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Evidencia con microdatos de transmisión incompleta de la política monetaria para un sector bancario no competitivo: el caso de Costa Rica

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Resumen

En un país con metas de inflación como Costa Rica, la estimación del traspaso de la tasa de política monetaria a las tasas ofrecidas por los bancos comerciales es fundamental. Tomar en cuenta la competencia imperfecta, la dolarización, la asimetría regulatoria y los tipos de bancos estatales y privados permite delimitar la efectividad de la Tasa de Política Monetaria (TPM). Con una generalización de un modelo de competencia tipo Cournot, con costes de ajuste y datos a nivel micro de préstamos y depósitos, se estima la magnitud y velocidad del traspaso. En general, existen importantes asimetrías en el traspaso debido al poder de mercado, asimetrías regulatorias y dolarización, todo lo cual merma la efectividad de la TPM. Mayor competencia, disminución de la dolarización, de los costos de ajuste y de las asimetrías regulatorias mejorarían la fuerza y la velocidad del traspaso. Por último, la evidencia muestra un traspaso más rápido respecto a estudios previos.

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Microdata Evidence of Incomplete Monetary Policy Transmission in a Non Competitive Banking Sector: The Case of Costa Rica

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Summary

In a country that adopted inflation targeting like Costa Rica, estimating the pass-through of the policy rate to banking retail rates is fundamental. We take into account imperfect competition, degree of dollarization, asymmetric regulation and whether banks are state or private to delimit the monetary policy rate (TPM) effectiveness. We generalize a Cournot-type competition model to allow for adjustment costs, and use loan and deposit micro-data to estimate the magnitude and speed of the pass-through. We find important pass-through asymmetries due to market power, regulatory asymmetries, and degree of dollarization, all of which lower pass-through. Our evidence shows that the pass-through has increased relative to previous studies.

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1 Introduction

After the Latin American debt crisis at the beginning of the 1980s, Costa Rica was unable to achieve a low and stable inflation for about two decades. In 2005, the Central Bank of Costa Rica (BCCR) started making changes in its policy, which resulted in a drastic drop of inflation and its volatility. Between 1983 and 2004 these quantities were 16.0% and 8.4%, whereas between 2005 and 2019 these were 5.9% and 4.5%.[1]

In January 2005, the BCCR approved a strategic project of explicit inflation targeting. Some steps were fundamental for that goal. The exchange rate regime was recognized as an impediment to controlling inflation, thus, in 2006 the BCCR changed its exchange rate policy from a crawling peg to a crawling band. In 2015 the exchange rate policy transitioned to managed flotation.[2] Finally, the BCCR made official the adoption of an inflation targeting in 2018 (Muñoz-Salas 2018). Hence, the monetary policy interest rate became, even more than before, a fundamental tool for policy makers and for the evaluation of the monetary policy effectiveness.

Central banks aim to do policy that allows to maintain macroeconomic stability, with a low and stable inflation. Typically, the instrument of choice is the monetary policy interest rate, which is expected to affect market rates. Via this mechanism, central banks affect aggregate demand and thus inflation.

The long-run effect that a change in the monetary policy interest rate has on the market rates is what is known as overall transmission. Of course, overall transmission is distributed over time, but most of it is desired to be clustered in the short-run. Central banks acknowledge

[1] If the period 2005-2009 is excluded, given the effects of the financial crisis, the average inflation and its volatility during the decade 2010-2019 would have been respectively 3.2% and 2.1%. These levels are close to those of the Costa Rican largest trade partners.

[2] The exchange rate managed flotation regime has a free exchange rate determined by market forces where the BCCR could intervene whenever it senses abrupt changes, i.e. hazardous excess volatility, in order to reduce uncertainties and foster efficient formation of expectations and decision making by agents.

this. Therefore, they are interested in knowing the overall transmission that their interest rate policy can achieve.

Several research projects have been dedicated to quantifying pass-through magnitudes in several countries, given its importance under an inflation targeting scheme. Empirical evidence for Costa Rica indicates a slow and incomplete pass-through effect (Barquero-Romero & Mora-Guerrero 2015). An imperfectly competitive banking market, which could be argued is the Costa Rican case, affects the competitive adjustments of the loan and deposit interest rates, hence becoming one explanation for the slow and incomplete transmission. Moreover, and in contrast with most worldwide financial sectors, Costa Rica's market is characterized by the presence of implicit leading clusters or dominant banks (some by costs, others by size, or by regulations that are different for state-owned and private banks). This makes the commonly used Cournot type models of competition not applicable. Research on this particular characteristic is important for Costa Rica's monetary policy effectiveness evaluation and possible improvements.

Our goal is to quantify the monetary policy transmission mechanism through the banking sector in Costa Rica. Namely, we want to evaluate the strength, direction and possible asymmetries of the pass-through of the monetary policy rate to the loan and deposit retail rates. To that end, we develop an extension to the model in Kopecky & Van Hoose (2012), to which we adapt the empirical framework in Banerjee et al. (2013). Kopecky & Van Hoose (2012)'s model is a Cournot-type bank competition with symmetric costs; we extend it to asymmetric costs. Banerjee et al. (2013)'s empirical framework accommodates Kopecky & Van Hoose (2012)'s model conclusion that banks use the expected market rates to define their retail rates. Thus it is a VECM model augmented with the expected market rates.

A novelty in Costa Rican literature, also rare for developing countries pass-through literature, is the use of vast micro-data. It comes from the Costa Rican financial regulator (SUGEF). Overall, we use the universe of loans and deposits. It allows us to delimit new loans and deposits issued in order to measure better the pass-through.

Here, the theoretical model is used only to define our empirical specification. We leave for future research the macroeconomic consequences of an imperfect banking sector, as well as counterfactual analysis with a DSGE framework.

This paper is organized as follows. The next section presents a literature review on monetary policy interest rate pass-through. Next, we present the generalized Cournot-type model along with its solution and reduced-form equations. The next section explains the empirical methodology based mainly on extensions to error correction models. The micro-data used, its treatment and its characteristics are showed in the subsequent section followed later by the results. Finally, we conclude with comments on the pass-through effects, how they compare to previous studies, and policy implications.

2 Literature Review

The body of research about monetary policy transmission mechanisms is abundant, given its importance as a policy tool and its effects on economic activity. As mentioned by Boivin et al. (2010), understanding the effect of monetary policy on the economy is necessary to evaluate its stance in a particular point in time. Additionally, to decide how to set their policy instruments, policy makers must have an accurate assessment of its effects and lags. This assessment requires understanding how and why monetary policy impacts real economic activity and inflation.

Gertler & Gilchrist (1993) perform a literature review on the debate as to whether credit market imperfections have a role in monetary policy transmission. Empirically, they used VAR models with United States (US) data. They argue that market imperfections are relevant in two complementary ways. First, they could force certain type of borrowers to be dependent on banking credit. Second, they could make the same type of borrowers, namely households and small firms, became excessively vulnerable to movements in the risk free interest rate. For the authors, this second consideration is important even if the monetary policy could not control directly the banking credit flow.

Again for the US, Boivin et al. (2010) discuss neoclassical and non-neoclassical transmission mechanisms, where the credit channel stands out in the latter. They revised the empirical evidence of changes in the effects from monetary policy actions on the real activity and inflation, using both FAVAR and DSGE models. They obtained four main findings. First, the neoclassical channels (direct effects of interests rates on investment, wealth, intertemporal substitution effects on consumption, and effects on trade through the exchange rate) have remained the fundamental channels in macroeconomic models. Second, the macroeconomic literature on non-neoclassical channels in general equilibrium models is scarce. Most of the analyses of the potential importance of the banking sector channel, for example, have focused on the heterogeneous effects of different lenders or borrowers types, without any movement to macroeconomic consequences. Third, there have been major changes in the regulatory structure for the US and other countries, with important implications for monetary policy transmission. Finally, they argue the monetary policy worldwide is more focused on inflation stabilization, which has affected inflation volatility and output responses to non-monetary shocks.

So far we have discussed about the importance of the monetary policy transmission mechanism, and the possible effect of the credit channel and financial frictions at the aggregate level. We have yet to discuss the role of banking competition. Gigineishvili (2011) used 70 countries from all regions and levels of income to look for the determinants of interest rate pass-through. With a wide range of macroeconomic variables, and the financial market structure, the author used ARDL models to estimate the pass-through coefficients. He concludes GDP per capita and inflation have positive effects on the pass-through, whereas market volatility has a negative effect. From the financial market determinants the exchange rate flexibility, the credit quality, the general expenses over total assets, and more banking competition seem to increase the pass-through, but excess liquidity decreases it.

Van Hoose (2010) describes there are multiple determinants for the magnitude of the pass-through from market rates to retail-bank rates. Country effects, differences in regulation, and time are common in the literature. Kopecky & Van Hoose (2012) examined the determinants of the interest rates pass-through to loan and deposit retail rates, and provided a unified framework for analysis. They used a microfounded theoretical model to determine the pass-through of market rate (securities' rate) to banks' deposit and loan rates. It is a dynamic quadratic cost adjustment model with imperfect competition (Cournot with n banks). They assumed a symmetric Nash equilibrium, and obtained loan and deposit quantities and interest rates. The main conclusion for empirical analysis is that models that exclude the expected future security rate would be misspecified and therefore provide biased coefficient estimates.

Following this recommendation, Banerjee et al. (2013) provided an empirical application based on a theoretical model following Kopecky & Van Hoose (2012). In addition, they argued that banks anticipate the short-run market rates when defining the interest rates for loans and deposits.

For the Costa Rican case, Durán-Víquez & Esquivel-Monge (2008) used a cointegration analysis with monthly data from 1996-2007, and found the pass-through effect to be 1.2 and 0.75 for the loan and deposit interest rates respectively, where the state-owned banks behave differently from the private banks. The authors state two conclusions. First that there is evidence in favor of a nonlinear pass-through, but not for asymmetry. Second that the pass-through seems to be unitary in the long-run. Monge-Badilla & Muñoz-Salas (2011) supported these findings again with a cointegration analysis, now for monthly data between 2000 and 2010, with pass-through effect of 0.8 to loan rates and 0.65 to deposit rates. They also don't find evidence of the pass-through coefficient being close to unity in the long-run.

More recently, Barquero-Romero & Mora-Guerrero (2015) estimate the pass-through for loan rates at 0.69 and for deposit rates at 0.82, which are also statistically different from unity. In contrast with the previous work, they found evidence of asymmetric effects. Two main differences exist between this paper and the previous ones. First, the sample period, from 2000 to 2013, covers the years in which the BCCR used for the first time a monetary policy interest rate. Second, the study considers many more factors in its analysis, like financial dollarization, banking market concentration, the financial position of the Central Government and the BCCR, all of which distort the pass-through effect.

Additionally, Barquero-Romero & Orane-Hutchinson (2015) look to determine the timing and magnitude of changes in the policy interest rate using SVAR models, with data from 1999 to 2014. They showed that changes in the monetary policy rate are reflected first on the deposit rates of the commercial banks and later in an indirect form to the loan rates. They also showed that state-owned banks react first than the private banks. Finally, they showed that the pass-through increased after exchange rate regime switched from a crawling peg to a crawling band; as expected more exchange rate flexibility helps the monetary policy transmission mechanisms. Focusing on this last mechanism, Esquivel-Monge (2018) quantifies the transmission of the monetary policy rate (TPM) to the rates in two of the money markets in Costa Rica.[3] The author used SVAR models to find that shocks to policy rate have significant and fast impact on the interest rate of one money market, but not on the other.

So far, the papers reviewed have abstracted from the degree of competitiveness in the banking market. Laverde-Molina & Madrigal-Badilla (2005) show there is imperfect competition in the Costa Rican market, while Durán-Víquez et al. (2009) argue the competition is not only oligopolistic, but more likely to be the Stackelberg type. The empirical results of Castro-Arias & Serrano-López (2013) support this conjecture as they conclude banks take their decisions sequentially, not simultaneously. They also conclude that the measure of market power increases the differential between deposit and loan rates at least in 1 percentage point. This can explain why Barquero-Romero & Orane-Hutchinson (2015) found the state-owned banks react before private banks, as state-owned ones are market leaders.

These last papers point to the importance of imperfect competition in Costa Rica. The following section documents that the banking market still shows evidence of being imperfectly competitive.

