some problems that came to light were:

- excess indebtedness among consumers, firms and banks themselves, which in an environment of rampant risk aversion triggered generalized illiquidity and insolvency;

- contagion effects among sectors: The loss of some economic sectors' payment capacity led to a reduction in payment capacity and indebtedness in other sectors, even on a global scale; and
- banks experienced a greater need to raise capital precisely at times when capital markets were closing.

The latter effect, reflected in the so-called procyclicality of bank capital buffers, has a particularly harmful interaction with the business cycle. Capital buffers are banks' holdings of regulatory capital on top of minimum capital requirements. When banks do not accumulate capital reserves during economic upturns they can become trapped with an insufficient level of capital during an economic downturn. Under these circumstances, and to avoid excessive and costly regulatory intervention, banks will have to adjust their capitalization levels. This adjustment tends to take place by reducing assets, mainly loans, or by recomposing risk-weighted assets. Both reactions tend to reduce the supply of bank credit, which accentuates the cycle. Another possible option is to raise new capital, which becomes more costly in recessions. Thus, a negative fluctuation between capital buffers and the business cycle is to be expected. This cyclical behavior of regulatory capital buffers would therefore amplify the effect of GDP shocks (Repullo and Suárez, 2013; Borio and Zhu, 2012).

To reduce those cyclical effects, Basel III requires banks to increase their capital buffers during economic expansions, through: *1)* a mandatory capital buffer of 2.5%, and *2)* a *discretionary countercyclical capital buffer* of 2.5% during periods of economic expansion. While these proposals have been calibrated with data from advanced economies, less evidence has been presented regarding the behavior of capital buffers in emerging countries. This paper aims to help close this gap by studying the behavior of capital buffers in an emerging region, Latin America and the Caribbean.

The empirical study uses bank data from systems of the region and examines the link between capital buffers and the business cycle, while controlling for the factors determining buffers mentioned in the literature. The following section reviews these factors in light of the literature. Section 3 presents the partial adjustment model that serves as a framework for the empirical work. Section 4 shows the data and results of the estimations. The final section gives the conclusions. Our results show that, although the general thinking behind the Basel III proposal for countercyclical capital buffers is based on the data, patterns vary across countries with determining variables being bank size and type, and levels of competition within the region's banking systems.

## 2. DETERMINANTS OF CAPITAL BUFFERS

To identify links that allow for explaining the behavior of capital buffers have been assessed different indicators on the related banking costs, which, following Fonseca and González (2010), can be classified into three categories: Cost of funding, cost of financial distress and adjustment costs. Market power and regulation, since they condition the size and direction of these costs, also form an important part of the analysis.

With respect to adjustment costs, it is common in the literature the idea that banks maintain sufficient buffers to take advantage of unexpected investment opportunities or be able to withstand the effects of adverse shocks (Berger, 1995), especially if their capital ratio is highly volatile. Larger capital buffers are also associated with high penalties imposed for noncompliance with minimum capital requirements or with significant costs for increasing capital.

As for costs of funding, Fonseca and González (2010) argues that bank shareholders' incentives for increasing capital ratios will depend on the margin between the cost of funding and the cost of capital. Faced with a situation of high leverage shareholders will demand higher returns on capital given the greater risk. In the case of the cost of funding, a situation of higher risk will increase the deposit rate only if there is no market discipline, that is, that the payment of deposits cannot be granted. In this case, the increase in the funding rate will lead shareholders to hold higher capital buffers in order to avoid higher payments for funding; for this reason, a positive relation between the cost of funding and capital buffers is to be expected.

Fonseca and González (2010) follows a methodology proposed by Demirgüc-Kunt and Huizinga (2004) for measuring the cost of deposits, defined as the ratio of interest expenses to interest-bearing debt minus the government interest rate. In contrast, as an approximate measure for the opportunity cost of capital, Ayuso et al. (2004) include return on equity (ROE), with the prediction of a negative relation between ROE and the capital buffer.

Regarding costs of financial distress, Keeley (1990) and Acharya (1996) have placed emphasis on the link between the level of capital maintained by an institution and its risk profile. The results suggest that a decrease in the charter value of banks, as a consequence of changes in competitive conditions, leads to assuming greater risks, and that high market power associated with large charter value reduces the incentives for taking risky decisions in order to maintain said value at high levels. Following the logic that levels of competition influence risk profile and capital buffers, Fonseca and González (2010) included the Lerner index in their analysis as a measure of banks' market power.

As an alternative measure for market power, Boone (2008) introduces a new approximation based on firms' profits. The idea is that the effect of an increase in the level of competition in an industry on a specific firm depends on how efficient it is: The less efficient its operation the greater the impact. If efficiency is defined as the capacity to produce the same number of products at lower costs, then a comparison of the profits of an efficient firm with those of a less efficient one provides information on the level of competition in that industry. The more competitive the market, the stronger the relation between efficiency differences and profit differences.

In general, most international empirical evidence for advanced economies and some emerging ones points towards a negative fluctuation between capital buffers and the business cycle.[2] Some studies, however, record varying cyclical patterns. For instance, Jokipii and Milne (2008) study the systems of the European Union, as well as the so-called recent member states, EU15 and EU25, separately. The authors found that the capital buffers of savings, commercial, and large banks fluctuate negatively, while those of cooperative and smaller banks do so positively. Fonseca and Gonzáles (2010) find differing patterns among advanced and emerging economies, as well as within their respective banking systems. Carvallo et al. (2015), studying the cyclical patterns of capital buffers in Latin America and the Caribbean, found variations between the signs associated to the business cycle across countries when specific bank variables were used.

2 See Ayuso et al. (for Spain, 2004), Lindquist (Norway, 2004), Bikker and Metzemakers (world, 2004), Stoltz and Wedow (Germany, 2006), García Suaza et al. (Colombia, 2012), Tabak (Brazil, 2011) and Shim (United States, 2013).

Finally, Barth, Caprio and Levine (2004) have sought to determine the effects supervision and regulation practices have on banking sector efficiency, fragility and development. They found evidence of the relationship between the performance of banks and this type of indicators.

## 3. EMPIRICAL MODEL

The estimation through the difference generalized method of moments (*difference* GMM) in dynamic groups, developed by Arellano and Bond (1991), allows for optimally exploiting three questions of importance to this work: *1)* the presence of unobservable bank-specific effects that are eliminated by taking first differences for all the variables; *2)* the autoregressive process in the data, that is, the need to use lagged dependent variables in the model to capture the dynamic nature of capital buffers, and *3)* the possibility of having not strictly exogenous explanatory variables. This therefore solves the problem of likely endogeneity derived from the inclusion of a lagged dependent variable term ($BUF_{i,t}$) in the model.

Nevertheless, the estimator developed by Arellano and Bond (1991) assumes that all the explicative variables are potentially related to individual effects, meaning that, when instruments are available that are not related, the data they could provide in levels on the behavior of relevant variables is lost. One scheme capable of extracting variables' information in levels is presented in Arellano and Bover (1995), which applies a GMM estimator in first differences to the system GMM estimator. Blundell and Bond (1998) present the restrictions that justify employing a system GMM estimator that uses variables in levels as instruments for equations in first differences and provide a more flexible variance-covariance structure. They also demonstrate that there is an efficiency gain in the use of the referred estimator.

Blundell and Bond (1998) characterize the problem of instrument weakness linked to the estimator of Arellano and Bond (1991) and show that this can be avoided by using the system GMM estimator. Taking these factors into account, a two-step system GMM estimator was chosen for this work.

In line with the previous references (Carvallo et al., 2015; Fonseca and González, 2010; Ayuso et al., 2004, and Jokipii and Milne, 2008), this paper proposes a partial adjustment model to explain the effects of the business cycle on bank capital buffers as follows:

$$BUF_{i,t} = \alpha_0 + \alpha_1 BUF_{i,t-1} + \alpha_2 CYCLE_t + \delta X_{i,t} + \eta_i + u_{i,t}. \quad (1)$$

Here, $BUF_{i,t}$ represents the bank's capital buffer $i$ at time $t$ and the associated coefficient $\alpha_1$ reflects adjustment costs, $\eta_i$ is associated with specific factors that affect the formation of each bank's capital and $u_{i,t}$ is the independent error term with zero mean. The $CYCLE_t$ variable is a measure of the business cycle at time $t$, in such way that the sign of coefficient $\alpha_2$ provides information on whether capital buffer fluctuations are negative or positive with respect to the economic activity indicator.

In order to find the group of specific variables for bank $i$ at time $t$ that correctly describe the behavior of the capital buffer, this paper proposes different $X_{i,t}$ vectors, taking into account the relations described previously.

## 4. DATA AND EMPIRICAL RESULTS

The results presented in this study were obtained with data from Bankscope for the banks, and from the World Bank for regulatory and financial development databases, and cover the 2001 to 2013 period. In the regional sphere, the results include data on 18 countries and 456 banks. Results are also presented for Argentina, Brazil, Mexico, Panama and Venezuela. This results in an unbalanced set of data because during the period considered some of the banks began operating while others stopped doing so. Annex A presents descriptive statistics of the bank variables used in the estimation. The dependent variable and explicative variables statistics are shown in Table A and, described in Table 1.

Controls for bank size were also included. In accordance with that presented in Ayuso et al. (2004), a binary variable (*SizeCo*) was generated with a value of one for banks whose size is above the 75th percentile in their country in order to test the common hypothesis that large banks tend to hold lower levels of capital since they believe they are *too big to fail*. The significance of the interaction between this variable associated to GDP growth (*GDPG*) is also measured.

**Table 1**

**DEFINITIONS**

| *Variable* | *Definition*[1] | *Sources* |
|---|---|---|
| Capital buffer (BUF) | Amount of banks' capital ratio above the minimum capital requirement (MCR).[2] Bank capital is approximated by the total capital ratio (TCR) variable. | MCR,[3] BM, TCR, Bankscope |
| Bank size (SIZE) | Calculated based on the natural logarithm of the total Bankscope assets variable. | Bankscope |
| Profit, return over average asset (ROAA) | As in previous literature,[4] return over equity (ROE) is used, and is taken here as the opportunity cost of capital. | |
| Loan loss reserve/gross loans (LLRGL) | A measure of the amount of reserves banks maintain to face possible losses in their portfolios and used as an indicator of the risk detected by each institution. | |
| Business cycle (CYCLE) | The economic growth indicator (GDPG) is used as a reference for the business cycle and its coefficient provides information on the procyclicality looked for. | World Bank |
| Boone indicator (BOONE) | Calculated as the elasticity of profit to marginal costs. An increase in the Boone indicator implies a deterioration of the competitive conduct of financial intermediaries. | |
| Overall capital stringency (OCS) | Indicates whether the capital requirement reflects certain elements of risk and reduces some losses in the market value of capital before determining the adequate minimum capital. | |
| Official supervisory power (OSP) | Indicator of whether supervisory authorities have the power to take specific actions to prevent and correct problems. | |
| Money and quasi money (MCM) | Includes bills and coins held by the public, checking accounts held by residents of the country, current account deposits, residents' bank deposits, public and private securities held by residents and retirement funds. | |

**Table 1 (cont.)**

| *Variable* | *Definition*[1] | *Sources* |
|---|---|---|
| Private monitoring index (PMI) | Measures whether there are incentives or capacity for private oversight of firms. High values indicate more private monitoring. | |
| Overall restrictions on banking activities (ORBA) | Reflects the sum of: *1)* securities' activities, defined as the degree in which banks can participate in securities' subscription, brokerage and operations, and all aspects of the mutual funds industry; *2)* insurance activities, which measures the degree in which banks can participate in the subscription and sale of insurance, and *3)* real estate activities, defined as the degree of participation banks can access in real estate investment, development and management. | |
| Bank accounting (BACC) | Reflects whether the income statement includes accrued or unpaid interest or principal on nonperforming loans and when banks are required to produce consolidated financial statements. | |
| Limitations on foreign bank entry/ ownership (LFBEO) | Specifies whether foreign banks can own national banks or if they can enter a country's banking industry. | |
| Funding with insured deposits (FID) | Measures the degree of moral hazard. | |
| Foreign-owned banks (FOB) | The extent of foreign ownership in the banking system. | |

[1] Supervision and regulation definitions follow Barth et al. (2004).
[2] Defined according to Jokipii and Milne (2008).
[3] MCR was obtained from the World Bank's Bank Regulation and Supervision Surveys for 2000, 2003, 2007 and 2012.
[4] Ayuso et al. (2004); includes return on equity (ROE) with expectations of a negative relations between this and the capital buffer.

The analysis considers commercial, cooperative, savings, real estate, and mortgage banks. In the same way, as in Jokipii and Milne (2008), binary variables were created for the type of specialization to identify deviations by type of bank. The significance of interactions between these binary variables and GDPG are also calculated.

Table 2 presents the results of the estimation of Equation 1, considering all the countries of the region for which information is available and different formulations for the vector $X_{i,t}$, including only those variables that were generally significant. The results of the Arellano-Bond and Hansen tests are presented to verify the validity of the instruments and that there is no serial correlation in the error term.

It can be seen that for each specification, the coefficient describing the relation between the growth of $GPIB_t$ and capital buffers is significant and negative, in such way that there is evidence, considering the five different models, of a negative fluctuation with respect to the business cycle if the 18 countries of the region are considered.

As for adjustment costs denoted by $BUF_{t-1}$, it shows that such costs are significant in the region, and if we consider the models that contain just one level of lag, the results are comparable to those obtained in Carvallo et al. (2015). The latter argues that this coefficient also provides information on the speed of adjustment, the closer it being to zero, the faster the recovery of capital. It can be said that, taking into account all the countries, access to capital is relatively fast in the region.

The results of the variable $SIZE_t$ are significant and negative for three formulas. In this case, they indicate that bank size is inversely related to the capital buffer, which is consistent with the *too big to fail* hypothesis since the provisions that induce banks to maintain high levels of capital decrease as their size increases.

Coefficients associated $ROAA_t$, that are positive and significant, indicate that when profitability among Latin American banks increases they tend to raise their capital buffer levels. As would be expected, the most profitable banks have a more solid base for the growth of their capital. With respect to $LLR_t$, which has a positive and significant coefficient in some of the regressions, it indicates a tendency to increase capital buffers when large losses are expected.

The positive and significant coefficients associated to the Boone indicator reflect the fact that in the face of deteriorating competitive conditions, capital buffers increase. According to theory, this is related with a change in bank risk profiles, therefore validating the *charter value* hypothesis.

Estimations for the variables $OCS_t$ and $OSP_t$, by being negative and significant, show that capital buffers are smaller in the face of more stringent regulation or more powerful regulatory authorities. This behavior might be related to the fact that the more closely monitored institutions are, the more confident they become about their capital and they stop taking precautionary measures beyond the minimum ones. More stringent regulation would therefore be acting as a substitute in the prudential role of buffers.

To identify the specific characteristics of the behavior of capital buffers in the region, the first model shown in Table 2 was estimated taking into account the type of specialization and relative size of a bank within its country of origin, as well as the respective interactions with the business cycle. Table 3 presents the results.

There are two significant results with respect to this new group of models. First, the coefficient of the binary variable for large banks and their respective interaction with the cycle is significant and negative, which provides further evidence of the *too big to fail* hypothesis. Those banks that are relatively large within their national markets tend to hold less capital buffers than the rest. Likewise, the magnitude of the size coefficient interacting with the cycle is greater than the one associated to the remaining banks. Second, the significant and positive result of the binary variable associated with savings banks indicates that these tend to behave positively with the cycle. Said banks also have larger buffers than the other banks, which could be associated with a more conservative profile of this bank group.

To identify specific relations for some countries of the region, estimations were made for Argentina, Brazil, Mexico, Panama and Venezuela, which are shown in Table 4. This group is representative, regarding dimension and heterogeneity, of the region's banking systems. A sample was available for the five countries that was adapted to the methodology and specification adopted for the country environment. It can be seen how the countercyclical behavior detected in the region continues, except in the case of Brazil. With respect to adjustment costs and the speed of access to capital, there are significant differences across countries. Argentina and Mexico for instance exhibit easier access to capital than the rest of the group. In the same way, as for the region as a whole, it can be seen that bank size is a very significant variable for the movement of capital buffers. As for the

**Table 2**

**LATIN AMERICA AND THE CARIBBEAN: RESULTS OF ESTIMATIONS**

| *Variable* | *M1_LA* | *M2_LA* | *M3_LA* | *M4_LA* | *M5_LA* |
|---|---|---|---|---|---|
| **$GPIB_t$** | −0.406[c] | −0.224[c] | −0.092[a] | −0.415[c] | −0.093[a] |
| | (0.06) | (0.06) | (0.05) | (0.06) | (0.04) |
| **$BUF_{t-1}$** | 0.178[c] | 0.175[c] | 0.731[c] | 0.185[c] | 0.759[c] |
| | (0.01) | (0.01) | (0.02) | (0.01) | (0.02) |
| **$BUF_{t-2}$** | | | 0.034[a] | | 0.037[a] |
| | | | (0.02) | | (0.02) |
| **$SIZE_t$** | −2.797[c] | −2.886[c] | −0.121 | −2.848[c] | −0.156 |
| | (0.21) | (0.25) | (0.13) | (0.19) | (0.14) |
| **$ROAA_t$** | 0.941[c] | | 0.154 | 0.862[c] | 0.121 |
| | (0.10) | | (0.10) | (0.11) | (0.10) |
| **$LLR_t$** | 0.337[a] | 0.213 | 0.253[b] | 0.228 | 0.218[c] |
| | (0.15) | (0.21) | (0.08) | (0.16) | (0.06) |
| **$BOONE_t$** | 35.690[c] | 37.874[c] | 14.784[b] | 33.240[c] | 13.188[b] |
| | (9.20) | (9.40) | (5.30) | (7.42) | (4.37) |
| **$OCS_t$** | −0.851[b] | −0.970[b] | −0.325 | −0.889[c] | −0.082 |
| | (0.32) | (0.35) | (0.18) | (0.26) | (0.17) |
| **$OSP_t$** | 0.04 | 0.121 | −0.282[a] | | |
| | (0.23) | (0.23) | (0.11) | | |
| **$CF_t$** | | −0.016[c] | −0.005[a] | −0.002 | −0.006[a] |
| | | (0.00) | (0.00) | (0.00) | (0.00) |
| **$MCM_t$** | | | | −0.001 | 0.034[a] |
| | | | | (0.02) | (0.02) |
| Constant | 54.036[c] | 41.632[c] | 2.455 | 41.799[c] | −28.247[b] |
| | (5.97) | (5.42) | (3.80) | (3.41) | (10.83) |
| N | 700 | 646 | 525 | 760 | 634 |
| j | 74 | 72 | 75 | 73 | 75 |
| Hansen | 55.556 | 60.312 | 39.017 | 51.613 | 42.412 |
| Hansen *p* | 0.454 | 0.228 | 0.959 | 0.528 | 0.91 |
| AR1 | −1.364 | −1.754 | −2.784 | −1.675 | −1.898 |
| AR1*p* | 0.173 | 0.079 | 0.005 | 0.094 | 0.058 |
| AR2 | 0.119 | 0.08 | −1.211 | 0.639 | −0.644 |
| AR2*p* | 0.905 | 0.937 | 0.226 | 0.523 | 0.52 |

Note: Standard errors in parenthesis. [a]$p < 0.05$; [b]$p < 0.01$; [c]$p < 0.001$.

**Table 3**

**LATIN AMERICA AND THE CARIBBEAN: RESULTS OF MODEL 1 ESTIMATION**

| *Variable* | *M1_LA* | *M2_LA* | *M3_LA* | *M4_LA* | *M5_LA* |
|---|---|---|---|---|---|
| **GPIB$_t$** | −0.406$^{c}$ | −0.360$^{c}$ | −0.270$^{c}$ | −0.397$^{c}$ | −0.411$^{c}$ |
| | (0.06) | (0.06) | (0.08) | (0.06) | (0.06) |
| **BUF$_{t-1}$** | 0.178$^{c}$ | 0.189$^{c}$ | 0.207$^{c}$ | 0.179$^{c}$ | 0.183$^{c}$ |
| | (0.01) | (0.01) | (0.02) | (0.01) | (0.01) |
| **SIZE$_t$** | −2.797$^{c}$ | | | −2.822$^{c}$ | −2.861$^{c}$ |
| | (0.21) | | | (0.21) | (0.22) |
| **ROAA$_t$** | 0.941$^{c}$ | 0.874$^{c}$ | 0.889$^{c}$ | 0.949$^{c}$ | 0.968$^{c}$ |
| | (0.10) | (0.12) | (0.12) | (0.10) | (0.12) |
| **LLR$_t$** | 0.337$^{a}$ | 0.465$^{b}$ | 0.594$^{c}$ | 0.329$^{a}$ | 0.391$^{b}$ |
| | (0.15) | (0.14) | (0.15) | (0.15) | (0.15) |
| **BOONE$_t$** | 35.690$^{c}$ | 33.697$^{c}$ | 44.021$^{c}$ | 35.536$^{c}$ | 39.858$^{c}$ |
| | (9.20) | (9.36) | (9.76) | (9.22) | (9.12) |
| **OCS$_t$** | −0.851$^{b}$ | 0.463 | −0.953$^{b}$ | −0.853$^{b}$ | −0.939$^{b}$ |
| | (0.32) | (0.33) | (0.32) | (0.32) | (0.32) |
| **OSP$_t$** | −0.04 | 0.3 | 0.17 | 0.012 | 0.049 |
| | (0.23) | (0.22) | (0.22) | (0.23) | (0.23) |
| SizeCo$_t$ | | −5.721$^{c}$ | | | |
| | | (0.59) | | | |
| SizeCo$_t$*GPIB | | | −0.310$^{b}$ | | |
| | | | (0.10) | | |
| Cooperative banks | | | | −0.013 | |
| | | | | (2.94) | |
| Savings banks | | | | 6.792$^{c}$ | |
| | | | | (1.16) | |
| CoopBanks*GPIB | | | | | −0.161 |
| SavingsBanks *GPIB | | | | | (0.61) |
| Constant | 54.036$^{c}$ | 7.27 | 4.864 | 53.844$^{c}$ | 43.272$^{c}$ |
| | (5.97) | (3.93) | (2.51) | (6.13) | (4.70) |
| N | 700 | 700 | 700 | 700 | 700 |
| j | 74 | 74 | 74 | 76 | 76 |
| Hansen | 55.556 | 51.203 | 56.223 | 56.789 | 60.204 |

**Table 3 (cont.)**

| *Variable* | *M1_LA* | *M2_LA* | *M3_LA* | *M4_LA* | *M5_LA* |
|---|---|---|---|---|---|
| Hansen *p* | 0.454 | 0.62 | 0.429 | 0.408 | 0.293 |
| AR1 | −1.364 | −1.317 | −1.288 | −1.367 | −1.388 |
| AR1*p* | 0.173 | 0.188 | 0.198 | 0.172 | 0.165 |
| AR2 | 0.119 | −0.224 | 0.358 | 0.088 | 0.159 |
| AR2*p* | 0.905 | 0.823 | 0.72 | 0.93 | 0.874 |

Note: Standard errors in parenthesis. $^{a}p < 0.05$; $^{b}p < 0.01$; $^{c}p < 0.001$.

**Table 4**

**LATIN AMERICA: RESULTS BY COUNTRY FOR MODEL 1 ESTIMATION**

| *Variable* | *Argentina* | *Brazil* | *Mexico* | *Panama* | *Venezuela* |
|---|---|---|---|---|---|
| **$GPIB_t$** | −0.195 | 0.347$^{c}$ | −0.110$^{c}$ | −0.031 | −0.044 |
| | (0.17) | (0.01) | (0.02) | (0.02) | (0.03) |
| **$BUF_{t-1}$** | 0.525$^{c}$ | 0.205$^{c}$ | 0.668$^{c}$ | 0.282$^{c}$ | 0.279$^{c}$ |
| | (0.05) | (0.00) | (0.01) | (0.01) | (0.04) |
| **$SIZE_t$** | −1.3 | −2.544$^{c}$ | −1.278$^{c}$ | −1.658$^{c}$ | −4.286$^{c}$ |
| | (1.16) | (0.08) | (0.18) | (0.09) | (0.44) |
| **$ROAA_t$** | −1.976 | −0.398$^{c}$ | 0.463$^{c}$ | 0.613$^{c}$ | 1.551$^{c}$ |
| | (0.94) | (0.01) | (0.04) | (0.00) | (0.11) |
| **$LLR_t$** | −1.277$^{a}$ | −0.235$^{c}$ | 0.117$^{a}$ | 1.557$^{c}$ | 0.932$^{c}$ |
| | (0.55) | (0.01) | (0.05) | (0.04) | (0.06) |
| Constant | 17.137 | 46.720$^{c}$ | 21.723$^{c}$ | 26.006$^{c}$ | 58.155$^{c}$ |
| | (18.98) | (1.09) | (2.91) | (1.05) | (6.93) |
| N | 41 | 806 | 191 | 214 | 165 |
| j | 13 | 82 | 40 | 76 | 78 |
| Hansen | 3.574 | 83.479 | 26.885 | 32.712 | 23.395 |
| Hansen *p* | 0.827 | 0.261 | 0.802 | 1.000 | 1.000 |
| AR1 | −1.660 | −1.725 | −1.777 | −1.405 | −2.495 |
| AR1*p* | 0.097 | 0.085 | 0.076 | 0.160 | 0.013 |
| AR2 | −1.332 | −1.352 | −1.228 | 0.854 | −0.551 |
| AR2*p* | 0.183 | 0.177 | 0.220 | 0.393 | 0.581 |

Note: Standard errors in parenthesis. $^{a}p < 0.05$; $^{b}p < 0.01$; $^{c}p < 0.001$.

$LLR_t$ and $ROAA_t$ indicators, Brazil exhibits the opposite behavior to the other countries by showing a decrease in capital buffers in response to an increase in profits and expected losses.

Tables 1 to 4 in Annex B show some results of robustness and differentiaton of results. Table B.1 presents the results of replacing the binary variable of relative size within the country with that of size in absolute terms. It is significant that the largest banks tend to have smaller capital buffers, confirming the previous results related to the *too large to fail* hypothesis. Table B.2 shows the interaction between the size variable and $GPIB_t$, which is significant for Brazil, Mexico and Panama. For these countries, not only large banks have a significant negative fluctuation with the cycle, but the sign and the significance also change for the other banks. Table B.3 presents the results of including binary variables by type of bank specialization. It is interesting that in Brazil cooperative banks follow a countercyclical behavior, while in Panama savings banks exhibit a positive fluctuation regarding capital buffers. Table B.4. shows the results of including interactions between the binary variables by type of bank specialization and $GPIB_t$.

## 5. CONCLUSIONS

In this paper, we conducted an empirical study of regulatory capital buffers' fluctuation patterns with respect to the business cycle for the 2001 to 2013 period using data of 18 countries and 456 Latina American and Caribbean banks. Results are also presented for Argentina, Brazil, Mexico, Panama and Venezuela.

Our results show that, although the general thinking behind the Basel III countercyclical capital buffer proposal is based on data, patterns vary across countries. It can be seen that for each different specification the coefficient describing the relation between $GPIB_t$ and capital buffers is significant and negative, meaning there is evidence, considering the five different models, of a negative fluctuation with respect to the cycle if the 18 countries of the region are taken into account. With respect to adjustment costs associated to the lagged variable $BUF_{t-1}$, said costs are shown to be significant in the region.

Among the variables that differentiate cyclical patters and the level of buffers are bank size, forms of organization and levels of competitiveness in the region's banking systems. In general, the most profitable and riskiest banks tend to hold more buffers. Savings banks seem to be more prudent in their cyclical behavior and the largest banks have smaller capital buffers. Lower levels of competition are associated to banks with higher buffer levels. More stringent banking regulation in the region seems to serve as a substitute for buffers, while tending to decrease their levels.

Thus, although, in the aggregate, banks of the region present a negative fluctuation with the cycle, which is in line with the proposal of Basel III, there are different patterns when the data is examined and disaggregated in the setting of countries, size and form of organization. This differentiation in the cyclical patterns of capital buffers leads to a more tailored calibration of countercyclical capital buffer requirements, particularly, in their discretionary behavior.

## ANNEXES

### Annex A

## Table A

**LATIN AMERICA AND THE CARIBBEAN: DESCRIPTIVE STATISTICS FOR THE VARIABLES EMPLOYED**

| Country | Number of banks | *BUF* | | *ROAA* | | *GDPG* | | *SIZE* | | *LLRGL* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Mean* | *Standard deviation* | *Mean* | *Standard deviation* | *Mean* | *Standard deviation* | *Mean* | *Standard deviation* | *Mean* | *Standard deviation* |
| Argentina | 17 | 3.285 | 17.801 | −0.710 | 11.193 | 4.065 | 6.075 | 12.616 | 2.019 | 8.473 | 13.381 |
| Brazil | 149 | 14.812 | 25.526 | 1.975 | 5.284 | 3.280 | 2.222 | 13.709 | 2.058 | 6.826 | 14.764 |
| Chile | 30 | 24.125 | 39.949 | 1.049 | 2.459 | 4.108 | 1.926 | 14.506 | 2.158 | 3.087 | 2.337 |
| Colombia | 17 | 9.027 | 14.676 | 1.575 | 2.712 | 4.291 | 1.664 | 14.080 | 1.672 | 6.771 | 11.742 |
| Costa Rica | 10 | 5.902 | 6.130 | 2.310 | 2.712 | 4.389 | 2.559 | 11.414 | 2.098 | 2.194 | 1.474 |
| Ecuador | 20 | 7.503 | 14.071 | −12.619 | 52.496 | 4.550 | 2.065 | 11.519 | 2.155 | 34.072 | 59.592 |
| El Salvador | 13 | 17.649 | 62.141 | 1.047 | 1.242 | 1.778 | 1.745 | 13.078 | 1.571 | 5.185 | 9.788 |
| Guatemala | 3 | 5.422 | 2.921 | −1.039 | 21.288 | 3.410 | 1.359 | 12.427 | 1.462 | 7.634 | 19.517 |
| Guyana | 3 | 13.801 | 6.710 | 1.779 | 0.722 | 2.342 | 3.353 | 12.229 | 0.653 | 6.500 | 5.484 |
| Honduras | 7 | 16.358 | 29.087 | 1.186 | 2.904 | 3.989 | 2.259 | 12.457 | 1.096 | 4.288 | 3.413 |
| Jamaica | 9 | 13.592 | 13.654 | 2.127 | 2.852 | −0.020 | 1.978 | 13.321 | 1.319 | 2.229 | 1.833 |
| Mexico | 45 | 18.469 | 46.446 | 0.039 | 6.890 | 2.065 | 2.739 | 14.042 | 2.109 | 6.292 | 8.460 |
| Nicaragua | 7 | 5.879 | 2.777 | −5.730 | 38.444 | 3.450 | 2.266 | 12.450 | 1.692 | 7.293 | 14.453 |
| Panama | 47 | 11.639 | 15.811 | 1.280 | 3.558 | 7.025 | 3.283 | 12.963 | 1.492 | 2.200 | 2.887 |
| Peru | 14 | 5.115 | 13.507 | 1.447 | 4.150 | 5.732 | 2.520 | 13.862 | 1.811 | 5.905 | 3.806 |
| Suriname | 3 | 1.801 | 3.340 | 0.904 | 1.699 | 4.452 | 1.509 | 12.239 | 1.025 | 9.766 | 1.090 |
| Trinidad and Tobago | 7 | 20.702 | 14.139 | 2.187 | 1.306 | 4.407 | 5.292 | 13.990 | 1.367 | 1.786 | 1.543 |
| Venezuela | 55 | 23.489 | 59.302 | 3.432 | 6.580 | 3.468 | 7.229 | 13.418 | 2.109 | 6.910 | 9.107 |

## Annex B

Table B.1

**LATIN AMERICA: RESULTS BY COUNTRY FOR MODEL 1 WITH BINARY VARIABLE FOR 25% OF THE LARGEST BANKS**

| *Variable* | *Argentina* | *Brazil* | *Mexico* | *Panama* | *Venezuela* |
|---|---|---|---|---|---|
| $GPIB_t$ | −0.161 | 0.300[c] | −0.091[c] | −0.048[c] | −0.217[c] |
| | (0.22) | (0.01) | (0.02) | (0.01) | (0.02) |
| $BUF_{t-1}$ | 0.512[c] | 0.235[c] | 0.685[c] | 0.305[c] | 0.229[c] |
| | (0.06) | (0.00) | (0.00) | (0.01) | (0.02) |
| $SizeCo_t$ | 5.881 | −6.917[c] | −2.134[c] | −2.594[c] | −6.373[c] |
| | (5.71) | (0.22) | (0.30) | (0.21) | (0.44) |
| $ROAA_t$ | 2.045 | −0.338[c] | 0.186[c] | 0.676[c] | 1.985[c] |
| | (1.00) | (0.01) | (0.03) | (0.00) | (0.13) |
| $LLR_t$ | −1.447[a] | −0.166[c] | 0.136[c] | 1.649[c] | 1.142[c] |
| | (0.59) | (0.01) | (0.04) | (0.03) | (0.06) |
| Constant | −1.91 | 11.992[c] | 3.024[c] | 3.900[c] | −2.648[a] |
| | (6.81) | (0.09) | (0.31) | (0.19) | (1.05) |
| N | 41 | 806 | 191 | 214 | 165 |
| j | 13 | 82 | 40 | 76 | 78 |
| Hansen | 3.317 | 85.999 | 27.926 | 30.190 | 18.472 |
| Hansen *p* | 0.854 | 0.203 | 0.759 | 1.000 | 1.000 |
| AR1 | −1.442 | −1.669 | −1.804 | −1.408 | −1.353 |
| AR1*p* | 0.149 | 0.095 | 0.071 | 0.159 | 0.176 |
| AR2 | −1.335 | −1.298 | −1.161 | 0.858 | −0.592 |
| AR2*p* | 0.182 | 0.194 | 0.246 | 0.391 | 0.554 |

Note: Standard errors in parenthesis. [a]$p < 0.05$; [b]$p < 0.01$; [c]$p < 0.001$.

**Table B.2**

**LATIN AMÉRICA: RESULTS BY COUNTRY FOR MODEL 1 WITH INTERACTION BETWEEN BINARY VARIABLE FOR 25% OF THE LARGEST BANKS AND GDP**

| *Variable* | *Argentina* | *Brazil* | *Mexico* | *Panama* | *Venezuela* |
|---|---|---|---|---|---|
| $GPIB_t$ | −0.854 | 0.794[c] | −0.061 | 0.064[b] | −0.274[c] |
| | (0.66) | (0.01) | (0.04) | (0.02) | (0.05) |
| $BUF_{t-1}$ | 0.508[c] | 0.243[c] | 0.695[c] | 0.315[c] | 0.292[c] |
| | (0.06) | (0.00) | (0.00) | (0.00) | (0.02) |
| $SizeCo_t$*GPIB | −0.685 | −1.417[c] | −0.216[c] | −0.290[c] | 0.048 |
| | (0.71) | (0.04) | (0.05) | (0.02) | (0.05) |
| $ROAA_t$ | −2.035 | −0.330[c] | 0.134[c] | 0.657[c] | 2.020[c] |
| | (0.99) | (0.00) | (0.02) | (0.01) | (0.10) |
| $LLR_t$ | −1.447[a] | −0.150[c] | 0.155[c] | 1.594[c] | 1.137[c] |
| | (0.60) | (0.01) | (0.04) | (0.04) | (0.09) |
| Constant | −3.833 | 9.425[c] | 2.145[c] | 2.857[c] | −6.488[c] |
| | (2.99) | (0.11) | (0.24) | (0.26) | (0.71) |
| N | 41 | 806 | 191 | 214 | 165 |
| j | 13 | 82 | 40 | 76 | 78 |
| Hansen | 3.23 | 92.20 | 27.25 | 31.37 | 18.42 |
| Hansen *p* | 0.863 | 0.100 | 0.787 | 1.000 | 1.000 |
| AR1 | −1.321 | −1.680 | −1.809 | −1.434 | −1.460 |
| AR1*p* | 0.186 | 0.093 | 0.070 | 0.152 | 0.144 |
| AR2 | −1.340 | −1.371 | −1.153 | 0.817 | −0.744 |
| AR2*p* | 0.180 | 0.170 | 0.249 | 0.414 | 0.457 |

Note: Standard errors in parenthesis. [a]$p < 0.05$; [b]$p < 0.01$; [c]$p < 0.001$.