3 The Loan and Deposit Markets in Costa Rica

We dedicate this section to describe some facts related to the loan and deposit markets in Costa Rica. First, we briefly summarise the data used and the characteristics of the financial institutions. Second, we describe new quantities of loans and deposits, as well as

[3]Namely the Integrated Liquidity Market (“Mercado Integrado de Liquidez” or MIL) organized by the BCCR, and the Money Market (“Mercado de Dinero” or MEDI) organized by the National Stock Market (“Bolsa Nacional de Valores” or BNV).

their respective weighted average interest rates. Third, we analyse the degree of market concentration.

We obtained amounts and rates of new loans and deposits from the client transaction log of financial institutions -transaction log for simplicity-; which is recorded each month by the Financial Institutions Regulator (SUGEF).[4] We used the accounting accounts and emission dates to identify with precision which transactions correspond to new loans and deposits. Therefore, for loans, we use monthly information from January 2008 to December 2019, to take into account the period of declining trend in Costa Rica's inflationary process. For deposits, banks were enforced to report their information beginning in September 2012. Therefore, our data ranges from September 2012 to December 2019. On the other hand, the monetary policy rate (TPM) can be found at the website of the BCCR.

In Costa Rica there are 14 retail banks that as a whole have placed and received more than 90% of new loans and deposits every month since September 2013; while the remnant of new loans and deposits is due to 47 cooperative associations.We focus on new loans and deposits, to determine the pass-through, since previously issued ones are mostly not affected by current changes in policy rate (except when the contract is linked to variable rates and a reference rate), therefore including them will bias the results. In other words, a current monetary policy rate movement will change retail interest rates today or in the future, but not in the past. Future research could disentangle the effects on contracts with variable rates.

Additionally, our focus is on banks since there are stark differences with cooperative associations: different regulations, tax schemes, and target populations.[5] We also exclude one of the retail banks: Banco Popular. It is also regulated differently: it receives 1% of all salaries in the economy, and its baking accounts could not be impounded by any reason, among other differences.[6]

3.1 Loans and deposits amounts and rates

We start by analyzing two basic quantities of the loan and deposit markets: new amounts placed and received and their weighted average rates. We document that about half of new loans and deposits are issued in dollars. Additionally, we find that retail rates are highly

[4]The accounting information in the transaction log is audited by SUGEF. There may be financial penalties if information is found not to be true, which incentivizes to provide trustworthy information.

[5]For example, cooperative associations do not pay some taxes. Also their financial products are directed towards specific small populations such as professional guilds or inhabitants of a particular town.

[6]As a result, Banco Popular does not need to compete at the money markets. Thus, its competitive behavior cannot be assessed as the rest of the banking sector due to important regulation asymmetries. For example, this bank is the only one with almost all its loans and deposits in local currency. Therefore, we believe including it would heavily bias our results.

correlated with their one-month lags and with the policy rate; this is more marked for local currency rates.

Stylized Fact 1. *Households and firms in Costa Rica show a strong preference to save and acquire debt in dollars; about half of their new deposits and loans are in that currency.*

Although in Costa Rica almost all goods are traded using the national currency, when it comes to acquiring a loan or making a deposit, the behavior of households and firms changes: each month about half of the deposits and loans are issued in dollars. Figure 1 shows that new deposits in dollars have been on average slightly lower than deposits in local currency; and that new loans in dollars have been on average greater than new loans in local currency between January 2008 and December 2019.[7]

The high volume of loans and deposits in dollars may represent a challenge to the effectiveness of monetary policy (see Figure 1 and Figure A1 which includes Banco Popular), if there is no pass-through from the policy rate to retail rates in dollars. Hence, it is worth exploring the relation between rates of new loans and deposits issued in local currency and dollars and the policy rate.

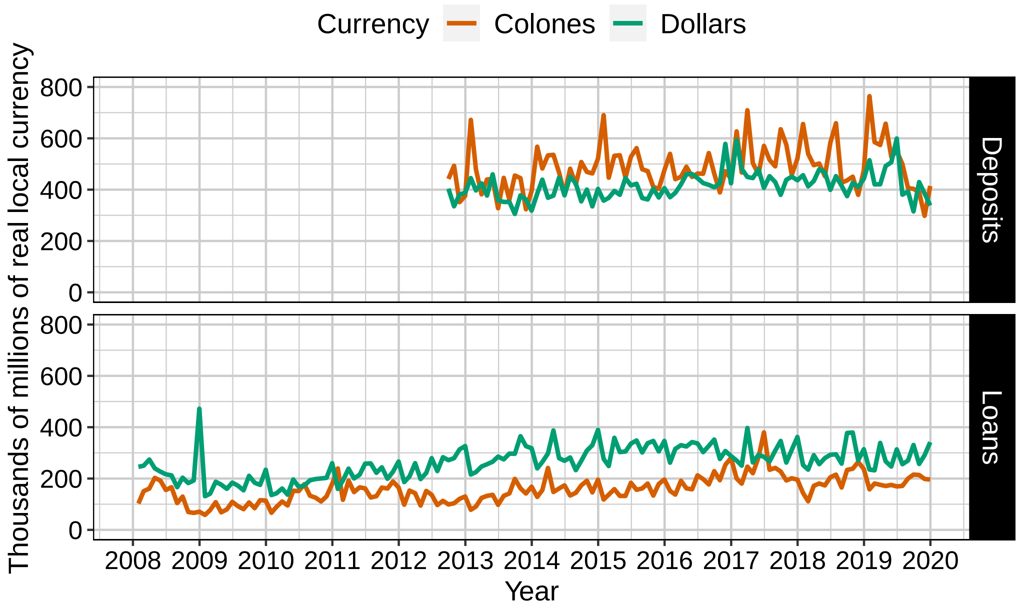
Stylized Fact 2. *During the period of our study the policy rate and retail rates have behaved in such a manner that the following properties are observed: (i) the correlation between the policy rate and retail rates in local currency is about 0.7; (ii) the correlation between the policy rate one-month lag and the retail rates in local currency is around 0.7; (iii) retail rates correlation with their one-month lag is greater than 0.8.*

Figure 2 shows the evolution of retail rates and of the policy rate during the sample period. Retail rates in local currency and the policy rate show strong comovement, while retail rates in dollars are relatively constant. This happens despite periods in which the rate in local currency drops considerably, providing an incentive for households and firms to acquire debt in local currency instead of dollars or to save in dollars instead of local currency. This represents an interesting puzzle, but more importantly, it suggests that the monetary policy is not influencing retail rates in dollars.

We calculate the correlation matrix for all retail rates in local currency and dollars, the policy rate and the one-month lag of all of these rates. It shows the correlation between the

[7]On one side, it could be the case banks enforce their clients to acquire loans in dollars due to strategic considerations (the exchange rate risk falls mainly on the customer). It could be possible given their market power. Another possibility is the clients are eager to take those loans because their current monthly payment is lower. On the other side, the high preference for deposits in dollars could be explained by a persistent habit formation, which arose at the time of the crawling peg. Exchange rate was always increasing, meaning one dollar will value more local currency each day, thus giving incentives to save in dollars. Nowadays, risk and wealth considerations could also arise for deposit decisions by currency. Proving these conjectures, however, goes beyond the scope of this study.

Figure 1: New loan and deposits in Costa Rica.
January 2008 to December 2019.



Note: All quantities are in local currency of January, 2019; and were computed using data of all banks except Banco Popular. SUGEF requires banks to indicate the equivalent amount in local currency of transaction that were done in dollars, so we don't have to worry about systematic errors because of exchange rate. Loans from January 2008 to December 2019, deposits from September 2012 to December 2019. Source: Own elaboration with SUGEF data.

policy rate and retail rates in dollars is much weaker than with retail rates in local currency.[8] The correlation between the policy rate and deposit rate in local currency is 0.70, while the correlation between the policy rate and the loans rate in local currency is 0.72. On the other hand, for dollars these coefficients are 0.06 and 0.53.

These matrices also show that the lag of the policy rate is highly correlated with retail rates in local currency, at around 0.7. Moreover, the correlation between any retail rate and its one-month lag is more than 0.8.

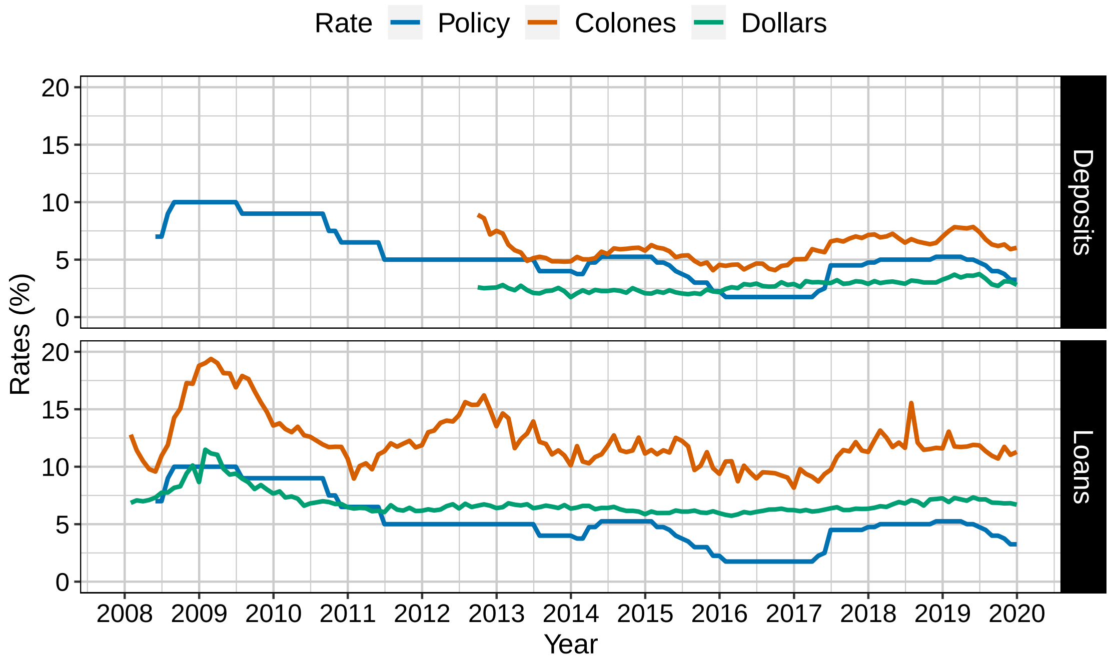
In the next section we develop a model that captures these links. The key element are adjustment costs. Bankers consider these when choosing the quantities they want to receive as deposits and place as loans each month, which causes interest rate persistence.

3.2 Banking competition

In Costa Rica there are 14 banks, eleven of which are private and three public banks (two state-onwed and the Banco Popular outside of the analysis). The first stages of development

[8]We show the correlation matrix in Table A1

Figure 2: Evolution of the policy and average retail rates in Costa Rica.
January 2008 to December 2019.



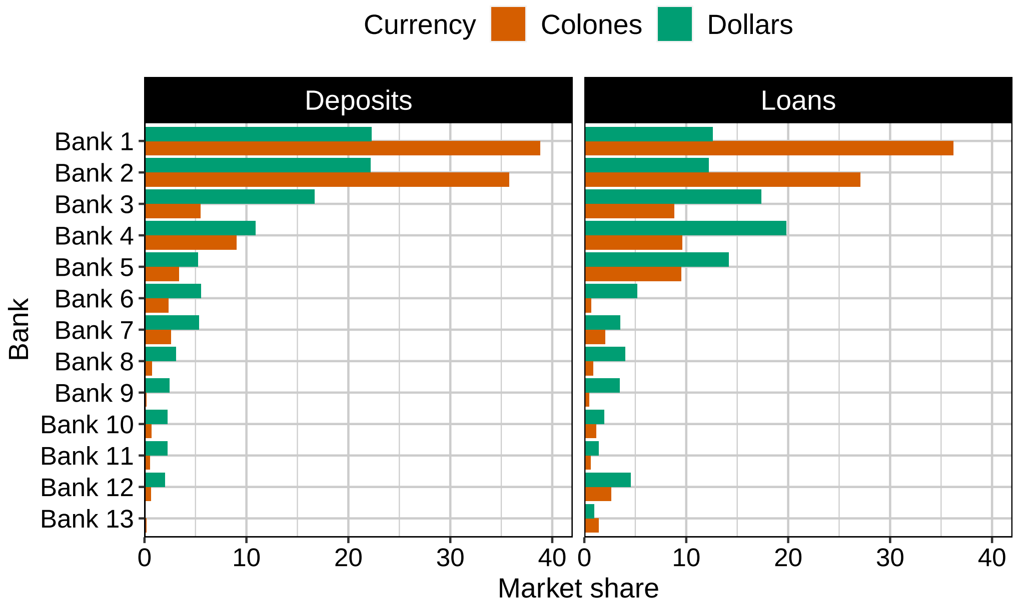
Note: All quantities were computed using data of all banks except Banco Popular. Average retail rates were computed using the weighted average of the rate of new loans and deposits weighted by their amount. Loans rate from January 2008 to December 2019, deposits rate from September 2012 to December 2019. Source: Own elaboration with SUGEF data

of the financial markets in Costa Rica were characterized by a weak role of private banks. These were not allowed to offer current accounts until 1995, so clients thought of private banks as places to save money for long terms. One can argue that in an economy with an underdeveloped financial system, for most people it is easier to acquire loans in the same bank that holds their savings. Therefore, public banks had an advantage over private banks.

In 1995 the National Banking System Act (NBSA) was approved, allowing private banks to offer current accounts to the public. This law arose at a moment in which the role of state-owned banks was being questioned. The margin between loan and deposit rates was large, which was interpreted as a consequence of an inefficient banking system. The closure of the state-onwed bank named "Banco Anglo" in 1994, due to mismanagement, aggravated this perception. With the approval of the NBSA, private banks started to grow so they were able to increase their portfolio of clients and to use funds in the current accounts to finance loans.

Although the NBSA helped to correct many issues arising from low levels of competition prior to 1995, the loan and deposit markets are still highly dominated by public banks. This is also true of the dataset we are using, which excludes one of the public banks.[9] Figure 3 shows the market shares considering only new loans and deposits. It suggests both markets in local currency and dollars are highly concentrated.

Figure 3: Average market shares of the loan and deposits markets in Costa Rica.
January 2008 to December 2019



Note: These are the simple averages of the monthly market shares. Dates range from September 2012 to December 2019 for deposits, and from January 2008 to December 2019 for loans. Source: Own elaboration with SUGEF data.

Stylized Fact 3. *The degree of concentration in the Costa Rican loan and deposit markets can be considered at least moderate according to commonly used metrics of market concentration.*

The concentration patterns in these markets can be measured using the Herfindahl-Hirschman Index (HHI), which is a common measure of market concentration. This index is computed by taking the sum of squares of the market shares of each bank. According to the Department of Justice of the United States, a market is highly concentrated if its HHI is greater than 25, moderately concentrated if its HHI is between 15 and 25 and not concentrated if its HHI is less than 15. Following this classification, the Costa Rican financial sector is characterized by one highly concentrated market (the loan market in local currency) and three moderately concentrated markets (the deposit market in local currency and the loan and deposit markets in dollars).[10]

[9] In fact, if Banco Popular was included, its share of the markets that are being studied would be one of the most important and our assertions would still be true.

[10] In Figure A2 we show the evolution of the HHI.

The reciprocal of this index also has an intuitive interpretation. Kelly (1981) and Adelman (1969) show that this is the number of banks that would yield the same concentration index, if each bank had an equal market share. By this interpretation, Costa Rica's banking sector would show the same concentration if about 4 banks were to split the market equally (recall we exclude Banco Popular).

These statistics on the loan and deposit markets reveal there is market concentration. Therefore, it is important to consider the market structure when analyzing the pass-through of the policy rate to retail rates. If market concentration is high, the policy rate may only affect directly a handful of market participants. In the next section we develop a model that captures the role of market concentration on the determination of retail rates.

4 A Structural Approach to Understand the Pass-Through of Security Rates to Retail Rates[11]

As shown previously, the distribution of the shares of new loans and deposits is concentrated on few banks. It suggests the presence of monopolistic competition in retail banking. In the short-run, small banks cannot place and receive the same amounts of loans and deposits as large banks. Letting aside factors such as brand name and number of branch offices, if small banks tried to place a similar amount of loans to that of large banks, they would have to increase deposits accordingly. That would heighten liabilities to an unsustainable level since the returns from new loans are received over a long term while most deposits must be paid in the short term. Moreover, current banking regulation requires banks to have capital provisions for each new loan.

In this model, each bank manager is conscious that she cannot spontaneously induce a radical change in market shares from one month to the next, because in the short-run the capital needed is not available. A Cournot game can describe this setting. The total supply of deposits and total demand for loans is known by bank managers, who consider in their profit function the deposits they received and the loans they placed in the last period. Therefore, these own lagged quantities are informative about the distribution of the market shares in the banking retail market.

[11]Whereas our theoretical framework relates security rates to retail rates, empirically we assess the effect of the policy rate instead. We acknowledge there is a middle step missed here: the effect of the policy rate on security rates (defined for example as the rates banks receive for their investments), and then the effect of the security rates to retail rates. We implicitly assume the effect goes directly from the policy rate. Nevertheless, Esquivel-Monge (2018) showed the effect of the policy rate on the money markets (Integrated Liquidity Market) rates is strong and fast; this market being fundamental for banks funds availability in the short-term, and hence over the decisions we analyze here. We leave the middle step mentioned for future research.

To fully specify the game, we link deposits and loans through securities. When equity is zero, banks save a proportion of deposits for the reserve requirement, lend money with part of the remaining and invest the remnant in securities. Hence, bank managers choose the amount of money to place in loans and receive in deposits based on the lagged amount of loans and deposits, expectations on security rates and the strategy of other bankers. Our model parts from a modified version of the demand of loans, supply of deposits, and cost function used in Kopecky & Van Hoose (2012). We show that although the market shares of banks are unequal, it is possible to reach a linear equation in which the coefficients depend on structural parameters. From this equation it is possible to make the leap towards obtaining an unbiased estimator of the pass-through level from securities rate to retail rates.

4.1 The Supply of Deposits and the Demand for Loans

Let D_t and r_t^d denote the total supply of deposits and the market return that is offered to depositors in month t. Similarly, let L_t and r_t^ℓ be the total demand for loans and the market rate that is charged for loans in month t. Finally, let r_t^s denote securities rate in month t. Then, we let total supply of deposits and total demand of loans be functions of the deposit and loan rates and of the security rates:

$$D_t = \Omega_t \left[r_t^d (r_t^s)^{-\chi_d} \right]^{1/\varepsilon_d} \quad \text{and} \quad L_t = \Lambda_t \left[(r_t^\ell)^{-1} (r_t^s)^{-\chi_\ell} \right]^{1/\varepsilon_\ell} \tag{1}$$

where χ_x, ε_x $(x \in \{d, \ell\})$ are positive parameters, and Ω_t and Λ_t are positive random variables such that $\mathbb{E}_\tau(X_t) = \bar{X}$, $\mathrm{Var}_\tau(X_t) = \sigma_X^2$, and $\mathrm{Cov}(r_t^s, X_t) = 0$ for $X \in \{\Omega, \Lambda\}$. Thus, given the interest rates r_t^d, r_t^ℓ, r_t^s, the random quantities Ω_t and Λ_t model how random shocks, that are not time dependent nor correlated with security rates, affect the supply of deposits and the demand of loans.

If deposit and loan rates are held constant, the supply and demand equations capture three general economic notions:

- An increase in the deposit rates implies an increase in deposits supply.
- An increase in loan rates prompts loans demand to decrease.
- An increase in the security rates causes the supply of deposits and the demand for loans to decrease.

Moreover, by taking logarithms and taking derivatives we arrive at

$$\frac{\partial \log D_t}{\partial \log r_t^d} = \varepsilon_d^{-1} \quad \text{and} \quad \frac{\partial \log D_t}{\partial \log r_t^s} = -\chi_d \frac{\partial \log D_t}{\partial \log r_t^d},$$

which means that the securities rate elasticity of deposits is inversely proportional to the deposit rate elasticity of deposits, meaning the securities rate acts directly on the deposits supply. Depositors consider securities and deposits as substitutes. Similarly for loans we have,

$$\frac{\partial \log L_t}{\partial \log r_t^\ell} = -\varepsilon_\ell^{-1} \quad \text{and} \quad \frac{\partial \log L_t}{\partial \log r_t^s} = \chi_\ell \frac{\partial \log L_t}{\partial \log r_t^\ell},$$

so the result is analogous to the one for deposits with one minor difference: instead of a inversely proportional relation between securities rate elasticity of loans and loan rate elasticity of loans, the relation is now directly proportional. Securities and loans are complements for potential debtors. We call χ_d, and χ_ℓ the *elasticity multipliers*.

The following result will be useful to estimate the pass-through effect of security rates on retail rates. The proof can be found in Appendix B.1.

Lemma 1. *Let $(\bar{r}^d, \bar{r}^\ell, \bar{r}^s)$ be the steady state vector of rates so that the steady states of deposits and loans are $\bar{D} = \bar{\Omega}[\bar{r}^d(\bar{r}^s)^{-\chi_d}]^{1/\varepsilon_d}$ and $\bar{L} = \bar{\Lambda}[(\bar{r}^\ell)^{-1}(\bar{r}^s)^{-\chi_\ell}]^{1/\varepsilon_\ell}$. Then, the first-order Taylor approximation of the inverse supply of deposits is*

$$r_t^d = (1 - \varepsilon_d - \chi_d)\bar{r}^d + \varepsilon_d \bar{r}^d \bar{D}^{-1} D_t + \chi_d \bar{r}^d (\bar{r}^s)^{-1} r_t^s + \eta_{dt} \tag{2}$$

and the first-order Taylor approximation of the inverse demand for loans is

$$r_t^\ell = (1 + \varepsilon_\ell + \chi_\ell)\bar{r}^\ell - \varepsilon_\ell \bar{r}^\ell \bar{L}^{-1} L_t - \chi_\ell \bar{r}^\ell (\bar{r}^s)^{-1} r_t^s + \eta_{\ell t} \tag{3}$$

where $\eta_{dt} = -\varepsilon \bar{r}^d[(\Omega_t/\bar{\Omega}) - 1]$ and $\eta_{\ell t} = \eta \bar{r}^\ell[(\Lambda_t/\bar{\Lambda}) - 1]$.

Proof. See appendix B.1 ■

Note that Lemma 1 states that if nonlinearities are ignored, then deposit (loan) rates can be expressed as linear functions of the security rates and the deposits made (loans placed). Hence, we have a set of structural equations which can be rewritten as linear models $r_t^d = a_0 + a_1 D_t + a_2 r_t^s + \eta_{dt}$ and $r_t^\ell = b_0 + b_1 L_t + b_2 r_t^s + \eta_{\ell t}$.

However, directly estimating the coefficients a_j and b_j via OLS would result in biased estimators: by construction quantities are related to the observed equilibrium and thus suffer from the endogeneity problem. In the next subsections we develop a model that allows us to solve this problem by identifying a set of instrumental variables. Those results provide a theoretical framework that justify lagged and expected security rates as instruments for the estimation of Equations (2) and (3). Moreover, this will allow us to estimate the pass-through effect of security rates on retail rates.

There are several aspects in regard to equation (1) and the subsequent analysis. First, an explanation for the expected effect of securities rates increments (or decreases) on both supply of deposits and demand for loans is needed to foster intuition.

On one hand, clients see deposits and securities as substitutes for savings, hence an increase in the securities rate will decrease deposits supply from the public, whereas the opposite occurs with an increase of the deposits rate. This explains the *elasticity multiplier* result for deposits.

On the other hand, in an undeveloped financial market (as the Costa Rican case), clients with liquidity needs are obliged to use banks for loans instead of, for example, obtain equity through issue or selling shares. Therefore the public translates increases in the securities rate as the same as increases in loan rates which lower their demand. This is true as banks treat loans and securities as substitutes; with a higher security rate, banks will prefer to lower loans given to clients and invest in securities, and due to a capture demand by banks, overall loans' equilibrium quantity falls as well. This explains the loans' *elasticity multiplier* result, meaning clients see loans and securities as complements to some extent.

Second, we acknowledge we observe equilibrium values between demand and supply, at each period t, for both deposits and loans. Nevertheless, for the theoretical analysis we abstract from equilibria and focus on deposits' quantity supplied and loans' quantity demanded, as an effect on each is translated at the end to the respective (observed) equilibria. As mentioned previously, from an empirical point of view, (equilibrium) quantities pose a problem due to endogeneity. However, the theoretical results following this approach overcome this issue as the final reduced-form equation for estimation does not depend on (equilibrium) quantities.