## Table B.3

**LATIN AMERICA: RESULTS BY COUNTRY FOR MODEL 1 WITH SPECIALIZATION BINARY VARIABLE OF COOPERATIVE AND SAVINGS BANKS**

| *Variable* | *Argentina* | *Brazil* | *Mexico* | *Panama* | *Venezuela* |
|---|---|---|---|---|---|
| $GPIB_t$ | −0.223 | 0.342[c] | −0.132[c] | −0.026[c] | −0.303[c] |
| | (0.19) | (0.01) | (0.03) | (0.01) | (0.02) |
| $BUF_{t-1}$ | 0.442[c] | 0.257[c] | 0.677[c] | 0.359[c] | 0.290[c] |
| | (0.06) | (0.00) | (0.01) | (0.00) | (0.02) |
| $ROAA_t$ | 1.916 | −0.304[c] | 0.171[c] | 0.602[c] | 1.974[c] |
| | (1.27) | (0.01) | (0.04) | (0.00) | (0.07) |
| $LLR_t$ | −0.876 | −0.149[c] | 0.307[b] | 1.525[c] | 1.047[c] |
| | (0.68) | (0.01) | (0.10) | (0.02) | (0.11) |
| Cooperative banks | −9.092 | −7.544[c] | −0.847 | | |
| | (8.36) | (0.75) | (11.20) | | |
| Savings banks | | | −24.836 | 1.870[c] | 0.704 |
| | | | (16.79) | (0.11) | (2.86) |
| Constant | 1.663 | 9.420[c] | 1.881[c] | 2.145[c] | −5.941[c] |
| | (3.53) | (0.10) | (0.41) | (0.08) | (0.69) |
| N | 41 | 806 | 191 | 214 | 165 |
| j | 13 | 82 | 41 | 76 | 78 |
| Hansen | 4.699 | 91.505 | 25.906 | 31.633 | 17.526 |
| Hansen *p* | 0.697 | 0.109 | 0.839 | 1.000 | 1.000 |
| AR1 | −1.676 | −1.635 | −1.783 | −1.470 | −1.339 |
| AR1*p* | 0.094 | 0.102 | 0.075 | 0.142 | 0.181 |
| AR2 | −1.278 | −1.309 | −1.071 | 0.888 | −0.742 |
| AR2*p* | 0.201 | 0.190 | 0.284 | 0.375 | 0.458 |

Note: Standard errors in parenthesis. [a]$p < 0.05$; [b]$p < 0.01$; [c]$p < 0.001$.

Table B.4

**LATIN AMERICA: RESULTS BY COUNTRY FOR MODEL 1 WITH INTERACTION BETWEEN THE SPECIALIZATION BINARY VARIABLE FOR COOPERATIVE AND SAVINGS BANK AND GDP**

| *Variable* | *Argentina* | *Brazil* | *Mexico* | *Panama* | *Venezuela* |
|---|---|---|---|---|---|
| $GPIB_t$ | −0.224 | 0.375[c] | −0.168[c] | −0.042[c] | −0.311[c] |
| | (0.19) | (0.01) | (0.02) | (0.01) | (0.02) |
| $BUF_{t-1}$ | 0.439[c] | 0.257[c] | 0.693[c] | 0.356[c] | 0.290[c] |
| | (0.06) | (0.00) | (0.00) | (0.00) | (0.02) |
| $ROAA_t$ | −1.901 | −0.301[c] | 0.126[c] | 0.606[c] | 1.961[c] |
| | (1.25) | (0.01) | (0.02) | (0.00) | (0.07) |
| $LLR_t$ | 0.906 | −0.145[c] | 0.139[c] | 1.548[c] | 1.059[c] |
| | (0.67) | (0.01) | (0.04) | (0.02) | (0.11) |
| CoopBanks*GPIB | 1.076 | −1.496[c] | 0.450[c] | | |
| | (0.98) | (0.19) | (0.06) | | |
| SavingsBanks | | | −0.025 | 0.212[c] | 0.122 |
| *GPIB | | | (0.06) | (0.04) | (0.24) |
| Constant | 1.805 | 9.278[c] | 2.176[c] | 2.269[c] | −5.832[c] |
| | (3.49) | (0.09) | (0.20) | (0.16) | (0.71) |
| N | 41 | 806 | 191 | 214 | 165 |
| j | 13 | 82 | 41 | 76 | 78 |
| Hansen | 4.681 | 93.096 | 27.105 | 33.314 | 17.196 |
| Hansen *p* | 0.699 | 0.089 | 0.793 | 1.000 | 1.000 |
| AR1 | −1.689 | −1.640 | −1.808 | −1.464 | −1.344 |
| AR1*p* | 0.091 | 0.101 | 0.071 | 0.143 | 0.179 |
| AR2 | −1.277 | −1.311 | −1.205 | 0.891 | −0.745 |
| AR2*p* | 0.202 | 0.190 | 0.228 | 0.373 | 0.456 |

Note: Standard errors in parenthesis. [a]$p < 0.05$; [b]$p < 0.01$; [c]$p < 0.001$.

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# Targeting Long-term Rates in a Model with Financial Frictions and Regime Switching

*Alberto Ortiz Bolaños*
*Sebastián Cadavid-Sánchez*
*Gerardo Kattan Rodríguez*

**Abstract**

*Decreases (increases) in long-term interest rates caused by compressions (dilations) of term premiums could be financially expansive (contractive) and might require monetary policy restraints (stimulus). This paper uses measures of the term premium calculated by Adrian et al. (2013) to perform Bayesian estimations of a Markov-switching vector autoregression (MS-VAR) model as Hubrich and Tetlow (2015), finding evidence of the importance of allowing for switching parameters (nonlinearities) and switching variance (non-Gaussian) when analyzing macrofinancial linkages in the United States. Using the specification with the best fit to the data of two Markov states for parameters and three Markov states for variances, we estimate a Markov-switching dynamic stochastic general equilibrium (MS-DSGE) macroeconomic model with financial frictions in long-term debt instruments developed by Carlstrom et al. (2017) to provide evidence on how financial conditions have evolved in the US since 1962 and how the Federal Reserve Bank has responded to the evolution of term premiums. Using the estimated model, we perform a counterfactual analysis of the potential evolution of macroeconomic and financial variables under alternative financial conditions and monetary policy responses. We analyze six episodes with the presence of high financial frictions*

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A. Ortiz Bolaños <ortiz@cemla.org>, CEMLA and EGADE Business School, Mexico; S. Cadavid-Sánchez <scadavid@cemla.org>, CEMLA; and G. Kattan Rodríguez < a00807607@itesm.mx>, EGADE Business School, Mexico. The authors thank Junior Maih for making his RISE toolbox for the solution and estimation of Markov-switching rational expectations models available <https://github.com/jmaih/RISE_toolbox> and for patiently answering all of our questions. The views expressed in this presentation are those of the authors, and not necessarily those of CEMLA or EGADE Business School of Instituto Tecnológico y de Estudios Superiores de Monterrey.

*and/or medium and high shocks volatility. In three of them there was a high monetary policy response to financial factors: 1978Q4-1983Q4 which helped to mitigate inflation at the cost of economic activity, and the 1990Q2-1993Q4 and 2010Q1-2011Q4 episodes in which the high response served to mitigate economic contractions. Meanwhile, in the three episodes where low response to financial factors is observed, if the monetary authority had responded more aggressively, from 1971Q1-1978Q3 it could have attained lower inflation at the cost of lower GDP, from 2000Q4-2004Q4 it could have delayed the GDP contraction to 2002Q3, but this would have been deeper and inflation larger, and in 2006Q1-2009Q4 it might have precipitated the GDP contraction. The presence of high financial frictions and high shock volatility makes recessions deeper and recoveries more sluggish showing the importance of the financial-macroeconomic nexus.*

*Keywords: monetary policy, term-structure, financial frictions, Markov-switching VAR, Markov-switching DSGE, Bayesian maximum likelihood methods.*

*JEL classification: El2, E43, E44, E52, E58, C11.*

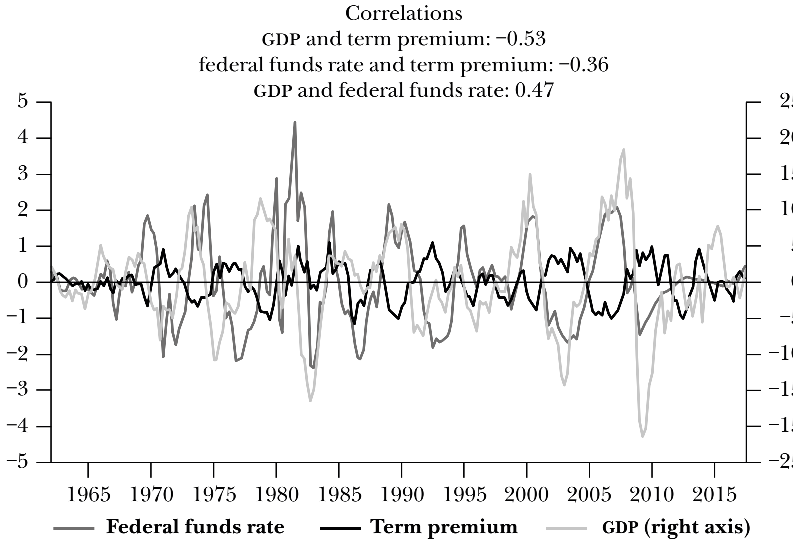
> *To the extent that the decline in forward rates can be traced to a decline in the term premium [...] the effect is financially stimulative and argues for greater monetary policy restraint, all else being equal. Specifically, if spending depends on long-term interest rates, special factors that lower the spread between short-term and long-term rates will stimulate aggregate demand. Thus, when the term premium declines, a higher short-term rate is required to obtain the long-term rate and the overall mix of financial conditions consistent with maximum sustainable employment and stable prices.*
>
> *"Reflections on the Yield Curve and Monetary Policy,"*
> *Ben S. Bernanke, chairman, Federal Reserve Bank,*
> *March 20, 2006.*

## 1. INTRODUCTION

The above quote states that yields on long-term debt and specially the term premium, which is the extra compensation required by investors for bearing interest rate risk associated with short-term yields not evolving as expected, are an important determinant

**Figure 1**

**CYCLICAL MOVEMENTS OF GDP, FEDERAL FUNDS RATE AND TERM PREMIUM: 1961Q1-2017Q4**




Note: This figure shows the deviation of each original series from its HP filter. GDP is the real gross domestic product (GDPC1 in Fred Economic Data from the Federal Reserve Bank of St. Louis), federal funds rate is the effective federal funds rate (FEDFUNDS also in Fred Economic Data), and term premium is the 10-year Treasury term premium computed following the methodology of Adrian et al. (2013) and reported by the Federal Reserve Bank of New York (ACM10TP).

of aggregate demand.[1] It also underlies that the monetary authority should respond to term premium movements to stabilize the effects that the financial sector could have in the macroeconomy. However, this task is complicated by the fact that the term premium is not observed and because the mechanisms through which developments in long-term debt instruments affect the macroeconomy are not completely understood.

The Federal Reserve Bank of New York reports a measure of the term-premium calculated by Adrian et al. (2013) which we will use

[1] Rudebusch et al. (2006) show that a decline in the term premium has typically been associated with higher future GDP growth.

in this study. Before discussing some of the potential mechanisms linking developments in long-term debt markets and the macroeconomy, it is useful to look at the cyclical movements between gross domestic product (GDP), the federal funds rate, and the term premium.[2] Figure 1 shows the difference between the observed series and the ones produced by applying a Hodrick Prescott filter. There is a strong negative correlation of −0.53 between the cyclical components of GDP and the term premium. Meanwhile the correlation among the cyclical components of the federal funds rate and the term premium is −0.36, and the correlation among the cyclical components of GDP and the federal funds rate is 0.47.

To further investigate the relation between long-term debt markets and the macroeconomy, we estimate a Markov-switching vector autoregressive model (MS-VAR) following Hubrich and Tetlow (2015), where we replace the post-December 1988 Federal Reserve Board staff's financial conditions index with the post-January 1962 term premium, to identify *stress events*. First, we analyze if the data favors a Markov-switching specification where coefficients and/or variances can switch relative to a time-invariant Gaussian VAR model. Our results show that the best fit is attained when we allow for two independent Markov states governing the coefficient switching and three independent Markov states governing the variance switching in all equations, providing evidence of nonlinear and non-Gaussian phenomena. Second, using that preferred specification, we identify the probability of being in a specific coefficient and a specific variance state. Third, the impulse response functions show big differences in the transmission of shocks across different coefficient and variance regimes.

Guided by the two-coefficient switching and three-variance switching specification of our MS-VAR, we modify the macroeconomic model with financial frictions in long-term debt instruments developed in Carlstrom et al. (2017) to a Markov-switching dynamic stochastic general equilibrium (MS-DSGE) version. This model helps us to: *1)* study how financial conditions, as measured by the degree

2 We thank Robert E. Lucas for his suggestion of having the high-frequency movements removed using a statistical filter to show if there is a long-run relation between these three series in a similar way he did to analyze inflation and money growth at <https://files.stlouisfed.org/files/htdocs/publications/review/2014/Q3/lucas.pdf>.

financial frictions and volatilities of credit market shocks, have evolved in the US since 1962; *2)* measure how the Federal Reserve has responded to the evolution of term premiums; and *3)* to perform counterfactual analysis of the potential evolution of macroeconomic and financial variables under alternative financial conditions, monetary policy responses, and credit shock volatilities.

The counterfactual exercises allow to separately analyze the effects of financial frictions, monetary policy responses and the volatility of credit market shocks in the evolution of macroeconomic and financial variables. We analyze six episodes when the estimation assigns a high probability[3] to high financial frictions and/or medium or high shock volatilities. In three of them, 1978Q4-1983Q4, 1990Q2-1993Q4, and 2010Q1-2011Q4, the estimation suggests that monetary policy was responsive to financial conditions with short-term interest rates having a high elasticity to the term premium of −1.16. In the other three episodes, despite the presence of worsening financial conditions, in 1971Q1-1978Q3, 2000Q4-2004Q4, and 2006Q1-2009Q4, the estimation suggests that there was a low response to financial factors with an elasticity of −0.24. The high monetary response allowed the authority to mitigate inflation at the cost of economic activity in the 1978Q4-1983Q4 episode and to mitigate economic contractions in the 1990Q2-1993Q4 and 2010Q1-2011Q4 episodes. If the monetary authority had responded more aggressively, when it decided not to, it would have attained lower inflation at the cost of lower GDP in the 1971Q1-1978Q3 episode, would have delayed the GDP contraction to 2002Q3, but it would have been deeper and inflation larger in 2000Q4-2004Q4, and it might have precipitated the GDP contraction in 2006Q1-2009Q4. The presence of high financial frictions and high shock volatility makes recessions deeper and recoveries more sluggish.

The rest of the paper is organized as follows. Section 2 presents the MS-VAR model including its specification and results. Section 3 presents a MS-DSGE version of a model of segmented financial markets where financial institutions net worth limits the degree of arbitrage across the term structure (a financial friction), a *loan-in-advance* constraint that increases the private cost of purchasing investment goods (creating real effects of the financial frictions), and

[3] We refer to *large* probability if the probability of a given Markov-state is larger or equal than 50 percent.

an augmented monetary policy with response to the term premium. Section 4 discusses the solution and estimation techniques of the MS-DSGE model. Section 5 presents the results showing first the parameter estimates; then the impulse response functions for the different regimes associated to financial frictions, monetary policy and credit shock volatilities; after this we present the regimes probabilities; and finally, counterfactual exercises to analyze the role of financial frictions, monetary policy and credit shock volatilities in the evolution of financial and macroeconomic variables in the 1962-2017 period. Section 6 presents our conclusions.

## 2. MS-VAR MODEL

In this section we present the MS-VAR model specification and the estimation results which *1)* provide evidence on the benefit of allowing for Markov switching in coefficients and variances, while identifying the model with the best goodness-of-fit to the data, *2)* give the coefficient and variances regime probabilities for the model with the largest posterior mode, and *3)* report the impulse response functions comparing the behavior for each coefficient-variance pair.

### 2.1 Model Specification

We introduce a MS-VAR to explore if macroeconomic and financial data provide evidence of switching parameters and switching variance, and to identify periods of high financial stress in the studied sample for the US economy, and hence highlight the importance of introducing these features in a structural modelling framework. We follow the approach presented by Hubrich and Tetlow (2015), which estimates a MS-VAR using the financial stress index to measure financial stress, but instead, we propose to use the term premium calculated by Adrian et al. (2013), that we will also use in our structural MS-DSGE, to measure *financial frictions.*

This specification adopts the spirit of smoothly time-varying parameters in VAR models presented by Primiceri (2005), Cogley and Sargent (2005), and Bianchi and Melosi (2017). Following the notation of Hubrich and Tetlow (2015), the nonlinear system can be written as follows:

1 $$y_t' A_0\left(s_t^c\right)=\sum_{l=1}^{p} y_{t-1}' A_l\left(s_t^c\right)+z_t' B\left(s_t^c\right)+\varepsilon_t' \Xi^{-1}\left(s_t^v\right),$$

where $y_t$ is an $n\times 1$ vector of endogenous variables and $A_0$ and $A_l$ are $n\times n$ matrices that contains the parameters of the contemporaneous and lagged endogenous variables, respectively; $z_t$ is a $n\times 1$ matrix of exogenous variables, and $B$ is a $n\times n$ matrix that includes parameters of the exogenous variables. The unobserved states variables $s_t^c$ and $s_t^v$ control the operating regimes for the coefficients and covariance matrix, respectively. These latent variables evolve according to first-order Markov processes[4] with transition matrixes of probabilities $H^c$ and $H^v$, respectively.

We use quarterly data-series for a sample from 1962Q1 to 2017Q3. In the estimation we use five variables: the log differences of monthly personal consumption expenditures, $C_t$, log differences of CPI excluding food and energy prices, $P_t$, nominal interest rate, $R_t$, growth in the nominal M2 monetary aggregate, $M_t$, and the term premium, $TP_t$; which corresponds to the data vector $y_t=\left[C_t \quad P_t \quad R_t \quad M_t \quad TP_t\right]'$. We use the Treasury term premium estimated by Adrian et al. (2013), available at the Federal Reserve Bank of New York website. All the other data are taken from the Federal Reserve Bank of St. Louis. Following Sims et al. (2008), standard Minnesota priors are introduced to perform the Bayesian estimation.

## 2.2 Estimation Results

### *2.2.1 Is There Markov-switching in Coefficients and/or Variances?*

To determine if the data favors a Markov-switching specification where coefficients and/or variances can switch relative to a time-invariant Gaussian VAR model, we compare the goodness of fit of alternative models. Specifically, use $\#c$ to designate the possible states of the Markov chains that govern the slope and intercepts of the coefficients, and $\#v$ to indicate the possible states of the Markov chain governing the switching variance of the system, where $\#=1, 2$, and 3. In addition, we could restrict shifts in structural parameters to be constrained to a particular equation(s), indicating by post-fixing the letter(s) of the variable(s), $l=\{\}$, $C, P, R, M, TP$, where {}

[4] $\Pr\left(s_t^y=j \middle| s_{t-1}^y=k\right)=p_{jk}^y,\ i,k=1,2,\ldots,h^y,$ for $y=\{c,v\}$.

**Table 1**

**MS-VAR ESTIMATION RESULTS**

| *Model specification* | *Posterior density* |
|---|---|
| 2c3v | −1,961.13 |
| 2cRM3v | −1,986.39 |
| 2cT P RM3v | −1,996.48 |
| 2cRM C3v | −2,008.31 |
| 1c3v | −2,014.16 |
| 2cT P3v | −2,039.96 |
| 3c3v | −2,052.12 |
| 2cT P CP3v | −2,066.24 |
| 2cT P C3v | −2,071.41 |
| 2cT P R3v | −2,074.19 |
| 2c2v | −2,087.19 |
| 1c2v | −2,091.26 |
| 2c1v | −2,116.98 |
| 1c1v | −2,134.26 |

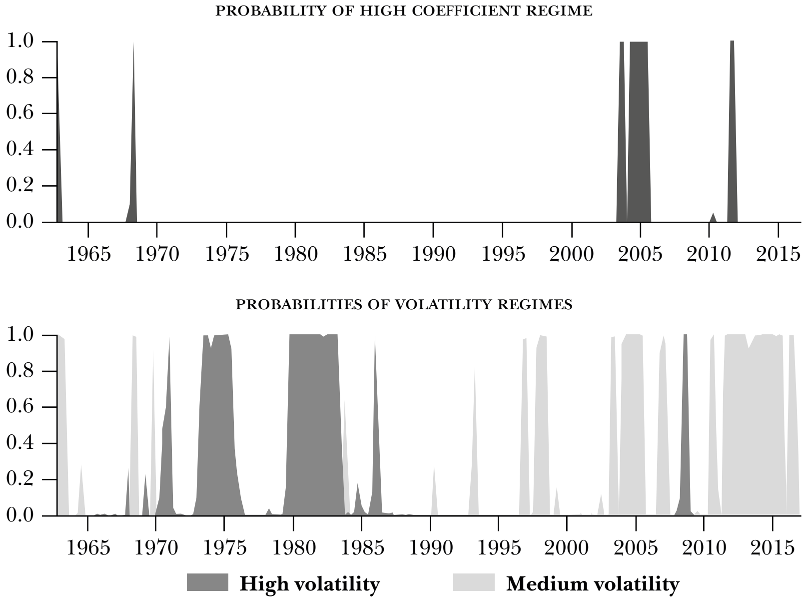
Note: Posterior modes are in logarithms for the estimated models.

represents a null entry where parameters are allowed to change in all equations. Then, a model labeled as $1c1v$ corresponds to the time-invariant Gaussian VAR model, while $2c1v$ has two regimes for the coefficients with variations in all the equations and one regime for the variances, and $2cTPR3v$ has two regimes for the coefficients restricted to the term premium and interest rate equations and three regimes for the variances.

Table 1 displays the posterior mode for each specification of the model. The models are ordered according to the goodness-of-fit criteria at the mode. Two results are worth noting: First, all the specifications allowing for regime switch are preferred to the constant model version, $1c1v$; second, the model with the best performance is $2c3v$, which allows for two-states in the Markov chain that controls the parameters in coefficients and intercepts simultaneously in all the equations of the system and three-states in the Markov chains

**Figure 2**

**SMOOTHED PROBABILITIES OF MS-VAR COEFFICIENTS AND VARIANCES REGIMES**




Note: The top panel reports the probability of a high-stress coefficient regime. The second panel reports the probabilities for the medium- and high-stress regimes.

that control variances; this result is similar to the selected specification in the estimation reported by Hubrich and Tetlow (2015) using the financial stress index for monthly data running from 1988M12 to 2011M12.

### *2.2.2 Probabilities of Switching Coefficients and Variance States*

Figure 2 displays the smoothed probabilities at the posterior mode for the high stress coefficient and the high and medium stress variance for the $2c3v$ MS-VAR model, which is the one with the best fit to the data.

The MS-VAR estimation identifies 12 quarters (5.5% of the MS-VAR sample that runs from 1962Q4 to 2017Q1) with a large probability of being in a high-stress coefficient state and the remaining 206 quarters (94.5%) of a low-stress coefficient state. Meanwhile, regarding variance switching the estimation identifies 32 quarters (14.7%) of high probability of being in a high-stress variance state, 49 quarters (22.5%) of medium-stress variance state and 137 quarters (62.8%) of low-stress variance state. We reserve the historical narrative of the regime switching in coefficients and variances to subsection 5.4 when we analyze the regime switches of the DSGE models.

### *2.2.3 MS-VAR Impulse Response Functions*

Figure 3 displays the impulse response functions for the $2c3v$ MS-VAR model, which is the one with the best fit to the data. There we see that the varying coefficients and the varying volatilities generate different responses for any given variable. The important differences in magnitude and persistence for the high (reds) versus low (blues) coefficient regimes, which yields a distorting scale in some responses, are notable. Also, there are significant differences in the responses when comparing the high (darker color), medium and low variance regimes. For example, for a term premium shock, a high coefficient regime has a transitory effect on term premiums, a sharp drop in consumption growth and raising interest rates, which contrast with the low coefficient regime where the effect on term premium lasts longer, and there is no contraction in consumption growth, neither changes in interest rates. Another example is the behavior of the variables to an interest rate shock, where under the high coefficient regime, the term premium raises sharply, and consumption growth declines, with the exception when the high coefficient regime intersects with the low variance regime (which only occurred in 2003Q4) where some of the dynamics are closer to the low coefficient regime.

Our estimations are consistent with empirical econometric approaches that model the role of financial frictions as a source of shock amplification allowing for Markov-switching dynamics using VAR models for the US economy (see Davig and Hakkio, 2010; and Hubrich and Tetlow, 2015). Guided by the evidence in this MS-VAR of varying coefficients and variances, we now move to a MS-DSGE model with macrofinancial linkages to analyze potential mechanisms.

## 3. MS-DSGE MODEL

Although the less restrictive MS-VAR econometric approach allows us to identify regime switches, it does not allow us to give an economic interpretation to the changes in parameters and variances. We will explore the possibility that the observed regime changes are related to shifts in financial conditions through changes in financial frictions and the volatility of credit market shocks. To do so, we use the model proposed by Carlstrom et al. (2017), and allow for two coefficient regimes associated to financial frictions and three variance regimes ordered by the volatility of credit market shocks. In addition, to analyze if monetary policy responded to those financial conditions, we allow for two independent regime shifts of a term premium-augmented monetary policy interest rate reaction function. Using the model, we will identify how financial frictions, credit market shock volatilities, and monetary policy have evolved in the US since 1962. The estimated model will provide us with a consistent framework to perform counterfactual analysis of what could have happened under alternative financial conditions, credit shock variances and monetary policy responses.

### 3.1 Model

This section presents the key elements of the DSGE model in Carlstrom et al. (2017) with our Markov-switching modification in the parameters that capture financial frictions, monetary policy responses and stochastic volatility of all the shocks in the model. Potential regime changes in financial frictions are captured by changes in the parameter associated with financial intermediaries' portfolio adjustment costs, $\psi_n$ , which is also related to the financial intermediaries (FIs) holdup problem. We use a state variable, $\xi_t^{ff}$ , to distinguish the level of financial friction regime at time *t*. Meanwhile, for regime changes in the monetary policy's response to the term premium, we use a state variable, $\xi_t^{mp}$ , to differentiate among elasticities of short-term interest rates to the term premium $\tau_{tp}$ regime at time *t*. Concurrently, to allow for regime changes in the stochastic volatilities we model a third independent Markov-switching process and use a state variable $\xi_t^{vol}$ to distinguish the volatility regime at time *t*.

The economy consists of households, financial intermediaries, and government agencies. Many of the ingredients are standard with

## Figure 3

**IMPULSE RESPONSE FUNCTIONS FOR THE FIVE EQUATIONS OF THE 2C3V MS-VAR**

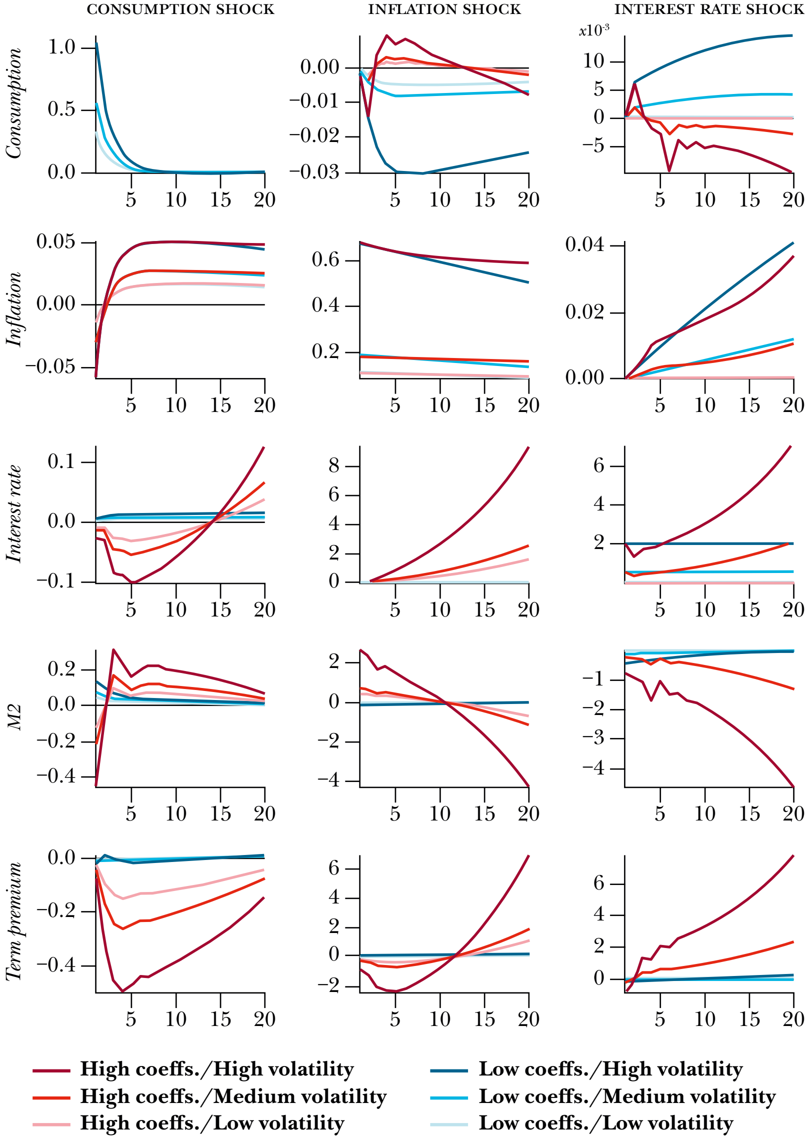
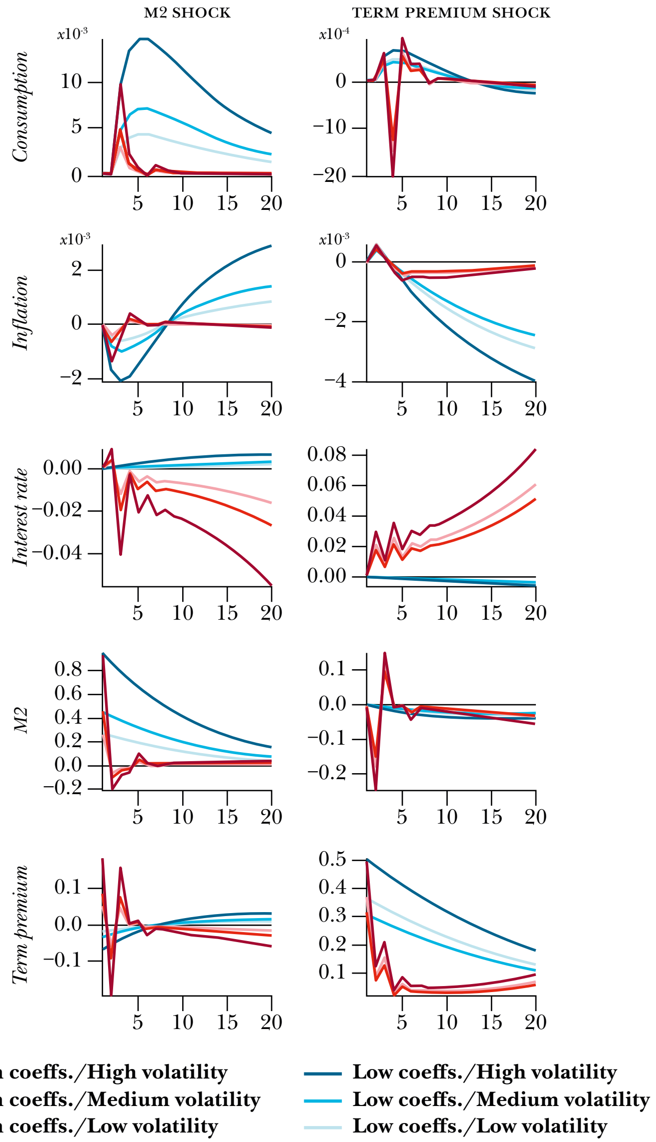


**Figure 3 (Cont.)**

**IMPULSE RESPONSE FUNCTIONS FOR THE FIVE EQUATIONS OF THE 2C3V MS-VAR**




Note: High coefficient regimes are presented in red colors, while low coefficient regimes are shown in blue colors. The darker the color of the line, the greater the variance volatility regime.

the chief novelty coming from their assumptions on household-FI interactions. Specifically, households do not have access to long-term debt markets, while FI do, creating a credit market segmentation. Households face a loan-in-advance constraint to finance investment which gives market segmentation a relevant role for real allocations. FIs have a hold-up problem as they can default on depositors who could only recover a fraction $(1-\Psi_t)$ of the FI's assets, where $\Psi_t$ is a decreasing function of FI's net worth, creating a financial-accelerator type of mechanism. FIs face portfolio adjustment costs which limits its ability to respond to changes in the government's relative supply of long-term debt having effects on lending and investment, as net worth and deposits cannot quickly sterilize central bank long-term debt purchases. Finally, the central bank interest rate reaction function is augmented with a potential response to the term-premium. These are the key elements of the macro-financial-monetary policy nexus of the model highlighted here.

In Carlstrom et al. (2017), the reader can find the other elements of the model as the description of households' supply of monopolistically specialized labor as in Erceg et al. (2000), which serves to introduce wage rigidities and wage markup shocks. Also, there is the description of the perfectly competitive final good producer problem which yields the aggregation of a continuum of intermediate goods for aggregate supply. The monopolistic competitive intermediate goods producers' problem is introduced as in Yun (1996). These firms are also used to introduce neutral technology shocks and price rigidities and price markup shocks. The new capital producers' problem which transforms investment goods into new capital goods through an investment adjustment costs and introduces an investment-specific technology shock.

### *3.1.1 Households*

Each household chooses consumption, $C_t$; labor supply, $H_t$; short-term deposits in the FI, $D_t$; investment bonds, $F_t$; investment, $I_t$; and next-period physical capital $K_{t+1}$ to maximize the optimization problem given by:

$$\max_{C_t,H_t,D_t,F_t,I_t,K_{t+1}} E_0 \sum_{s=0}^{\infty} \beta^s e^{rn_{t+s}} \left\{ \ln\left(C_{t+s} - hC_{t+s-1}\right) - L\frac{H_{t+s}^{1+\eta}}{1+\eta} \right\}, \quad (2)$$

subject to:

$$C_t + \frac{D_t}{P_t} + P_t^k I_t + \frac{F_{t-1}}{P_t} \leq W_t H_t + R_t^k K_t - T_t + \frac{D_{t-1}}{P_t} R_{t-1} + \frac{Q_t(F_t - \kappa F_{t-1})}{P_t} + div_t, \tag{3}$$

$$K_{t+1} \leq (1-\delta) K_t + I_t, \tag{4}$$

$$P_t^k I_t \leq \frac{Q_t(F_t - \kappa F_{t-1})}{P_t} = \frac{Q_t CI_t}{P_t}. \tag{5}$$

Before defining the variables and parameters, it is important to highlight that households do not have access to long-term bonds, while FIs do, creating a market segmentation. Also, very important for the macrofinancial nexus, Equation 5 is a loan-in-advance constraint through which all investment purchases must be financed by issuing *investment bonds*, $F_t$, that are purchased by the FI. The endogenous behavior of the distortion related to the Lagrange multiplier of the loan-in-advance constraint is fundamental for the real effects arising from market segmentation.