4.2 A Model of Retail Banking Competition

Now we set the framework to incorporate banking competition in our model. Our starting point are equations for the supply of deposits and the demand for loans similar to those in Kopecky & Van Hoose (2012), and use the same specification of profits as theirs; however, we relax the assumption that all banks control equal shares of the market.

Let $\mathcal{B} = \{B_1, ..., B_n\}$ be the set of banks in the economy. Let D_{it} and L_{it} denote the deposits received and loans placed by bank i. Then, the supply of deposits and the demand for loans in month t are

$$D_t = \sum_{i \in \mathcal{B}} D_{it} \quad \text{and} \quad L_t = \sum_{i \in \mathcal{B}} L_{it}. \tag{4}$$

Banks are required to keep a percentage ρ of new deposits in reserves at the central bank. Assuming that bank equity is zero, in month t bank i is left with $(1 - \rho)D_{it}$, from which it lends L_{it} and invests the remaining in securities S_{it}. Thus,

$$S_{it} = (1-\rho)D_{it} - L_{it}, \tag{5}$$

so that earnings of bank i in month t are given by $r_t^s S_{it} + r_t^\ell L_{it} - r_t^d D_{it}$. Then, to set the profits of bank i in month t we need to state the costs that bank i incurs. We assume quadratic costs as in Kopecky & Van Hoose (2012), but we allow cost parameters to differ across banks.

Assumption 1 (Profits). *Let the profit function of bank $i \in \mathcal{B}$ be*

$$\pi_{it} = r_t^s[(1-\rho)D_{it} - L_{it}] + r_t^\ell L_{it} - r_t^d D_{it} - C_{it} \tag{6}$$

where C_{it} corresponds to the cost function

$$C_{it} = \underbrace{\frac{\theta_{\ell i1}}{2}(L_{it})^2}_{\text{Loans size operating cost}} + \underbrace{\frac{\theta_{\ell i2}}{2}(L_{it} - L_{it-1})^2}_{\text{Loans adjustment cost}} + \underbrace{\frac{\theta_{di1}}{2}(D_{it})^2}_{\text{Deposits size operating cost}} + \underbrace{\frac{\theta_{di1}}{2}(D_{it} - D_{it-1})^2}_{\text{Deposits adjustment cost}}$$

where $\frac{\theta_{di1}}{2} > 0$ is the operating cost per squared dollar in which bank i incurs to maintain D_{it} in deposits, while $\frac{\theta_{di2}}{2} > 0$ is the cost per squared dollar of adjustments in which bank i incurs due to adjustments with respect to the previous month's deposits. The meaning of the coefficients related to loans, $\frac{\theta_{\ell i1}}{2}$ and $\frac{\theta_{\ell i2}}{2}$, is analogous to that of deposits.

This function considers two sources of costs: operating and adjustment costs for loans and deposits. Intuitively, one would expect cost coefficients $\frac{\theta_{di1}}{2}$ and $\frac{\theta_{\ell i1}}{2}$ to be greater than zero to reflect a positive relation between the size of bank i, i.e. the amount of the stock of deposits and loans, and what it costs to keep that bank operating at that scale. On the other hand, the adjustment cost coefficients $\frac{\theta_{di2}}{2}$ and $\frac{\theta_{\ell i2}}{2}$ are also expected to be positive: an increase in the adjustment of deposits received or loans placed would mean that the bank i is growing or shrinking, which increases costs. A bank needs to invest to grow (e.g, in infrastructure and workers) and to incur in certain expenses to become smaller (e.g, pay wage settlements if employees are fired).

The profit maximization problem of bank i in month τ consists in maximizing the expected present value of profits given a deterministic discount factor $\beta \in (0,1)$. Hence, bank i in month τ solves

$$\max_{\{D_{it}, L_{it}: t \geq \tau\}} \mathbb{E}_{i\tau}\left(\sum_{t=\tau}^{\infty} \beta^{t-\tau}\pi_{it}\right), \tag{7}$$

where $\mathbb{E}_{i\tau}(X)$ stands for the expected value of any random variable X given the information set of bank i in month τ.

The maximization problem of banks has two important properties. First, the problem is dynamic since lagged deposits and loans are part of the profit function. Second, we know from Lemma 1 that retail rates r_t^d and r_t^ℓ are a function of total supply of deposits D_t and total demand for loans L_t, which implies that bank i has to take into account the optimal strategy of its rivals. In the next proposition we provide the solution for this problem in terms of structural parameters, lagged and expected quantities, and expected security rates.

Proposition 1 (**Optimal choice**). *Let i be any bank in $\mathcal{B}$, $\mathcal{B}_i'$ be the set that includes all banks except i, and for simplicity use the representation of deposits' and loans' subscripts and quantities by $(x, X) \in \{(d, D), (\ell, L)\}$. Assume that $\mathbb{E}_{i\tau}(X_{t+k})$ and $\mathbb{E}_{i\tau}(r_{t+k}^s)$ are bounded for $k \in \mathbb{N}$. Let the pair $\lambda_{xi1}, \lambda_{xi2}$ be the solutions of the system*

$$
\begin{aligned}
&\lambda_{xi1}\lambda_{xi2} = \beta \\
&\lambda_{xi1} + \lambda_{xi2} = (1+\beta) + \theta_{xi2}^{-1}\left[\theta_{xi1} + 2\chi_x \bar{r}^x (\bar{r}^s)^{-1}\bar{X}^{-1}\right]
\end{aligned}
\tag{8}
$$

Without loss of generality $0 < \lambda_{xi1} < 1$ and $\lambda_{xi2} > 1$. Let $\nu_{ix} = \beta/(\lambda_{xi1} + \lambda_{xi2})$. Then, in month $\tau = t$ bank i's solution to maximization problem (7) is

$$
\begin{aligned}
D_{it} = (\lambda_{di1} + \lambda_{di2} - \nu_{id})^{-1} \Bigg\{ &\frac{(\varepsilon_d + \chi_d - 1)\bar{r}^d}{\theta_{di2}} \sum_{k=0}^{\infty} \nu_{id}^k + D_{it-1} + \sum_{k=1}^{\infty} \nu_{id}^{k+1}\mathbb{E}_{it-1}(D_{it+k}) \\
&- \frac{\varepsilon_d \bar{r}^d}{\theta_{di2}\bar{D}} \sum_{k=0}^{\infty}\sum_{j\in\mathcal{B}_i'} \nu_{id}^k \mathbb{E}_{it-1}(D_{jt+k}) - \frac{\chi_d \bar{r}^d (\bar{r}^s)^{-1} - (1-\rho)}{\theta_{di2}} \sum_{k=0}^{\infty} \nu_{id}^k \mathbb{E}_{it-1}(r_{t+k}^s) \Bigg\} + \gamma_{dit}
\end{aligned}
\tag{9}
$$

$$
\begin{aligned}
L_{it} = (\lambda_{\ell i1} + \lambda_{\ell i2} - \nu_{i\ell})^{-1} \Bigg\{ &\frac{(1 + \varepsilon_\ell + \chi_\ell)\bar{r}^\ell}{\theta_{\ell i2}} \sum_{k=0}^{\infty} \nu_{i\ell}^k + L_{it-1} + \sum_{k=1}^{\infty} \nu_{i\ell}^{k+1}\mathbb{E}_{it-1}(L_{it+k}) \\
&- \frac{\varepsilon_\ell \bar{r}^\ell}{\theta_{\ell i2}\bar{L}} \sum_{k=0}^{\infty}\sum_{j\in\mathcal{B}_i'} \nu_{i\ell}^k \mathbb{E}_{it-1}\left(L_{jt+k}\right) - \frac{1 + \chi_\ell \bar{r}^\ell (\bar{r}^s)^{-1}}{\theta_{\ell i2}} \sum_{k=0}^{\infty} \nu_{i\ell}^k \mathbb{E}_{it-1}(r_{t+k}^s) \Bigg\} + \gamma_{\ell it},
\end{aligned}
\tag{10}
$$

where $\gamma_{xit} = X_{it} - \mathbb{E}_{t-1}(X_{it})$ represents the random deviation of the realized X_{it} from bank i's expectation given its information at time $t-1$. Equations (9) and (10) are the Subgame Perfect Nash Equilibrium.

Proof. See appendix B.2 ■

A key implication of Proposition 1 is that it states a linear model in which X_{it} is explained by the following quantities: (i) bank i's 1-month lag of X; (ii) the expectations bank i has on the future values of X_i; (iii) the expectations bank i has on current and future values of X of its competitors; and (iv) bank i's expectations on current and future security rates. We call these quantities determinants. We state this in Corollary 1.

Corollary 1. *Let $i \in \mathcal{B}$, $(x, X) \in \{D, L\}$, where i is each of the banks, and x, X are the representation of deposits' and loans' subscripts and quantities respectively, and denote $\hat{X}_{it+k} = \sum_{j \in \mathcal{B}_i'} X_{jt+k}$. Under the assumptions of Proposition 1 it follows that X_{it} can be described by the linear model*

$$X_{it} = \alpha_{xi0} + \psi_{xi,-1} X_{it-1} + \sum_{k=1}^{\infty} \psi_{xik} \mathbb{E}_{it-1}(X_{it+k}) + \sum_{k=0}^{\infty} \psi_{\hat{x}ik} \mathbb{E}_{it-1}(\hat{X}_{it+k}) + \sum_{k=0}^{\infty} \psi_{sxik} \mathbb{E}_{it-1}(r^s_{t+k}) + \gamma_{xit}, \tag{11}$$

where $\mathbb{E}_{it-1}(\gamma_{xit}) = 0$ and the coefficients are functions of the structural parameters.

Proof. Denote the indicator function by $I(\cdot)$ and let

$$\alpha_{xi0} = \frac{\varepsilon_d + \chi_d - 1}{\theta_{di2}(\lambda_{di1} + \lambda_{di2} - \nu_{id})} I(x = d) + \frac{1 + \varepsilon_\ell + \chi_\ell}{\theta_{\ell i2}(\lambda_{\ell i1} + \lambda_{\ell i2} - \nu_{i\ell})} I(x = \ell)$$

$$\psi_{xi,-1} = \frac{1}{(\lambda_{di1} + \lambda_{di2} - \nu_{id})} I(x = d) + \frac{1}{(\lambda_{\ell i1} + \lambda_{\ell i2} - \nu_{i\ell})} I(x = \ell)$$

$$\psi_{xik} = \frac{\nu_{id}^{k+1}}{(\lambda_{di1} + \lambda_{di2} - \nu_{id})} I(x = d) + \frac{\nu_{i\ell}^{k+1}}{(\lambda_{\ell i1} + \lambda_{\ell i2} - \nu_{i\ell})} I(x = \ell)$$

$$\psi_{\hat{x}ik} = \frac{-\varepsilon_d \bar{r}^d \nu_{id}^k}{\theta_{di2}(\lambda_{di1} + \lambda_{di2} - \nu_{id})} I(x = d) + \frac{-\varepsilon_\ell \bar{r}^\ell \nu_{i\ell}^k}{\theta_{\ell i2}(\lambda_{\ell i1} + \lambda_{\ell i2} - \nu_{i\ell})} I(x = \ell)$$

$$\psi_{sxik} = \frac{[(1-\rho) - \chi_d \bar{r}^d (\bar{r}^s)^{-1}] \nu_{id}^k}{\theta_{di2}(\lambda_{di1} + \lambda_{di2} - \nu_{id})} I(x = d) + \frac{-[1 + \chi_\ell \bar{r}^\ell (\bar{r}^s)^{-1}] \nu_{i\ell}^k}{\theta_{\ell i2}(\lambda_{\ell i1} + \lambda_{\ell i2} - \nu_{i\ell})} I(x = \ell)$$

Then, the result follows. ■

Corollary 1 shows we could have started with a reduced-form model such as the one stated in Equation (11), to understand the quantities observed in the sector of retail banking. This results makes unnecessary to derive the optimal solution to the maximization problem (7) in that regard. To estimate Equation (11), we would need a reliable survey to know what banks expect for all future periods. Instead, we impose some structure in the way banks form expectations. One approach follows Kopecky & Van Hoose (2012) who used only two periods ahead as it is difficult and costly for banks to obtain forecasts for further future periods. Another possibility is to rely on statistical tests to approximate a reasonable amount of periods to forecast ahead. Here, we assumed banks are myopic as they could see only two periods ahead (Kopecky & Van Hoose 2012).[12]

4.3 A reduced-form model to study the pass-through

The mechanism described by Proposition 1 allows to study how current and expected security rates affect the quantities that are received and lent by banks. This effect is a pass-through on quantities but not on interest rates. Nonetheless, we are looking for the interest rates pass-through.