In this optimization, $h \in (0, 1)$ is the degree of habit formation, $\beta^t \in (0, 1)$ is the discount factor which has intertemporal preferences shocks, $e^{rn}$, which follows the stochastic process $rn_t = \rho_{rn} rn_{t-1} + \sigma_{rn,\xi_t^{vol}} \varepsilon_{rn,t}$, where $\sigma_{rn,\xi_t^{vol}}$ is the standard deviation of the stochastic volatility of the intertemporal preferences $\varepsilon_{rn,t} \sim \text{iid } N(0, \sigma_{rn}^2)$, whose $\xi_t^{vol}$ subscript denotes that it is allowed to change across regimes at time $t$. We follow the same convention in the notation for each shock. Aside from this switching volatility, the household problem does not have switching coefficients.

Equation 3 tells us that households sources of income are labor supply with real wage $W_t$; capital rents at a real rate $R_t^k$; previous period deposit holdings with gross nominal interest rate $R_{t-1}$; new issues of perpetuities of investment bonds $CI_t = F_t - \kappa F_{t-1}$ with price $Q_t$; and dividend flow from the FIs $div_t$. Households use their resources to pay lump-sum taxes $T_t$, consume, deposit at FIs, buy investment goods with a real price of capital $P_t^k$ and pay for outstanding investment bonds. $P_t$ is the price level. Meanwhile, Equation 4 is the standard capital accumulation equation with depreciation rate $\delta$ and, as already mentioned, Equation 5 is the loan-in-advance constraint for investment purchases.

*3.1.2 Financial Intermediaries*

Financial intermediaries choose net worth, $N_t$, and dividends to maximize its value function, $V_t$, to solve the optimization problem given by:

$$V_t = \max_{N_t, div_t} E_t \sum_{j=0}^{\infty} (\beta\zeta)^j \Lambda_{t+j} div_{t+j}, \tag{6}$$

subject to the resource constraint:

$$div_t + N_t\left[1 + f(N_t)\right] \leq \frac{P_{t-1}}{P_t}\left[\left(R_t^L - R_{t-1}^d\right)L_{t-1} + R_{t-1}^d\right]N_{t-1} \tag{7}$$

and the incentive compatibility constraint that ensures that the FI repays deposits, given that depositors can seize at most a fraction $(1-\Psi_t)$ of the FI's assets:

$$E_t V_{t+1} \geq \Psi_t E_t R_{t+1}^L \left(\frac{D_t}{P_t} + N_t\right), \tag{8}$$

where $\zeta \in (0, 1)$ is an additional impatience rate to prevent that the short-term and long-term market segmentation vanishes through the *excessive* accumulation of net worth, $\Lambda_t$ is the household's marginal utility of consumption.

Regarding the resource constraint, FIs uses accumulated net worth, $N_t$, and short-term liabilities, $D_t$, to finance investment bonds, $F_t$, and the long-term bonds $B_t$. The FI's balance sheet is thus given by $\frac{B_t}{P_t}Q_t + \frac{F_t}{P_t}Q_t = \frac{D_t}{P_t} + N_t = L_t N_t$ where $Q_t$ is the price of a new-debt issue at time $t$ and where $R_t^L \equiv \left(\frac{1+\kappa Q_t}{Q_{t-1}}\right)$ is the return on lending, $R_t^d$ is the interest rate on deposits. On the left-hand side of Equation 7, those profits are used to distribute dividends and accumulate net worth which has an adjustment cost function $f(N_t) \equiv \frac{\Psi_{n,\xi_t^{ff}}}{2}\left(\frac{N_t - N_{ss}}{N_{ss}}\right)^2$ that dampens the ability of the FI to adjust the size of its portfolio in response to shocks. The $\xi^{ff}$ subscript indicates that this financial market segmentation parameter, which is related to financial frictions, is allowed to change across regimes at time *t*.

Assuming that $\Psi_t \equiv \Phi_t\left[1 + \frac{1}{N_t}\left(\frac{E_t g_{t+1}}{E_t X_{t+1}}\right)\right]$, is a function of net worth in a symmetric manner with $f(N_t)$, the binding incentive constraint 8, which yields leverage as a function of aggregate variables but independent of each FI's net worth, is given by

$$E_t \frac{P_t}{P_{t+1}} \Lambda_{t+1}\left[\left(\frac{R^L_{t+1}}{R^d_t} - 1\right)L_t + 1\right] = \Phi_t L_t E_t \Lambda_{t+1} \frac{P_t}{P_{t+1}} \frac{R^L_{t+1}}{R^d_t}. \tag{9}$$

Then, the FI's optimal accumulation decision is given by

$$\Lambda_t\left[1 + N_t f'(N_t) + f(N_t)\right] = E_t \beta\zeta\Lambda_{t+1} \frac{P_t}{P_{t+1}}\left[\left(R^L_{t+1} - R^d_t\right)L_t + R^d_t\right], \tag{10}$$

where $\Phi_t \equiv e^{\phi t}$ is a credit shock that in logarithms follows an AR(1) process:

$$\phi_t = (1 - \rho_\phi)\phi_{ss} + \rho_\phi \phi_{t-1} + \sigma_{\phi,\xi_t^{vol}} \varepsilon_{\phi,t}, \tag{11}$$

where $\sigma_{\phi,\xi_t^{vol}}$ is the standard deviation of the stochastic volatility of the credit shock, $\varepsilon_{\phi,t} \sim \text{iid } N\left(0, \sigma^2_\phi\right)$, whose $\xi_t^{vol}$ subscript denotes that it is allowed to change across regimes at time *t*. When we allow for regime switching in volatilities, regimes will be classified by the magnitude of this shock.

Increases in $\phi_t$ will exacerbate the hold-up problem, and act as *credit shocks*, which will increase the spread and lower real activity.

### *3.1.3 The Effect of Financial Friction*

To gain further intuition of the financial frictions, first log-linearize the FI incentive compatibility constraint (equation 9) and the FI optimal net worth accumulation decision (equation 10) to get

12 $$E_t\left(r_{t+1}^L - r_t\right) = \upsilon l_t + \left[\frac{1+(s-1)L_{ss}}{L_{ss}-1}\right]\phi_t$$

and

13 $$\psi_{n,\xi_t^{ff}} n_t = \left[\frac{sL_{ss}}{1+L_{ss}\left(s-1\right)}\right]E_t\left(r_{t+1}^L - r_t\right) + \left[\frac{\left(s-1\right)L_{ss}}{1+L_{ss}\left(s-1\right)},\right]l_t$$

where $\upsilon \equiv \left(L_{ss} - 1\right)^{-1}$ is the elasticity of the interest rate spread to leverage; $s$ denotes the gross steady-state premium. Equation 12 is quantitatively identical to the corresponding relation in the more complex costly state verification environment of Bernanke et al. (1999). Combining 10 and 11, we get the following expression:

14 $$E_t\left(r_{t+1}^L - r_t\right) = \frac{1}{L_{ss}}\psi_{n,\xi_t^{ff}} n_t + \left(s-1\right)\phi_t.$$

This expression shows the importance of $\psi_{n,\xi_t^{ff}}$ for the supply of credit. If $\psi_{n,\xi_t^{ff}} = 0,$ the supply of credit is perfectly elastic, independent of the financial intermediaries' net worth. $\psi_{n,\xi_t^{ff}}$ becomes larger, the financial friction becomes more intense, and the supply of credit depends positively on the financial intermediaries' net worth.

### *3.1.4 Fiscal Policy*

Fiscal policy is entirely passive. Government expenditures are set to zero. Lump-sum taxes move endogenously to support the interest payments on the short- and long-term debt.

### *3.1.5 Debt Market Policy*

We consider a policy regime of exogenous debt. Long-term debt is assumed to follow

$$b_t = \rho_1^b b_{t-1} + \rho_2^b b_{t-2} + \epsilon_{b,t}, \tag{15}$$

where $b_t \equiv \ln\left(\frac{\bar{B}_t}{\bar{B}_{ss}}\right)$ and could fluctuate due to long bond purchases (QE) or changes in the mix of short debt to long debt in its maturity. An AR(2) process is included to be consistent with the QE policy and denote the persistence of the monetary policy shock.

*3.1.6 Central Bank Policy*

We assume that the central bank follows a term premium ($tp_t$) augmented Taylor rule over the short rate (T-bills and deposits):

$$\begin{aligned}\ln(R_t) = \rho_{R,\xi_t^{mp}} \ln(R_{t-1}) + (1+\rho_{R,\xi_t^{mp}})\big(\tau_{\pi,\xi_t^{mp}}\Pi_t + {}_{y,\xi_t^{mp}} y_t^{gap} \\ + \tau_{tp,\xi_t^{mp}} tp_t\big) + \sigma_{r,\xi_t^{vol}}\epsilon_{r,t},\end{aligned} \tag{16}$$

where $y_t^{gap} \equiv \left(Y_t - Y_t^f\right)/Y_t^f$ denotes the deviation of output from its flexible price counterpart, $\pi_t$ is CPI inflation rate, and $\epsilon_{r,t}$ is an exogenous and autocorrelated policy shock with AR(1) coefficient $\rho_m$. The coefficient $\rho_{R,\xi_t^{mp}}$ captures the degree of persistence of the interest rate, and the parameters $\tau_{\pi,\xi_t^{mp}}$, $\tau_{y,\xi_t^{mp}}$, and $\tau_{tp,\xi_t^{mp}}$, capture the elasticity of the interest rate to inflation, output gap, and term premium, respectively. $\xi_t^{mp}$ indicates that these parameters can change across regime at time $t$. We will order regimes according to the relative response to the term premium.

The term premium is defined as the difference between the observed yield on a ten-year bond and the corresponding yield implied by applying the expectation hypothesis of the term structure to the series of short rates.

# 4. SOLUTION AND ESTIMATION OF THE MS-DSGE MODEL

## 4.1 MS-DSGE Model Solution Methods

Given that the traditional stability concepts for constant DSGE models does not hold for the Markov-switching case, to solve the linear version of the model we use the solution method proposed by Maih (2015),[5] which uses the minimum state variable[6] concept to present the solution of the system in the following form:

$$X_t\left(s_t,s_{t-1}\right)=T\left(\xi_t^{sp},\theta^{sp}\right)X_{t-1}\left(s_{t-1},s_{t-2}\right)+R\left(\xi_t^{vol},\theta^{sp}\right)\varepsilon_t, \tag{17}$$

where $T$ and $R$ matrices contain the model's parameters. $X_t$ stands for the $(n\times 1)$ vector of endogenous variables, $\varepsilon_t$ is the $(k\times 1)$ vector of exogenous processes.

As mentioned in the previous section, we introduce the possibility of regime change for two structural parameters (*sp*) and to shock volatilities(*vol*) through three independent Markov chains: $\xi_t^{ff}$, $\xi_t^{mp}$, and $\xi_t^{vol}$, respectively. The three chains denote the unobserved regimes associated with the market segmentation, $\psi_{n,\xi_t^{ff}}$, monetary policy response to the term premium, $\tau_{tp,\xi_t^{mp}}$, and volatilities. These processes are subject to regime shifts and take on discrete values $i\in\{1,\ 2\}$, while regime one implies high absolute values for parameters of market segmentation, the monetary policy response to the term premium and volatilities, and the opposite is true for low parameters.[7]

The three Markov chains are assumed to follow a first-order process with the following transition matrices, respectively:

$$H^i=\begin{pmatrix} H_{12} & H_{12} \\ H_{21} & H_{22} \end{pmatrix} \text{ for } i=ff,\ mp,\ vol, \tag{18}$$

---

5 Based in perturbation methods as the approach presented by Barthélemy and Marx (2011) and Foerster et al. (2014).

6 See McCallum (1983).

7 The identification for each regime will be described in detail in subsection 4.4.

where $H_{ij} = p\left(sp_t = j \middle| sp_{t-1} = i\right)$, for $i, j = 1, 2$. Then, $H_{ij}$ stands for the probability of being in regime $j$ at $t$ given that one was in regime $i$ at $t-1$.

Various authors have focused on the concept of mean square stability solutions[8] for 17. As is emphasized by Maih (2015) and Foerster (2016), this condition implies finite first and second moments in expectations for the system:

19
$$\lim_{j\to\infty} \mathbb{E}_t\left[X_{t+j}\right] = \bar{x},$$

20
$$\lim_{j\to\infty} \mathbb{E}_t\left[X_{t+j}X'_{t+j}\right] = \Sigma.$$

Additionally, as pointed by Costa et al. (2006) and Foerster (2016), the solution of the system 17 given that the matrix $T(\xi^{sp}, \theta^{sp}, H)$ does not satisfy the standard stability condition, a necessary and sufficient condition of mean square stability implies that all the eigenvalues of the matrix $\Psi$ are in the unit circle (Alstadheim et al., 2013):

21
$$\Psi = \left(\mathbb{H} \otimes I_{n^2}\right)\begin{bmatrix} T_1T_1 & & \\ & \ddots & \\ & & T_hT_h \end{bmatrix}.$$

Finally, to complete the state form of the model, 17 is combined with the measurement Equation 22:

22
$$Y_t^{obs} = MX_t,$$

where $Y_t^{obs}$ are the observables.

## 4.2 MS-DSGE Model Estimation Methods

The standard Kalman filter cannot be used to compute the likelihood, because of the presence of unobserved states of the Markov

[8] See Costa et al. (2006); Cho (2014); Foerster et al. (2014); and Maih (2015).

chains, the filtering inferences must be conditioned on information of the current and past state of the system, $s_t$ and $s_{t-1}$, respectively. If the filter considers all the possible paths of the system, in each iteration, these will be multiplied by the number of possible regimes, $h$. In a few number of steps, the number of paths of the systems would increase making the computation of the problem infeasible as pointed by Alstadheim et al. (2013). To make treatable this problem, Kim and Nelson (1999) propose an approximation that averages across states.[9] Following the approach outlined in Alstadheim et al. (2013) and Bjørnland et al. (2018), an averaging operation (collapse) is applied during the filtering procedure. This form of calculation has computational savings and similar numeric results to the Kim-Nelson approach (Kim and Nelson, 1999; Bjørnland et al., 2018).

This paper uses the Bayesian approach to estimate the model with the following procedure:

*1)* We compute the solution of the system using an algorithm found in Maih (2015) and employing a modified version of the Kim and Nelson (1999) filter to compute the likelihood with the prior distribution of the parameters.

*2)* Construct the posterior kernel result from stochastic search optimization routines.[10]

*3)* We use the mode of the posterior distribution as the initial value for a Metropolis-Hasting algorithm,[11] with 500,000 iterations, to construct the full posterior distribution.

*4)* Utilizing mean and variance of the last 100,000 iterations, we compute moments.

9 This algorithm involves running the Kalman-filter for each of the paths and taking a weighted average using the weights given by the probability assigned to each path from the filter proposed in Hamilton (1989).

10 Provided in the RISE toolbox.

11 With an acceptance ratio of $\alpha = 0.28$.

| Table 2 | |
|---|---|
| **CALIBRATED PARAMETERS** | |
| *Parameter* | *Value* |
| $\beta$ | 0.99 |
| $\alpha$ | 0.33 |
| $\delta$ | 0.025 |
| $\rho_{r_t^{10}}$ | 0.85 |
| $\epsilon_p = \epsilon_w$ | 5 |
| $L_{ss}$ | 6 |
| s | 0.01 |
| $R^L_{ss}$ | $1/\beta$ |
| $(1-\kappa)^{-1}$ | 40 |

## 4.3 Database

We use US data from 1962Q1 to 2017Q3 for the estimation of the model. The database takes the original series reported in Carlstrom et al. (2017) but extend the sample from 2008Q4 to 2017Q3.

Quarterly series were selected for the annualized growth rates of real GDP, real gross private domestic investment, real wages, inflation rate–personal consumption expenditure index–and real wages.[12] The labor input series was constructed substituting the trend component from the nonfarm business sector (hours of all persons) series. The series for the federal funds rate is obtained averaging monthly figures downloaded from the Federal Reserve Bank of St. Louis's website. Additionally, for the term premium, we take the Treasury term premia series from the Federal Reserve Bank of New York's website, estimated by Adrian et al. (2013). All data are demeaned.

[12] Defined as nominal compensation in the nonfarm business sector divided by the consumption deflator.

### 4.4 Prior Specification

Following Carlstrom et al. (2017), we calibrate several parameters to match the long-run features of the US data, which are reported in Table 2. Regarding the nonswitching block of parameters in the model, following Bjørnland et al. (2018), rather than setting means and standard deviations for the prior densities, these are set using quantiles of the distributions. Specifically, we use 90% probability intervals of the respective distribution to uncover the underlying hyperparameters, based on the results reported by Carlstrom et al. (2017). The choice of prior distributions for the constant and switching parameters are displayed in the right panel of Tables 3 and 4, respectively.

For identification purposes, we characterized the high financial market segmentation regime, $\xi_t^{ff} = 1$, to be a regime where credit market present high portfolio adjustment cost (that is, $\psi_{n,\xi_t^{ff}=1} > \psi_{n,\xi_t^{ff}=2}$). Meanwhile, for regime changes in the monetary policy's response to term premium, we define, $\xi_t^{mp} = 1$, to be the regime where the central bank responds strongly to changes in this variable (that is, $\left|\tau_{tp,\xi_t^{mp}=1}\right| > \left|\tau_{tp,\xi_t^{mp}=2}\right|$). The model also allows for regime switching in all the shocks; thus we let the volatility shocks to follow an independent three-state Markov-process. Then, we indicate the high, medium and low volatility regimes, $\xi_t^{vol} = 1$, $\xi_t^{vol} = 2$, and $\xi_t^{vol} = 3$, respectively, which implies the following nonlinear restriction: $\sigma_{\phi,\xi_t^{vol}=1} > \sigma_{\phi,\xi_t^{vol}=2} > \sigma_{\phi,\xi_t^{vol}=3}$.

## 5. MS-DSGE ESTIMATION RESULTS

### 5.1 Parameter Estimation

In this section, we report the posterior parameter estimates. The Bayesian estimation uses the posterior mode as initial value. Table 3 reports the estimates of the constant parameters, while Table 4 reports the estimates of the switching parameters, shocks standard deviations, and elements of the transition matrices. We focus our discussion on the results of the switching elements.

The first thing to notice is that there are big differences in the parameter that characterizes the financial frictions related to the financial intermediaries' hold-up problem. Remember that if $\psi_n = 0$, the supply of credit is perfectly elastic, independent of the financial

## Table 3

**POSTERIOR MEANS, MODES, AND PROBABILITY INTERVALS, AND PRIOR PROBABILITY INTERVALS OF THE CONSTANT-BLOCK PARAMETERS**

| | | *Posterior* | | | | *Prior* | |
|---|---|---|---|---|---|---|---|
| *Parameter* | *Density* | *Mean* | *Mode* | *10%* | *90%* | *10%* | *90%* |
| $\eta$ | Gamma | 1.4324 | 1.4633 | 1.1024 | 1.7624 | 1.2673 | 2.7526 |
| $h$ | Beta | 0.6890 | 0.7014 | 0.6367 | 0.7412 | 0.5760 | 0.6687 |
| $\psi_i$ | Gamma | 3.4380 | 3.2967 | 2.9914 | 3.8846 | 2.1857 | 4.3639 |
| $\iota_p$ | Beta | 0.4118 | 0.4201 | 0.2103 | 0.6133 | 0.2752 | 0.5610 |
| $\iota_w$ | Beta | 0.5109 | 0.5157 | 0.3987 | 0.6231 | 0.4085 | 0.6205 |
| $\kappa_{pc}$ | Beta | 0.1000 | 0.0966 | 0.0014 | 0.1986 | 0.0104 | 0.1544 |
| $\kappa_w$ | Beta | 0.0057 | 0.0054 | 0.0020 | 0.0093 | 0.0001 | 0.0004 |
| $\rho_a$ | Beta | 0.9659 | 0.9412 | 0.9421 | 0.9898 | 0.9841 | 0.9997 |
| $\rho_\mu$ | Beta | 0.8483 | 0.8364 | 0.7853 | 0.9112 | 0.8281 | 0.9122 |
| $\rho_\phi$ | Beta | 0.9919 | 0.9871 | 0.9878 | 0.9960 | 0.9682 | 0.9963 |
| $\rho_{mk}$ | Beta | 0.5312 | 0.5501 | 0.4302 | 0.6322 | 0.4945 | 0.8405 |
| $\rho_w$ | Beta | 0.3798 | 0.3706 | 0.3556 | 0.4039 | 0.1036 | 0.3027 |
| $\rho_m$ | Beta | 0.2240 | 0.2503 | 0.0516 | 0.3963 | 0.0646 | 0.2515 |
| $\rho_{rn}$ | Beta | 0.9126 | 0.9361 | 0.9316 | 0.9936 | 0.9212 | 0.9751 |

### Table 4

**POSTERIOR MEANS, MODES, AND PROBABILITY INTERVALS, AND PRIOR MEANS AND STANDARD DEVIATIONS OF THE SWITCHING-BLOCK PARAMETERS**

Switching parameters, variances, and transition matrices

| | | *Posterior* | | | | *Prior* | |
|---|---|---|---|---|---|---|---|
| *Parameter* | *Density* | *Mean* | *Mode* | *10%* | *90%* | *Mean* | *Standard deviation* |
| $\psi_{n,\xi_t^{ff}=1}$ | Uniform | 1.9778 | 1.9928 | 1.6412 | 2.3143 | 1.00 | 0.50 |
| $\psi_{n,\xi_t^{ff}=2}$ | Uniform | 0.1060 | 0.0870 | 0.0124 | 0.1996 | 1.00 | 0.50 |
| $\tau_{tp,\xi_t^{mp}=1}$ | Normal | −1.1597 | −1.2100 | −1.2280 | −1.0914 | −1.00 | 0.50 |
| $\tau_{tp,\xi_t^{mp}=2}$ | Normal | −0.2395 | −0.3352 | −0.3564 | −0.1226 | −0.50 | 0.50 |
| $\rho_{R,\xi_t^{mp}=1}$ | Beta | 0.6507 | 0.8016 | 0.5401 | 0.7612 | 0.50 | 0.30 |
| $\rho_{R,\xi_t^{mp}=2}$ | Beta | 0.7957 | 0.8016 | 0.7401 | 0.8512 | 0.50 | 0.30 |
| $\tau_{\pi,\xi_t^{mp}=1}$ | Normal | 1.3659 | 1.2864 | 1.2813 | 1.4505 | 1.50 | 0.50 |
| $\tau_{\pi,\xi_t^{mp}=2}$ | Normal | 1.7504 | 1.6697 | 1.6532 | 1.8477 | 1.50 | 0.50 |
| $\tau_{y,\xi_t^{mp}=1}$ | Normal | 0.1330 | 0.1276 | 0.1123 | 0.1538 | 0.50 | 0.30 |
| $\tau_{y,\xi_t^{mp}=2}$ | Normal | 0.0778 | 0.0771 | 0.0635 | 0.0921 | 0.50 | 0.30 |
| $\sigma_{\phi,\xi_t^{vol}=1}$ | Inv. gamma | 7.5666 | 7.5643 | 6.1589 | 8.9712 | 0.50 | 1.00 |
| $\sigma_{\phi,\xi_t^{vol}=2}$ | Inv. gamma | 4.0118 | 4.1237 | 3.1283 | 4.8953 | 0.50 | 1.00 |
| $\sigma_{\phi,\xi_t^{vol}=3}$ | Inv. gamma | 3.8361 | 3.8928 | 3.0082 | 4.6640 | 0.50 | 1.00 |
| $\sigma_{a,\xi_t^{vol}=1}$ | Inv. gamma | 0.7868 | 0.8025 | 0.7581 | 0.8154 | 0.50 | 1.00 |
| $\sigma_{a,\xi_t^{vol}=2}$ | Inv. gamma | 0.6029 | 0.6087 | 0.5664 | 0.6394 | 0.50 | 1.00 |
| $\sigma_{a,\xi_t^{vol}=3}$ | Inv. gamma | 0.4463 | 0.4314 | 0.3733 | 0.5192 | 0.50 | 1.00 |

| | | *Posterior* | | | | *Prior* | |
|---|---|---|---|---|---|---|---|
| *Parameter* | *Density* | *Mean* | *Mode* | *10%* | *90%* | *Mean* | *Standard deviation* |
| $\sigma_{\mu,\xi_t^{vol}=1}$ | Inv. gamma | 7.6323 | 7.6133 | 7.6041 | 7.6604 | 0.50 | 1.00 |
| $\sigma_{\mu,\xi_t^{vol}=2}$ | Inv. gamma | 4.3343 | 4.2359 | 4.0826 | 4.5860 | 0.50 | 1.00 |
| $\sigma_{\mu,\xi_t^{vol}=3}$ | Inv. gamma | 2.1677 | 2.1365 | 2.0281 | 2.3072 | 0.50 | 1.00 |
| $\sigma_{mp,\xi_t^{vol}=1}$ | Inv. gamma | 0.4639 | 0.3254 | 0.2815 | 0.6462 | 0.50 | 1.00 |
| $\sigma_{mp,\xi_t^{vol}=2}$ | Inv. gamma | 0.1371 | 0.1282 | 0.0953 | 0.1789 | 0.50 | 1.00 |
| $\sigma_{mp,\xi_t^{vol}=3}$ | Inv. gamma | 0.1100 | 0.1088 | 0.0944 | 0.1255 | 0.50 | 1.00 |
| $\sigma_{mk,\xi_t^{vol}=1}$ | Inv. gamma | 0.4100 | 0.4068 | 0.3741 | 0.4459 | 0.50 | 1.00 |
| $\sigma_{mk,\xi_t^{vol}=2}$ | Inv. gamma | 0.3119 | 0.3047 | 0.2826 | 0.3411 | 0.50 | 1.00 |
| $\sigma_{mk,\xi_t^{vol}=3}$ | Inv. gamma | 0.2422 | 0.2389 | 0.2217 | 0.2627 | 0.50 | 1.00 |
| $\sigma_{w,\xi_t^{vol}=1}$ | Inv. gamma | 1.1244 | 1.0900 | 1.0818 | 1.1670 | 0.50 | 1.00 |
| $\sigma_{w,\xi_t^{vol}=2}$ | Inv. gamma | 0.5095 | 0.4953 | 0.4862 | 0.5327 | 0.50 | 1.00 |
| $\sigma_{w,\xi_t^{vol}=3}$ | Inv. gamma | 0.4305 | 0.4257 | 0.3989 | 0.4621 | 0.50 | 1.00 |
| $\sigma_{rn,\xi_t^{vol}=1}$ | Inv. gamma | 0.2338 | 0.2223 | 0.2146 | 0.2530 | 0.50 | 1.00 |
| $\sigma_{rn,\xi_t^{vol}=2}$ | Inv. gamma | 0.0838 | 0.0793 | 0.0723 | 0.0953 | 0.50 | 1.00 |
| $\sigma_{rn,\xi_t^{vol}=3}$ | Inv. gamma | 0.0677 | 0.0635 | 0.0559 | 0.0795 | 0.50 | 1.00 |
| $H_{1,2}^{ff}$ | Dirichlet | 0.2072 | 0.2126 | 0.1803 | 0.2341 | 0.05 | 0.03 |
| $H_{2,1}^{ff}$ | Dirichlet | 0.2003 | 0.1974 | 0.1696 | 0.2310 | 0.05 | 0.03 |
| $H_{1,2}^{mp}$ | Dirichlet | 0.0850 | 0.0845 | 0.0719 | 0.0981 | 0.05 | 0.03 |
| $H_{2,1}^{mp}$ | Dirichlet | 0.0374 | 0.0443 | 0.0216 | 0.0532 | 0.05 | 0.03 |

| Parameter | Density | Posterior Mean | Posterior Mode | Posterior 10% | Posterior 90% | Prior Mean | Prior Standard deviation |
|---|---|---|---|---|---|---|---|
| $H_{1,2}^{vol}$ | Dirichlet | 0.0144 | 0.0100 | 0.0053 | 0.0235 | 0.05 | 0.03 |
| $H_{1,3}^{vol}$ | Dirichlet | 0.0697 | 0.0660 | 0.0560 | 0.0833 | 0.05 | 0.03 |
| $H_{2,1}^{vol}$ | Dirichlet | 0.1719 | 0.1801 | 0.1528 | 0.1910 | 0.05 | 0.03 |
| $H_{2,3}^{vol}$ | Dirichlet | 0.1907 | 0.1803 | 0.1697 | 0.2117 | 0.05 | 0.03 |
| $H_{3,1}^{vol}$ | Dirichlet | 0.1728 | 0.1811 | 0.1459 | 0.1996 | 0.05 | 0.03 |
| $H_{3,2}^{vol}$ | Dirichlet | 0.1776 | 0.1816 | 0.1569 | 0.1982 | 0.05 | 0.03 |

Note: The reported priors for Dirichlet distributions correspond to the resultant transition probabilities of the respective hyperparameters combination.

intermediaries' net worth, while as $\psi_n$ becomes larger, the financial friction becomes more intense and the supply of credit depends positively on the financial intermediaries' net worth. As is shown later in Figures 4 and 5, the high financial frictions regime, with $\psi_{n,\xi_t^{ff}=1} = 1.98,$ gives an important role to financial factors into the macroeconomic determination; while the low financial frictions regime, with $\psi_{n,\xi_t^{ff}=2} = 0.11,$ is close to a frictionless case, where financial factors do not determine macroeconomic outcomes. The transition matrix has a relatively high probability of regime switching with a $H_{1,2}^{ff} = 21\%$ probability of moving from high to low financial frictions and $H_{2,1}^{ff} = 20\%$ probability of moving from a low to a high financial frictions regime.

Regarding monetary policy, when it responds strongly to the term premium, $\xi_t^{mp}=1,$ the posterior mean of the policy rule is

$$\ln(R_t) = 0.65\ln(R_{t-1}) + (1-0.65)\left(1.37\pi_t + 0.13y_t^{gap} - 1.16tp_t\right);$$

meanwhile, for the low response regime, $\xi_t^{mp} = 0,$ we have

$$\ln(R_t) = 0.80\ln(R_{t-1}) + (1-0.80)\left(1.75\pi_t + 0.08y_t^{gap} - 0.24tp_t\right).$$

As shown in Figures 4 and 5, the model dynamics are different as the central bank's response to the term premium is more aggressive. The policy rules exhibit important differences across regimes in the persistence of interest rates and the relatively weights on inflation and output gap. The transition matrix has a relatively low probability of regime switching with a $H_{1,2}^{mp} = 9\%$ probability of moving from high to low interest rate response to the term premium and only $H_{2,1}^{mp} = 4\%$ probability of moving from a low to a high interest rate response regime.

The standard deviations of the seven shocks included in the model can change across regimes. High, medium and low volatility regimes are classified by the size of the standard deviation $\sigma_{\phi,\xi_t^{vol}}$ of the credit shocks $\varepsilon_{\phi,t}$. Remember that this shock, by increasing the interest rate spread, lowers real activity. It is noticeable that for the seven shocks the 90% confidence intervals of the high volatility regimes are larger than those of medium volatility regimes, which in turn are larger than those of low volatility regimes.[13] The probabilities of exiting a high volatility regime are $H_{1,2}^{vol} = 1\%$ to medium volatility and $H_{1,3}^{vol} = 7\%$ to low volatility. The probabilities of exiting a medium volatility regime are $H_{2,1}^{vol} = 17\%$ to high volatility and $H_{2,3}^{vol} = 19\%$ to low volatility. Finally, the probabilities of exiting a low volatility regime are $H_{3,1}^{vol} = 17\%$ to high volatility and $H_{3,2}^{vol} = 18\%$ to medium volatility.

## 5.2 Impulse Response Functions

This subsection presents the impulse response functions in response to a one-standard deviation shock to credit, $\sigma_\phi$, and monetary policy, $\sigma_{mp}$. The impulse responses to a one-standard deviation shock to neutral technology, $\sigma_a$, investment-specific, $\sigma_\mu$, price markup, $\sigma_{mk}$, wage markup, $\sigma_w$, and intertemporal preference, $\sigma_{rn}$ are included in the Annex. Each graph has 12 lines which depict the responses under the two alternative financial friction (H Seg. and L

[13] The only exceptions are the 90% confidence intervals for the medium and low volatility regimes for credit and monetary policy shocks, which exhibit some overlap, but the medium volatility means are larger than the low volatility ones.

Seg.), the two monetary policy response to term premium (H T P Resp. and L T P Resp.), and the three-credit-shock volatility (H Vol., M Vol. and L Vol.) regimes. High financial frictions regimes are presented in red-like colors, while low ones are presented in blue-like colors. High monetary policy response regimes are presented in solid lines, while low ones are presented in dashed lines. High volatility regimes have the darkest colors, medium mild tones, and low ones are in the lightest tones.

Figure 4 shows the impulse response functions of selected variables to a one-standard deviation credit shock. An unexpected increase of the credit shock increases the 10-year bond yield and the term premium. Keeping everything else constant, the effect of this shock on the term premium is larger if the economy is in a high financial friction regime (reds) or if the interest rate response to the term premium is low (dashed). The costlier financing causes a drop in investment, with the effect being larger under high financial frictions (reds) or low interest rate response (dashed). Despite the transitory increase in output, it eventually drops with the decline being larger under high financial frictions (reds) and low interest rate response (dashed). Inflation and nominal interest rates increase more under low financial frictions (blues) and high interest rate response (solids). Obviously, the larger the volatility of the shock (darkest), the greater the amplification of the responses.

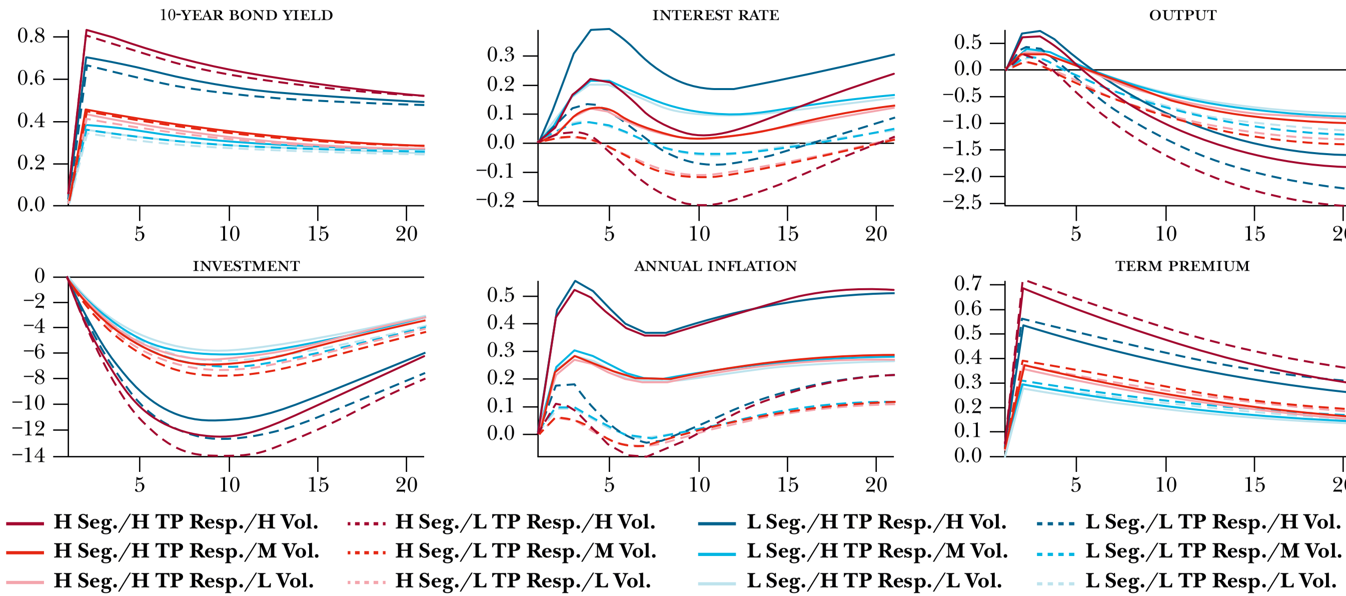
Figure 5 shows the impulse response functions of selected variables to a one-standard deviation monetary policy shock. The unexpected increase lowers investment, output, and inflation, with larger drops when monetary policy has a low term premium interest rate elasticity (dashed). The term premium increase is higher when there are financial frictions (reds) and when interest rate response is low (dashed).