A way to overcome this issue is to express retail rates as functions of security rates in a way that any error terms must not be correlated with any other variables in the functional form. Also, we need to avoid problems in expectation differences across banks. By assuming common knowledge about quantities across bankers, we show that there is a linear relationship between retail rates and security rates.

Assumption 2. *All banks have the same information set at any month t.*

This assumption simplifies the analysis. At month t each bank i knows that their market share of the expected quantity X_t is a fraction q_{xi}, which implies $\mathbb{E}_{it-1}(X_{it}) = \mathbb{E}_{t-1}(X_{it}) = q_{xi}\mathbb{E}_{t-1}(X_t)$. This fact is vital for deriving an expression for the expected value of X_t, which in turn is the key to obtain an expression that describes the pass-through from security rates to retail rates.

Proposition 2. *Under Assumption 2 the expected value of X_t can be written as a linear function of its one month lag, the expectation on future values and of security rates:*

$$\mathbb{E}_{t-1}(X_t) = A_{xi}^{-1}\left\{\alpha_{xi0} + \psi_{xi,-1}q_{xi}X_{t-1} + \sum_{k=1}^{\infty}\psi_{xik}q_{xi}\mathbb{E}_{t-1}(X_{t+k}) \right. \tag{12}$$
$$\left. + \sum_{k=1}^{\infty}\psi_{\hat{x}ik}(1-q_{xi})\mathbb{E}_{t-1}(X_{t+k}) + \sum_{k=0}^{\infty}\psi_{sxik}\mathbb{E}_{t-1}(r^s_{t+k})\right\},$$

Hence, retail rates can be expressed as a linear structural model in which the linear coefficients

[12]This implies our previous optimal solution is indeed the Subgame Perfect Nash Equilibrium (SPNE). However, if we assume banks are not myopic and they forecast over infinite periods (as it is usual in the baseline rational expectations assumption used in game theory) the SPNE would be much more complicated. To relax the myopic assumption poses difficulties to find an optimal solution. Exploring this scenario goes beyond the scope of this study which is more focused on empirical results.

depend only on structural parameters:

$$r_t^x = \beta_{x0} + \beta_{xs,-1} r_{t-1}^s + \beta_{xx} r_{t-1}^x + \beta_{xs0} \mathbb{E}_{t-1}(r_t^s) + \sum_{k=1}^{\infty} \beta_{xsk} \mathbb{E}_{t-1}(r_{t+k}^s) + \kappa_{xt}, \tag{13}$$

where $\kappa_{xt} = r_r^x - E_{t-1}(r_t^x)$ and the coefficients β_j depend on the structural parameters.

Proof. See appendix B.3 ■

Recall that Lemma 1 presents two equations that relate contemporaneous security rates with retail rates; however, those equations cannot be estimated directly. As equilibrium quantities are included, the error terms are systematically related to the explanatory variables; estimates would be biased. Proposition 2 indicates that under a common set of information, we can reach an expression in which retail rates are expressed as a function of its lag and the lagged, present, and expected values of security rates. Therefore, Proposition 2 helps to overcome the endogeneity problem as the retail rates do not depend on quantities, but on the observed lagged retail rate and the securities rate.

5 Empirical Methodology

One naive way to address the issue of estimation under the result from Proposition 2 is to assume that the processes involved follow the martingale property,[13] so that Equation (11) becomes

$$\begin{aligned} X_{it} &= \alpha_{xi0} + \underbrace{\left(\psi_{xi,-1} + \sum_{k=1}^{\infty} \psi_{xik}\right)}_{\alpha_{xi1}} X_{it-1} + \underbrace{\left(\sum_{k=0}^{\infty} \psi_{\hat{x}ik}\right)}_{\alpha_{xi2}} \hat{X}_{it-1} + \underbrace{\left(\sum_{k=0}^{\infty} \psi_{sik}\right)}_{\alpha_{xi3}} r_{t-1}^s + \gamma_{xit}, \\ &= \alpha_{xi0} + \alpha_{xi1} X_{it-1} + \alpha_{xi2} \hat{X}_{it-1} + \alpha_{xi3} r_{t-1}^s + \gamma_{xit}; \end{aligned} \tag{14}$$

where the α_{xij} $(j = 1, 2, 3)$ are well defined and finite.[14] Therefore Equation (12), and thus Equation (13) are also well defined for estimation purposes.

From the theoretical analysis, Equation (13) refers to the determinants of the retail rates in the short-run. We need to transform this reduced-form equation to accommodate both short-run and long-run. We follow the usual approach in the literature and use cointegration relationships. Namely, we use the steady state form of Equation (13) as follows

[13] Broadly speaking, a stochastic process $\{Y_t\}_{t \in \mathbb{N}_0}$ follows the martingale property if $\mathbb{E}(Y_{t+k} | Y_s, s \leq t) = Y_t$ for any $t, k \in \mathbb{N}_0$.

[14] The proof of Corollary 1 shows that ψ_{jik}, $j \in \{x, \hat{x}, s\}$ depend on $\nu_{ix} \in [0, 1/2)$. Therefore, the sum over its possible values for k converges.

$$\bar{r}^x_t = \beta_{x0} + \beta_{xx}\bar{r}^x + \beta_{xs,-1}\bar{r}^s + \beta_{xs0}\bar{r}^s + \beta_{xsK}\bar{r}^s \tag{15}$$

Where $\beta_{xsK} = \sum_{k=1}^{\infty} \beta_{xsk}$. Rearranging we obtain the long-run equation

$$\bar{r}^x = \nu + \kappa\bar{r}^s \tag{16}$$

Where $\nu = \frac{\beta_{x0}}{1-\beta_{xx}}$ and $\kappa = \frac{\beta_{xs,-1}+\beta_{xs0}+\beta_{xsK}}{1-\beta_{xx}}$. The respective short-run dynamics are given by the error correction model, which, as stated by Equation (13) must be augmented by the expected values of the security's rate. The short-run dynamics equation is the following

$$\Delta r^x_t = v + \alpha(r^x_{t-1} - \nu - \kappa r^s_{t-1}) + \sum_{m=0}^{M} \xi_m \Delta r^s_{t-m} + \sum_{j=1}^{J} \zeta_j \Delta r^x_{t-j} + \sum_{i=1}^{I} \vartheta_i \Delta E_t r^s_{t+i} + \varepsilon \tag{17}$$

Equation (17) is the baseline for the pass-through measurement. Coefficient κ is the long-run effect of the securities rate to the respective retail rate, in other words, the magnitude of the pass-through. $\kappa = 1$ means a complete pass-through, whereas $\kappa < 1$ is incomplete pass-through; $\kappa > 1$ is an overreaction of banks to monetary policy movements, to our knowledge not present in the literature; lastly $\kappa < 0$ is technically possible but theoretically and intuitively implausible. Another important coefficient relates to the speed of adjustment: α the percentage of the adjustment in each period from the moment of a disequilibrium until the equilibrium is achieved again. α is expected to be negative and statistically significant for a cointegration relationship to hold.

Before moving on with the estimation, several points need to be raised. To begin with, our theoretical model relates the retail rates to security rates. Choosing a security rate in Costa Rica is not a trivial task, since the financial market is not fully developed. Large participants (including banks) trade for liquidity purposes in a liquidity market called "Mercado Integrado de Liquidez" (MIL), which is organized by the BCCR. This market is also where the BCCR's monetary policy rate operates. As liquidity management affects decisions on loans and deposits, we take both the monetary policy rate, TPM from now on, and the average interest rate from the MIL market, MIL rate from now on, for estimation. We will talk about the benchmark security rate referring to any these rates. We consider the MIL rate to be a good approximation for monetary policy movements as Esquivel-Monge (2018) showed the TPM pass-through is fast and strong to the MIL rate, the latter being more similar to a “market” rate.

Also recall the expected securities rate is an important variable in our specification. However, it is an unobserved variable. We approximate this expectation, for the overall market, by predicting from the best ARIMA.

Although we do not separate by maturities or the type of bank in our theoretical formulation, Equation (12) is general enough to account for that, as the market shares will differ. Therefore, it is possible to estimate diverse specifications for Equation (13).

We choose to aggregate and separate the state-owned and the private banks to compare the estimates. Also, we estimate the pass-through for the aggregate of the maturities and for specific ones:

- For deposits:
  - Less than 1 month.
  - Between 1 and 4 months.
  - Between 4 and 7 months.
  - Between 7 and 13 months.
  - More than 13 months
- For loans:
  - Less than 2 years.
  - Between 2 and 5 years.
  - Between 5 and 10 years.
  - Between 10 and 20 years.
  - More than 20 years.

Data availability allow us to perform such estimations. With the results, we could measure asymmetries in pass-through magnitude and speed, conditional on term and type of bank.

It is also important to assess whether monetary policy movements trigger another asymmetric response: if increases or decreases in the monetary policy rate have different effects on retail rates. Banks could increase their intermediation margin so as to increase first loan rates when the monetary policy rate increase, or decrease first the deposit rates when the monetary policy rate decreases.

Taking the long-run Equation (16) we can define the deviation from the long-run as $\mu = \bar{r}^x - (\nu + \kappa\bar{r}^s)$, and therefore these deviations are as follows: i) there is an increase in the monetary policy rate when $\bar{r}^x < \nu + \kappa\bar{r}^s$ implying $\mu < 0$. As it is a negative deviation from the long-run equilibrium we call it μ^-. And ii) there is a decrease in the monetary policy rate when $\bar{r}^x > \nu + \kappa\bar{r}^s$ implying $\mu > 0$. Analogously, we call it μ^+ as it is a positive deviation from the steady state. Then we re-state the short-run dynamics, Equation (17), in order to test the asymmetry hypothesis, as follows:

$$\Delta r_t^x = \upsilon + \alpha^+\mu^+ + \alpha^-\mu^- + \sum_{k=0}^{K} \xi_k \Delta r_{t-k}^s + \sum_{j=1}^{J} \zeta_j \Delta r_{t-j}^x + \sum_{i=1}^{I} \vartheta_i \Delta E_t r_{t+i}^s + \varepsilon \tag{18}$$

We think of two types of asymmetry. If the coefficients α^+ and α^- are statistically significant and different from each other, there is strong evidence of asymmetry. The sign of movements in the benchmark interest rate matters, which results in different speeds of adjustment. If only one is significant, but are statistically different, there is weak evidence of asymmetry meaning both null hypotheses of asymmetry or no asymmetry cannot be rejected. Here we focus on strong evidence. We call it speed of adjustment sign asymmetry.

In previous sections, we documented how deposit and loans in dollars have a large share in the banking market. Thus, it is imperative to assess whether the policy rate in local currency affects the retail rates for instruments in dollars. Moreover, we include the 3 and 6-month Libor rates to assess if local retail rates in dollars follow more closely external benchmarks. Again, our theoretical framework is sufficiently flexible to allow for different currencies.

Now that we have presented our empirical approach, the following step is to apply it. For that, we use monthly data on new loans and deposits for estimation. The next section presents the estimation results.

6 Results

Our estimations provide evidence on the pass-through magnitudes, the speed of adjustment, and the importance of future market rates for the banks' decision on deposit and loans retail rates in Costa Rica. In addition, we compare the effect of the TPM and MIL interest rates on the aggregate retail rate, and on several maturities. We also find differences between the effect on local currency and on US dollars rates, which are important due to the high degree of dollarization. These results help to understand the monetary policy effects on the interest rate curve faced by both firms and households. This is particularly important as the financial market is not highly developed in Costa Rica, so that the funds for investment, housing or consumption are mainly obtained from banks (economic agents are mainly banking dependant).

First we show results from the unit root tests on retail rates. We need this to study the following section: cointegration tests to assess whether the TPM or MIL rates have a meaningful relationship with banking retail rates. We find those to be present, so we follow it up with estimates of pass-through and speed of adjustment coefficients. Then we validate the inclusion of the expected securities rate, its consistency with only one speed of adjustment, and its statistical significance. Next, we provide evidence of asymmetry of the effects between increases and decreases in the security rate. Finally, we compare models using Bayesian Information Criteria (BIC) to conclude that expected security rates should be included in the final model.