### 5.3 Regime Probabilities

The estimation provides us the probabilities of the high and low financial frictions and monetary policy response to the term premium regimes. Figure 6 shows the smoothed probabilities of each regime. The Bayesian maximum likelihood estimation of the MS-DSGE model identifies 59 quarters (27% of the sample that runs from 1962Q1 to 2017Q4) when financial frictions, measured by the financial intermediaries' portfolio adjustment costs to their net worth, had a

Figure 4

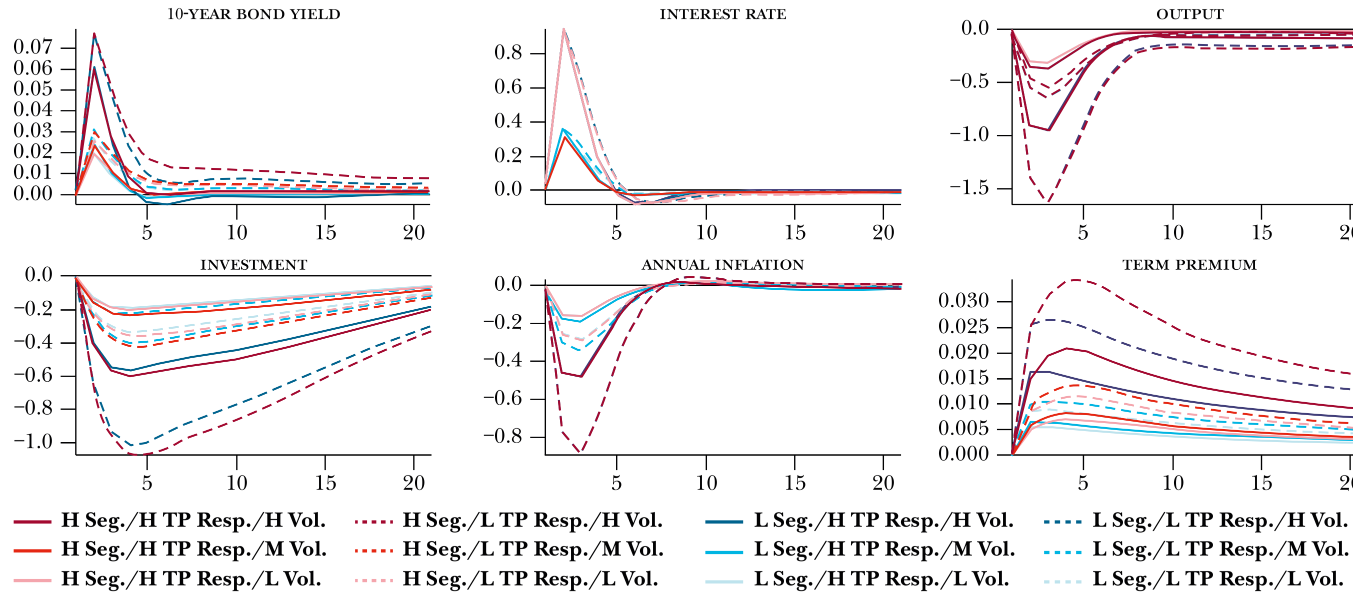
**IMPULSE RESPONSE FUNCTIONS OF THE MS-DSGE MODEL TO A ONE STANDARD DEVIATION CREDIT SHOCK UNDER ALTERNATIVE REGIMES FOR FINANCIAL FRICTIONS, MONETARY POLICY AND VOLATILITY**




Note: High financial frictions regimes are presented in red-like colors, while low ones are presented in blue-like colors. High monetary policy response regimes are presented in solid lines, while low ones are presented in dashed lines. High volatility regimes have the darkest colors, medium mild tones, and low ones are in the lightest tones.

## Figure 5

**IMPULSE RESPONSE FUNCTIONS OF THE MS-DSGE MODEL TO A ONE STANDARD DEVIATION MONETARY POLICY SHOCK UNDER ALTERNATIVE REGIMES FOR FINANCIAL FRICTIONS, MONETARY POLICY AND VOLATILITY: SMOOTHED PROBABILITIES**




Note: High financial frictions regimes are presented in red-like colors, while low ones are presented in blue-like colors. High monetary policy response regimes are presented in solid lines, while low ones are presented in dashed lines. High volatility regimes have the darkest colors, medium mild tones, and low ones are in the lightest tones.

large probability of being high with the following relevant intervals: 1971Q1-1971Q4, 1976Q3-1978Q3, 1983Q4-1985Q4, 1990Q2-1991Q2, 2002Q3-2003Q3, 2006Q1-2008Q1, and 2009Q2-2010Q1. Also, there are 43 quarters when the interest rate response to the term premium is estimated high with the following intervals: 1978Q4-1983Q4, 1990Q2-1993Q4, and 2010Q1-2011Q4. In addition, the MS-DSGE model estimation has 34 quarters of large probability of high credit shock volatility, 46 quarters (20.6%) with large probability of medium credit shock volatility and 142 quarters (64%) with large probability of low credit shock volatility. In subsection 5.4 of counterfactual analysis we provide a historical narrative of the most representative of these regime switching episodes.

Comparing the MS-VAR and MS-DSGE there are 17 quarters (8%) which are at the same time high-stress variance and high credit shock volatility, 24 quarters (11%) that are at the same time medium-stress variance and medium credit shock volatility, and 99 quarters (45%) that are identified both as low-stress variance and low credit shock volatility states. However, from Figure 7 the intersection of the two models yields 43 quarters (20%) that are identified at the same time both either medium or high-stress variance and medium and high credit shock volatility. These quarters are 1971Q1, 1973Q2-1974Q1, 1975Q2 and Q3, 1981Q3-1983Q4, 1993Q2, 1996Q4-1997Q1, 1997Q4-1981Q1, 2003Q3, 2004Q1 and Q2, 2008Q3 and Q4, 2011Q3-2014Q3, 2015Q4, and 2016Q2 and Q3.

In the next subsection we review the most relevant episodes.

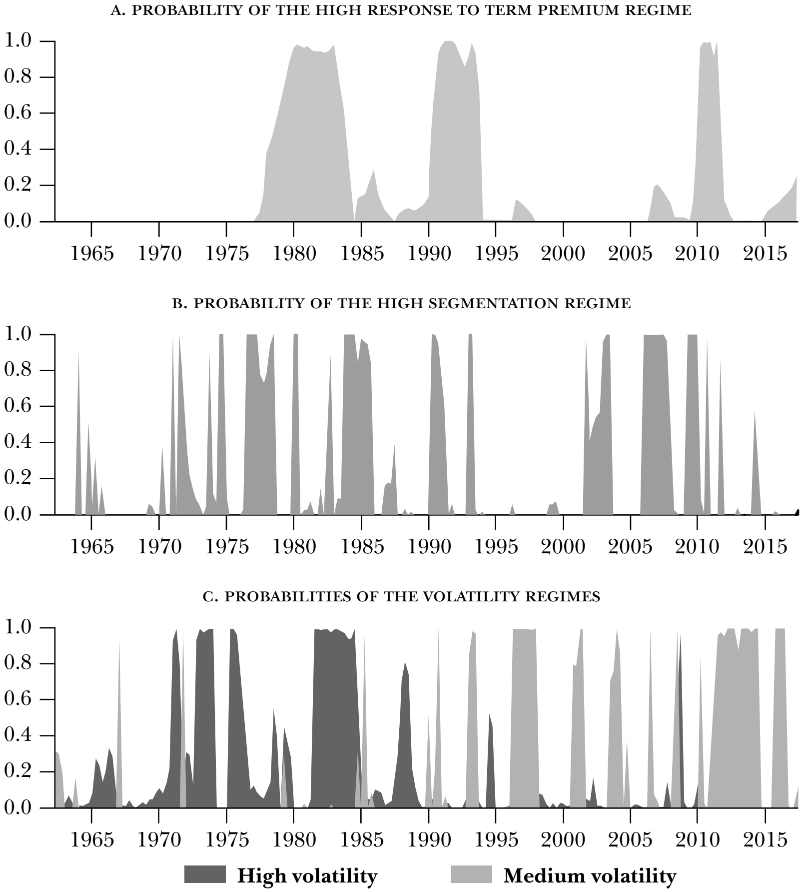
## 5.4 Counterfactual Analysis

To explore the characteristics of the MS-DSGE model with multiple parameters and variances regimes, in this exercise we generate counterfactual series based on conditional forecast simulations. Particularly, this analysis will permit us to have an idea of what could have happened if financial frictions, monetary policy regimes, and volatility regimes would have remained constant, one at a time, in each of six selected episodes.

In what follows, we will examine two blocks of counterfactual simulation exercises when financial frictions and/or financial credit shocks were estimated as high or medium, which are shown chronologically in Figures 8-13. Figures 9, 10, and 13 corresponds to the three episodes in which the monetary policy posture was responsive to the

Figure 6

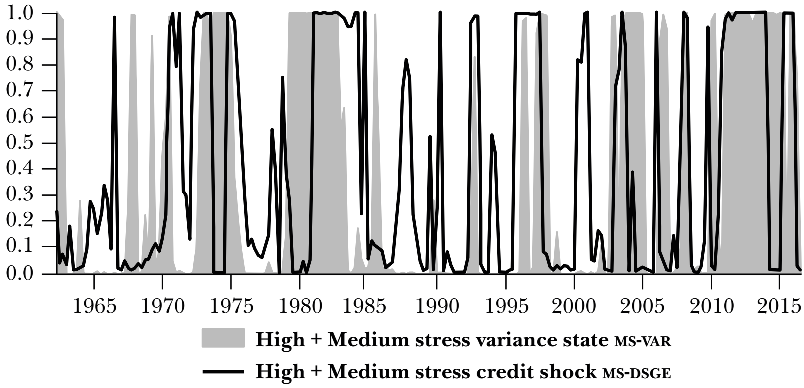
**REGIME PROBABILITIES OF THE MS-DSGE MODEL AT THE POSTERIOR MODE**




Notes: Panel A depicts the probability of the high response to term premium regime; panel B, the probability of the high segmentation regime; and panel C, the probabilities of the high and medium volatility regimes.

## Figure 7

**COMPARISON OF MS-VAR HIGH AND MEDIUM FRICTIONS STATES, AND MS-DSGE HIGH AND MEDIUM CREDIT SHOCK VOLATILITIES**




Note: The gray area reports the probabilities of the high and medium stress regime variance (as a sum) for the MS-VAR model. The black solid line reports the probabilities of the high and medium stress regime variance (as a sum) for the MS-DSGE model.

term premium in the intervals 1978Q4-1983Q4, 1990Q2-1993Q4, and 2010Q1-2011Q4, respectively. Meanwhile, Figures 8, 11, and 12 are three episodes in which the interest rate response to the term premium was low. These episodes correspond to the intervals: 1971Q1-1978Q3, 2000Q4-2004Q4, and 2006Q1-2009Q4, respectively. To complement the evidence, Table 5 reports the mean and standard deviation of each variable, in deviation from steady state, under the alternative counterfactuals for the analyzed episodes.

Counterfactual figures show alternative paths where only one feature of the regime switching can change, while keeping everything else constant. Red lines compare counterfactual according to the degree of financial frictions, red solid lines show the potential evolution of the variables under high credit market segmentation, while red dashed lines report potential evolution for the low financial frictions case. Green lines compare counterfactual according to the monetary policy response to the term premium; green solid lines show the case of high policy response and green dashed lines of low reaction. Blue lines compare counterfactual under different degrees of credit shock volatility, blue solid lines are the hypothetical

**Table 5**

**MEAN AND STANDARD DEVIATION OF VARIABLES BY PERIOD**

| | | | *MP* | | *Segmentation* | | *Volatilities* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Period* | *Variable* | | *High* | *Low* | *High* | *Low* | *High* | *Medium* | *Low* | *Data* |
| 1971Q1–1978Q3 | Term premium | M | 0.23 | 0.14 | 0.02 | 0.22 | −0.07 | −0.14 | 0.02 | 0.06 |
| | | SD | 0.29 | 0.40 | 0.47 | 0.20 | 0.58 | 0.34 | 0.24 | 0.41 |
| | Interest rate | M | 0.85 | 1.29 | 1.43 | 0.58 | 1.78 | 0.93 | 0.71 | 1.28 |
| | | SD | 1.52 | 1.57 | 1.37 | 1.37 | 1.99 | 1.13 | 0.73 | 1.23 |
| | GDP growth | M | 0.23 | 0.37 | 0.05 | 0.37 | 1.45 | −0.01 | 0.49 | 0.24 |
| | | SD | 5.23 | 6.39 | 6.31 | 5.97 | 6.78 | 4.71 | 5.26 | 4.56 |
| | Inflation rate | M | 2.03 | 2.60 | 3.02 | 1.86 | 3.71 | 2.86 | 2.49 | 2.65 |
| | | SD | 2.43 | 2.64 | 2.64 | 2.11 | 3.21 | 2.53 | 1.96 | 2.37 |
| 1978Q4–1983Q4 | Term premium | M | −0.14 | −0.64 | −0.29 | −0.10 | −0.40 | −0.21 | −0.13 | −0.10 |
| | | SD | 0.50 | 0.53 | 0.37 | 0.49 | 0.73 | 0.37 | 0.31 | 0.50 |
| | Interest rate | M | 6.14 | 7.91 | 7.21 | 6.04 | 9.04 | 6.72 | 5.85 | 5.75 |
| | | SD | 1.79 | 2.40 | 1.92 | 2.17 | 2.42 | 2.12 | 2.23 | 2.72 |
| | GDP growth | M | −1.10 | −2.84 | −1.76 | −1.37 | −1.21 | −1.21 | −0.73 | −0.59 |
| | | SD | 5.48 | 4.79 | 5.53 | 6.48 | 7.26 | 4.56 | 3.40 | 5.14 |
| | Inflation rate | M | 4.34 | 5.44 | 3.82 | 4.13 | 5.28 | 4.01 | 2.52 | 3.89 |
| | | SD | 1.82 | 2.41 | 2.96 | 2.75 | 1.99 | 1.65 | 2.45 | 2.32 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990Q2–1993Q4 | Term premium | M | 0.22 | 0.52 | −0.01 | 0.32 | 0.24 | 0.17 | 0.08 | 0.01 |
| | | SD | 0.48 | 0.76 | 0.40 | 0.60 | 0.55 | 0.43 | 0.36 | 0.64 |
| | Interest rate | M | 0.15 | −1.60 | −0.35 | 0.52 | 0.09 | 0.36 | 0.94 | 0.85 |
| | | SD | 1.67 | 2.93 | 2.17 | 1.32 | 2.02 | 1.65 | 1.33 | 2.08 |
| | GDP growth | M | −0.10 | −0.16 | −0.23 | −0.16 | −2.01 | −1.08 | −1.05 | −0.84 |
| | | SD | 2.53 | 5.26 | 3.26 | 4.42 | 4.42 | 2.51 | 3.56 | 2.11 |
| | Inflation rate | M | −0.28 | −1.16 | −1.03 | −0.23 | −1.58 | −0.02 | −0.36 | −0.08 |
| | | SD | 1.32 | 1.78 | 1.71 | 0.86 | 2.46 | 1.13 | 1.28 | 1.21 |
| 2000Q4–2004Q2 | Term premium | M | −0.22 | −0.17 | −0.09 | −0.10 | 0.55 | −0.14 | −0.06 | 0.24 |
| | | SD | 0.39 | 0.37 | 0.32 | 0.26 | 0.73 | 0.33 | 0.45 | 0.50 |
| | Interest rate | M | −1.93 | −2.38 | −2.20 | −1.89 | −4.84 | −1.52 | −1.50 | −1.87 |
| | | SD | 1.42 | 1.75 | 1.53 | 1.28 | 3.30 | 1.33 | 1.92 | 1.95 |
| | GDP growth | M | −1.87 | −1.64 | −1.51 | −1.23 | −1.24 | −0.76 | −0.77 | −0.27 |
| | | SD | 4.85 | 4.23 | 3.29 | 3.41 | 5.94 | 2.88 | 3.33 | 2.47 |
| | Inflation rate | M | −0.54 | −2.32 | −1.85 | −1.43 | −3.03 | −1.01 | −0.10 | −1.35 |
| | | SD | 1.62 | 1.19 | 1.48 | 1.69 | 1.96 | 0.93 | 1.39 | 0.92 |

| | | | *MP* | | *Segmentation* | | *Volatilities* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Period* | *Variable* | | *High* | *Low* | *High* | *Low* | *High* | *Medium* | *Low* | *Data* |
| 2006Q1–2009Q4 | Term premium | M | −0.27 | −0.21 | −0.30 | −0.31 | −0.23 | −0.26 | −0.37 | −0.26 |
| | | SD | 0.40 | 0.55 | 0.62 | 0.55 | 0.75 | 0.56 | 0.41 | 0.62 |
| | Interest rate | M | −0.76 | −2.24 | −1.19 | 0.10 | −0.57 | −1.09 | −1.59 | −2.07 |
| | | SD | 1.59 | 2.03 | 2.84 | 1.27 | 1.52 | 0.78 | 0.90 | 1.71 |
| | GDP growth | M | −3.39 | −2.72 | −2.81 | −1.40 | −2.60 | −1.82 | −1.75 | −2.16 |
| | | SD | 4.23 | 4.57 | 3.50 | 2.11 | 4.47 | 1.65 | 2.60 | 3.28 |
| | Inflation rate | M | −1.18 | −0.73 | −0.99 | −0.33 | −1.44 | −1.14 | −1.22 | −1.14 |
| | | SD | 1.66 | 2.86 | 2.28 | 1.80 | 4.02 | 1.38 | 1.26 | 2.40 |
| 2010Q1–2011Q4 | Term premium | M | 0.40 | 0.88 | 0.49 | 0.40 | 0.42 | 0.52 | 0.43 | 0.55 |
| | | SD | 0.39 | 0.30 | 0.31 | 0.19 | 0.65 | 0.34 | 0.35 | 0.33 |
| | Interest rate | M | −5.53 | −5.70 | −5.16 | −5.03 | −5.73 | −4.99 | −4.93 | −4.98 |
| | | SD | 0.74 | 0.40 | 0.25 | 0.58 | 0.45 | 0.11 | 0.11 | 0.23 |
| | GDP growth | M | −0.97 | −1.49 | −0.38 | 0.69 | −1.34 | −1.29 | −0.08 | −2.70 |
| | | SD | 2.99 | 2.63 | 2.23 | 1.26 | 3.00 | 1.85 | 1.91 | 3.72 |
| | Inflation rate | M | −2.31 | −3.34 | −2.11 | −2.05 | −0.97 | −1.33 | −1.32 | −2.21 |
| | | SD | 0.98 | 1.42 | 1.04 | 1.03 | 1.76 | 0.90 | 0.76 | 2.55 |

Note: This table reports the mean and standard deviation of each variable, in deviation from steady-state, under the alternative counterfactuals for the analyzed episodes.

behavior under high volatility, blue dashed lines report the medium volatility case, and blue dotted lines report a scenario when low credit shock volatility had prevailed during the analyzed period. The solid black line is the data in deviation from steady state. Each figure presents four quarters before the regime switch, and conditions the fifth observation which corresponds to first quarter of the episode, say 1971Q1 or 1978Q4, to be the same and then let the conditional forecasts differ for each case, say high financial frictions while using other estimated transition matrices for monetary policy response and shocks volatility. In our attempt to determinate the role of each specific regime, we isolate the effects of the several sources of regime changes in the model.[14]

Since the start of our sample in 1962Q2 and until 1971Q1, the estimation assigns a high probability to a low credit market segmentation [$\psi_{n,\xi_t^{ff}=2} = 0.11\ (0.01, 0.20)$] and low credit shock volatility [$\sigma_{\phi,\xi_t^{vol}=3} = 3.83\ (3.00, 4.67)$] regime.[15] This despite the 1966 *credit crunch* and the Vietnam War expenses run by the government, the tighter monetary policy in 1967Q3 and 1968Q3, and that according to the NBER's Business Cycles Dating Committee there was an economic contraction from 1969Q4 to 1970Q4. During this period, the estimation assigns a high probability to a low interest rate response to the term premium [$\tau_{tp,\xi_t^{mp}=2} = -0.24\ (-0.36, -0.12)$]. Given that there is scant evidence of regime switching of either financial frictions, financial shocks or monetary policy response during this 1962Q2-1971Q1 period, we do not perform a counterfactual exercise for it.

In contrast, in the 31 quarters running from 1971Q1 to 1978Q3, our estimation identifies 15 quarters with a high probability of credit

[14] Following Sims and Zha (2006) and Bianchi and Ilut (2017), to isolate the effects of changes in the financial frictions mechanisms or monetary policy rules, we remove the credit shocks and monetary policy shocks in the respective simulations. For the counterfactuals that analyze changes in the monetary policy we remove the Taylor rule shock and keep the other sequence of shocks unaltered; while for the counterfactuals that examine the effects of the segmentation changes, we remove the credit shock and keep the other sequence of shocks changeless. For the counterfactuals that simulate the prevalence of the three volatility shocks, all the sequence of shocks remain invariable.

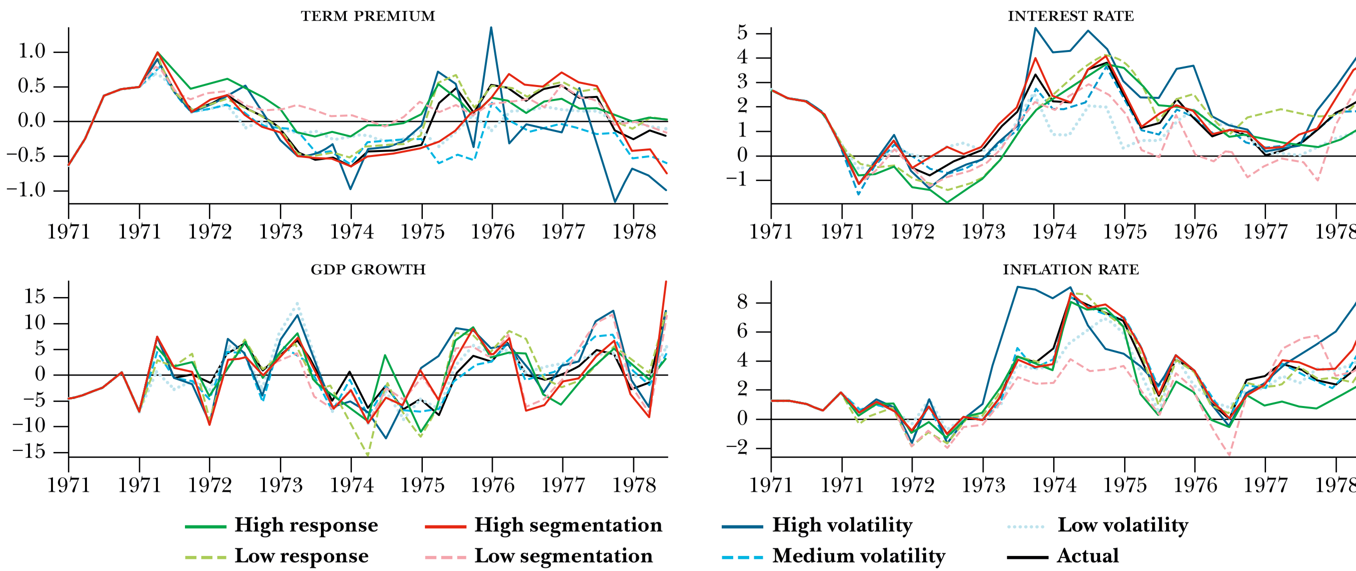
[15] The only exceptions are 1964Q1 and 1964Q4 when there is a high probability of high credit market segmentation, and 1967Q1 when there is a high probability of a medium credit shock variance [$\sigma_{\phi,\xi_t^{vol}=2} = 4.01\ (3.13, 4.90)$].

market segmentation [ $\psi_{n,\xi_t^{ff}=1} = 1.98$ with a 90% probability interval in (1.64, 2.31)] and 14 quarters of high probability of high credit shock variance [ $\sigma_{\phi,\xi_t^{vol}=1} = 7.57 \ (6.16, 8.97)$]. Despite these financial factors, in this whole period, the estimation does not provide evidence of a high interest rate response to the term premium even when the Federal Reserve raised rates in 1971Q3 and 1972Q1 to fight inflation. It is important to keep in mind that during this period, Richard Nixon unilaterally cancelled the international convertibility of the US dollar to gold in 1971Q3; the world economy faced the 1973Q3 oil shock due to the Organization of the Petroleum Exporting Countries' embargo; and the US government ran deficits to pay for the Vietnam war and President Lyndon Johnson's Great Society Programs. Also, according to the NBER's Committee, there was an economic contraction from 1973Q4 to 1975Q1.

Figure 8 shows the first counterfactual exercise focused on this episode when as mentioned there is a high a probability of regime switches related to financial frictions and shocks volatility. In 1971Q1, the term premium was above its steady-state level, interest rates dropped from 8.98% in December 1970 to 3.72% in February 1971, GDP growth was below steady state and inflation was low but above steady state. Comparing the effects of financial frictions, the red solid line of high credit market segmentation partially explains why the term premium dropped sharply, inflation rose, the interest rates increased, and output growth was smaller, relative to the red dashed line of low credit market segmentation where the term premium would have stayed closer to steady state, there would have been a more moderate increase in inflation, interest rates would have increased less, and output growth would have been bigger than the data. Obviously, there were other important domestic and external factors affecting the economy, but these factors would have been present regardless of the level of financial frictions. The opening quote in the paper by Bernanke talks about the dangerous effects of persistent deviations of the term premium from its steady state, here we see that high credit market segmentation caused these deviations to be larger and more persistent. What could have happened if the monetary authority had responded more aggressively to the term premium (solid green versus dashed green lines)? Interest rates would have remained lower during the whole episode, and although inflation would have been slightly higher until 1973Q2, for

## Figure 8

**COUNTERFACTUAL SIMULATION FROM 1971Q1 TO 1978Q3**




Note: For the counterfactuals, the solid green lines show the simulated series for the high response to term premium scenario, while the green dashed lines display the simulated series for the low response to term premium scenario. The solid red lines show the simulated series for the high segmentation scenario, while the dashed red lines display the low segmentation scenario. The solid blue lines report the simulated series for the high volatility scenario, while the dashed blue lines and the dotted blue lines report the simulated series for the medium volatility and low volatility scenarios, respectively. The solid black line shows the observed series.

the remaining of the sample (1973Q3-1978Q3) it would have been on average 1% lower than with a 100% probability of high response and 1.2% lower than the data. The trade-off to this important inflation reduction is that output growth would have been lower by 0.5%. If shocks volatility has been lower (dotted blue), inflation and interest rates would have been lower and less volatile, while average output growth would have been higher than the data.

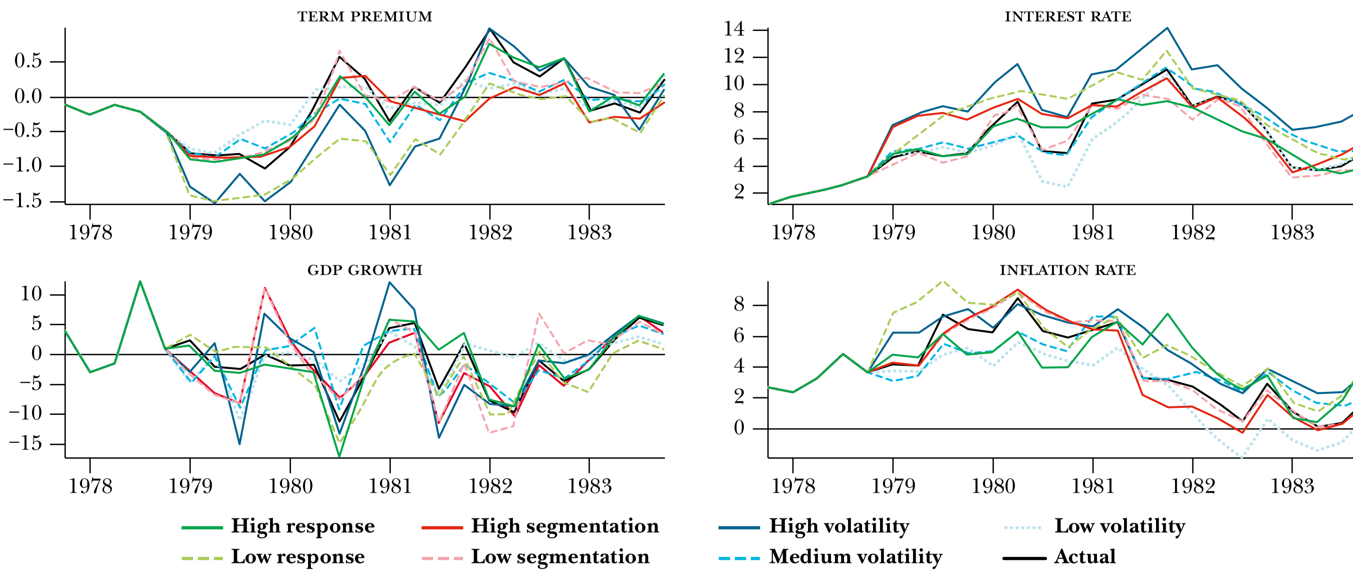
Figure 9 shows the first time when our estimation assigns a high probability to a high interest rate response to the term premium [ $\tau_{tp,\xi_t^{mp}=1} = -1.16\ (-1.20, -1.10)$] from 1978Q4 to 1983Q4. In this episode, the estimation assigns a high probability to high credit market segmentation in 1980Q1 and 1980Q2, 1982Q3 and 1982Q4, and 1983Q4. Meanwhile, the estimation assigns a high probability of a high credit shock volatility from 1981Q3 to 1984Q4. With inflation and interest rates rising during the late 1970s and early 1980s, savings and loan institutions that had regulation on maximum interest rates that they could pay to depositors saw their funding base eroded, while the fixed-rate interest that they earned in their mortgages represented large valuation losses in their assets. Despite the Depository Institutions Deregulation and Monetary Control Act of 1980, which prompted industry deregulation, it turned out insufficient eventually requiring taxpayer's bailout.

The high interest rate response to term premium, which according to the estimation started three quarters before Paul Volcker were appointed as Federal Reserve's chairman, came when the term premium was below steady state, inflation was relatively high and rising, interest rates were also rising, and GDP was above trend. In 1979Q4 there was a negative oil supply shock related to the Iraq and Iran war. The NBER's Committee identifies two recessions in this episode, from 1980Q1 to 1980Q3 and from 1981Q3 to 1982Q4.

What if the interest rate response had not changed (dashed green line) relative to a fully credible regime switch in monetary policy (solid green line)? With a low response interest rate, the term premium would have been much lower deviating from the steady state until 1982Q1, GDP would have expanded, but at the cost of much higher inflation, which eventually would have required higher interest rates. Meanwhile, if credit shock volatility would have been lower (dotted blue), the term premium would have been closer to the steady-state level, with lower inflation and interest rates without excessive GDP fluctuations.

## Figure 9

**COUNTERFACTUAL SIMULATION FROM 1978Q4 TO 1983Q4**




Note: For the counterfactuals, the solid green lines show the simulated series for the high response to term premium scenario, while the green dashed lines display the simulated series for the low response to term premium scenario. The solid red lines show the simulated series for the high segmentation scenario, while the dashed red lines display the low segmentation scenario. The solid blue lines report the simulated series for the high volatility scenario, while the dashed blue lines and the dotted blue lines report the simulated series for the medium volatility and low volatility scenarios, respectively. The solid black line shows the observed series.

Figure 10 displays the counterfactual exercise for our next analyzed episode is 1990Q2 to 1993Q4 when interest rate response to the term premium is also estimated high with high probability. Starting in 1990Q3, the Federal Open Market Committee lowered interest rates from 8.25% to 4% by the end of 1991 and to 3% by 1992Q3. Meanwhile, the NBER's Committee dates a contraction from 1990Q3 to 1991Q1.

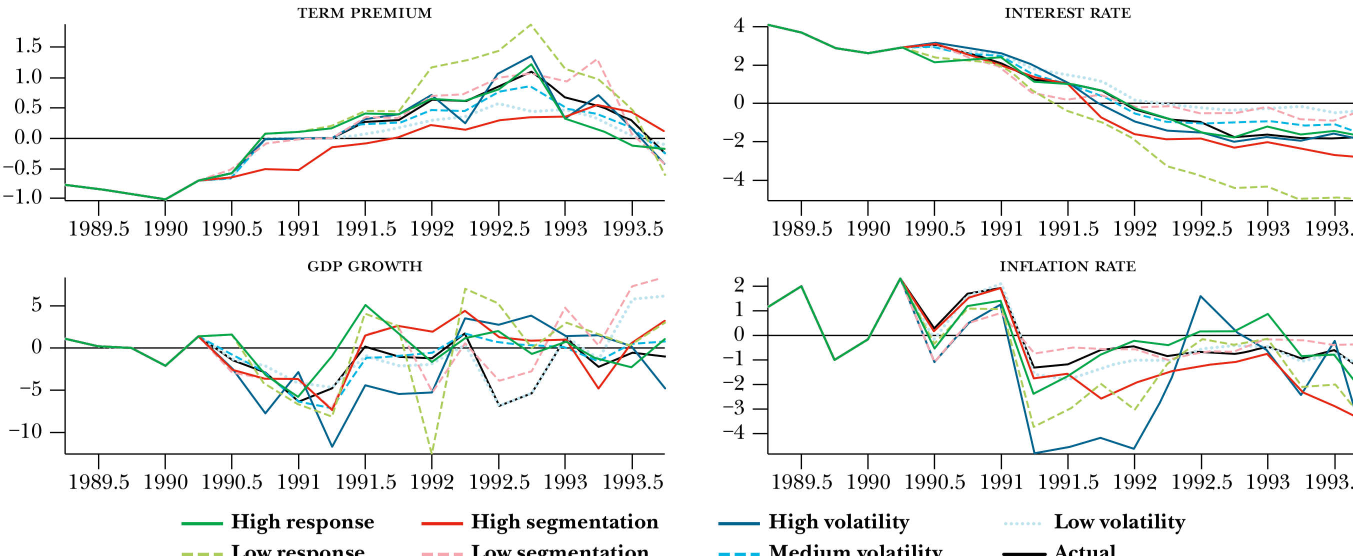
The estimation assigns a high probability to high financial frictions from 1990Q2 to 1991Q2 and on 1993Q1 and 1993Q2, while credit shock volatility has a high probability of being of medium magnitude in 1990Q4 and from 1993Q1 to 1993Q3. The Federal Deposits and Insurance Corporation (FDIC) experienced an improvement after president George H. W. Bush responded to the problems in the banking and thrift industries which have their origins two decades before. By the end of 1991, nearly 1,300 commercial banks either failed or required failing assistance from the FDIC causing its severe undercapitalization. The main overarching provisions of the FDIC Improvement Act, which was implemented in 1994, include *prompt corrective action* and *least cost resolution*. This process was followed by the Riegle-Neal Act of September 1994 that allowed banks to branch at intra-and interstate levels.

In this episode, term premium was below the steady state but rose quickly. A low response to term premium (green dashed) would have implied a sharper cut in interest rates and a longer and deeper recession, while a fully-credible high response policy (green solid) would have cut interest rates less, but earlier, and could have shortened and mitigated the recession. According to the low response policy, term premium would have spiked, and there could have been a huge economic contraction in 1992Q1. Regarding financial frictions, it calls the attention that with higher credit market segmentation (solid red) the term premium would have raised less, interest rates would have fallen more since 1990Q3 and the GDP growth recovery would have been strong until 1993Q1 when the observed high financial frictions dragged GDP growth. Low shocks volatility (blue dotted) would have implied a lower term premium, and the recession would have been smaller despite less aggressive interest rate cuts, while high volatility (blue solid) would cause higher term premium and a much deeper recession.

Figure 11 shows the counterfactual exercise for our next analyzed episode is 2000Q4 to 2004Q2 when there is a high probability

## Figure 10

**COUNTERFACTUAL SIMULATION FROM 1990Q2 TO 1993Q4**




Note: For the counterfactuals, the solid green lines show the simulated series for the high response to term premium scenario, while the green dashed lines display the simulated series for the low response to term premium scenario. The solid red lines show the simulated series for the high segmentation scenario, while the dashed red lines display the low segmentation scenario. The solid blue lines report the simulated series for the high volatility scenario, while the dashed blue lines and the dotted blue lines report the simulated series for the medium volatility and low volatility scenarios, respectively. The solid black line shows the observed series.

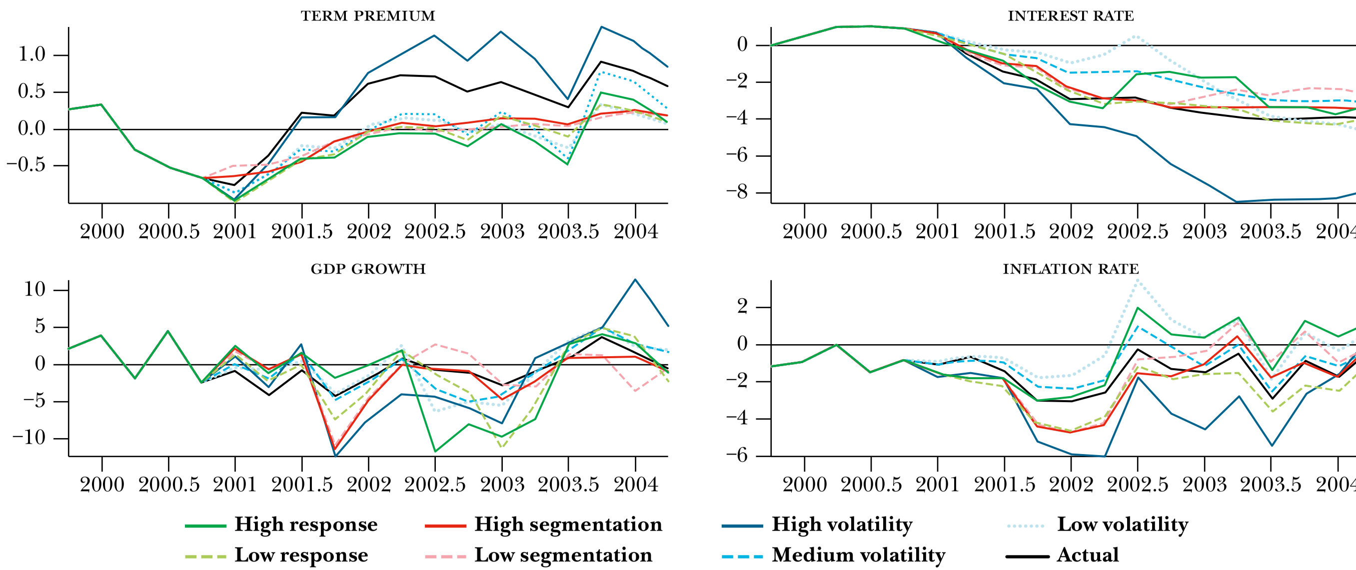
of medium credit shock volatility from 2000Q4 to 2001Q3 and from 2003Q3 to 2004Q2, and of high financial frictions in 2001Q4 and from 2002Q3 to 2003Q3. It is important to mention that in 1999Q4 President Bill Clinton signed into law the Financial Services Modernization Act, commonly called Gramm-Leach-Bliley Act. This law repealed the Glass-Steagall Act and gave the Federal Reserve new supervisory powers. With this legislation, it was intended to promote the benefits of financial integration for consumers and investors, while safeguarding the soundness of the banking and financial systems. Now the commercial and investment banking, separated since 1933, would not have restrictions of integration between them leading to the creation of the financial holding groups (Mahon, 2013). The most common case is the merger and acquisition of Travelers Group with Citicorp, forming the nowadays well-known Citigroup. In this period the Federal Reserve also played an active role as a supervisor of the financial holding companies (FHC). The Federal Reserve supervises the consolidated organization, while primarily relying on the reports and supervision of the appropriate state and federal authorities for the FHC subsidiaries, taking the role of an *umbrella* supervisor. This necessity surge because these large FHC had risk spread across their subsidiaries but managed it as a consolidated entity.

In this episode there is a low probability of a high monetary policy response to the term premium. The NBER's Committee dates a contraction from 2001Q1 to 2001Q4 and starting in January 2001; the Federal Open Market Committee cut interest rates 11 times that year from 6.5% to 1.75%. Comparing the green lines, we see that with a more responsive monetary policy rate, that had lowered interest rates more steeply, would have resulted in a lower term premium and it might have delayed an output contraction until 2002Q3, but the contraction might have ended being more severe, while inflation would have been larger. The red dashed line provides evidence that if high financial frictions had not been present the economy would have experienced a stronger recovery since 2002Q3. The solid blue line shows that if shocks had been high, the economy would have suffered a much more volatile cycle with higher term premium, much lower interest rates, greater output contraction, and even a prolonged deflation.

Figure 12 displays the counterfactual exercise for our next analyzed episode is 2006Q1 to 2009Q4 when there is a high probability

## Figure 11

**COUNTERFACTUAL SIMULATION FROM 2000Q4 TO 2004Q2**




Note: For the counterfactuals, the solid green lines show the simulated series for the high response to term premium scenario, while the green dashed lines display the simulated series for the low response to term premium scenario. The solid red lines show the simulated series for the high segmentation scenario, while the dashed red lines display the low segmentation scenario. The solid blue lines report the simulated series for the high volatility scenario, while the dashed blue lines and the dotted blue lines report the simulated series for the medium volatility and low volatility scenarios, respectively. The solid black line shows the observed series.

of medium credit shock volatility in 2006Q3, 2008Q2, and 2008Q3, and high volatility in 2008Q4, while high frictions are identified in 2006Q1-2008Q1 and 2009Q2-2010Q1. Despite being the episode directly related with our opening quote, where recently appointed Chairman Bernanke was highlighting the risks of financially stimulative declines in the term premium and the need of greater monetary policy restraint, in this episode there is a low probability of a high monetary policy response to the term premium.

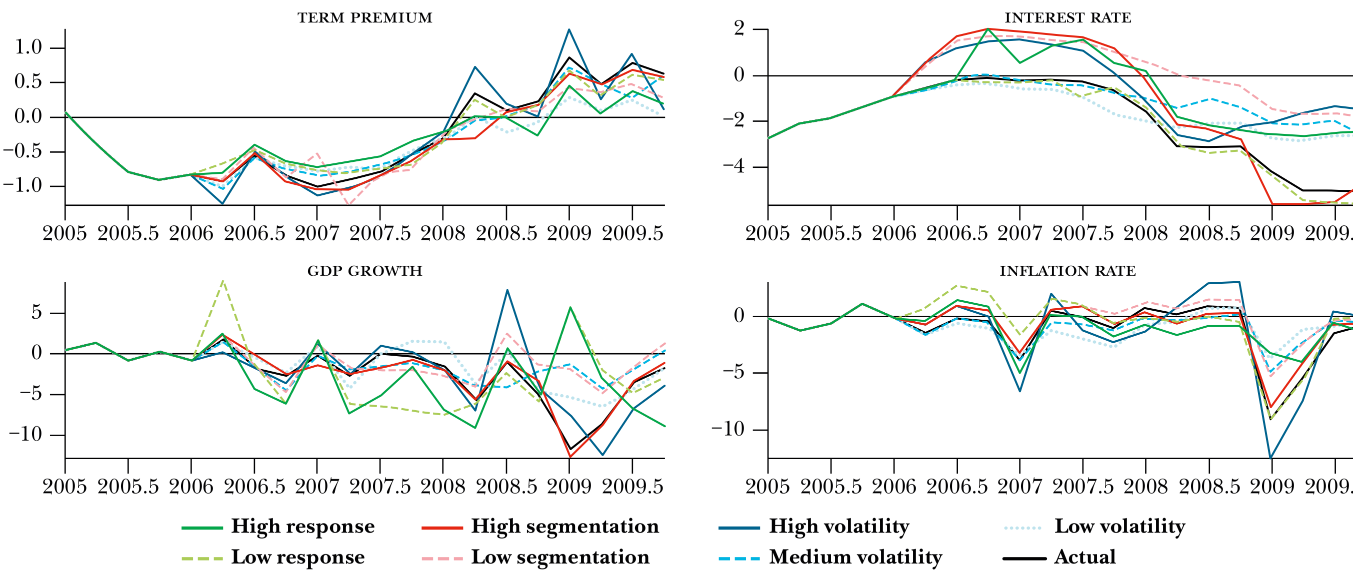
This episode is preceded by a Federal Reserve's funds target that in June 30, 2004, started an upward trend from the 1% prevailing since June 25, 2003, to 2.25% by the end of 2004, and 4.25% by the end of 2005. During the first half of the year the Federal Open Market Committee added other four 0.25% increments to 5.25% by June 2006. What could have happened if monetary policy was more responsive towards the term premium? According to the counterfactual, the solid green line shows that this would have implied rising interest rates by an additional 2%, which would have significantly slowed down economic activity. However, GDP growth did not have the large boom-bust cycle implied by a 100% probability of low monetary policy response as depicted by the dashed green line.

The comparison of the red solid line of high financial frictions and red dashed line of low financial frictions allows us to see the important role that credit market imperfections played in the 2007Q4 to 2009Q2 output contraction. The presence of high financial frictions also allows us to understand why the Federal Reserve needed to be so aggressive lowering interest rates during the recession lowering them to 4.25% by the end of 2007 and to [0%-0.25%] on December 16, 2008. Meanwhile, the comparison of the three blue lines related to the magnitude of shocks volatility shows that if this had remained high in 2009Q1 and 2009Q2, the output contraction would have deepened.

This period includes the most critical events of the subprime crisis. According to Calomiris and Haber (2014), there is no consensus among scholars, practitioners, and politicians about the key causes of the subprime crisis. Some theories explaining this crisis include the creation of new and riskier financial securities like the mortgage back securities and other financial derivatives; the excessive risk taking by government-sponsored enterprises such as Fannie Mae and Freddie Mac; and the Bush-era free market ideology. Pushing Fannie and Freddie to purchase highly leveraged risky mortgages

## Figure 12

**COUNTERFACTUAL SIMULATION FROM 2006Q1 TO 2009Q4**




Note: For the counterfactuals, the solid green lines show the simulated series for the high response to term premium scenario, while the green dashed lines display the simulated series for the low response to term premium scenario. The solid red lines show the simulated series for the high segmentation scenario, while the dashed red lines display the low segmentation scenario. The solid blue lines report the simulated series for the high volatility scenario, while the dashed blue lines and the dotted blue lines report the simulated series for the medium volatility and low volatility scenarios, respectively. The solid black line shows the observed series.

to increase the liquidity and the capability of the lenders to extend more credits targeted to specific borrowers had huge effects on the mortgage markets. The mortgage securities market was highly unregulated. Financial indicators such as the LIBOR/OIS spread gave signs of stress and uncertainty in the US economy. Rating agencies played a big role in this event. Credit ratings assigned by rating agencies affected the allocation of risk capital in the economy. Higher credit ratings allowed firms to borrow at better terms and thus positively affect a firm's value (Bae et al., 2015). After the market crash, the Federal government of the US and the Federal Reserve took unprecedented actions. Fannie Mae and Freddie Mac became government owned bank after their bailout. Liquidity-support programs were designed to support the different markets in distress (Calomiris and Haber, 2014). As a measure of prevention and supervision, President Obama passed the Dodd-Frank Act to reform and regulate the banking system through the creation of a series of governmental agencies.

Figure 13 shows the counterfactual exercise for our last analyzed episode is 2010Q1 to 2011Q4 when there is a high probability of a high interest rate response to the term premium. Financial frictions are estimated to be high in 2010Q4 and 2011Q4, while medium credit shock volatility has a high probability of having taken place in 2010Q2 and from 2011Q2 to 2011Q4. It is important to have in mind that the Federal Reserve funds rate was in a zero-lower bound from December 2008 to December 2015. The economy was recovering from a recession, and the term premium was above the steady state. The behavior of the term premium is followed closely by the one of high monetary policy response, high financial frictions, and medium and low shocks volatility. The high interest rate response would have implied lowering interest rates by an additional 1.5% in 2010Q4, which compares to an average −0.95% in 2010Q4 and −1.23% in 2011 according to the quantitative easing adjusted shadow interest rate in Wu and Xia (2015). If financial frictions had been low during the entire episode GDP growth could have always been above the observed level, while if responsive monetary policy had been fully credible GDP growth would have been also higher until 2011Q2.

In the aftermath of the 2007-2009 crisis, President Barack Obama noticed that "the financial sector was governed by antiquated and poorly enforced rules that allowed some to take risks that endangered the economy." The US Congress, the White House, and the Federal Reserve took actions to improve the actual regulation of the financial sector. By the last quarters of 2009, these authorities began their participation in the craft of the Dodd-Frank Wall Street Reform and Consumer Protection Act.

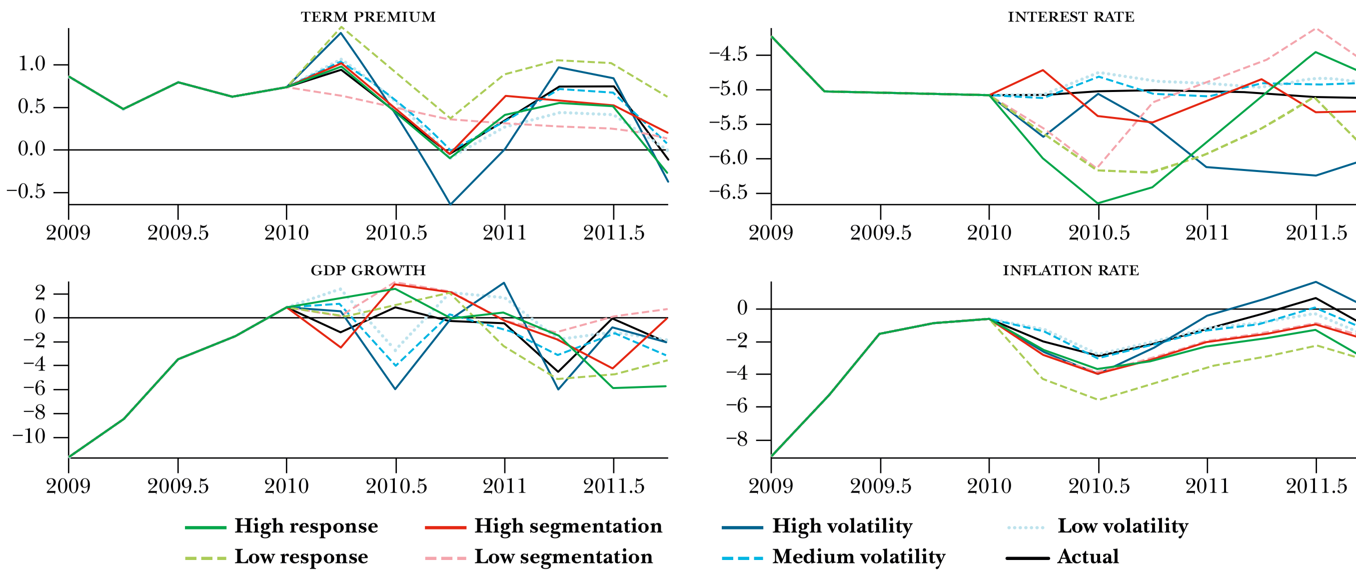
In 2010Q1, Federal Reserve announced QE2, buying USD 600 billion in long-term Treasury securities and reinvestment of proceeds from prior mortgage-backed security purchases. By this time, Bernanke began his second term as Federal Reserve chairman. Also, the Dodd-Frank financial reform became law, and the Federal Reserve issued guidelines for evaluating large bank holding companies' capital action proposals. By 2011, the Consumer Financial Protection Bureau opened its doors, procuring the health and protection of the consumers supervising disclosure of banks, lenders, and other financial companies. Around the globe, Greece admitted a deficit-to-GDP ratio of 12% (2009Q4) so that the International Monetary Fund and the European Central Bank ran the first rescue plan and completed it two quarters later. By the third quarter of 2011 the Financial Stability Board cleared to purchase sovereign bonds.

## 6. CONCLUSIONS

In this paper, we use a MS-VAR to provide evidence of the importance of allowing for switching parameters (nonlinearities) and switching variance (non-Gaussian) when analyzing macrofinancial linkages in the US. Using the preferred specification of two regimes in coefficients and three regimes in volatilities, we modify the DSGE model in Carlstrom et al. (2017) by allowing Markov-switching in the parameters that capture financial frictions, monetary policy responses, and stochastic volatility. Classifying regimes as high and low financial frictions, high and low interest rate response to term premium and high, medium, and low credit shock volatility; we perform a Bayesian estimation of the model to identify those regimes. The Bayesian maximum likelihood estimation of the MS-DSGE model identifies 59 quarters (27% of the sample that runs from 1962Q1 to 2017Q4) when financial frictions, measured by the financial intermediaries' portfolio adjustment costs to their net worth, had a large probability of being high with the following relevant intervals: 1971Q1-1971Q4, 1976Q3-1978Q3, 1983Q4-1985Q4, 1990Q2-1991Q2, 2002Q3-2003Q3, 2006Q1-2008Q1, and 2009Q2-2010Q1. Also, there are 43 quarters (19.3%) when the interest rate response

Figure 13

**COUNTERFACTUAL SIMULATION FROM 2010Q1 TO 2011Q4**




Note: For the counterfactuals, the solid green lines show the simulated series for the high response to term premium scenario, while the green dashed lines display the simulated series for the low response to term premium scenario. The solid red lines show the simulated series for the high segmentation scenario, while the dashed red lines display the low segmentation scenario. The solid blue lines report the simulated series for the high volatility scenario, while the dashed blue lines and the dotted blue lines report the simulated series for the medium volatility and low volatility scenarios, respectively. The solid black line shows the observed series.

to the term premium is estimated high with the following intervals: 1978Q4-1983Q4, 1990Q2-1993Q4, and 2010Q1-2011Q4. In addition, the MS-DSGE estimation has 34 quarters (15.2%) of large probability of high credit shock volatility, 46 quarters (20.6%) with a large probability of medium credit shock volatility and 142 quarters (63.7%) with a large probability of low credit shock volatility.

We analyzed six episodes when financial frictions were high and/or credit shocks volatility was either medium or high denoting disruptions in financial markets. In three of those episodes, 1978Q4-1983Q4, 1990Q2-1993Q4, and 2010Q1-2011Q4, short-term interest rates had a high response to the term premium. In the other three periods of financial distress, 1971Q1-1978Q3, 2000Q4-2004Q4, and 2006Q1-2009Q4, short-term interest rates had a low response. Counterfactual exercises allowed us to analyze what could have happened under alternative credit market conditions and monetary policy responses. These counterfactuals provide evidence of the amplifying effects of financial factors and the role that monetary policy has had mitigating financially driven business cycles.

## ANNEX

### Impulse Response Functions

This annex shows the impulse response to a one-standard deviation shock to neutral technology, $\sigma_a$, investment-specific, $\sigma_\mu$, price markup, $\sigma_{mk}$, wage markup, $\sigma_w$, and intertemporal preference, $\sigma_{rn}$. As described in the text, each figure has 12 lines which depict the responses under the two alternative financial friction (H Seg. and L Seg.), the two monetary policy response to term premium (H T P Resp. and L T P Resp.), and the three credit shock volatility (H Vol., M Vol. and L Vol.) regimes. High financial frictions regimes are presented in red-like colors, while low ones are presented in blue-like colors. High monetary policy response regimes are presented in solid lines, while low ones are presented in dashed lines. High volatility regimes have the darkest colors, medium mild tones, and low ones are in the lightest tones.

Figure 14

**IMPULSE RESPONSE FUNCTIONS OF THE MS-DSGE MODEL TO A ONE STANDARD DEVIATION NEUTRAL TECHNOLOGY SHOCK UNDER ALTERNATIVE REGIMES FOR FINANCIAL FRICTIONS, MONETARY POLICY AND VOLATILITY**

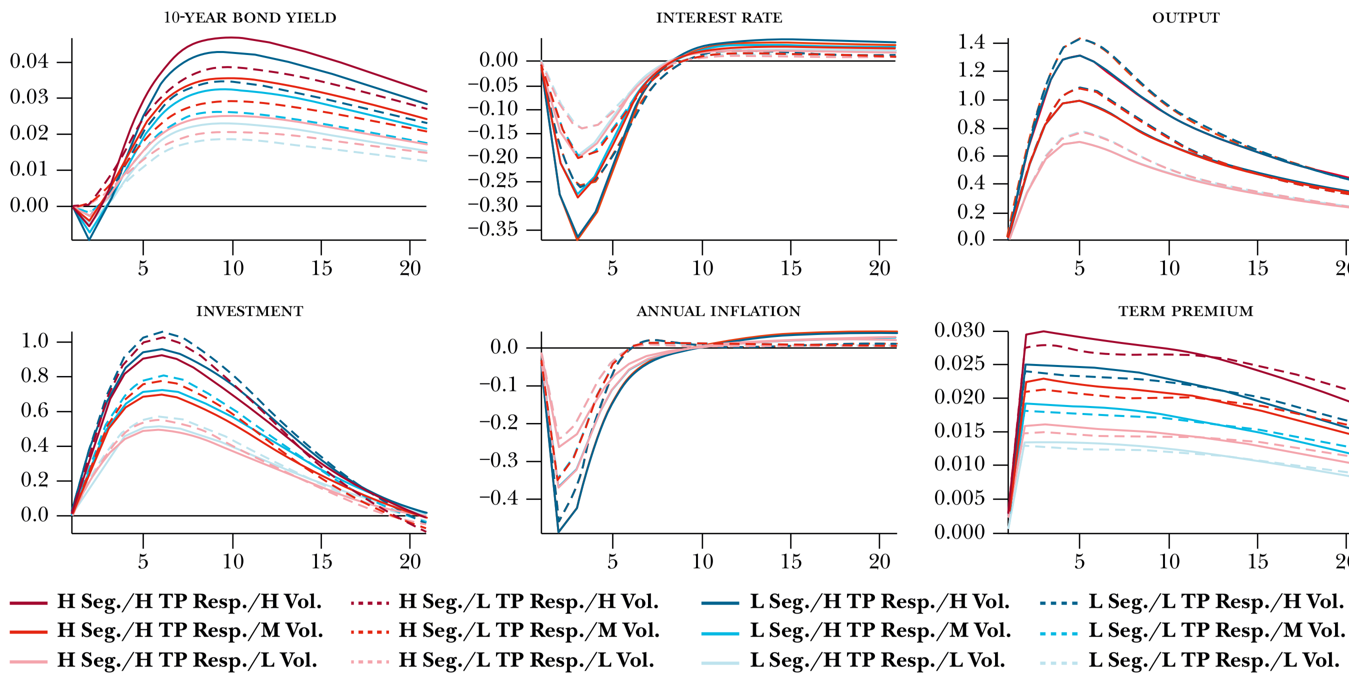


**Figure 15**

**IMPULSE RESPONSE FUNCTIONS OF THE MS-DSGE MODEL TO A ONE STANDARD DEVIATION INVESTMENT-SPECIFIC TECHNOLOGY SHOCK UNDER ALTERNATIVE REGIMES FOR FINANCIAL FRICTIONS, MONETARY POLICY AND VOLATILITY**

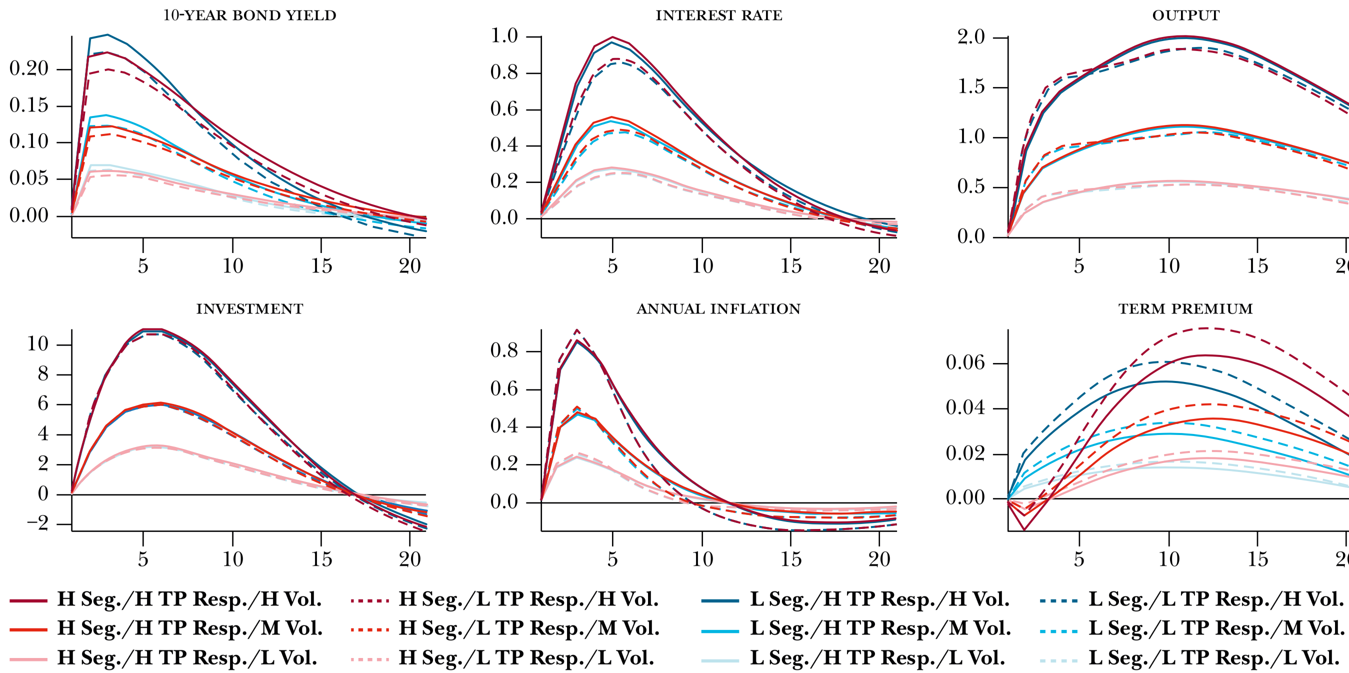
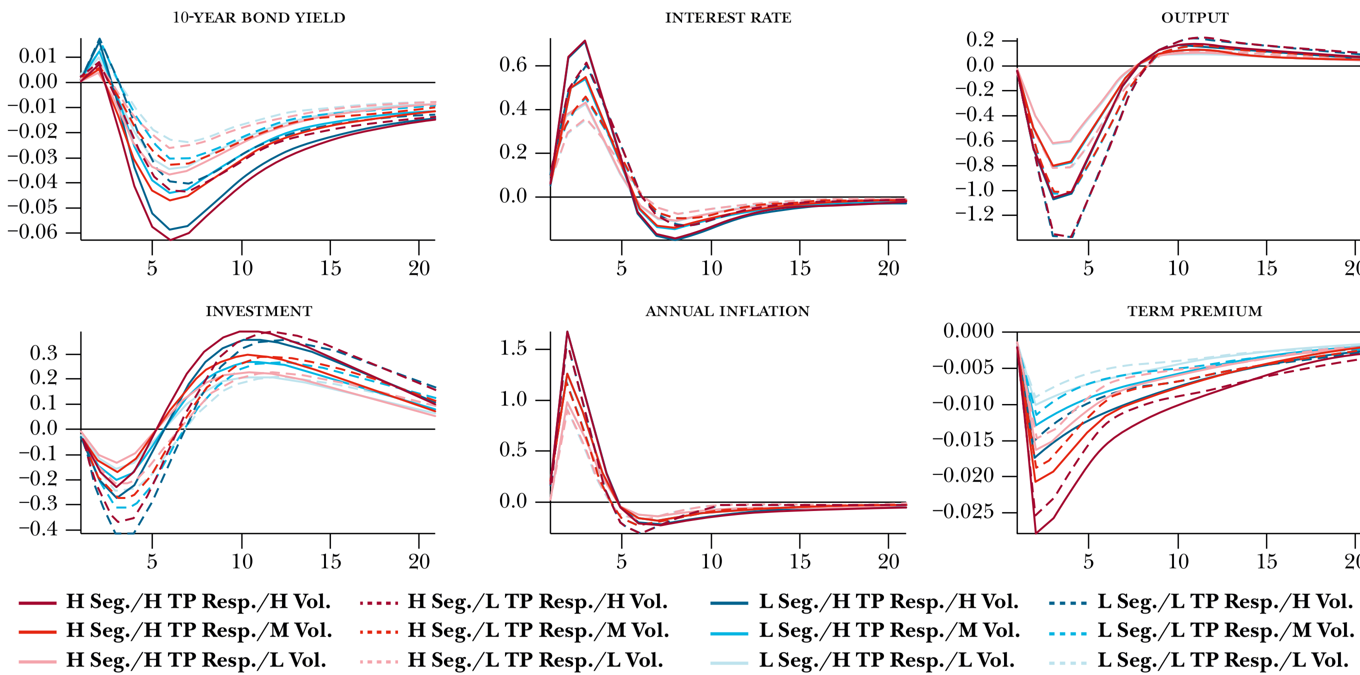


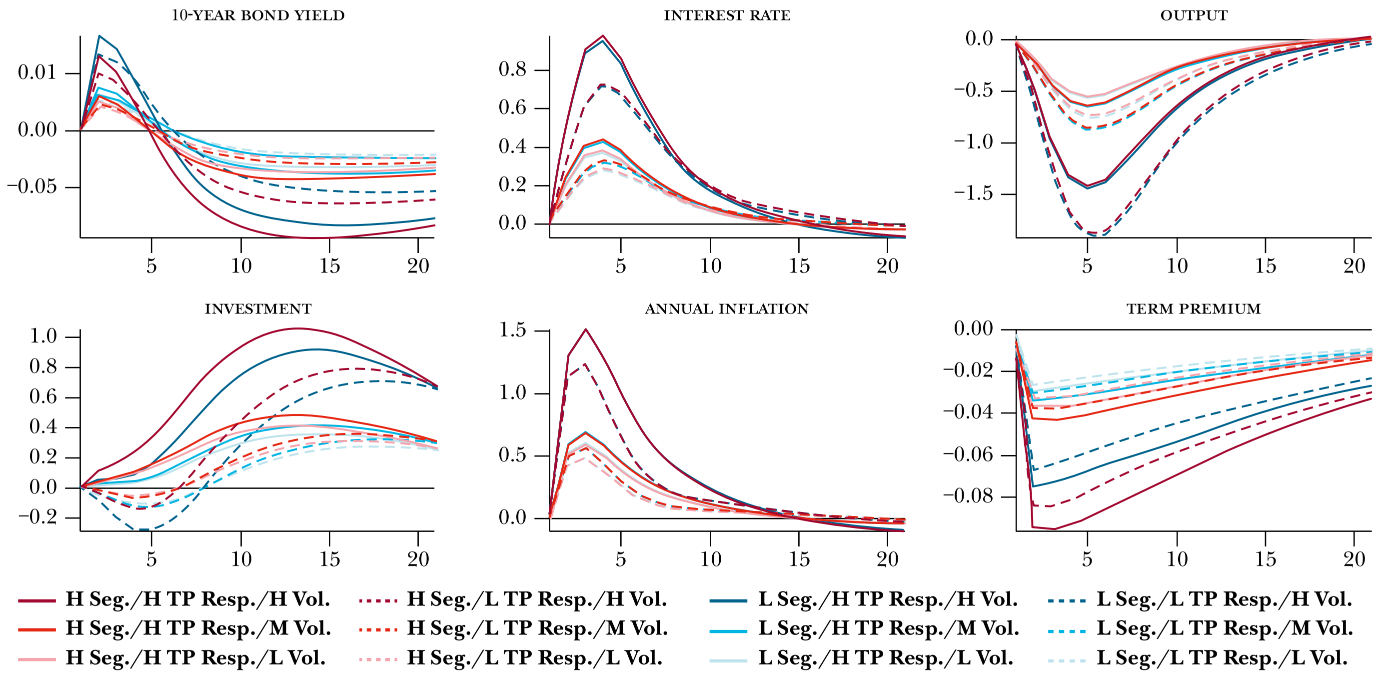
Figure 16

**IMPULSE RESPONSE FUNCTIONS OF THE MS-DSGE MODEL TO A ONE STANDARD DEVIATION PRICE MARK-UP SHOCK UNDER ALTERNATIVE REGIMES FOR FINANCIAL FRICTIONS, MONETARY POLICY AND VOLATILITY**



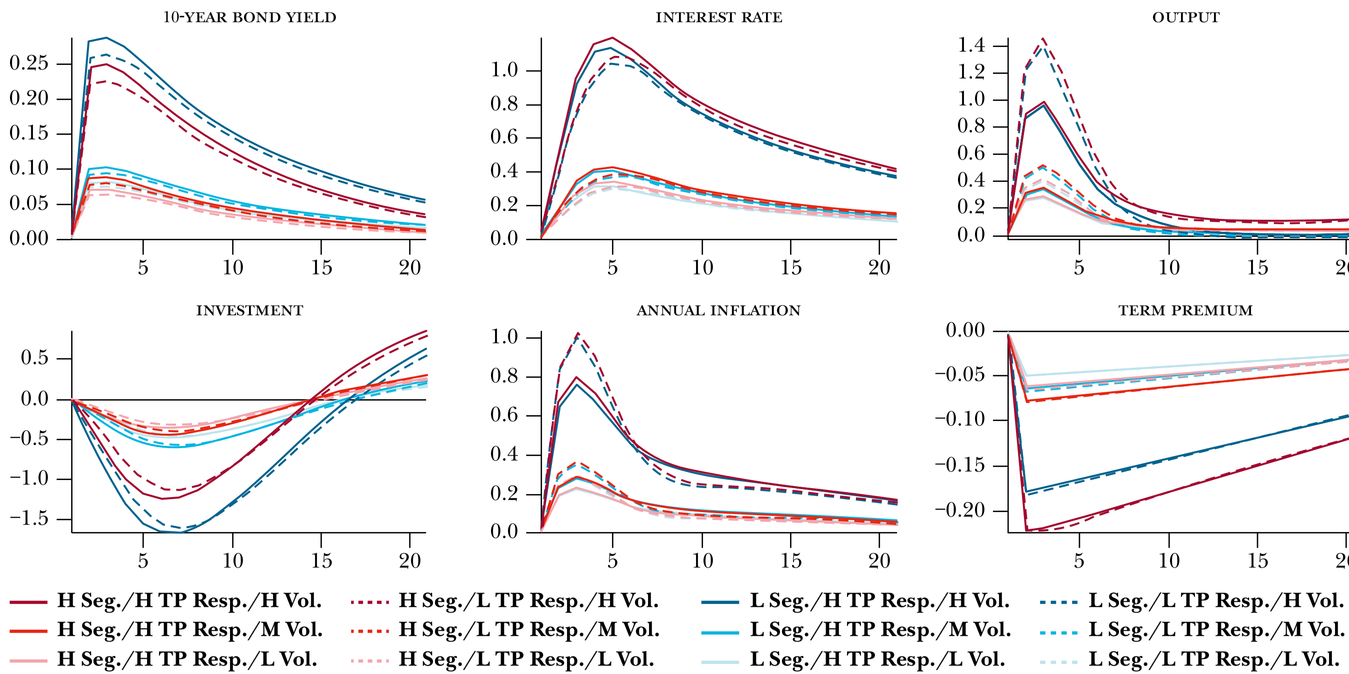
## Figure 17

**IMPULSE RESPONSE FUNCTIONS OF THE MS-DSGE MODEL TO A ONE STANDARD DEVIATION WAGE MARK-UP SHOCK UNDER ALTERNATIVE REGIMES FOR FINANCIAL FRICTIONS, MONETARY POLICY AND VOLATILITY**



## Figure 18

**IMPULSE RESPONSE FUNCTIONS OF THE MS-DSGE MODEL TO A ONE STANDARD DEVIATION INTERTEMPORAL PREFERENCE SHOCK UNDER ALTERNATIVE REGIMES FOR FINANCIAL FRICTIONS, MONETARY POLICY AND VOLATILITY**



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# Two Models of FX Market Interventions: The Cases of Brazil and Mexico

***Martín Tobal***
***Renato Yslas***

## Abstract

*This chapter empirically compares the implications of two distinct models of FX intervention, within the context of inflation targeting regimes. For this purpose, it applies the VAR methodology developed by Kim (2003) to the cases of Mexico and Brazil. Our results can be summarized in three points. First, FX interventions have had a short-lived effect on the exchange rate in both economies. Second, the Brazilian model of FX intervention entails higher inflationary costs and this result cannot be entirely explained by differences in the level of pass-through. Third, each model is associated with a different interaction between exchange rate and conventional monetary policies.*

*Keywords: foreign exchange intervention, exchange rate, inflation, exchange rate pass-through, monetary policy.*

*JEL classification: F31, E31, E52.*

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M. Tobal <martin.tobal@banxico.org.mx> and R. Yslas <renato.yslas@banxico.org.mx> are staff at Banco de México. The authors would like to thank Alberto Ortiz, Daniel Chiquiar, Fabrizio Orrego, João Barroso, Julio Carrillo, Fernando Ávalos, Fernando Tenjo, Nicolás Magud, Victoria Nuguer and other participants of the Meeting of the Central Bank Researchers Network of CEMLA. The opinions expressed in this publication are those of the authors. They do not purport to reflect the opinions or views of Banco de México or its Board of Governors. Part of this work was developed while the authors were affiliated with CEMLA.