6.1 Unit root tests

Tables C1 and C2 summarize several unit root tests for deposit and loan retail rates. As it was the case in previous studies for the Costa Rican aggregate rates, there exists strong evidence of unit root presence. Banks' adjustment costs could explain this result. Having confirmed the presence of unit roots, the following steps are to test for cointegration relationships to assess if it is appropriate to estimate error correction models.

6.2 Cointegration tests

If two or more time series cointegrate, they have a stable long-run relationship, meaning their stochastic processes are related and co-move to some extent. Hence, cointegration between two variables implies their time paths are influenced by any deviation from their long-run equilibrium. In other words, after a shock any stable cointegrated system returns to its long-run equilibrium. For the monetary policy to be effective, it is important the monetary policy interest rate to have cointegration relationships with the retail rates of the banking system. When this is the case, any movement in the policy rate will provoke corresponding co-movement in retail rates to attain the long-run equilibrium.

As expected, the evidence in tables C3 and C4 suggest the existence of cointegration relations between all maturities for deposit and loan retail rates in local currency and the two benchmarks of monetary policy rates: the TPM and the MIL rate. However, and also as expected, the cointegration relationships are not as strong for interest rates in dollars. These are mostly driven by international benchmarks as these cointegrate with the 3 and 6 month Libor rates. As we show in the following sections, the Costa Rican monetary policy is not effective on the interest rates in dollars: there is no local benchmark to drive the banks' adjustment costs.

The degree of dollarization in Costa Rica poses a challenge to monetary policy, and this analysis suggests two alternatives to increase its efficacy. The first is a creation of a credible analogous to the TPM in dollars in order to affect local banks' adjustment costs in that currency. In that case, our theoretical model predicts a cointegration relationship to be present which would drive retail rates. However, Costa Rica already has independent free capital movements. Via interest rate parities, this instrument in dollars would lose independence. A possible solution to this would be to impose capital controls. This would be counterproductive due to the distortions that could arise.

The second is to decrease the degree of dollarization. Strict regulation forbidding dollars for deposits and loans would be too strong, as there could be some financial exclusion, and loss of opportunities for investment in dollars. The BCCR has already been working with less stringent regulations: i) borrowers in dollars must have income in that currency to some extent; and ii) the flexible exchange rate regime that places the exchange rate risk on banks and economic agents. These measures are far from being strict, but have resulted in an important reduction in the financial market dollarization.

6.3 Pass-through strength

Recall we want to measure the pass-through strength (long-run effect) and the speed of adjustment (amount of time to achieve that effect) of changes in the monetary policy rate or the benchmark rates on several retail rates. In this section we focus on the results of the pass-through strength. Next, we summarise the results about the speed of adjustment.

For deposits, our model specifications include all deposits, and different horizons: less than 1 month, between 1 and 4 months, between 4 and 7 months, between 7 and 13 months, and more than 13 months. For loans, we use all loans aggregated and the following maturities: less than 2 years, between 2 and 5 years, between 5 and 10 years, between 10 and 20 years, and more than 20 years.[15] Also, interest rates are differentiated by local currency or dollars. The pass-through is measured with respect to movements in the monetary policy rate (TPM), the liquidity market rate (MIL), and the 3 and 6 month Libor rates.

Table C5 reports our estimates for the pass-through coefficients on deposits. Our results reveal that the pass-through with respect to the TPM is strong in local currency but near zero for interest rates in dollars. It is similar with the MIL rate. This is not surprising. The 3 and 6 month Libor rates are the benchmarks that interest rates in dollars follow.

Additionally, the magnitude of the pass-through is higher for the local currency rates (with respect to the TPM) relative to the rates in dollars for all horizons (with respect to Libor rates). This may be due to decisions by banks on the level of interest rates in dollars being driven by developments in the exchange rate market. This risk management considerations end up leaving a weaker pass-through from foreign benchmark rates.

[15]This classification responds to loan usage by clients, specifically for consumption or cash flow considerations, housing and car purchases, among others.

Overall, the pass-through coefficient for all deposit rates with respect to the TPM is 0.61, meaning a change of 100 basis points in the TPM is associated with an overall change of 61 basis points on the same direction, achieved completely in the long-run. For dollars, there is no difference as to whether we use 3 or 6 month Libor, overall the pass-through coefficient is 0.46. Also, in local currency, the pass-through coefficient is higher for short horizons: 0.74 for less than one month compared to 0.56 for more than 13 months.

We find one significant difference when analyzing rates in local currency by banks' type: private banks show no pass through for deposits of less than a month. Regulatory asymmetries may be behind this. One that may be of particular importance requires private banks to maintain 17% of all less-than-one-month deposits (in addition to the legal minimum reserve) for specific loans to small business. Alternatively, they may give those funds to public banks with that same purpose. On the other side, for deposits in dollars, the pass-through seems to be greater for state-owned banks.

The pass-through coefficient is almost the same for the local currency when taking changes in the TPM or the liquidity market rate (MIL). This is expected as the TPM pass-through to the MIL rate is strong as shown by Esquivel-Monge (2018), hence the causal relationship seems to go from the TPM as a benchmark interest rate.

Table C6 presents our results for loan rates. Relative to deposits, the pass-through seems to be stronger for loan retail rates. The pass-through coefficient for all loans is 0.74, which is greater than the 0.61 estimated for deposits. Using the liquidity market rate, instead of the monetary policy rate yields similar results. This points to the TPM to be the causal root for movements in local currency loan retail rates.

As expected, pass-through with respect to the TPM is lower for rates in dollars. Differently to deposit rates, we find statistically significant coefficients for all maturities in dollars. We believe that the BCCR's regulations to decrease dollarization are behind this result.

While somewhat surprising, less surprising is that banks use instead foreign rates as their benchmark. Pass-through is significant and stronger for 3 and 6 month Libor rates, with coefficients of 0.43 and 0.35. This suggests that foreign, well established reference rates lead loan rates in dollars, not the local policy rate. A plausible explanation (which we do not explore further) is that shocks affecting these Libor rates also induce changes in the BCCR's policy rate.

We're interested in tracking the effect of monetary policy changes on the whole loan retail rates curve, conditional on the type of bank, and on currency. Overall, pass-through coefficients are weaker for medium horizon loans, with 0.37 for loans between 2 and 5 years and 0.36 for loans between 5 and 10 years. The coefficients for long maturity loans are 0.64 and 0.50 for loans between 10 and 20 years and more than 20 years. Finally, for loans of less than 2 years the pass-through coefficient is 1, not rejecting the null hypothesis of unitary pass-through. Nonetheless, differences are even more pronounced when separating by state-owned and privates banks. For loans in local currency, pass-through coefficients are higher in private banks (except for loans over 20 years), even greater than one for loans of less than 2 years. For loans in dollars, pass-through coefficients are higher in public banks (except for loans over 20 years).

These results point out to a characteristic behavior from all monopolistically competitive banking markets: banks move their interest rates in accordance to their market power relative to their clients. On one side, short-term loans (less than 2 years) are mainly given to businesses or households which are good clients, as they are primarily loans for liquidity purposes and there is a close bank-client relationship. Hence, banks adjust strongly their interest rates to avoid getting those clients poached. Having more banking competition for good clients (scarce in the market) leads to unitary pass-through coefficients in the long-run. On the other side, loans of more than 20 years are mainly for housing, where clients have low market power and banks have the possibility to partially adjust any change in the monetary policy rate.

Moreover, banks also have strategic considerations. Consider the leaders of each sub-market. Deposits and loans in dollars are mainly the focus of private banks, whereas local currency are the focus of state-owned banks. Given the estimates of pass-through coefficients, it seems banks have stronger pass-through on sub-markets they do not lead. This implies that banks with lower market power behave more closely to a competitive setting, characterized by pass-through coefficients closer to unity.

6.4 Speed of adjustment

Tables C7 and C8 report the speed of adjustment coefficients for deposits and loans. These come from estimating the dynamic short-run equations: the coefficient associated to the error correction term in the retail rate equation measures how fast deviations from the long-run equilibrium disappear. A negative and significant coefficient is an indicative of a stable cointegrating relationship.[16]

That is the case for the monetary policy rate and retail rates in local currency; and also for the retail rates in dollars with Libor rates. However, we also confirm the weak evidence for monetary policy transmission to retail rates in dollars, specially for loan rates. The aggregate

[16]We refer here about the stability of the dynamic system. It could be the case there exists a cointegration relationship, but any perturbation makes the variables to diverge. Also, the negative sign ensures the endogenous variable (the retail rate) moves to the same direction as the benchmark rate. As we want to address whether retail rates react as desired with movement of the benchmark rates, we focus on the stability concept and the negative sign.

of all loans and those for less than 2 years do not have statistically significant adjustment coefficients; meaning there is not a stable cointegration relation and, as expressed previously, imposing an important limitation to monetary policy effectiveness.

As usual, the magnitude of the adjustment coefficient says by what percent any deviation is corrected in each period. For example, taking into account we used monthly data, the estimated coefficient for all deposits is -0.15 indicating a 15% of the deviation is corrected in each month in the same direction as the monetary policy rate movement. In other words, it will take near 6.67 months (200 days) to reach its long-run equilibrium. Similarly, the speed of adjustment for all loans is 0.16 or 16% each month, arriving to the equilibrium approximately in 188 days. Thus the evidence of cointegration allows us to see the effect of monetary policy movements on the whole interest rate curve dynamically, not only in the aggregate but also in detail given some maturities move faster than others.

For the deposits case in local currency, summarized in table C7, medium term deposit rates seems to move slower, particularly for those between 1 and 4 months with an speed of adjustment 0.16, whereas for those between 4 and 7 months and 7 and 13 months the coefficients are -0.27 and -0.32. Deposit rates for less than 1 month converge to equilibrium relatively faster (coefficient -0.62). Finally, long term deposit rates (more than 13 months) adjust immediately the next month after the shock with a unity coefficient. In dollars, the speed of adjustment with respect to Libor rate movement seems to be faster relative to local currency adjustments, but with a similar shape as the one commented before. Here deposit rates for more than 13 months have an unitary coefficient.

Again the associated speed of adjustment for deposits brings evidence of regulatory asymmetries, as well as market power, and strategic considerations. We begin to point out the few differences in state-owned and private banks.

For the local currency, less than one month deposit rates adjust considerably slower for private banks, as there are no incentives to adjust given that the asymmetric regulation previously addressed will drain those resources. But also for deposits of more than 13 months, state-owned banks adjust almost immediately in local currency. This seems to be an optimal strategy as the law requires public companies or government institutions to only deposit funds in public banks. Those clients put with them huge amounts of money fundamentally in long maturities. These are costumers that have a high amount of market power, which impose quick adjustments up to avoid lose the client, but also down adjustments to decrease financial costs. Overall, the adjustment is faster for state-owned banks in local currency, but slower in dollars relative to private banks. This means banks react faster on sub-markets they lead to avoid client losses, but also to decrease costs.

On the loans side in table C8, the interest rate for the aggregate of all loans in local currency has a speed of adjustment to equilibrium of 0.16. However, in contrast to the deposits case, long maturities react slower relative to shorter maturities. The pass-through speed of adjustment for loans of less than 2 years is 0.22, similar to loans between 5 and 10 years (0.21), whereas for loans between 2 and 5 years the convergence is relatively faster (0.49). When looking at loans between 10 and 20 years, and more than 20 years the pass-thorough speed falls considerable to 0.16 and 0.08.

The speed of adjustment is relatively similar for loans between dollars interest rates and local currency rates, each at its respective maturity. Relative to Libor rates, an important difference among the two currencies is that coefficients are greater in absolute value for loans in dollars between 10 and 20 years (-0.27) and for loans in dollars for more than 20 years (-0.18). Different degrees of competition could be the reason for this.

On one hand, loans in local currency have demand only in the domestic economy and it is difficult to use the exchange rate to perform international comparisons. On the other hand, loans in dollars are easier to be compared to their international counterparts. Some big clients could have access to international loan markets implying more competition to attract them, all of which makes the pass-through faster for dollars loan rates.

As in the deposits' case, banks seem to adjust at different speeds for loans, but in contrast, they are faster on markets they do not lead. Private banks are faster in local currency, and lower in dollars for almost all maturities, whereas state-owned banks are faster in dollars and slower in local currency. Maybe it is useful to attract clients when rates are going down, but they compensate with a faster increase.