# 1. INTRODUCTION

Historically, Latin America has seen a wide range of choices in terms of exchange rate and monetary policy regimes. Since the early 2000s a number of countries have opted for an inflation targeting regime and devoted interest rate setting to meet the target. During this period, the goal of monetary policy has been almost exclusively to keep inflation under control. However, inflation targets and interest rate setting have come with varying degrees of exchange rate flexibility: Latin American economies currently perform foreign exchange (FX) interventions under substantially different models. This chapter investigates whether a country's choice of FX intervention model constrains their impact on the exchange rate, the country's inflation rate, and the nature of interaction between exchange rate and conventional monetary policies (interest rate setting). For this purpose, it uses the vector autoregression (VAR) model developed by Kim (2003) to compare the cases of Mexico and Brazil, two inflation targeting countries with two distinct models of FX intervention.

When asked about the exchange rate policies followed by Mexico and Brazil, most economists would probably classify them as *managed floating* policies (see Ilzetzki et al., 2008; Tobal, 2013; and IMF, 2015 for alternative exchange rate regime classifications).[1] However, as illustrated in Figures 1 and 2, using a single category for both

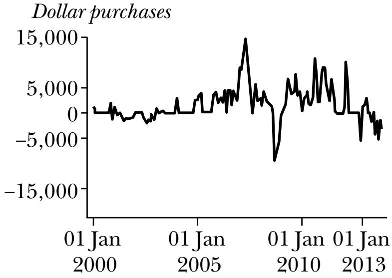
[1] The IMF Annual Report of Exchange Arrangements and Exchange Restrictions (2015) classifies both economies as inflation-targeters. As for their exchange rate regimes, there exists some variation. Ilzetzki et al. (2008) extend Reinhart and Rogoff's classification of de facto exchange rate regimes for the period 2000-2010 and find that, over this period, both Brazil and Mexico had managed floating regimes. In a different research, Tobal (2013) conducts a survey and assembles a unique database on foreign currency risk and exchange rate regimes. Using this information, he constructs an alternative classification based on self-report perceptions of regimes for seventeen Latin America and the Caribbean economies. According to this database, Brazil and Mexico had pegged float exchange rate regimes over the period 2000-2012. In an expanded classification that accounts for regulatory measures, Tobal (2013) reclassifies the Brazilian regime as foreign exchange controls over 2000 Q1-2005 Q2 to capture the existence of two regulated FX markets. Finally, in the IMF annual report (2015), the Brazilian and Mexican regimes are classified as floating and free floating, respectively.

**Figures 1-2**

**FOREIGN EXCHANGE INTERVENTION IN BRAZIL AND MEXICO, 2000-2013**

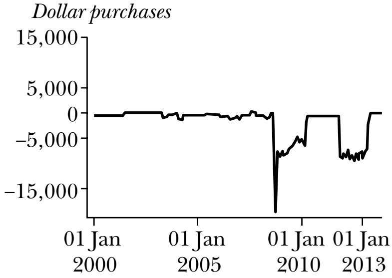
Millions of dollars

1. BRAZIL




Notes: Most interventions involved US dollar purchases. FX interventions includes dollar purchases in the forward and spot markets, repurchases and foreign currency loans.
Source: Banco Central do Brasil.

2. MEXICO




Notes: Most interventions involved US dollar sales. FX interventions includes dollars auctions, put options, mechanisms to slow the pace of reserve accumulation, and contingent dollar sales.
Source: Banco de México.

countries would hide substantial differences across the two emerging markets. Figure 1 shows that the majority of Brazilian interventions have involved net dollar purchases and, importantly, they have been performed on a regular basis. On the other hand, the majority of Mexican interventions have involved net dollar sales and interventions have been more sporadic (mostly in the aftermath of the 2008-2009 financial crisis). Moreover, whereas Mexico has followed a preestablished rule, Brazil has primarily used discretionary interventions. In summary, although both Mexico and Brazil are inflation targeting countries, they represent two distinct models of FX interventions.

This research compares the two models of FX interventions by employing the VAR structure setup with short-run restrictions developed by Kim (2003). We adapt Kim's restrictions to the case of an emerging market and estimate his model with Mexican data on the one hand and with Brazilian data on the other hand.[2] Our choice of Kim's methodology is based on three facts. First, this method allows us to directly address the simultaneity bias present in studies on the effects of intervention on the exchange rate. Second, we can use a single model to estimate the effects of FX interventions on a set of macroeconomic variables (and not solely the exchange rate). Third, this method provides a unified framework to analyze the interaction between FX interventions, exchange rates, and monetary policies. Therefore, the estimations of ths research are not biased by the fact that these two policies are frequently chosen jointly.[3]

Our first result shows that FX interventions have had a short-lived effect on the exchange rate in both Mexico and Brazil: a positive one-standard deviation shock in FX interventions is associated with depreciations of the Brazilian real and of the Mexican peso during one and two months, respectively. This result is consistent with findings in the literature that fully sterilized interventions have significant effects on the exchange rate in the short run (interventions are found to be sterilized in our model; see Tapia and Tokman, 2004; Rincón and Toro, 2010; Kamil, 2008; Echavarría et al., 2010; Echavarría et al., 2009; Kohlscheen and Andrade, 2013; Guimarães, 2004; and Section 2 for a review of this literature).

Our second result demonstrates that FX interventions have no inflation costs in Mexico but have costly inflation effects in Brazil. We investigate whether this result is driven by cross-country differences in exchange rate pass-through by studying the response of inflation to a shock in the exchange rate. Neither the timing nor the level of this response suggests that pass-through can entirely explain the higher inflation costs borne by Brazil. We then conclude that FX interventions are associated with higher inflation rates in Brazil, regardless of their effect on the exchange rate. Put differently, the FX interventions model adopted by Brazil seems to be inherently related to higher inflation rates (relative to the Mexican model).

[2] As mentioned, Kim (2003) examines the interaction between FX interventions and interest rate setting for the case of the United States.

[3] For example, when devaluating the exchange rate, purchases of dollars could generate inflationary pressures. In order to counteract these pressures, the central bank could raise the interest rate, partially offsetting the depreciation and, therefore, the initial impact of interventions on the exchange rate. So not taking into account the impact of monetary policy would generate a downward bias in the estimated effect.

Our third result deals with the interaction between exchange rate and conventional monetary policies. We study the response of interest rate setting to a FX intervention shock. The outcome shows that this interaction is of a different nature in each FX intervention model. Whereas the Banco de México raises the interest rate immediately after the shock, the response of the Banco Central do Brasil appears four months later. We speculate that this can be attributed to particular characteristics of the Brazilian model: A high frequency of interventions makes it harder to accompany each of them with increases in the interest rate. One implication is that, within the context of the Brazilian model, the interest rate tends to be less responsive to the inflation rate. At the same time, the later response of the interest rate in Brazil partially explains our second result, where FX interventions have higher inflation costs in the country.

As more thoroughly explained in Section 2, this chapter makes two main contributions to studies that investigate the effectiveness of FX interventions in Mexico and Brazil. First, we base our study on a single model for conventional monetary policy, FX interventions, and exchange rate. From a methodological point of view, this contribution is relevant because FX interventions, monetary policy, and exchange rate interact with each other and not accounting for this interaction may generate sizable bias (Kim, 2003). Second, we compare the two countries and assess the implications of choosing different models of FX interventions.

The rest of the chapter is organized as follows. Section 2 reviews the related literature and highlights the contributions of this research to the literature. Section 3 explains the data, the methodology, and the identifying assumptions employed in the analysis. Section 4 discusses the empirical results and Section 5 examines the robustness of the results. Finally, section 6 concludes.

## 2. RELATED LITERATURE

This research relates to a set of studies investigating whether sterilized FX interventions are effective in influencing the level and volatility of the exchange rate. To investigate this issue, the literature has primarily employed single equation econometric models such as GARCH specifications, cross-country studies, and event study approaches. Overall, the literature is not conclusive on the effectiveness of FX interventions. Whereas some papers support the idea that FX interventions are effective solely in the short run, others find no evidence of significant effects (see Sarno and Taylor 2001; Neely, 2005; and Menkhoff, 2013, for literature reviews).

For the particular case of Latin America, most studies show that FX interventions affect the level of the exchange rate in the short-run but are mixed about their effects on volatility (see Tapia and Tokman, 2004; Domaç and Mendoza, 2004; Kamil, 2008; Rincón and Toro, 2010; Adler and Tovar, 2011; Kohlscheen and Andrade, 2013; Broto, 2013; García-Verdú and Zerecero, 2014; and García-Verdú and Ramos-Francia, 2014). For Brazil, Stone et al. (2009) show that measures aimed at providing liquidity to the FX market affect the level and volatility of the Brazilian real/US dollar rate.[4] Kohlscheen and Andrade (2013) use intraday data to demonstrate that a central bank's offer to buy currency swaps appreciates the exchange rate in Brazil.[5] For Mexico, Domaç and Mendoza (2004) find that dollar sales by the central bank appreciate the peso and have a negative impact on its volatility, while dollar purchases are found to be not statistically significant. In contrast, Broto (2013) employs a larger period (July 21, 1996 to June 6, 2011) to show that both foreign currency purchases and sales are associated with lower exchange rate volatility. García-Verdú and Zerecero (2014) investigate the effects of dollar auctions without a minimum price on liquidity and orderly conditions. They show that, when these conditions are measured by bid-ask spreads, the aforementioned auctions improve liquidity and promote order in the FX market.[6] García-Verdú and Ramos-Francia (2014) take a lower frequency approach and use intraday data to investigate the consequences of FX interventions. Their result show

4 Stone et al. (2009) study measures taken in the aftermath of the 2008-2009 financial crisis. They find that spot dollar sales and the announcements on futures market intervention appreciate the local currency.

5 Note that by selling a currency swap to the central bank, the financial institution receives the equivalent of the exchange rate variation plus a local onshore US interest rate. This reduces its demand for foreign currency, consequently appreciating the exchange rate.

6 The interventions considered by García-Verdú and Zerecero (2014) lasted five minutes. They show that this modality of intervention is associated with a lower bid-ask spread of the peso/dollar exchange rate.

that the effects of FX interventions on exchange rate risk-neutral densities are statistically little.[7]

In contrast with the studies on the effectiveness of FX interventions mentioned above, this research does not employ a uniequational econometric model for the exchange rate. Instead, we analyze this issue in a unifying framework for FX interventions, monetary policy, exchange rate, and inflation (among other variables). This is relevant because, as argued by Kim (2003), the two types of policies and the exchange rate interact with each other.

The research also relates closely to a strand of literature that estimates a rich set of macroeconomic relations and interactions between FX interventions and conventional monetary policy (see Kim, 2003; Guimarães, 2004; and Echavarría et al., 2009). To estimate these relations, the literature employs structural VAR frameworks with short-run restrictions. For instance, Kim (2003) uses monthly data to show that net purchases of foreign currency substantially depreciate the exchange rate in the United States (US). He also finds that even if these purchases are sterilized, they have significant effects on monetary variables in the medium run. Following Kim's framework (2003), Echavarría et al. (2009) jointly analyze the effects of FX intervention and conventional monetary policy on the exchange rate, interest rate, and other macroeconomic variables for Colombia. They show that foreign currency purchases devalue the nominal exchange rate over one month.[8]

In line with the VAR literature on FX interventions outlined above, we estimate the effects of interventions on a broader set of macroeconomic variables (including inflation and interest rates). In contrast with Kim (2003), Guimarães (2004), and Echavarría et al. (2009), we estimate these effects for two countries (Brazil and Mexico) that follow different models of intervention and analyze the implications of such differences in terms of inflation costs and interactions between FX intervention and conventional monetary policies.

Finally, this research is related to those studying the existence of exchange rate pass-through. A number of papers have documented

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7 García-Verdú and Ramos-Francia (2014) use options data to estimate the exchange rate risk-neutral densities.

8 Guimarães (2004) finds that yen purchases by the Bank of Japan appreciate the nominal exchange rate but have no significant effects on either money supply or interest rates.

a notable reduction in the level of pass-through in both Mexico and Brazil since the early 2000s (for example, Cortés, 2013; Capistrán et al., 2012; Nogueira and León-Ledesma, 2009; Mihaljek and Klau, 2008; Nogueira, 2007; and Belaisch, 2003). For instance, Nogueira (2007) shows the adoption of inflation targeting regimes has reduced the level of pass-through in Mexico and Brazil (among other emerging economies). Notwithstanding its reduction, there are still references to exchange rate pass-through in both countries (see Barbosa-Filho, 2008, for the case of Brazil and Banco de México's Inflation Report from April-June 2011 for the case of Mexico). In this chapter, we argue that this pass-through cannot entirely explain the inflation costs associated with FX interventions.

## 3. DATA AND METHODOLOGY

### 3.1 Variable Definition and Structural VAR with Short Run Restrictions

We opt for restrictions linking endogenous variables in the short run for two reasons. First, the literature that uses long-run restrictions frequently assumes money neutrality to identify effects of monetary policy shocks (see Lastrapes and Selgin, 1995; Fackler and McMillin, 1998; and McMillin, 2001). Money neutrality is reasonable when linking real variables, but most of the variables in our VAR system are nominal. Second, models with short-run restrictions perform better in terms of accurately identifying FX market intervention and conventional monetary policy shocks (see Kim, 2003, and Faust and Leeper, 1997).[9]

Let $y_t$ be the 7×1 vector which includes first differences of the endogenous variables we consider. These variables and the corresponding data are summarized by the following list: the money market

[9] The correct identification of structural shocks rests on the correct estimation of the structural parameters. In this line, Faust and Leeper (1997) show that inferences from VARs based on long run assumptions might not be reliable because of data limitations. They argue that the long-run effects of structural shocks are not precisely estimated in small samples, and this inaccuracy transfers to impulse-response exercises. In other words, structural shocks might not be correctly identified when assuming long-run restrictions in finite samples.

interest rate is used for the interest rate ($i_t$), the monetary base is employed for the monetary aggregate ($m_t$), the consumer price index is employed for consumer prices ($cpi_t$), industrial production is used as a proxy for output ($ip_t$), the local currency price of US dollars is used for exchange rate ($e_t$), a commodity price index is employed for commodity prices ($pc_t$) and, finally, net purchases of dollars are used for foreign exchange interventions ($fei_t$)[10,11]. These endogenous variables and data are the same as those considered by Kim (2003) and very closely followed by Echavarría et al.'s approach (2009). In contrast with those investigations, we take first differences to ensure that all the variables are stationary.[12]

The period under interest is defined to comprise the *inflation targeting* period and we use monthly data (*high-frequency information*) to capture the impact of FX market interventions on the exchange rate. The sample period is thus defined as 2000M1-2013M12. The data come from different sources: the Banco Central do Brasil, the International Financial Statistics of the IMF, and the Banco de México.

The dynamics of the Brazilian and the Mexican economies are defined by the following structural model:

1 $$A_0 y_t = A(L) y_{t-1} + \varepsilon_t,$$

where $A_0$ is a matrix of contemporaneous coefficients, $A(L)$ is a polynomial matrix in the lag operator $L$, and $\varepsilon_t$ is a 7×1 structural disturbance vector. The variance-covariance matrix of the structural disturbances is denoted by $\mathrm{var}(\varepsilon_t) = \Sigma_\varepsilon$, where the diagonal elements

[10] All variables are in log terms (multiplied by 100), with the exception of foreign exchange intervention and interest rates that are in percentage terms. We normalize foreign exchange intervention by the quadratic trend of the monetary base.

[11] For Brazil, foreign exchange interventions refer to interventions in the forward and spot markets, repo lines of credit, and foreign currency loans. For Mexico, foreign exchange interventions concern interventions through US dollar auctions, put options, contingent dollar sales mechanisms, and sales aimed at slowing the pace of reserve accumulation.

[12] According to the unit root tests for both Mexico and Brazil, all variables except foreign exchange interventions are integrated to an order of one. Foreign exchange interventions are stationary in levels (see Annex for further details).

are the variances of structural disturbances and the nondiagonal elements are assumed to equal zero (so that the structural disturbances are assumed to be mutually uncorrelated).

The reduced form of the structural model is obtained by multiplying the inverse of $A_0$ on both sides of Equation 1, and is written as follows:

$$y_t = B(L)y_{t-1} + u_t, \tag{2}$$

where $B(L)$ is 7×7 polynomial matrix in the lag operator $L$ and $u_t$ is the 7×1 vector of reduced form (estimated) residuals with $\mathrm{var}(u_t) = \Sigma_u$. By estimating Equation 2, we will obtain estimates of $\mathrm{var}(u_t) = \Sigma_u$ that will allow us to recover the structural parameters of the model defined in Equation 1.

In order to recover the structural parameters, it is important to note that the residuals of the structural and of the reduced form are related by $\varepsilon_t = A_0 u_t$. This implies $\Sigma_\varepsilon = A_0 \Sigma_u A_0'$ and yields a system of 49 equations. Thus, to recover the structural parameters, we need to impose at least 28 restrictions on $A_0$ and $\Sigma_\varepsilon$ because 28 of the system's equations are independent and by plugging the sample estimates of $\mathrm{var}(u_t) = \Sigma_u$, we are left with 56 unknowns[13, 14]. As explained below, we will impose 35 parameter restrictions and over identify the system (see the next subsection for further details).

When imposing restrictions on $A_0$, the literature on structural VAR with short-run restrictions frequently employs the conventional normalization of the simultaneous equation literature. That is, it assumes that the seven diagonal elements of $A_0$ are equal to one.

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[13] In general, there are $n(n+1)/2$ independent equations, where $n$ equals the number of endogenous variables: all the $n(n-1)/2$ off-diagonal elements of $A_0\Sigma_u A_0'$ are equal to zero, and the diagonal elements of $A_0\Sigma_u A_0'$ are equal to the structural error variances. Furthermore, there are $n(n+1)$ structural parameters: the $n^2$ elements of $A_0$ plus the $n$ diagonal elements of $\Sigma_\varepsilon$. Thus, once we assume the diagonal elements of $A_0$ or $\Sigma_\varepsilon$ are equal to one, we need to impose at least $n(n-1)/2$ additional restrictions. However, imposing those $n(n+1)/2$ restrictions is a necessary but not a sufficient condition to identify the structural system. For a necessary and sufficient condition see propositions 9.1 and/or 9.3 of Lütkepohl (2005).

[14] Imposing only 28 restrictions is a necessary but insufficient condition to identify the structural system.

Also very frequently, the additional 21 restrictions arise from the assumption that $A_0$ is the lower triangular matrix (this assumption is referred to as the Cholesky decomposition in this literature).

An issue with the Cholesky decomposition is that it imposes a recursive structure on the contemporaneous relations among the variables given by $A_0$; that is, each variable is contemporaneously affected by those variables above it in the vector of endogenous variables $y_t$, but it does not contemporaneously affect them.[15] From a practical perspective, the problem with the recursive structure is that outcomes are frequently sensitive to changes in the variable ordering. In other words, each ordering might imply a different system of equations and thus yield different results.

## 3.2 Defining Contemporaneous Restrictions

In contrast with the common practice in the VAR literature that assumes that the seven diagonal elements of $A_0$ are equal to one, we follow Cushman and Zha's (1997) and Sims and Zha's (2006) approach by restricting the main diagonal elements in $\Sigma_\varepsilon$ to equal one. This approach has the advantage of simplifying some formulas used in the inference and does not alter the economic substance of the system (Sims and Zha, 2006).[16]

With regard to the remaining 28 restrictions, we depart from the standard Cholesky decomposition by using the generalized method proposed by Blanchard and Watson (1986), Bernanke (1986), and Sims (1986). This approach allows for a broader set of contemporaneous relations among the variables so that $A_0$ can have any structure, whether recursive or not. In particular, we impose the 28 short-run restrictions on $A_0$ listed in Table 1.[17] Each row in this

[15] Note that when $A_0$ is assumed to have a recursive structure, the assumption that the elements of its main diagonal equal one provides the additional restrictions to exactly identify the structural parameters.

[16] Sims and Zha (2006) argue that this method "compels the reader to remain aware that the choice of *left-hand-side* variable in the equations of models with the more usual normalization is purely a matter of notational convention, not economic substance" (p. 248).

[17] The overidentification is not rejected by the likelihood ratio test at any conventional level. In particular, the statistic $\chi^2$ equals 11.34 in the case of Brazil and 3.15 in the case of Mexico, with significance levels of 0.125 and 0.871 respectively (see Table A.2 in the Annex).

**Table 1**

**$A_0$ MATRIX AND CONTEMPORANEOUS RESTRICTIONS**

| | $\Delta fei_t$ | $\Delta i_t$ | $\Delta m_t$ | $\Delta cpi_t$ | $\Delta ip_t$ | $\Delta e_t$ | $\Delta pc_t$ |
|---|---|---|---|---|---|---|---|
| $\Delta fei_t$ | $g_{11}$ | 0 | 0 | 0 | 0 | $g_{16}$ | 0 |
| $\Delta i_t$ | $g_{21}$ | $g_{22}$ | $g_{23}$ | 0 | 0 | 0 | 0 |
| $\Delta m_t$ | 0 | $g_{32}$ | $g_{33}$ | $g_{34}$ | $g_{35}$ | 0 | 0 |
| $\Delta cpi_t$ | 0 | 0 | 0 | $g_{44}$ | $g_{45}$ | $g_{46}$ | 0 |
| $\Delta ip_t$ | 0 | 0 | 0 | 0 | $g_{55}$ | 0 | 0 |
| $\Delta e_t$ | $g_{61}$ | $g_{62}$ | $g_{63}$ | $g_{64}$ | $g_{65}$ | $g_{66}$ | $g_{67}$ |
| $\Delta pc_t$ | 0 | 0 | 0 | 0 | 0 | 0 | $g_{77}$ |

table can be interpreted as a contemporaneous equation. For instance, the first row tells us how foreign exchange interventions react contemporaneously to movements in the remaining variables (the interest rate, among others).

Note in the first row of Table 1 we assume that foreign exchange interventions react contemporaneously solely to the exchange rate. This assumption is consistent with the evidence provided by the leaning-against-the-wind literature and follows closely Kim (2003) and Echavarría et al. (2009)'s approach for the cases of the US and Colombia, respectively.[18]

The second row introduces the contemporaneous responses of $\Delta i_t$. The $g_{21}$ and $g_{23}$ parameters are left free to allow for the possibility that interventions are not fully sterilized and, interestingly, to capture their contemporaneous interaction with monetary policy. The contemporaneous response of $\Delta i_t$ to output and prices is assumed to be null

[18] See, for instance, Adler and Tovar (2011) for a reference in this literature in which the main goal of interventions is to stabilize the exchange rate.

($g_{24}$ and $g_{25} = 0$, which is based on Kim's argument that information on output and prices is not available within a month).[19] The contemporaneous response to the exchange rate is set to zero because both Mexico and Brazil (formally) conduct monetary policy under inflation targets. Furthermore, in line with Echavarría et al. (2009) but in contrast with Kim (2003), $g_{27}$ is assumed to equal zero. Kim (2003) assumes otherwise in order to solve the standard *price puzzle* that characterizes the US economy. The Annex shows this puzzle appears only for Brazil and, to tackle this issue, Section 4 shows that allowing for $g_{27}$ to be different from zero does not alter any of our qualitative results.

The third row in Table 1 denotes the conventional money demand equation and the fourth and fifth rows (contemporaneously) determine price and output (see Sims and Zha 2006; Kim, 1999; Kim and Roubini, 2000; Kim, 2003; and Echavarría et al., 2009; for other papers using the same money demand specification). The $g_{41}$, $g_{42}$, $g_{43}$, $g_{47}$, $g_{51}$, $g_{52}$, $g_{53}$, $g_{54}$, $g_{56}$, and $g_{57}$ parameters are set to zero because, as argued by Kim (2003), inertia, adjustment costs, and planning delays preclude firms from changing either prices or output immediately in response to monetary policy and financial signals. On the other hand, we take an agnostic approach with regard to contemporaneous *exchange rate pass-through*. That is, we let prices contemporaneously respond to the exchange rate and thus leave the $g_{46}$ parameter free. Section 4 shows that changing this assumption does not alter our qualitative results. See Section 2 for comments about pass-through in Cortés (2013), Capistrán et al. (2012), Nogueira and León-Ledesma (2009), Barbosa-Filho (2008), Mihaljek and Klau (2008), Nogueira (2007), and Belaisch (2003).

In the sixth row, we let the exchange rate respond contemporaneously to all of the variables. These assumptions are in line with Echavarría et al. (2009) but contrast with Kim (2003). Our justification and Echavarría et al. (2009)'s argument for the case of Colombia is that commodity prices are more relevant in determining the local currency in developing countries than in determining the US dollar.

Finally, in the seventh row, we assume that commodity prices are contemporaneously exogenous. This assumption arises from the fact

[19] This assumption has been widely used in the monetary literature of the business cycles. See Gordon and Leeper (1994); Kim and Roubini (2000) and Sims and Zha (2006) for references.

that the economic conditions of Brazil and Mexico do not have such a strong impact on the IMF's price index of commodities as the economic conditions of the US. Brazil, for instance, is a large exporter of sugar, coffee, beef, poultry meat, soybeans, soybean meal, and iron ore. However, these products represent only 0.16% of non-fuel commodities, which in turn represent only an average of 0.37% for the commodity price index used in this research. Along the same lines, Mexico produces only a small world share of its main export commodity: crude petroleum.[20]

## 4. RESULTS

We add a constant, four lags, the US federal funds rate, and a dummy variable for 2008M10-2009M6 to the reduced-form in Equation 2 and estimate the resulting model.[21]

### 4.1 Impulse Responses to FX Intervention Shocks

Figures 3-8 and 11-18 report the responses of the endogenous variables to a one standard deviation shock in FX interventions. The figures that appear on the right refer to the impulse responses for Mexico and those on the left refer to Brazil. In order to facilitate the comparison we use the same scale in all figures.

Figures 3-4 provide information on the effectiveness of FX market interventions. These figures show that net dollar purchases are associated with a significant impact on the exchange rate. In both Brazil and Mexico, the sign of the response is as expected since a positive shock in FX intervention generates a depreciation of the Brazilian real and of the Mexican peso (Figures 3 and 4, respectively). In both

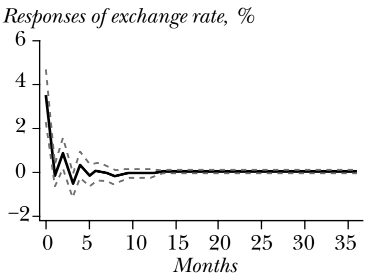
[20] These data refer to the IMF's commodity price index calculated between 2004 and 2013 (http://www.imf.org/external/np/res/commod/index.aspx).

[21] The dummy variable is included to account for the recent financial crisis. The resulting reduced form of the model is written as follows: $y_t = B_0 + B(L)y_{t-1} + Fx_t + u_t$, where $B_0$ is the vector of constants, $B(L)$ is a polynomial matrix in the lag operator $L$, $F$ is the matrix of coefficients associated with the exogenous variables, $x_t$ is the vector of exogenous variables, and $u_t$ is the vector of reduced form residuals.

## Figures 3-6

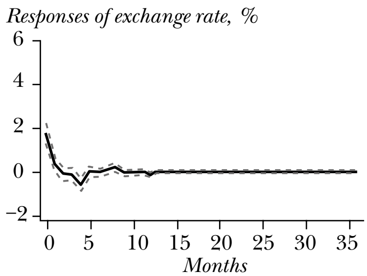
**IMPULSE RESPONSES TO FX INTERVENTION SHOCKS**

3. BRAZIL: EXCHANGE RATE



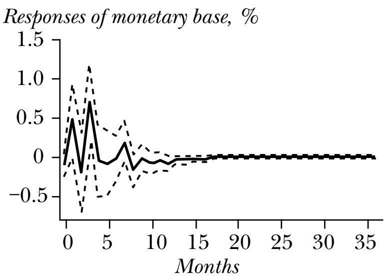

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Exchange rate depreciates on impact and goes up further two months later. Exchange rate is defined as national currency per US dollar.
Sources: Banco Central do Brasil and authors' calculations.

4. MEXICO: EXCHANGE RATE



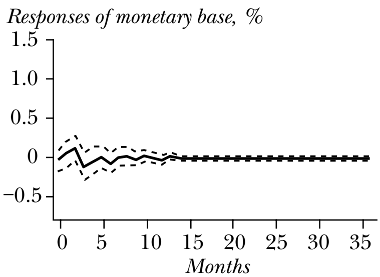

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Exchange rate depreciates on impact and rises further one month later. Four months after the shock, it appreciates a bit. Exchange rate is defined as national currency per US dollar.
Sources: Banco de México and authors' calculations.

5. BRAZIL: MONETARY BASE




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Monetary base fluctuates a bit in response: it increases one and three months after a shock. Monetary base is defines as the sum of the currency issued by the central bank and the banking reserves.
Sources: Banco Central do Brasil and authors' calculations.

6. MEXICO: MONETARY BASE

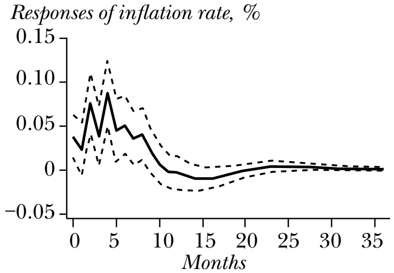



Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Monetary base does not respond significantly to intervention shocks. Monetary base is defines as the sum of the currency issued by the central bank and the banking reserves.
Sources: Banco de México and authors' calculations.

## Figures 7-8

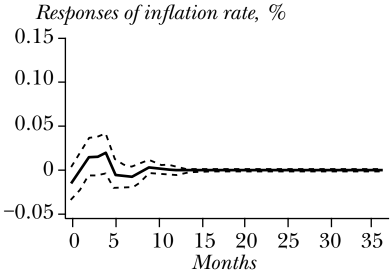
**IMPULSE RESPONSES TO FX INTERVENTION SHOCKS (Cont.)**

7. BRAZIL: INFLATION RATE




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Inflation rises on impact and then continues increasing from two to eight months after the shock. Inflation is defined as the percentage change in the consumer price index.
Sources: Banco Central do Brasil and authors' calculations.

8. MEXICO: INFLATION RATE




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Inflation does not respond significantly to intervention shocks. Inflation is defined as the percentage change in the consumer price index.
Sources: Banco de México and authors' calculations.

countries the effect is short-lived: whereas in Mexico this effect lasts two months, in Brazil the effect lasts only one month.

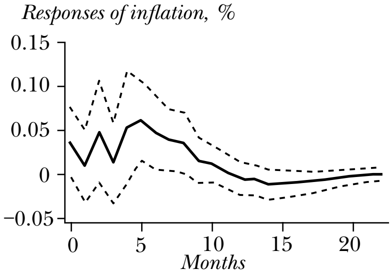
Figures 5-6 refer to the reaction of monetary bases to the positive FX intervention shock. Note that there are some fluctuations right after the shock in Brazil. However, the contemporaneous response of the monetary base is not significant in either Mexico or Brazil. This result, along with the evidence displayed in Figures 11-12, shows that FX interventions are not associated with an immediate expansion in the monetary conditions (that is, an increase in the monetary base and a fall in the interest rate). Hence, we conclude that the interventions are fully sterilized in both Mexico and Brazil.

Putting together Figures 3-6 allows us to link our results with the empirical literature. In particular, the results presented are consistent with the findings that fully sterilized interventions have significant effects on the exchange rate in the short run (see Tapia and Tokman, 2004; Rincón and Toro, 2010; Kamil, 2008; Echavarría et al., 2010; Echavarría et al., 2009; Kohlscheen and Andrade, 2013; and Guimarães, 2004; and Section 2 for a review of this literature). This

## Figures 9-10

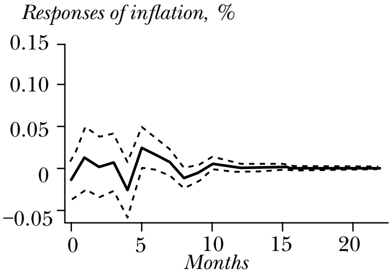
**RESPONSE OF INFLATION TO EXCHANGE RATE SHOCKS**

9. BRAZIL: INFLATION RATE




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Inflation goes up in response five months after the shock and keeps rising until the eighth month. Inflation is defined as the percentage change in the consumer price index. In order to facilitate visualization, we plot the response over a 22-month horizon. The effect is, however, not significant after month 22.
Sources: Banco Central do Brasil and authors' calculations.

10. MEXICO: INFLATION RATE




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Inflation goes down in response eight months after the shock. Inflation is defined as the percentage change in the consumer price index. In order to facilitate visualization, we plot the response over a 22-month horizon. The effect is, however, not significant after month 22.
Sources: Banco de México and authors' calculations.

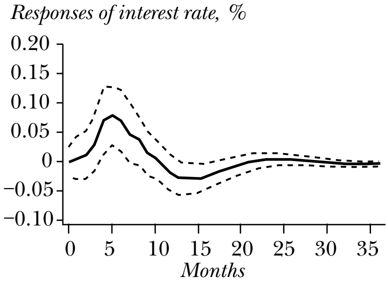
consistency with the empirical literature provides external validity to the identification strategy we have pursued.

Figures 7-8 provide information on the inflationary costs of FX interventions: They show the response of the inflation rate to a positive FX interventions shock in Brazil and Mexico, respectively. Note in these figures that the response of the inflation rate differs significantly across countries. In Brazil, a positive FX intervention shock is associated with significant increases in the inflation rate. This rate increases on impact and remains significantly high in Brazil until the eighth month (the effect is not statistically significant in the first month). The response of the inflation rate peaks at months two and four with significant increases of 0.074% and 0.086%, respectively. Note in Figure 8 that the shock, on the other hand, does not have a significant impact on inflation in Mexico at any period of time.

## Figures 11-14

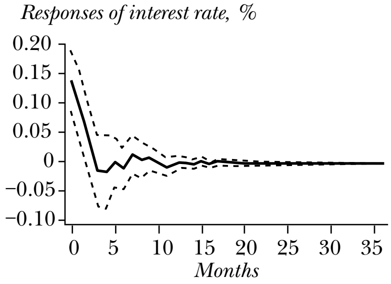
**IMPULSE RESPONSES TO FX INTERVENTION SHOCKS**

11. BRAZIL: MONETARY POLICY



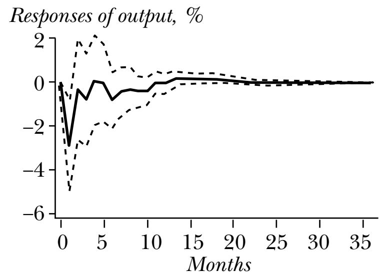

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Interest rate increases four months after a shock and remains increasing until the seventh month. Money market interest rate is used for the interest rate.
Sources: Banco Central do Brasil and authors' calculations.