6.5 Speed of adjustment sign asymmetry evidence

All the previous results show there are differences in the pass-through coefficients and the speeds of adjustment, both between state-owned and private banks, as well as for loans and deposits. Nevertheless, there is still one type of asymmetry we want to acknowledge: sign asymmetry in the speed of adjustment. It measures whether the sign of the change in the benchmark rate leads to faster or slower movements of the retail rate towards long-run equilibrium.

We formally test for these asymmetries and the results are in Table C9. We consider the monetary policy rate to be the benchmark in colones, and the 3 month Libor rate in dollars. We find new evidence of sign asymmetry when we group by public and private banks. This is not the case when we aggregate all banks, consistent with past studies. This is a very important result, which highlights how micro-data helps us reach new insights.

Banks could take advantage of the benchmark interest rate changes to increase temporally their intermediation margin. With positive changes, they could increase faster loan rates relative to deposits rates. With negative changes, they would prefer to lower faster deposit rates instead. That is possible due to market power.

Nonetheless, state-owned banks do not seem to take advantage of this asymmetry for their loans in local currency. They use it partially in dollars (the sub-market they do not lead), where in overall, both loan and deposit rates increase faster with the respective TPM or Libor movement relative to the decreases. We consider the faster increase in deposits in dollars to be a form to attract clients from the competition.

On the contrary, private banks systematically use sign asymmetries. They increase faster (relative to decreases) loan and deposit rates in local currency (the sub-market they do not lead). Again a signal they want to attract clients from the competition. Also, they take advantage of their leading position in the dollars market. To us, they look to attract more deposits with faster increases in the longest maturities. Also, they seek to discourage less than 1 month deposits (faster decreases and slower increases of the interest rate), as the previously mentioned regulatory asymmetry takes away the discretionary use of these funds. When it comes to loan rates, they increase theirs faster for maturities between 5 and 20 years (two bins/groups), where clients with little market power lie, fundamentally with consumption purposes or vehicles purchases.

6.6 Model adequacy

It is fundamental to assess whether our empirical approach is adequate, as it is not based on common error correction models. The use of the expected securities rate, though necessary in accordance with our theoretical results, presents important complications. Given the recursive nature of error correction models, security rates have two long-run effects on the process of the retail rates; one via the long-run equation, the second via the expected security rate impacting the retail rates each period until the long-run. To overcome this problem, as discussed by Banerjee et al. (2013), it is imperative to measure whether our results support a unique speed of adjustment. We consider our model to be adequate when this happens. From equation (17) it must be the case that the restriction $\vartheta = -\alpha * \kappa$ is satisfied. If it holds, and α and κ are statistically significant, then ϑ also is.

We performed a Wald test with the null hypothesis $\vartheta = -\alpha * \kappa$, for both deposits and loans summarized in Tables C10 and C11. Their results confirm model adequacy for all local currency specifications and almost for all dollars counterparts.

We also ran another specification test excluding expected security rates. We measure if one model outperforms the other using the BIC, and found no evidence of misspecification.

Tables C12 and C13 summarize our results, where we find no differences. This also reaffirms the evidence of the Wald tests about a unique speed of adjustment, and the importance of including the expected securities rate for the pass-through measurement.

7 Discussion of results and policy implications

As the BCCR moved to an inflation targeting scheme, the monetary policy interest rate became a fundamental tool for policy makers. Hence, the institution has devoted efforts to measure the monetary policy effectiveness with the pass-through to retail rates. This paper is part of that effort, bringing new evidence to that analysis. Particularly, we acknowledge market concentration and develop a theoretical framework to consider imperfect competition. The novel aspect is using micro-data for the first time in this kind of studies for Costa Rica.

The theoretical construct serves us to define an empirical specification that relates quantities and retail rates, but without the endogeneity problem. The main difference with previous studies for Costa Rica lies in the importance of the expected securities rate (an instrumental variable). Also, our model presents an explanation why interest rate lags are fundamental due to banks' adjustment costs. Retail interest rates are hence determined by its lag, and the lag, current and expected future securities rate; specification which helped us to obtain pass-through estimates for loans and deposits.

Additionally, with the micro-data we were able to measure pass-through conditional on the maturity, type of bank, and currency. The strength and speed are explained by structural parameters, in other words, by adjustment costs linking the results to regulatory asymmetries, market power, client-bank relationships, and different interest rate benchmarks between local currency and dollars.

Results differ for the aggregate, the state-owned and the private banks, mainly due to diverse adjustment costs and market power. Thus, aggregation could provide biased results, as leaders by quantity (those with higher market share) will be over-represented in the estimates. Then, it was fundamental to segregate state-owned a private banks as there exists important regulatory asymmetries. They pose conditions on competition for liquidity (for example the regulatory asymmetry for low maturity deposits for private banks), and even they circumscribed market segments (public institutions could only deposit their funds on public banks).

Nonetheless, regulatory asymmetries are not the only distortion. The high degree of dollarization in the banking market provides complications. Recall pass-through is possible as changes in a benchmark rate affect the "expected prices" and thus the demand and supply. Dollarization implies there is a dual market (two supplies and two demands) where the benchmark rate is not necessarily the same. In fact, we showed here empirically that Libor rates are at least a better benchmark than TPM for loans and deposits in dollars.

All the previous pass-through evidence signals a common implication of any non-competitive setting: it is feasible and optimal for banks to obtain rents due to their competitive power. Still, it is difficult and not straightforward to compare deposit and loan retail rates behavior.

With movements in the benchmark rate, rent extraction seems to come in two ways. First, pass-through coefficients or strength for both deposits and loans are far below from being unitary. Whereas banks react to monetary policy rate movements, the market power they have traps clients who do not have other options. This is especially true in Costa Rica's under-develped financial market. This allows banks to smooth quantities and thus interest rates movements fall below the perfectly competitive (unitary) adjustment.

Pass-through is unitary only for loans of less than 2 years and mostly in private banks. It seems to respond to a particular characteristics of this type of loans: being of lower maturity, good clients (specially business) could apply for these loans to tackle short-term cash flow problems. Hence, interest rates adjust more for this type of loans: i) down as to maintain the good client; ii) up to compensate with more profits the decreases. The latter is feasible as the higher competitive environment for good clients will make the reaction similar for all banks. It is also possible a good client-bank relationship could allow banks to increase interest rates, but only with a valid reason. In other words, for clients it is also costly or risky to translate to other bank and build again a relationship, meaning they would understand reasonable interest rates increases.[17]

The second way of rent extraction lies in the adjustment costs. They make banks eager to see their balance sheet developments in order to avoid losses. This leads to important differences between deposit and loan rates, which increases the intermediation margin temporally in the short-run relative to the long-run.

Deposit interest rates' reaction is faster. When the benchmark interest rate increases, it is optimal to adjust deposit rates faster as banks expect both securities and loan rates to increase. Thus, in order to obtain more profits, banks demand more liquidity. By offering marginal but quick increases in deposit rates, they capture those funds. With decreases in the interest rates, it is expected a faster reaction for deposits relative to loans as the intermediation margin will temporally increase.

The speed of adjustment is lower for loan interest rates, specially for long maturities. When banks expect interest rates to increase, it is also optimal to smooth the quantity of loans they offered to clients. This is explained by the fact banks invest in securities as a substitute for loans in the profit function. Thus, they could obtain short term profits without

[17]This could be stated in a theoretical framework, but it goes out of the scope for this study.

the necessity to increase liquidity provisions as it is the case with loans. Nevertheless, when the interest rates are expected to decrease, there are less options to make profits through investment in securities. Additionally, the adjustment costs make impossible for banks to quickly increase the supply they offer by “selling quantity at a low price”. Therefore the option is to decrease slowly loan rates to smooth profits. As clients are banking dependant, due to the under-developed financial market, the interest rate changes are managed entirely by banks.

As expected, higher competition makes the pass-through more effective, i.e. faster and closer to unity. Notwithstanding, this is not an option for any Central Bank. While it is true regulation could affect competition mainly by its reduction, the recent evidence from the 2008 financial crisis states the banking sector “could not be led alone” to compete. Good regulation is a must for financial and macroeconomic stability.

Another possibility to enhance monetary policy effectiveness comes following Kopecky & Van Hoose (2012). It is slightly different from the previous argument of making banks face abrupt adjustment costs due to greater competition. Instead, if the adjustment costs themselves are reduced overall in the banking market, banks would have more space to make larger period-by-period changes in deposit and loan quantities. As a consequence, market quantities will change more in response to the contemporaneous and expected future security rate, and less to the lagged retail and security rates. This would lead to greater pass-through in magnitude and speed. However, this approach needs to bring additional incentives to the banks for them to be willing to increase period-by-period changes in quantities instead of using market power and the lower adjustment cost to increase profits. Again both points can be done by the monetary authority with regulation, for example lowering the provision requirements for new loans, but again there is a trade-off with financial stability.

Nonetheless, the monetary policy effectiveness seems to be stronger than before. Previous evidence from Barquero-Romero & Mora-Guerrero (2015) stated the pass-through effect lasts from 8 to 12 months in contrast to the 3 to 8 months found here (with similar strength). Several policy changes as more flexibility of the exchange rate, efforts to lower the dollarization degree, the explicit use of a policy rate to control inflation, among others have played an important role. Future research on the exact determinants and their impact for the increased monetary policy effectiveness is fundamental for the policy makers.

8 Conclusions

Since the strategic project to enforce an explicit inflation targeting in January 2005, the BCCR define the monetary policy interest rate as a fundamental tool. Its effectiveness is measured with the pass-though strength and speed to the banks' retail rates.

Hence, the institution has devoted efforts to study the pass-through to retail rates. This paper is part of that effort. Particularly, we acknowledge the evidence of market concentration in Costa Rica, and develop a theoretical framework to consider imperfect competition. The novel aspect is using micro-data for the first time in this kind of studies for Costa Rica.

As a result, our empirical specification relates quantities and retail rates, without the endogeneity problem. Also, adjustment costs (including regulation) are the explanation on the slow interest rates movements.

Overall, on one side, banks have stronger pass-through on markets they do not lead. This could be similar to them as more competition. On the other side, the pass-through is slower for long-term loans, and faster where each type of bank does not lead. Finally, there exists strong pass-through asymmetries in magnitude and speed, and also there are speed of adjustment sign-asymmetries for private banks to increase the intermediation margin.

Another important issue is that regulatory asymmetries and dollarization negatively affects monetary policy effectiveness. It is due to the existence of foreign benchmarks for sub-market in dollars, the impact on adjustment costs, and fuzzy information for clients.

Therefore, the monetary policy effectiveness could be enhanced by limiting dollarization, but at the cost of possible financial exclusion. Other option is higher banking competition. However, it is not in control of the BCCR. Finally, lowering banking adjustment costs could enhance interest rates pass-through. This is primarily achieved by deregulation, but there is a trade-off with financial stability.

Nonetheless, the monetary policy effectiveness seems to be stronger than before. Several policy changes as more flexibility of the exchange rate, efforts to lower the dollarization degree, the explicit use of a policy rate to control inflation, among others have played an important role. Future research on the exact determinants and their impact for the increased monetary policy effectiveness is fundamental for the policy makers.