12. MEXICO: MONETARY POLICY



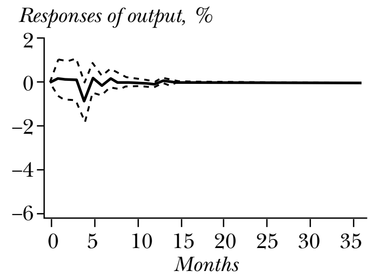

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Interest rate goes up on impact and increases again the next month. Money market interest rate is used for the interest rate.
Sources: Banco de México and authors' calculations.

13. BRAZIL: OUTPUT




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Output falls in response 1 month after the shock. Industrial production is used as a proxy for output.
Sources: Banco Central do Brasil and authors' calculations.

14. MEXICO: OUTPUT

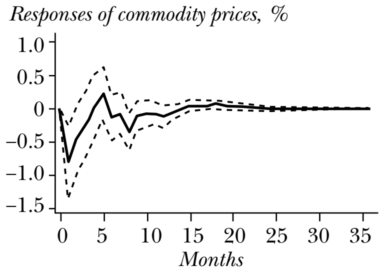



Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Output does not significantly respond to intervention shocks. Industrial production is used as a proxy for output.
Sources: Banco de México and authors' calculations.

## Figures 15-18

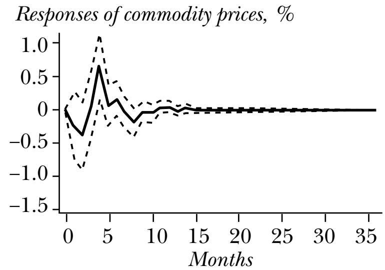
**IMPULSE RESPONSES TO FX INTERVENTION SHOCKS (Cont.)**

15. BRAZIL: COMMODITY PRICES



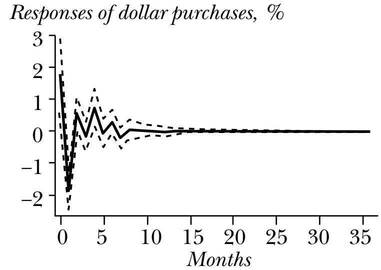

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Commodity prices fall in response one month after the shock, and goes down further seven months later. IMF's commodity price index is used for commodity prices.
Sources: Banco Central do Brasil and authors' calculations.

16. MEXICO: COMMODITY PRICES



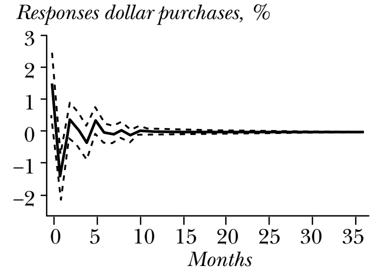

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Commodity prices go up in response four months after the shock. IMF's commodity price index is used for commodity prices.
Sources: Banco de México and authors' calculations.

17. BRAZIL: FX INTERVENTIONS




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Dollar purchases increase on impact and then fluctuate in the next four months.
Sources: Banco Central do Brasil and authors' calculations.

18. MEXICO: FX INTERVENTIONS




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Dollar purchases increase on impact and reduce in the next month.
Sources: Banco de México and authors' calculations.

Table 2

**FORECAST ERROR VARIANCE DECOMPOSITION OF INFLATION IN BRAZIL**

| | *Shocks* | | | | | | |
|---|---|---|---|---|---|---|---|
| *Months* | *FX interventions* | *Interest rate* | *Money demand* | *Consumer prices* | *Output* | *Exchange rate* | *Commodity prices* |
| 1 | 0.037 | 0.000 | 0.000 | 0.936 | 0.004 | 0.021 | 0.002 |
| | (0.028) | (0.000) | (0.000) | (0.054) | (0.010) | (0.027) | (0.003) |
| 6 | 0.175 | 0.030 | 0.036 | 0.559 | 0.061 | 0.058 | 0.081 |
| | (0.075) | (0.035) | (0.037) | (0.083) | (0.044) | (0.063) | (0.045) |
| 12 | 0.206 | 0.032 | 0.040 | 0.506 | 0.059 | 0.079 | 0.078 |
| | (0.089) | (0.033) | (0.038) | (0.088) | (0.042) | (0.075) | (0.041) |
| 24 | 0.208 | 0.034 | 0.042 | 0.499 | 0.060 | 0.081 | 0.078 |
| | (0.090) | (0.035) | (0.040) | (0.090) | (0.042) | (0.077) | (0.042) |
| 36 | 0.208 | 0.034 | 0.042 | 0.499 | 0.060 | 0.081 | 0.078 |
| | (0.090) | (0.035) | (0.040) | (0.090) | (0.042) | (0.077) | (0.042) |

Note: Standard error in parentheses.
Sources: Banco Central do Brasil and authors' calculations.

Table 3

**FORECAST ERROR VARIANCE DECOMPOSITION OF INFLATION IN MEXICO**

| | Shocks | | | | | | |
|---|---|---|---|---|---|---|---|
| *Months* | *FX Interventions* | *Interest rate* | *Money demand* | *Consumer prices* | *Output* | *Exchange rate* | *Commodity prices* |
| 1 | 0.008 | 0.002 | 0.000 | 0.959 | 0.027 | 0.003 | 0.000 |
| | (0.012) | (0.004) | (0.000) | (0.032) | (0.025) | (0.005) | (0.001) |
| 6 | 0.029 | 0.023 | 0.074 | 0.810 | 0.033 | 0.016 | 0.015 |
| | (0.026) | (0.017) | (0.039) | (0.054) | (0.024) | (0.012) | (0.019) |
| 12 | 0.032 | 0.025 | 0.074 | 0.799 | 0.033 | 0.021 | 0.017 |
| | (0.029) | (0.017) | (0.038) | (0.056) | (0.024) | (0.014) | (0.019) |
| 24 | 0.032 | 0.025 | 0.074 | 0.799 | 0.033 | 0.021 | 0.017 |
| | (0.029) | (0.017) | (0.038) | (0.056) | (0.024) | (0.014) | (0.020) |
| 36 | 0.032 | 0.025 | 0.074 | 0.799 | 0.033 | 0.021 | 0.017 |
| | (0.029) | (0.017) | (0.038) | (0.056) | (0.024) | (0.014) | (0.020) |

Note: Standard error in parentheses.
Sources: Banco de México and authors' calculations.

Hence, whereas FX market interventions are costless in Mexico, they have inflation costs in Brazil.

The different responses of the inflation rate in Mexico and Brazil may refer to cross-country differences in pass-through. If the inflation rate responded more quickly and to a significantly greater extent in Brazil, the inflation costs borne by this country would be entirely explained by differences in the level and timing of pass-through. To further investigate this issue, we examine the responses of the inflation rate to a shock in the exchange rate and display the results in Figures 9-10.

Figure 10 shows that, in line with the evidence provided by Cortés (2013), Capistrán et al. (2012), and Nogueira (2007), the response of the inflation rate is statistically nonsignificant in Mexico (except for a tiny fall in the eighth month). Figure 9 shows that the response is significant in Brazil, but its timing and extent suggest that pass-through cannot entirely explain the results observed in Figure 7. The inflation increases on impact and peaks in the fourth month in response to the FX interventions shock (Figure 7), but it only begins to increase significantly in the fifth month in response to the shock in the exchange rate (Figure 9). Furthermore, the maximum response of the inflation rate to this shock equals 0.061 percentage points, which suggests a relatively small pass-through in Brazil. This result is consistent with the evidence presented in Section 2 , where we have observed a significant reduction in the response of inflation of this country to variations in the exchange rate (Nogueira and León-Ledesma, 2009; Mihaljek and Klau, 2008; Nogueira, 2007; and Belaisch, 2003).

The fact that pass-through cannot entirely explain the different inflationary costs of FX interventions in Mexico and Brazil suggests the Brazilian model is inherently associated with higher inflation rates. To put it differently, FX interventions are associated with higher inflation in Brazil, regardless of their impact on the exchange rate. Thus, these interventions must cause an inflation increase through alternative mechanisms. A probable mechanism refers to the discretionary nature of the net dollar purchases performed by the central bank. Because one would expect expectations on inflation to be more unstable in a discretionary model, FX interventions may increase these expectations, thereby actually increasing the inflation rate.

Before proceeding to the next subsection, we compare the interaction between exchange rate and conventional monetary policies across the two FX interventions models. Figures 11 and 12 display the responses of the interest rate to the FX interventions shock in Brazil and Mexico, respectively. Note in these figures that the nature of the interaction between the policies is of a different nature in each country. Whereas the interest rate increases immediately in response to the shock in Mexico, the Banco Central do Brasil raises this rate only four months after the shock. In other words, we observe a *late* response of interest rate setting in Brazil relative to Mexico. This result is not surprising given that the Brazilian model entails FX interventions that are performed on a more regular basis. Because interventions are relatively more frequent in Brazil than in Mexico, it may make it more difficult for Brazil to raise the interest rate during each intervention. Thus, we observe in Figure 12 a later response of the interest rate to the FX interventions shock.

The fact that interest rate setting responds later in Brazil may partially explain the results observed in Figures 7-8. Whatever the mechanism through which the Brazilian inflation increases is, the later response of monetary policy does not help reduce the different responses of the inflation rate to the FX interventions shock.

## 4.2 Variance Decomposition

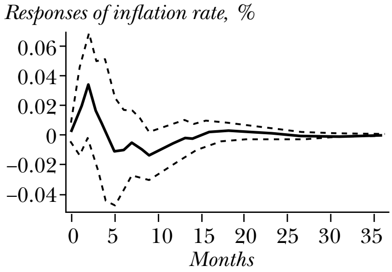
Tables 2-3 display the forecast error variance decomposition of inflation for Brazil and Mexico, respectively. Each column in these tables refers to one of the seven shocks and shows the proportion of the variance in the inflation rate that is explained by the corresponding shock at a given horizon. Let us first focus on how the proportions associated with FX interventions and exchange rate shocks vary over time. The first column in Table 2 shows that in Brazil the proportion of the variance in the inflation rate explained by FX interventions shocks increases over time and stabilizes by the 24th month. The sixth column shows that a similar conclusion can be drawn with regard to exchange rate shocks. This behavior is also observed for Mexico in Table 3, with the only difference being that the proportions stabilize earlier in this country –by the twelfth month.

There are substantial differences, however, in the magnitude of the proportions across countries. FX interventions shocks explain 3.7% of the variance in the Brazilian inflation rate one month after the shock and 20.8% from two years onwards. These figures are substantially higher than the corresponding 0.8% and 3.2% observed

## Figures 19-20

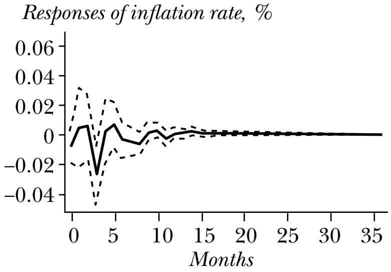
**RESPONSE OF INFLATION RATE TO INTEREST RATE SHOCKS UNDER $G_{27} \neq 0$**

19. BRAZIL: INFLATION RATE




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. We do not find evidence of the price puzzle; that is, inflation rate does not rise significantly in response to interest rate shocks. Inflation is defined as the percentage change in the consumer price index.
Sources: Banco Central do Brasil and authors' calculations.

20. MEXICO: INFLATION RATE




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Inflation rate goes down in response three months after the shock. Inflation is defined as the percentage change in the consumer price index.
Sources: Banco de México and authors' calculations.

in the first column of Table 3 for the case of Mexico. Although the forecast error variance decomposition analysis does not aim at establishing a causal relation between exchange rate policy and inflation rate, it supports the result that FX interventions are more costly in Brazil than in Mexico (as mentioned in the previous subsection).

As for the proportions explained by shocks in the exchange rate, the figures are notably small in both countries. For Brazil, these proportions equal 2.1% and 8.1% at 1 and at 24 months, respectively. For Mexico, the proportions equal 0.3 and 2.1. These numbers support the idea that the level of pass-through is small in both economies.

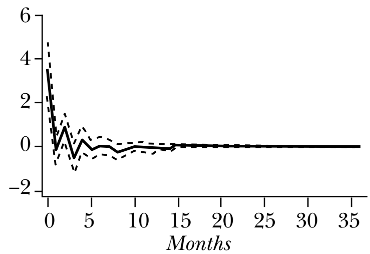
Certainly, the level of pass-through is greater for Brazil than it is for Mexico in absolute terms. However, the proportion explained by exchange rate shocks is smaller relative to the corresponding proportion associated with FX interventions shocks for the case of Brazil. For instance, the difference between the figures that appear in the sixth and first columns equals 1.6% and 12.7% at 1 and 24 months

Figures 21-22

**IMPULSE RESPONSES TO FOREIGN EXCHANGE INTERVENTIONS SHOCKS UNDER ALTERNATIVE IDENTIFYING ASSUMPTIONS: $g_{27} \neq 0$**

21. BRAZIL: EXCHANGE RATE

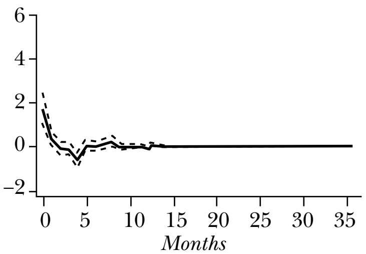
*Responses of exchange rate, %*




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Exchange rate depreciates on impact and rises further 2 months later. Exchange rate is defined as national currency per US dollar.
Sources: Banco Central do Brasil and authors' calculations.

22. MEXICO: EXCHANGE RATE

*Responses of exchange rate, %*




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Exchange rate depreciates on impact and goes up further one month later. Four months after the shock, it appreciates a bit. Exchange rate is defined as national currency per US dollar.
Sources: Banco de México and authors' calculations.

for Brazil and 0.5% and 1.1% for Mexico. This result supports the result that differences in the level of pass-through cannot entirely explain the fact that FX interventions have higher inflationary costs in Brazil than in Mexico.

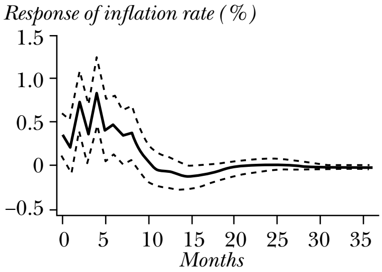
## 5. ROBUSTNESS

This subsection examines the robustness of our results by changing identifying restrictions. We focus on two cases: the contemporaneous response of the interest rate to commodity prices and the response of consumer prices to the exchange rate (concerning the $g_{27}$ and $g_{46}$ parameters, respectively). Three reasons motivate this analysis. First, by imposing these restrictions, our model departs from either Kim's (2003) setup and Echavarría et al.'s (2009) approach. Second,

## Figures 23-26

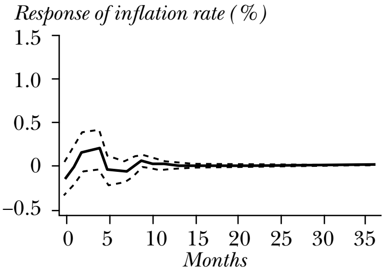
**IMPULSE RESPONSES TO FOREIGN EXCHANGE INTERVENTIONS SHOCKS UNDER ALTERNATIVE IDENTIFYING ASSUMPTIONS: $g_{27} \neq 0$**

23. BRAZIL: INFLATION RATE



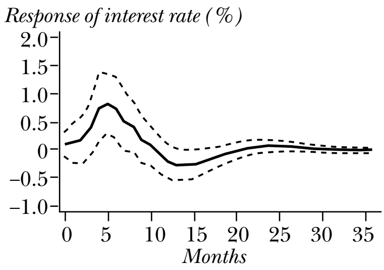

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Inflation goes up on impact and then continues increasing from two to eight months after the shock. Inflation is defined as the percentage change in the consumer price index.
Sources: Banco Central do Brasil and authors' calculations.

24. MEXICO: INFLATION RATE



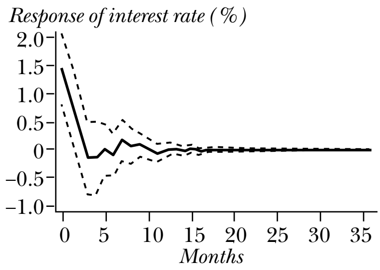

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Inflation does not respond significantly to intervention shocks. Inflation is defined as the percentage change in the consumer price index.
Sources: Banco de México and authors' calculations.

25. BRAZIL: MONETARY POLICY




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Interest rate increases four months after the shock and remains increasing until the sixth month. Money market interest rate is used for the interest rate.
Sources: Banco Central do Brasil and authors' calculations.

26. MEXICO: MONETARY POLICY

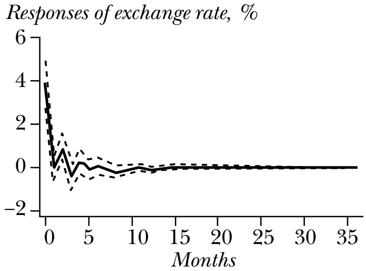



Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Interest rate goes up on impact and increases again the next month. Money market interest rate is used for the interest rate.
Sources: Banco de México and authors' calculations.

## Figures 27-30

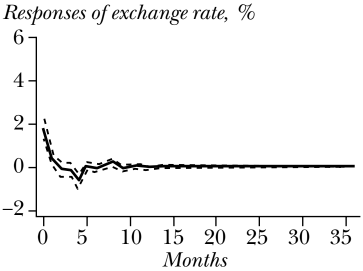
### IMPULSE RESPONSES TO FOREIGN EXCHANGE INTERVENTIONS SHOCKS UNDER ALTERNATIVE IDENTIFYING ASSUMPTIONS: $g_{46} = 0$

27. BRAZIL: EXCHANGE RATE



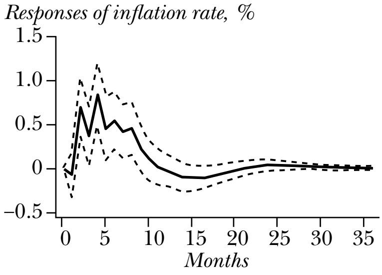

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Exchange rate depreciates on impact and rises further two months later. Exchange rate is defined as national currency per US dollar.
Sources: Banco Central do Brasil and authors' calculations.

28. MEXICO: EXCHANGE RATE



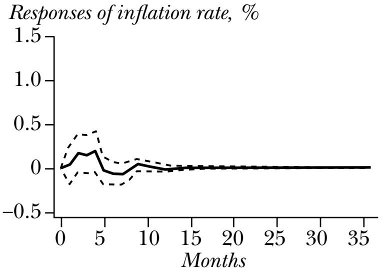

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Exchange rate depreciates on impact and goes up further one month later. Four months after the shock, it appreciates a bit. Exchange rate is defined as national currency per US dollar.
Sources: Banco de México and authors' calculations.

29. BRAZIL: INFLATION RATE




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Inflation goes up two months after the shock and keeps rising until the eighth month. Inflation is defined as the percentage change in the consumer price index.
Sources: Banco Central do Brasil and authors' calculations.

30. MEXICO: INFLATION RATE



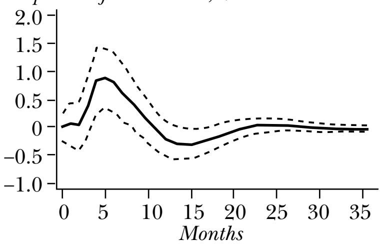

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Inflation does not respond significantly to interventions shocks. Inflation is defined as the percentage change in the consumer price index.
Sources: Banco de México and authors' calculations.

## Figures 31-32

### IMPULSE RESPONSES TO FX INTERVENTIONS SHOCKS UNDER ALTERNATIVE IDENTIFYING ASSUMPTIONS: $g_{46}$ = 0 (Cont.)

31. BRAZIL: MONETARY POLICY

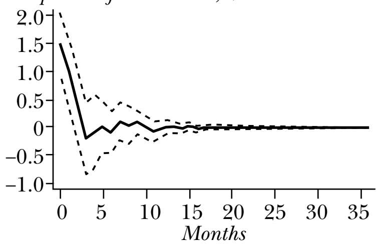
*Responses of interest rate, %*




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Interest rate increases four months after the shock and remains increasing until the eighth month. Money market interest rate is used for the interest rate.
Sources: Banco Central do Brasil and authors' calculations.

32. MEXICO: MONETARY POLICY

*Responses of interest rate, %*



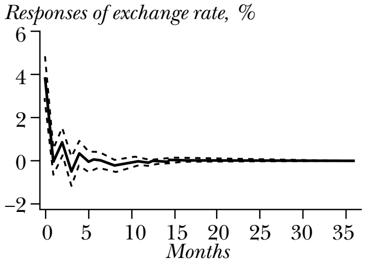

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Interest rate goes up on impact and increases again the next month. Money market interest rate is used for the interest rate.
Sources: Banco de México and authors' calculations.

## Figures 33-34

### IMPULSE RESPONSES TO FX INTERVENTIONS SHOCKS UNDER ALTERNATIVE IDENTIFYING ASSUMPTIONS: $g_{46}$ = 0 AND $g_{27} \neq 0$

33. BRAZIL: EXCHANGE RATE

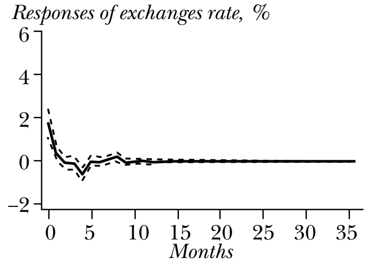
*Responses of exchange rate, %*




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Exchange rate depreciates on impact and rises further two months later. Exchange rate is defined as national currency per US dollar.
Sources: Banco Central do Brasil and authors' calculations.

34. MEXICO: EXCHANGE RATE

*Responses of exchanges rate, %*

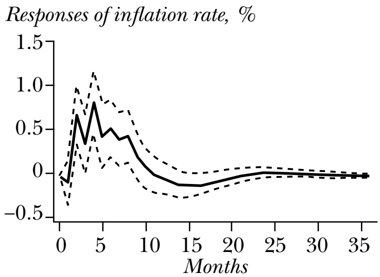



Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Exchange rate depreciates on impact and goes up further one month later. Exchange rate is defined as national currency per US dollar.
Sources: Banco de México and authors' calculations.

## Figures 35-38

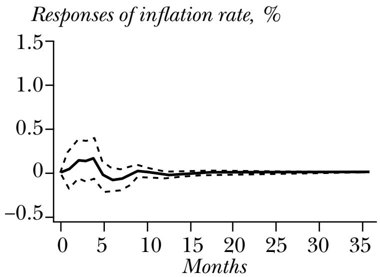
### IMPULSE RESPONSES TO FX INTERVENTIONS SHOCKS UNDER ALTERNATIVE IDENTIFYING ASSUMPTIONS: $g_{46} = 0$ AND $g_{27} \neq 0$ (Cont.)

35. BRAZIL: INFLATION RATE



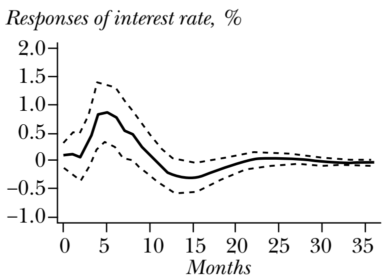

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Inflation goes up two months after the shock and keeps rising until the eighth month. Inflation is defined as the percentage change in the consumer price index.
Sources: Banco Central do Brasil and authors' calculations.

36. MEXICO: INFLATION RATE



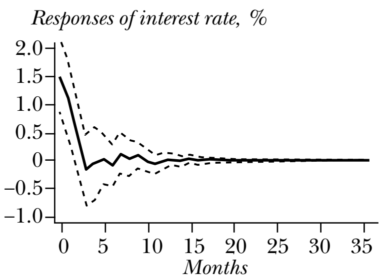

Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Inflation does not respond significantly to interventions shocks. Inflation is defined as the percentage change in the consumer price index.
Sources: Banco de México and authors' calculations.

37. BRAZIL: MONETARY POLICY




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Interest rate increases four months after the shock and remains increasing until the eighth month. Money market interest rate is used for the interest rate.
Sources: Banco Central do Brasil and authors' calculations.

38. MEXICO: MONETARY POLICY




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. Interest rate goes up on impact and increases again the next month. Money market interest rate is used for the interest rate.
Sources: Banco de México and authors' calculations.

the restriction on $g_{27}$ is connected to the empirical finding that some economies present a *price puzzle*, i.e., prices do not always respond in the expected direction to conventional monetary policy. This finding is relevant to our study because the original set of contemporaneous restrictions we have imposed generates a *price puzzle* for the case of Brazil.[22] Third, the restriction on $g_{46}$ is connected to contemporaneous pass-through and, therefore, is at the core of our main results.

The review of the two identifying restrictions yields the three alternative models that are described by the following conditions: $g_{27} \neq 0$; $g_{46}=0$; and $g_{46}=0$ and $g_{27} \neq 0$. For the sake of brevity, we present solely the response of $\Delta cpi_t$ to a shock in $\Delta i_t$ for the first case and the responses of $\Delta cpi_t$ and $\Delta i_t$ to the FX interventions shock for the three cases. Presenting these responses allows us to show that the *price puzzle* disappears when $g_{27} \neq 0$ and to examine the robustness of the model to changes in the two identifying restrictions. Figures 19-38 show the responses for the three alternative models.

Note in Figure 19 that when $g_{27} \neq 0$, the *price puzzle* disappears in Brazil; thus a rise in the interest rate is not associated with an increase in the inflation rate.[23] In both this model and in the remaining

---

22 The result that shows that inflation increases in response to a tightening of monetary policy in Brazil is due, at least, to two main reasons. First, this response could be part of a more general problem identified in the SVAR literature, according to which the prospective nature of central banks might not be fully captured: given that the central bank reacts in advance to inflationary pressures, SVAR models that do not include information on these pressures would be unable to identify true monetary policy shocks. In order to solve the so-called price anomaly, some authors include the prices of commodities in the VAR model estimates, arguing that these prices reflect inflationary pressures that are not incorporated in other variables (Sims, 1992, Christiano et al., 1999; Kim, 1999, 2003; and Sims and Zha, 2006). This chapter shows the result of this exercise in the Annex. Second, the unexpected response of the inflation rate to monetary policy could also be the result of the characteristics of the Brazilian economy. As discussed, it is likely that the fact that Brazil intervenes frequently in the foreign exchange market introduces noise into the relation between the interest rate and inflation. This fact could make it more difficult to raise the interest rate during each intervention to counteract any inflationary pressure.

23 However, leaving the parameter $g_{27}$ free do not solve completely the puzzle; we do not observe a fall in the inflation rate in response to a contractionary monetary policy shock as would be predicted by standard economic theory.

two setups, the consideration of alternative identifying restrictions modifies neither the qualitative results nor the significance of the responses. In particular, in the three alternatives we observe that *1)* FX interventions are effective in both countries and their effects on the exchange rate are short-lived; *2)* the inflation rises in response to the shock in Brazil but does not respond significantly in Mexico; and *3)* the central bank increases the interest rate immediately after the shock in Mexico but it does not do that in Brazil.

## 6. CONCLUSIONS

We have provided evidence of three major results. First, FX interventions have been successful in having a short-run impact on the exchange rate in both Mexico and Brazil. This outcome is consistent with an existing literature that investigates the effects of FX interventions in Latin America. Second, we have found that different FX intervention models generate differential inflationary costs, with the costs being higher in a model that involves interventions that are discretionary and of a higher-frequency. Third, the evidence suggests that this second result cannot not be entirely driven by cross-country differences in the level of exchange rate pass-through.

Indeed, the higher inflationary costs associated with the Brazilian model seem to be at least partially associated with the implicit interaction between FX interventions and interest rate setting (conventional monetary policy). In particular, adopting a model that entails interventions on a regular basis seems to make it more difficult to compensate them with increases in the interest rate. That is, this intervention model makes the relation between interest rates and inflation significantly noisier.

## ANNEX

**Table A.1**

**UNIT ROOT TEST STATISTICS**

| *Variable* | *Augmented Dickey-Fuller* | | | *Phillips-Perron* | | |
|---|---|---|---|---|---|---|
| | *Brazil* | *Mexico* | *95% critical value* | *Brazil* | *Mexico* | *95% critical value* |
| | | | In levels | | | |
| *fei* | −3.57[b] | −2.46[b] | −1.94 | −4.91[b] | −3.01[b] | −1.94 |
| *i* | −3.31[a] | −3.53[b] | −3.44 | −2.78[a] | −3.01[a] | −3.44 |
| *m* | −1.47[a] | −1.40[a] | −3.44 | −5.25[b] | −2.06[a] | −3.44 |
| *cpi* | −2.02[a] | −1.40[a] | −3.44 | −1.52[a] | −4.17[b] | −3.44 |
| *ip* | −2.78[a] | −2.41[a] | −3.44 | −2.50[a] | −2.18[a] | −3.44 |
| *e* | −2.26[a] | −3.38[a] | −3.44 | −2.37[a] | −3.24[a] | −3.44 |
| *pc* | −3.25[a] | −3.25[a] | −3.44 | −2.68[a] | −2.68[a] | −3.44 |
| | | | In first differences | | | |
| $\Delta fei$ | – | – | – | – | – | – |
| $\Delta i$ | −5.11[b] | −4.08[b] | −1.94 | −4.18[b] | −10.81[b] | −1.94 |
| $\Delta m$ | −3.90[b] | −7.57[b] | −2.88 | −21.72[b] | −19.90[b] | −2.88 |
| $\Delta cpi$ | −5.79[b] | −3.75[b] | −2.88 | −5.83[b] | −9.72[b] | −2.88 |
| $\Delta ip$ | −11.77[b] | −4.88[b] | −2.88 | −11.73[b] | −15.03[b] | −2.88 |
| $\Delta e$ | −8.41[b] | −11.54[b] | −1.94 | −8.40[b] | −11.54[b] | −1.94 |
| $\Delta pc$ | −4.37[b] | −4.37[b] | −1.94 | −8.84[b] | −8.84[b] | −1.94 |

Notes: The tests for variables in levels (panel A) include a constant and a liner trend, except for *fei*. The tests for $\Delta m$, $\Delta cpi$ and $\Delta ip$ (in panel B) include only a constant, and for *fei* (in panel A), $\Delta i$, $\Delta e$, $\Delta pc$ (in panel B) include neither a constant nor a liner trend. The lag lengths were chosen based on the AIC.
[a] The null hypothesis of a unit root cannot be rejected at 95% confidence level.
[b] The null hypothesis of a unit root is rejected at 95%confidence level.
Sources: Banco Central do Brasil, Banco de México and authors' calculations.

Table A.2

**LIKELIHOOD RATIO TEST FOR OVER-IDENTIFYING RESTRICTIONS (BASELINE MODEL)**

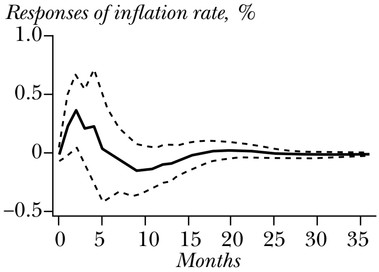
| | *Likelihood ratio statistic* $\left(\chi^2\right)$ | p-*value* |
|---|---|---|
| VAR model for Brazil | 11.34 | 0.125[a] |
| VAR model for Mexico | 3.15 | 0.871[a] |

[a] Overidentifying restrictions are not rejected at 1%, 5% and 10% levels.
Sources: Banco Central do Brasil, Banco de México, and authors' calculations.

Figures A.1 - A.2

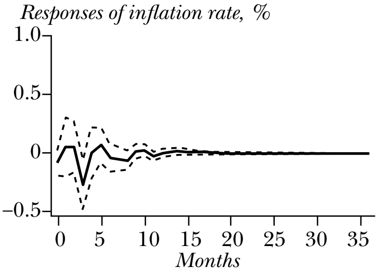
**RESPONSE OF INFLATION RATE TO INTEREST RATE SHOCKS**
**Baseline model**

A.1 BRAZIL: INFLATION RATE




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. We find the *price puzzle:* inflation rate increases in response two months after the shock. Money market interest rate is used for the interest rate.
Sources: Banco Central do Brasil and authors' calculations.

A.2 MEXICO: INFLATION RATE




Notes: The figure depicts the response to a positive FX intervention shock at $t = 0$. The dashed lines are 90% confidence bounds. We do not find the *price puzzle:* inflation rate falls in response three months after the shock. Money market interest rate is used for the interest rate.
Sources: Banco de México and authors' calculations.

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# Realized Volatility as an Instrument to Official Intervention

***João Barata R. B. Barroso***

**Abstract**

*This chapter proposes a novel orthogonality condition based on realized volatility that allows instrumental variable estimation of the effects of spot intervention in foreign exchange markets. We consider parametric and nonparametric instrumental variable estimation and propose a test based on the average treatment effect of intervention. We apply the method to a unique dataset for the BRL/USD market with full records of spot intervention and net order flow intermediated by the financial system. Overall the average effect of a one billion dollars sell or buy intervention is close to 0.51% depreciation or appreciation, respectively, estimated in the linear framework, which is therefore robust to nonlinear interactions. The estimates are a bit lower when controlling for derivative operations, which suggests the intervention policies (spot and swaps) are complementary.*

*Keywords: realized volatility, intervention, exchange rate, order flow, instrumental variable, nonparametric.*

*JEL classification: F31, C26, C54*

J. B. R. B. Barroso <joao.barroso@bcb.gov.br>, Research Department, Banco Central do Brasil The views expressed in the papers are those of the author and do not necessarily reflect those of the Banco Central do Brasil.

## 1. INTRODUCTION

Estimating the effect of official spot intervention on the level of the foreign exchange rate is challenging due to the simultaneity problem. Instrumental variables related to news, market expectations, and the reaction function of the Central Bank have been used with mixed results (Domingues and Frankel, 1993; Galati and Melick, 1999; Galati et al. 2005; Kearns and Rigobon, 2002; Tapia and Tokman, 2004). We argue that realized volatility calculated from intraday data is an ideal instrument for intervention on a daily frequency. The argument is built from deductive reasoning based on formal properties of conditional volatility models. We apply this idea to a unique dataset for the Brazilian foreign exchange market with full records of spot official intervention and net order flow intermediated by the financial system. The results of standard parametric tests and novel nonparametric tests based on the average treatment effect are both consistent with effective intervention.

The intuition for the use of observed realized volatility as an instrument for intervention is straightforward. First, since excessive volatility is the most common motivation for intervention policy in foreign exchange markets, intervention activity should be correlated with realized measures of volatility. Second, suppose the error in the conditional expectation of the foreign exchange return is the product of a time-varying scale factor and a standardized random variable. To the extent there is an appropriate orthogonality condition relating the scale factor and realized volatility, we have the second condition for an instrumental variable.

The required orthogonality condition can be obtained by exploring some extensions of the GARCH family of models that incorporate intraday information (Hansen et al., 2011; Shephard and Sheppard, 2010; Engle and Gallo, 2006). For concreteness, we motivate our proposed orthogonality condition in the context of the realized-GARCH framework of Hansen et al. (2011). In that model, realized volatility is related to latent volatility through measurement and state equations, such that lagged realized volatility satisfies the orthogonality condition. In contrast, the contemporaneous realized volatility is not an instrument due to the presence of leverage effects, that is, high volatility associated with negative returns. We also show that the idea is more general and applies to other realized measures and related volatility models.

The orthogonality condition can be used for classical parametric inference as well as for recently developed nonparametric instrumental variable estimation (Ai and Chen, 2003). In the latter case, we propose to summarize the effect of intervention with the average treatment effect. This statistic is also suggested in Fatum and Hutchison (2010), so our nonparametric instrumental variable estimator can be seen as an alternative to their propensity-score matching methodology. The testing framework proposed here is novel and is based on an application of the wild bootstrap to the average treatment effect statistic so as to account for conditional heteroscedasticity.

Realized volatility has been investigated before in the context of official intervention. However, the direction of causality explored in previous papers has been from intervention to the realized measure (Beine et al., 2007; Beine et al., 2009; Hillebrand et al., 2009; Cheng et al., 2013). As far as we can tell, realized volatility is not explored as an identification source for level effects of intervention. In any case, the results from these studies are consistent with the view that official intervention affects realized measures of volatility. This means realized volatility is unlikely to be a weak instrument and therefore supports the approach adopted here. Nonetheless, it remains an empirical question if the instrument is weak in a particular context.

Moving to our empirical application, it is important to mention other papers investigating level effects of spot intervention on the BRL/USD market.[1] Novaes and Oliveira (2005) assume a known generating process for intervention; Meurer et al. (2010) adopts an event study methodology; Wu (2010) assumes structural VAR based on a microstructure model; Kohlscheen (2013) compares intervention and nonintervention samples and applies propensity scores. Only the last two papers use actual intervention data as is the case here. Our dataset is also larger and more recent than the typical one in the literature, with daily information from 2007 to 2011. Although

[1] There are many papers not mentioned here investigating effects of spot intervention on volatility and other features of the market, as well as a few papers studying the effect of swap interventions (e.g. Novaes and Oliveira, 2005; and Kohlscheen and Andrade, 2013). This paper considers only spot interventions and level effects, with a robustness exercise for swap interventions.

instrumental variable identification is not generally more efficient or transparent than the methods used in these papers, we believe this is the case for our particular instrumental variable estimator. Our approach is also less demanding on the identifying assumptions. As for substantive results, we find very robust evidence of effective intervention regardless of the specific window of events as often emphasized in the literature.

An important advantage of the dataset used here is the possibility to control for costumer order flow through financial intermediaries. Although order flow is a well-known proximate driver of exchange rate dynamics (e.g., Evans and Lyons, 2002; Vitale, 2007), none of the previous papers using an instrumental variable approach controlled for this variable (e.g., Domingues and Frankel, 1993; Galati and Melick, 1999; Galati et al., 2005; Kearns and Rigobon, 2002; Tapia and Tokman, 2004). For the BRL/USD market, Wu (2010) and Kohlscheen (2013) also use order flow information but with other identification strategies. The possibility of nonlinear interactions between order flow and intervention is raised in Kohlscheen (2013), since order flow coefficient is not stable in intervention and nonintervention periods. Recent papers exploring nonlinear level effects of intervention (Taylor, 2004 and 2005; Reitz and Taylor, 2008 and 2012; and Beine, Grauwe and Grimaldi, 2009) also do not control for order flow information, and the nonparametric approach adopted here is more flexible than the parametric specifications generally adopted.

The paper is structured as follows. In the following section, realized volatility is presented as an instrument for intervention policy. Considering the need for robust results, section three proposes a nonparametric instrumental variable estimator and corresponding test statistic. The fourth section reports the results applying our framework to Brazilian intervention data. The final section offers some conclusions and comments on the general applicability of the methodology developed in this paper.

## 2. REALIZED VOLATILITY AS AN INSTRUMENT

Let $r_{t,i}$ be the log return on the foreign exchange rate on tick $i$ of day $t$ such that with $n_t$ ticks available the daily return is $r_t = \sum_{i=0}^{n_t} r_{t,i}$. Define realized variance as $rv_t = \sum_{i=0}^{n_t} r_{t,i}^2$, and realized volatility its square root, $rv_t^{1/2}$. If returns are not correlated, it can be shown (e.g., Macleer and Medeiros, 2008, under Brownian motion) that realized variance is an unbiased, consistent and asymptotically normal estimator for the conditional variance of the foreign exchange rate $\sigma_t^2 = \mathrm{Var_t}(\mathrm{r_t})$. The index *t* in variance and expectation operators indicate measurability with respect to information known at the beginning of period *t*. The conditional variance is determined by the error process $\varepsilon_t$ in the conditional expectation, such that $r_t = E_t(r_t) + \varepsilon_t$.

For concreteness, consider the following log-linear realized-GARCH model (see Hansen et al., 2011):

1
$$\begin{aligned} \varepsilon_t &= \sigma_t \eta_t \\ \log \sigma_t^2 &= \omega + \delta \log \sigma_{t-1}^2 + \rho \log rv_{t-1} \\ \log rv_t &= \xi + \varphi \log \sigma_t^2 + \tau(\eta_t) + u_t, \end{aligned}$$

with $\eta_t \sim iid(0,1)$, $u_t \sim iid(0, \sigma_u^2)$ and $\tau(\cdot)$ a nonlinear leverage function. The last equation incorporates the fact that the realized variance is a consistent estimator of the conditional variance. The second equation incorporates the measurability requirements and induces an autoregressive process in the log conditional variance. These are the measurement and state equations, respectively.

The most significant consequence of this model for our purpose is the orthogonality condition: $E(\varepsilon_t \mid rv_{t-1}^{1/2}) = 0$. This can be verified by simple algebra, since

2
$$\begin{aligned} E\left(\varepsilon_t \middle| rv_{\mathrm{t}-1}^{1/2}\right) &= E\left(\sigma_t \eta_t \middle| rv_{\mathrm{t}-1}^{1/2}\right) \\ &= E\left(s(\sigma_t) e^{\omega/2} \sigma_{t-1}^{\delta} rv_{\mathrm{t}-1}^{\rho/2} \eta_t \middle| rv_{\mathrm{t}-1}^{1/2}\right) \\ &= rv_{t-1}^{\frac{(\varphi\rho+\delta)}{2\varphi}} e^{\frac{\omega}{2} - \frac{\xi\delta}{2\varphi}} E\left( s(\sigma_t) e^{-\frac{u_{t-1}\delta}{2\varphi}} e^{-\frac{\tau(\eta_{t-1})\delta}{2\varphi}} \eta_t \middle| rv_{\mathrm{t}-1}^{1/2} \right) = 0, \end{aligned}$$

where $s(\cdot)$ is the sign function. That is, as long as $u_{t-1}, \eta_{t-1}, \eta_t$ are independent conditionally on $s(\sigma_t), rv_{t-1}^{1/2}$, which we shall assume. In this case, in the last step we may use the law of iterated expectations for the term inside the expectation operator and then use conditional independence. It is interesting to observe that $E\left(\varepsilon_t \middle| rv_{t-1}\right)$ is generally different from zero due to the contemporaneous leverage effect in the measurement equation. Also, we may drop the sign condition if $\sigma_t$ is assumed positive. Finally, note the exact same argument applies to the realized variance, so that the orthogonality condition $E\left(\varepsilon_t \middle| rv_{t-1}\right)=0$ is also available as long as $u_{t-1}, \eta_{t-1}, \eta_t$ are independent conditional on lagged realized variance.

The orthogonality condition with realized volatility is the basis for an instrumental variable estimator. In fact, consider the following model for the conditional expectation of the log exchange rate return

$$E_t\left(r_t\right)=\alpha+\theta \operatorname{int} v_t+\beta' x_t, \tag{3}$$

where the intervention variable int $v_t$ is endogenous and the covariates $x_t$ are exogenous, that is, $E\left(\varepsilon_t \middle| \operatorname{int} v_t\right) \neq 0$ and $E\left(\varepsilon_t \middle| x_t\right)=0$. If the intervention policy is such that it is correlated with realized volatility as known at the beginning of the period, that is, $\operatorname{Cov}\left(rv_{t-1}^{1/2}, \operatorname{int} v_t\right) \neq 0$, then realized volatility is a useful instrument. Even if the reaction function actually responds to contemporaneous realized volatility, the autoregressive structure in the state equation along with the measurement equation would imply the necessary correlation. Of course, it will always be an empirical question if the instrument is sufficiently strong for inference. For implementation, one must use realized volatility obtained from the raw exchange rate series, since a measure for the residual of the model is not available at this frequency. We assume both are essentially the same, a sensible proxy variable assumption given the hard time we have to explain the exchange rate process and the high level of noise in the data.

Note that lagged and contemporaneous intervention could be included in the measurement and state equations, respectively, such that the orthogonality condition would be $E\left(\varepsilon_t \middle| rv_{t-1}^{1/2}, \operatorname{int} v_{t-1}\right)=0$. Again, the adequate condition must be judged empirically, as indicated by over-identification and weak instrument diagnostic tools. As illustrated below, it is possible to extend the argument for interventions in the futures market, as well as to pool the instrumental variables for both kinds of interventions using the covered parity relation. Also note that other realized measures, such as bipower variation, intraday range, and squared return could be used in place of realized volatility or realized variance. The measurement equation is probably better specified in the case of realized volatility since it is a relatively more efficient estimator of conditional volatility. For this reason, in the application to our dataset we focus on the realized volatility as our observed measure of volatility. Finally, note other conditional volatility models incorporating intraday information would imply similar orthogonality conditions; for instance, Engle and Gallo (2006) estimate a model that has essentially a realized GARCH specification and so similar arguments would apply.

## 3. NONPARAMETRIC ESTIMATOR AND AVERAGE TREATMENT EFFECT

For robustness, it is interesting to estimate a more general model, such as

$$E_t(r_t) = \alpha + \theta \operatorname{int} v_t + \beta'(x_{1t}, x_{2t}) + f(\operatorname{int} v_t, x_{2t}), \tag{4}$$

for an unknown function $f(\cdot)$ and under the same endogeneity assumption as before, with $x_t = (x_{1t}, x_{2t})$ so as to allow for flexible nonlinear interactions with a subgroup of the control variables. We may consider the nonparametric instrumental variable estimator of Ai and Chen (2003) which is consistent for the real parameters and for the unknown function, as well as asymptotically normal for the real parameters. One may use the wild bootstrap for inference so as to account for conditional heteroscedasticity.

If the intervention is excluded from the nonparametric part of the model, $\theta$ continues to summarize the effect from intervention. But such a restriction would be hard to justify. In order to summarize the effect from intervention without arbitrary exclusion restrictions, we may consider the average treatment effect

$$\text{ATE} = T^{-1} \sum \left( E\left(r_t \middle| x_t, \operatorname{int} v_t\right) - E\left(r_t \middle| x_t, \operatorname{int} v_t = 0\right) \right). \tag{5}$$

This is a parameter as long as we condition on the sample covariates and intervention policy. Using the estimated conditional expectations instead results in a random variable. As mentioned before, we may test the null of zero average treatment effect by applying the wild bootstrap.

Indeed, consider testing the null that $H_0\colon \mathrm{ATE} \leq 0$ against the alternative that $H_1\colon \mathrm{ATE} > 0.$ Let $\hat{\delta}_t = E\left(r_t \middle| x_t, \mathrm{int}\, v_t\right) - E\left(r_t \middle| x_t, \mathrm{int}\, v_t = 0\right).$ The test statistic is $t = \sqrt{T}\bar{\delta}_t \big/ A\,\mathrm{var}(\bar{\delta}_t).$ We propose the following wild bootstrap algorithm

*1)* Generate the wild bootstrap residuals $\left\{\varepsilon_t^*\right\}_{t=1}^{T}$ from $\varepsilon_t^* = \hat{\varepsilon}_t \eta_t,$ where $\eta_t$ is a sequence of iid random variables with zero mean and unit variance, $\hat{\varepsilon}_t = r_t - \hat{E}_t\left(r_t\right),$ and such that $r_t^* = \hat{E}_t\left(r_t\right) + \varepsilon_t^*.$

*2)* Calculate the bootstrap test statistic $t^*$ on the sample $\left\{r_t^*, \mathrm{int}\, v_t, x_t\right\}_{t=1}^{T}.$

*3)* Repeat this procedure several times and calculate the $p$-values for the $t$ statistic with the empirical distribution of the bootstrapped $t^*$ statistics.

Notice how we assume that the orthogonality condition associated with realized volatility is sufficiently strong to result in consistent estimates of the true model. Otherwise, the average treatment effect would have to be estimated by other methods, such as propensity-score matching methodology (e.g., Fatum and Hutchison, 2010).

One may also consider the weighted average treatment effect, perhaps with weights given by the inverse of realized standard deviation. That is,

$$w\mathrm{ATE} = T^{-1}\frac{\omega_t}{\sum \omega_t}\sum\left(E\left(r_t \middle| x_t, \mathrm{int}\, v_t\right) - E\left(r_t \middle| x_t, \mathrm{int}\, v_t = 0\right)\right), \tag{6}$$

with $\omega_t = 1\big/\sqrt{rv_t}$. If the endogeneity problem is particularly severe in high volatility periods, with the intervention failing to completely reverse foreign exchange shocks, then it makes sense to down weight such periods. Although the instrumental variable estimation is consistent, it may not be particularly efficient in finite samples.[2] The

[2] Ai and Chen (2003) efficiency results refer only to the finite dimensional parameters and does not allow for time series dependency. Although

weighted average treatment effect imposes a second layer of protection against possible finite sample biases.

Finally, when defining the average treatment effect for period with positive and negative interventions, it is necessary that negative interventions enter with a negative sign, so as to avoid shrinking the average effect to zero. Taking advantage of the nonlinear estimation, it may be also of interest to obtain separate average treatment effects for both positive and negative interventions. We illustrate these possibilities in the application section below.

## 4. APPLICATION: OFFICIAL INTERVENTION IN BRAZIL

It can be argued that the Banco Central do Brasil tries to minimize exchange rate volatility. Indeed, apart from the official goal of international reserves accumulation, the public discourse of the monetary authority is consistent with this. In our sample, there is no announced rule or commitment for intervention policy. Intervention tends to be correlated with order flow, with the stated purpose of not upsetting underlying market trends (see e.g., Barroso and Sales, 2012). There are large and frequent spot market interventions and occasional interventions in the futures market through derivative instruments with cash settlement (swaps for short).

*Data.* Our database begins on July 11, 2007 and ends on November 30, 2011. The series are sampled at a daily frequency. The BRL/USD foreign exchange rate is measured in domestic currency so that an increase shows depreciation. The order flow variable is from the Banco Central do Brasil electronic records of private spot transactions intermediated by financial institutions and covers the entire market; a positive reading means domestic institutions are net buyers of foreign currency against other parties. The actual spot intervention policy of the Banco Central do Brasil is used as a regressor, as compared to a proxy based on international reserves, and a positive number means buying dollars. See Kohlscheen (2012) for further details regarding order flow and spot intervention. In robustness

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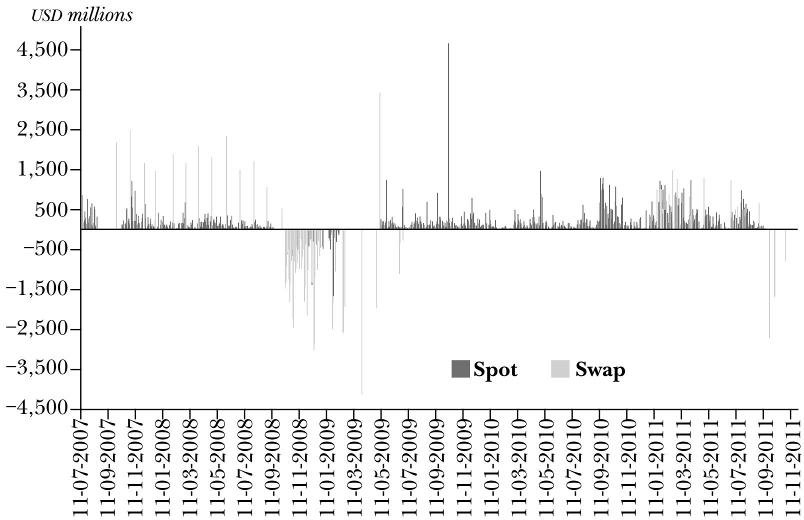
the estimation of the nonparametric part is consistent in an appropriate metric, there are no results establishing efficiency or finite sample properties.

Figure 1

**OFFICIAL INTERVENTION**




exercises we also consider swap interventions, and the data is publicly available in the Banco Central do Brasil web site. Both interventions are plotted in Figure 1. The realized volatility measure is from Bloomberg and is based on 48 intraday measures of return. The set of covariates includes the CRB commodity price index, the implicit volatility index VIX, the dollar index DOL and the emerging market spread index from JPMorgan EMBI+. The interest rate differential measured as the Selic minus the Federal Reserves funds rate was considered as a possible covariate.

*Parametric.* We estimate linear regressions using ordinary least squares, instrumental variable, and weighted instrumental variables. In the second and third cases, realized volatility is an instrument for spot intervention and identification is exact. In the third case realized volatility is used as a consistent estimator for conditional volatility in an attempt to obtain more efficient estimators.

The results are summarized in Table 1. There is a clear simultaneity bias in the ordinary least squares estimator for the spot intervention coefficient. The negative coefficient means that the domestic currency depreciates when the central bank sells foreign currency,

**Table 1**

**EFFECT OF INTERVENTION: LINEAR REGRESSION**
Dependent variable: d(BRL_USD)

| | *OLS* | | *IV* | | *W-IV* | |
|---|---|---|---|---|---|---|
| c | 0.02 | 0.03 | −0.15[d] | −0.15[d] | −0.17[a] | −0.16[b] |
| | 0.72 | 0.92 | −1.49 | −1.53 | −2.72 | −2.66 |
| spot | −0.33[b] | −0.22[b] | 1.24[d] | 1.18[c] | 0.59[c] | 0.51[c] |
| | −2.07 | −1.52 | 1.53 | 1.71 | 1.63 | 1.66 |
| d(crb) | −0.39[a] | −0.40[a] | −0.48[a] | −0.47[a] | −0.20[a] | −0.19[a] |
| | −6.18 | −6.31 | −6.59 | −6.88 | −5.16 | −5.43 |
| d(dol) | 0.35[a] | 0.38[a] | 0.42[a] | 0.41[a] | 0.35[a] | 0.36[a] |
| | 5.60 | 5.96 | 5.66 | 6.10 | 7.98 | 8.82 |
| d(embi) | 0.14a | 0.15[a] | 0.16[a] | 0.16[a] | 0.05[a] | 0.07[a] |
| | 9.56 | 10.07 | 7.84 | 8.68 | 6.41 | 10.20 |
| d(vix) | 0.13 | | 0.34 | | 0.02[a] | |
| | 0.21 | | 0.51 | | 5.14 | |
| netflow | 0.15[a] | | −0.04 | | −0.06 | |
| | 3.33 | | −0.43 | | −0.87 | |
| Number of observations | 973 | 973 | 972 | 972 | 972 | 972 |
| $R^2$ | 0.40 | 0.40 | 0.27 | 0.28 | 0.25 | 0.26 |
| Endogeneity (dJ) | | | 17.39 | 19.44 | 5.83 | 4.87 |
| Cragg-Donald (F) | | | 81.79 | 106.25 | 32.69 | 35.99 |

Notes: *t*-values below estimates; HAC [a]1%, [b]5%, [c]10%, [d]15 percent.

or that it appreciates when the monetary authority is buying dollars. In reality, this only reflects that the monetary authority is leaning against the wind of exogenous variation in the foreign exchange rate. The coefficient on the net order flow variable may also be qualified as counterintuitive, since dollar inflows would be associated with depreciation of the domestic currency. The coefficients on the other variables are reasonably signed and are highly significant, except for the global risk aversion indicator. Excluding this variable and the net order flow does not change the results on the other variables.

Using realized volatility as an instrument for spot intervention leads to completely different results. The spot intervention effect is now estimated to be positive. It is either marginally significant when including all controls and significant at 10% when including only significant controls. For each one billion dollars buy intervention there is a corresponding depreciation of 1.18% of the domestic currency in our preferred model. The test for endogeneity is significant and the Cragg-Donald F statistic from the first stage regression is much larger than Stock-Yogo critical values. Overall, the instrumental variable specification seems appropriate. The net order flow variable shows an inverted sign, although it is no longer significant. The remaining control variables preserve the sign and significance pattern from the ordinary least squares estimation.

These results are similar when using the weighted instrumental variable estimator. The spot intervention is correctly signed and is statistically significant at 10%, at the margin of 5%. For each one billion dollars buy intervention there is a corresponding depreciation of 0.51% of the domestic currency according to our preferred model. Net order flow continues to show no significance, but the proxy for international risk aversion gains significance with the lower standard errors.

The interest differential variable was not found to be significant in any of the specifications and its exclusion had no impact on the size and significance of other parameters. For this reasons, we reported only results excluding the variable. This is consistent with results from Kohlscheen (2012) using the same dataset.

The instability of the estimated effect of net order flow is also consistent with results from Kohlscheen (2012) according to which this effect is not constant in intervention and nonintervention subsamples. Since order flow has often been found to be one of the best proximate determinants of foreign exchange rates in sample and out of sample, we investigate a more flexible specification allowing for flexible nonlinear interactions between official intervention and selected controls including order flow.

*Nonparametric.* We estimate the general model with a linear and nonparametric part defined in Equation 4, with $x_{2t}$ set to the net order flow variable so as to focus on possible nonlinear interactions suggested by the literature and by the results from the linear parametric model. We consider the Ai and Chen (2003) estimator. Accordingly, we use power series sieves to approximate the conditional expectation in a first step using third degree polynomials. The nonparametric part is approximated in a second step with a power series sieve of second degree. The resulting model is used to calculate the average treatment effect defined in Equation 5 and the test statistic for such average. The wild bootstrap defined in Section 3 is used to obtain $p$-values. The effect of negative interventions is multiplied by minus one throughout, so that a positive effect for negative interventions is correctly signed, showing that the domestic currency appreciates when the central bank sells foreign currency.

The results are reported in Table 2. The scaled average treatment effect allows us to think of the average effect of a counterfactual one billion dollars intervention. For each one billion dollars acquisition of foreign currency, there is an average depreciation in the range of 0.445% and 0.608% depending on the controls in the model. The effect is significant at 5% in the preferred model including all the controls except for the interest rate differential (model 2 in the Table). Moving on, for each one billion dollars selling of foreign currency, there is an average appreciation in the range of 0.552% and 0.728% depending on the controls in the model. The effect is once again significant at 5% in the preferred model. For the average effect, we obtain the range 0.470% and 0.608% variation, and this is significant at 1% in the preferred model.

The analogous results for the weighted estimator are reported in Table 3. For a counterfactual one billion dollars acquisition of foreign currency, there is an average depreciation in the range of 0.463% and 0.647%, down-weighting volatile episodes, depending on the controls in the model. The effect is significant at 5% in the preferred model including all the controls except for the interest rate differential (again, model 2 in the table). Now, for a counterfactual one billion dollars selling of foreign currency, there is an average appreciation in the range of 0.508% and 0.636%, down-weighting volatile episodes, depending on the controls in the model. The effect is once again significant at 5% in the preferred model. Considering the overall average effect, down-weighting volatile episodes, the variation in the corresponding direction of the intervention is in the range 0.487% and 0.660%, and this is significant at 5% in the preferred model.

Overall the average effect or even the conditional effects of sell or buy interventions are close to the 0.51% estimated in the linear framework, which is therefore robust to nonlinear interactions. In

Table 2

**AVERAGE TREATMENT EFFECT OF INTERVENTION: NONPARAMETRIC ESTIMATION**

Dependent variable: d(BRL_USD)

| *Model* | *ATE* | *Scaled ATE* | *t-stat* | *p-value* |
|---|---|---|---|---|
| all[1] | 0.091 | 0.608 | 35.872 | 0.0234 |
| pos[1] | 0.114 | 0.614 | 32.956 | 0.0862 |
| neg[1] | 0.170 | 0.552 | 31.941 | 0.0280 |
| all[2] | 0.070 | 0.470 | 51.649 | 0.0092 |
| pos[2] | 0.083 | 0.445 | 50.096 | 0.0440 |
| neg[2] | 0.224 | 0.728 | 32.959 | 0.0280 |
| all[3] | 0.079 | 0.525 | 45.159 | 0.0120 |
| pos[3] | 0.095 | 0.511 | 42.105 | 0.0598 |
| neg[3] | 0.204 | 0.665 | 32.739 | 0.0202 |

Notes: Wild bootstrap using N(0,1); 5,000 replications. Newey-West variance estimator of asymptotic variance. Power series sieve; 3rd degree cond. expectation; 2nd degree nonparametric part.
Models: [1]nonlinear: spot, netflow; linear: spot, netflow, d(crb), d(dol), d(embi), d(vix), d(drate). [2]nonlinear: spot, netflow; linear: spot, netflow, d(crb), d(dol), d(embi), d(vix). [3]nonlinear: spot, netflow; linear: spot, netflow, d(crb), d(dol), d(embi).
all stands for average effect of all interventions; negative interventions $x(-1)$.
pos stands for average effect off positive interventions $x(+1)$.
neg stands for average effect off negative interventions $x(-1)$.

any case, in the nonparametric framework, the effect of each individual intervention will depend in a very nonlinear way on system conditions and intervention attributes. The effects reported above refer to the estimated average across many different system conditions observed in the sample. It should not be interpreted as a linear coefficient that scales with the size of the intervention. Policymakers and market participants should estimate a similar nonparametric model to forecast the impact of any particular policy in any given system condition. If the conditional expectation were linear, there would be a one to one correspondence between the average effects and the coefficient in the linear model.

*Swaps.* So far we have not addressed the possible bias coming from the use of other forms of official intervention that might be correlated

**Table 3**

**WEIGHTED AVERAGE TREATMENT EFFECT OF INTERVENTION: NONPARAMETRIC ESTIMATION**

Dependent variable: d(BRL_USD)

| *Model* | *wATE* | *Scaled wATE* | *t-stat* | *p-value* |
|---|---|---|---|---|
| all[1] | 0.107 | 0.711 | 17.564 | 0.0638 |
| pos[1] | 0.125 | 0.676 | 22.638 | 0.0592 |
| neg[1] | 0.145 | 0.472 | 30.649 | 0.0690 |
| all[2] | 0.076 | 0.510 | 32.200 | 0.0136 |
| pos[2] | 0.089 | 0.479 | 35.067 | 0.0204 |
| neg[2] | 0.175 | 0.569 | 44.229 | 0.0290 |
| all[3] | 0.088 | 0.589 | 27.434 | 0.0226 |
| pos[3] | 0.103 | 0.555 | 28.601 | 0.0364 |
| neg[3] | 0.164 | 0.535 | 39.020 | 0.0406 |

Notes: Wild bootstrap using N(0,1); 5,000 replications. Newey-West variance estimator of asymptotic variance. Power series sieve; 3rd degree cond. expectation; 2nd degree nonparametric part. Weighted by the inverse of realized standard deviation.
Models: [1]nonlinear: spot, netflow; linear: spot, netflow, d(crb), d(dol), d(embi), d(vix), d(drate). [2]nonlinear: spot, netflow; linear: spot, netflow, d(crb), d(dol), d(embi), d(vix). [3]nonlinear: spot, netflow; linear: spot, netflow, d(crb), d(dol), d(embi).
all stands for average effect of all interventions; negative interventions $x$ (−1).
pos stands for average effect off positive interventions $x$ (+1).
neg stands for average effect off negative interventions $x$ (−1).

with spot market intervention. In particular, in our sample, derivative market interventions with cash settlement (swaps for short) correlate positively with spot interventions, introducing the possibility of an upward bias in the results reported above. Our first answer to this is that the results can always be interpreted as the structural impact of spot interventions used in association with swaps as observed in the sample. This is still a relevant structural parameter for the policy maker. The results for this parameter are still a nice illustration of the identification strategy proposed in the paper.

We perform three additional robustness exercises: First, we estimate the effect of spot intervention excluding from the sample the days of swap intervention; second, we estimate on the full sample with

Table 4

**EFFECT OF INTERVENTION: LINEAR REGRESSION, ROBUSTNESS TO SWAPS**

Dependent variable: d(BRL_USD)

| | *No-swap sample* | | | *Swap sample* | | |
|---|---|---|---|---|---|---|
| | *OLS* | *IV* | *w-IV* | *OLS* | *IV* | *w-IV* |
| c | 0.04 | −0.12[b] | −0.13[b] | 0.04 | −0.11[b] | −0.14[a] |
| | 1.07 | −2.02 | −5.11 | 1.30 | −1.41 | −3.85 |
| spot | −0.21[b] | 0.89[b] | 0.31[b] | −0.27[c] | 0.90[c] | 0.31[c] |
| | −1.98 | 2.25 | 2.10 | −1.83 | 1.67 | 1.91 |
| d(crb) | −0.42[a] | −0.44[a] | −0.18[a] | −0.41[a] | −0.47[a] | −0.18[a] |
| | −6.42 | −6.40 | −4.37 | −6.48 | −7.12 | −5.10 |
| d(dol) | 0.31[a] | 0.34[a] | 0.35[a] | 0.38[a] | 0.41[a] | 0.36[a] |
| | 4.95 | 5.31 | 8.90 | 5.96 | 6.20 | 9.22 |
| d(embi) | 0.14[a] | 0.14[a] | 0.07[a] | 0.15[a] | 0.16[a] | 0.07[a] |
| | 10.45 | 9.96 | 8.76 | 9.96 | 9.23 | 10.41 |
| swap | | | | 0.16[c] | 0.11 | 0.24 |
| | | | | 1.90 | 0.23 | 0.68 |
| Number of observations | 884 | 883 | 883 | 973 | 972 | 972 |
| $R^2$ | 0.41 | 0.32 | 0.30 | 0.39 | 0.32 | 0.26 |
| Endogeneity (dJ) | | 20.58 | 17.63 | | 23.73 | 10.16 |
| Cragg-Donald (F) | | 62.93 | 121.75 | | 8.30 | 11.02 |

Notes: $t$-values below estimates; HAC [a] 1%, [b] 5%, [c] 10%, [d] 15%. Sample with or without days of swap operations; instrument list includes lagged realized variance, net order flow and, for the IV-swap sample, squared variation of exchange rate futures; when applicable, overidentifying conditions are not rejected at five percent.

Table 5

**AVERAGE TREATMENT EFFECT OF INTERVENTION: NONPARAMETRIC, ROBUSTNESS TO SWAPS**

Dependent variable: d(BRL_USD)

| *Model* | *ATE* | *Scaled ATE* | *t-stat* | *p-value* |
|---|---|---|---|---|
| all | 0.054 | 0.360 | 51.243 | 0.0082 |
| pos | 0.063 | 0.337 | 48.510 | 0.0402 |
| neg | 0.180 | 0.586 | 36.205 | 0.0128 |
| w-all | 0.058 | 0.385 | 32.450 | 0.0124 |
| w-pos | 0.067 | 0.361 | 35.303 | 0.0190 |
| w-neg | 0.141 | 0.458 | 48.064 | 0.0230 |

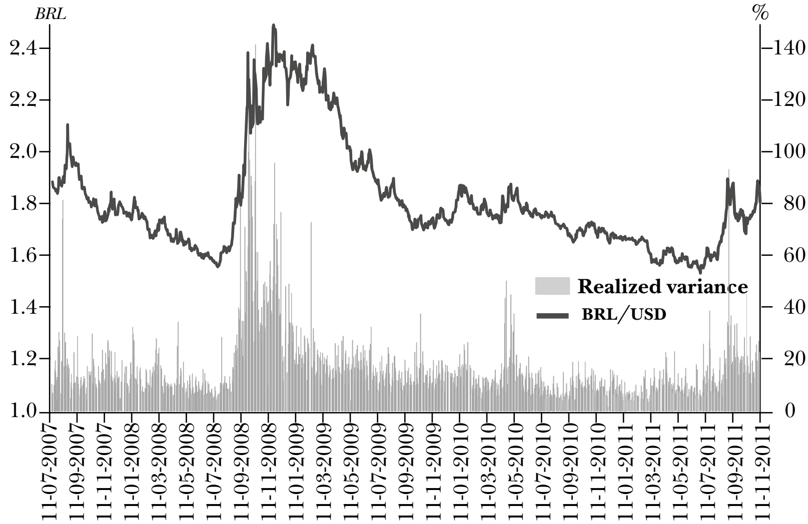
Notes: Wild bootstrap using N(0,1); 5,000 replications. Newey-West variance estimator of asymptotic variance. Power series sieve; 3rd. degree cond. expectation; 2nd. degree non parametric part. Nonlinear: spot, netflow; linear: spot, swap, netflow, d(crb), d(dol), d(embi), d(vix). Intervention instrumented by lagged realized volatility.
Models: all stands for average effect of all interventions; negative interventions $x\,(-1)$. pos stands for average effect off positive interventions $x\,(+1)$. neg stands for average effect off negative interventions $x\,(-1)$. w-, weighted average treatment effect.

additional instruments for the swap operations; third, we estimated a nonparametric instrumental variable model controlling for swaps. In the case of instrumental variables in the linear framework, the instrument list includes *1)* a realized variable for the future market, namely the squared variation of the nearest future quotation, and *2)* the net order flow variable. From the covered interest parity, innovations in future and spot exchange rate variation should be close to each other, so that a realized measure in the future could provide additional information. Previous results exclude net order flow from the linear model, and the statements by policy makers suggest order flow is associated with spot market interventions. Both factors suggest net order flow could be used as an instrument. In the nonparametric model, the focus is on neglected nonlinearity in order flow, so we do not include it as an instrument.

The results for the linear robustness exercises are summarized in Table 4. Consider first the no swap sample. As before, there is a clear simultaneity bias in the ordinary least squares estimator and using

Figure 2

**EXCHANGE RATE AND REALIZED VOLATILITY**




realized volatility as an instrument for spot intervention inverts the sign of the coefficient. The effect is significant at 10%. Consider now the full sample. Again there is a clear endogeneity bias in spot interventions. With instrumental variable estimation, the effect has the opposite sign, at 0.31% for each one USD billion intervention, and is significant at 5%. There is no robust evidence of level effects of swap operations. Moreover, there is no robust evidence of bias in our previous estimates for the effects of spot interventions. The estimated effect in our preferred specification in the last column is lower than the estimates obtained in the previous section, which supports the hypothesis of a positive bias in intervention effects obtained without controlling for swaps.

The results for the nonparametric robustness exercise for swaps are reported in Table 5. Using realized volatility and squared future returns as instruments for both interventions does not result in significant results. We report the regression using only realized volatility to instrument for spot interventions. The scaled average effects are of the order of 0.36% for each one USD billion intervention, and this is significant at 1%. This is close to the result from the linear model and lends further support to a small positive bias without controlling for swap operations. We interpret these results as evidence of complementarity of both types of official intervention.

## 5. CONCLUSION

This paper contributes to the tradition of instrumental variable estimation of the effect of official intervention. We propose a novel orthogonality condition formally deduced from standard properties of conditional volatility models. In particular, we show that realized volatility is orthogonal to the innovation in a log-linear realized-GARCH model, as well as argue that it is correlated to intervention by reference to empirical literature relating both variables and to standard policy rationale often presented by monetary policy authorities. We consider both parametric and nonparametric instrumental variable estimation, in the latter case also proposing a statistical test based on the average treatment effect of official intervention.

We apply the proposed instrumental variable approach to a unique dataset for the Brazilian foreign exchange market with full records of official intervention and net order flow intermediated by the financial system. In the linear framework, for each one billion dollars buy (sell) intervention there is a corresponding depreciation (appreciation) of 0.51% of the domestic currency. In the nonparametric framework incorporating nonlinear interaction between official intervention and the underlying market conditions represented by order flow information, for each one billion dollars buy (sell) intervention there is a corresponding depreciation (appreciation) of 0.48% (0.57%) of the domestic currency. The effects were significant at 5%. The nonparametric estimates suggest larger effects on sell interventions and point to the relevance of nonlinear interactions. These effects assume swap operations are conducted in the same way as in the sample. Estimated effects of spot interventions are a bit lower controlling for official derivate market interventions, and range from 0.31% to 0.38% in the linear and nonparametric models, respectively. This suggests both official intervention policies (spot and swaps) are complementary.

The deductive reasoning leading to our orthogonality condition may be generalized and adapted in several directions as appropriate for other empirical applications. For example, as illustrated in our robustness exercises involving derivative operations, one may consider other realized measures, such as bipower variation, intraday range, or the squared return. It is also possible to include the intervention variable in the model equations leading to more general orthogonality conditions. Finally, one may extend the results to other conditional volatility models with intraday information beyond the log-linear realized-GARCH model considered in our application. The positive empirical results found here should provide sufficient motivation for such extensions.

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