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Appendices

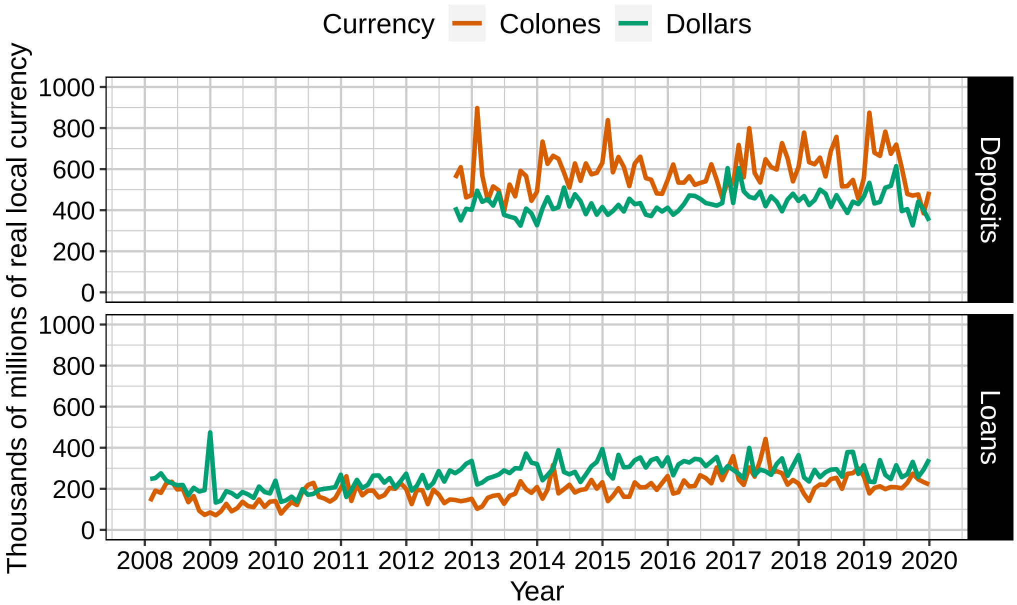
A Supporting Evidence of Stylized Facts

Table A1: Correlation Matrix of Rates.
September 2013 to December 2019.

	r_t^s	r_{t-1}^s	$r_t^{d\mathbb{C}}$	$r_{t-1}^{d\mathbb{C}}$	$r_t^{d\$}$	$r_{t-1}^{d\$}$	$r_t^{\ell\mathbb{C}}$	$r_{t-1}^{\ell\mathbb{C}}$	$r_t^{\ell\$}$	$r_{t-1}^{\ell\$}$
r_t^s	1.0000									
r_{t-1}^s	**0.9670**	1.0000								
$r_t^{d\mathbb{C}}$	0.6999	0.6695	1.0000							
$r_{t-1}^{d\mathbb{C}}$	0.6957	0.6951	**0.9475**	1.0000						
$r_t^{d\$}$	0.0571	0.0248	0.5441	0.4842	1.0000					
$r_{t-1}^{d\$}$	0.0967	0.0571	0.5382	0.5168	**0.8840**	1.0000				
$r_t^{\ell\mathbb{C}}$	0.7185	0.7462	0.6471	0.6950	0.0188	0.0100	1.0000			
$r_{t-1}^{\ell\mathbb{C}}$	0.6649	0.7134	0.5814	0.6730	(0.0498)	0.0127	**0.7924**	1.0000		
$r_t^{\ell\$}$	0.5331	0.5247	0.6000	0.6153	0.5803	0.6022	0.4336	0.4174	1.0000	
$r_{t-1}^{\ell\$}$	0.5402	0.5411	0.5764	0.5885	0.5167	0.5783	0.4069	0.4304	**0.9044**	1.0000

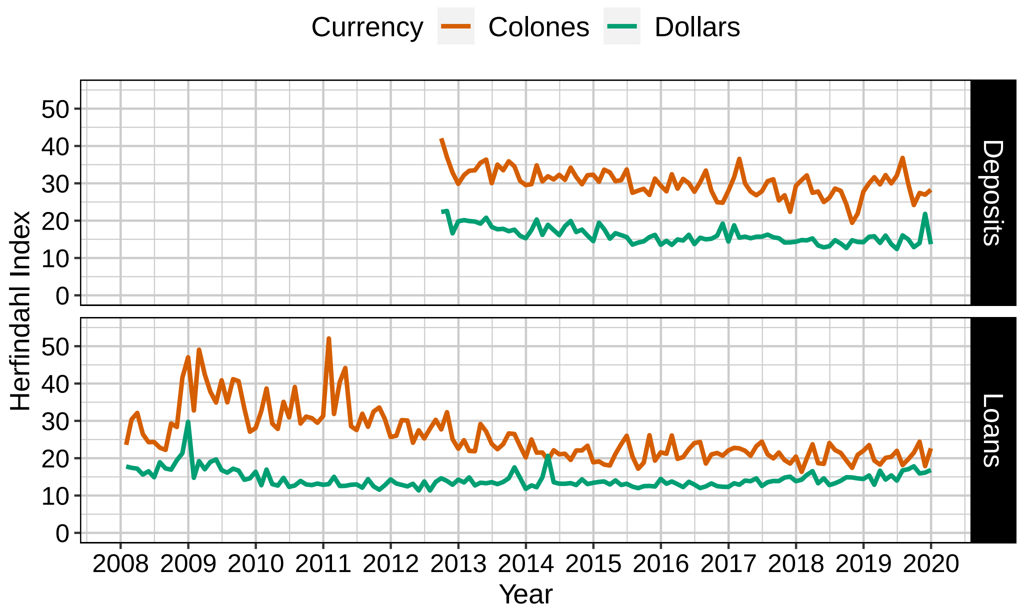
This correlation matrix uses the rates of all banks except Banco Popular. Source: Own elaboration with SUGEF data.

Figure A1: New loan and deposits in Costa Rica.
January 2008 to December 2019.



All quantities are in local currency of January, 2019; and were computed using data of all banks including Banco Popular. Dollar amounts reported in colones at current exchange rate. Loans from January 2008 to December 2019, deposits from September 2012 to December 2019. Source: Own elaboration with SUGEF data.

Figure A2: Evolution of the Herfindahl-Hirschman Index in Costa Rica.
January 2008 to December 2019.



All quantities were computed using data of all banks except Banco Popular. For deposits from September 2012 to December 2019, for loans from January 2008 to December 2019. Source: Own elaboration with SUGEF data.

B Proof of Theoretical Results

B.1 Proof of Lemma 1

Proof. Let $f : \mathbb{R}^p \to \mathbb{R}$. Recall that the Taylor first-order approximation for this function around a point $\bar{\boldsymbol{x}} = (\bar{x}_1, ..., \bar{x}_p)$ is

$$f(x_1, ..., x_p) \approx f(\bar{\boldsymbol{x}}) + \sum_{i=1}^{p} \frac{\partial f(\bar{\boldsymbol{x}})}{\partial x_i}(x_i - \bar{x}_i). \tag{B1}$$

where we abuse notation and use the equality symbol.

<u>*First-order approximation for D_t.*</u> Let $\boldsymbol{s_D} = (\bar{\Omega}, \bar{r}^d, \bar{r}^s)$ denote the steady state of the supply of deposits. Notice that

$$\frac{\partial D_t(\boldsymbol{s_D})}{\partial r_t^d} = (\varepsilon_d \bar{r}^d)^{-1}\bar{D}, \quad \frac{\partial D_t(\boldsymbol{s_D})}{\partial r_t^s} = -\chi_d(\varepsilon_d \bar{r}^s)^{-1}\bar{D}, \quad \frac{\partial D_t(\boldsymbol{s_D})}{\partial \Omega_t} = \bar{\Omega}^{-1}\bar{D},$$

so applying Equation (B1) to the deposits supply function results in

$$D_t = \bar{D}(1 - \varepsilon_d^{-1} + \chi_d \varepsilon_d^{-1}) + (\varepsilon_d \bar{r}^d)^{-1}\bar{D}r_t^d - \chi_d(\varepsilon_d \bar{r}^s)^{-1}\bar{D}r_t^s + \bar{D}[(\Omega_t/\bar{\Omega}) - 1], \tag{B2}$$

and clearing for r_t^d results in Equations (2).

<u>*First-order approximation for S_t.*</u> Similarly, with $\boldsymbol{s_L} = (\bar{\Lambda}, \bar{r}^\ell, \bar{r}^s)$ denoting the steady state of the demand for loans. The partial derivatives of S_t evaluated at $\boldsymbol{s_L}$ are

$$\frac{\partial L_t(\boldsymbol{s_L})}{\partial r_t^\ell} = -(\varepsilon_\ell \bar{r}^\ell)^{-1}\bar{L}, \quad \frac{\partial L_t(\boldsymbol{s_L})}{\partial r_t^s} = -\chi_\ell(\varepsilon_\ell \bar{r}^s)^{-1}\bar{L}, \quad \frac{\partial L_t(\boldsymbol{s_L})}{\partial \Lambda_t} = \bar{\Lambda}^{-1}\bar{L},$$

$$\Rightarrow L_t = \bar{L}(1 + \varepsilon_\ell^{-1} + \chi_\ell \varepsilon_\ell^{-1}) - (\varepsilon_\ell \bar{r}^\ell)^{-1}\bar{L}r_t^\ell - \chi_\ell(\varepsilon_\ell \bar{r}^s)^{-1}\bar{L}r_r^s + \bar{L}[(\Lambda_t/\bar{\Lambda}) - 1], \tag{B3}$$

so clearing for r_t^ℓ results in Equation (3). ■

B.2 Proof of Proposition 1

Proof. Let i be a bank in $\mathcal{B}$. Substitute the retail rates r_t^d and r_t^ℓ given in Equations (2) and (3) into profits (6) to obtain

$$\begin{aligned} \pi_{it} = {} & r_t^s\big[(1-\rho)D_{it} - L_{it}\big] \\ & + \Big[(1 + \varepsilon_\ell + \chi_\ell)\bar{r}^\ell - \varepsilon_\ell \bar{r}^\ell \bar{L}^{-1}\left(L_{it} + \textstyle\sum_{j \in \mathcal{B}_i'} L_{jt}\right) - \chi_\ell \bar{r}^\ell (\bar{r}^s)^{-1} r_t^s + \nu_{\ell t}\Big] L_{it} \end{aligned} \tag{B4}$$

$$+ \left[(\varepsilon_d + \chi_d - 1)\bar{r}^d - \varepsilon_d \bar{r}^d \bar{D}^{-1}\left(D_{it} + \sum_{j\in\mathcal{B}'_i} D_{jt}\right) - \chi_d \bar{r}^d (\bar{r}^s)^{-1} r^s_t + \nu_{dt}\right] D_{it} - C_{it}$$

To keep expressions short, we define the following variables:

$$c_{\ell 0} = (1+\varepsilon_\ell + \chi_\ell)\bar{r}^\ell, \quad c_{\ell 1} = -\varepsilon_\ell \bar{r}^\ell \bar{L}^{-1}, \quad c_{\ell 2} = -\chi_\ell \bar{r}^\ell (\bar{r}^s)^{-1},$$

$$c_{d0} = (\varepsilon_d + \chi_d - 1)\bar{r}^d, \quad c_{d1} = -\varepsilon_d \bar{r}^d \bar{D}^{-1}, \quad c_{d2} = -\chi_d \bar{r}^d (\bar{r}^s)^{-1}.$$

Assuming that the sum of discounted profits $\sum_{\tau=t}^{\infty} \beta^{t-\tau}\pi_{it}$ is bounded and from the fact that π_{it+k} only depends on X_{it} when $k \in \{0,1\}$ for $X \in \{D, L\}$, we have that the first-order conditions of the maximization problem (7) are

$$\mathbb{E}_{i\tau}\left[\frac{\partial \pi_{it}}{\partial X_{it}} + \beta \frac{\partial \pi_{it+1}}{\partial X_{it}}\right] = 0 \quad \text{for } X \in \{D,\, L\} \text{ and } \geq \tau. \tag{B5}$$

Let $(x, X) \in \{(d, D), (\ell, L)\}$. Denote $\xi_x = (1-\rho)$ if $x = d$ and $\xi_x = -1$ otherwise. Substituting (B4) at t and $t+1$ into (B5) implies

$$\begin{aligned} 0 = \mathbb{E}_{i\tau}\Big\{\xi_x r^s_t + \Big[c_{x0} + c_{x1}\Big(X_{it} + \textstyle\sum_{j\in\mathcal{B}'_i} X_{jt}\Big) + c_{x2} r^s_t\Big] + c_{x1} X_{it} \\ -\theta_{xi1} X_{it} - \theta_{xi2}(X_{it} - X_{it-1}) + \beta\theta_{xi2}(X_{it+1} - X_{it})\Big\}. \end{aligned} \tag{B6}$$

Let Δ be the lag operator, i.e, $\Delta^k \mathbb{E}_{i\tau}(X_t) = \mathbb{E}_{i\tau}(X_{t-k})$. Then (B6) can be rewritten as

$$\begin{aligned} &-\theta_{xi2}^{-1} c_{x0} - \theta_{xi2}^{-1}(\xi_x + c_{x2})\mathbb{E}_{i\tau}(r^s_t) - \theta_{xi2}^{-1} c_{x1} \textstyle\sum_{j\in\mathcal{B}'_i} \mathbb{E}_{i\tau}(X_{jt}) \\ &= \underbrace{\left[\Delta^2 - [(1+\beta) + \theta_{x12}^{-1}(\theta_{xi1} - 2c_{x1})]\Delta + \beta\right]}_{(\Delta-\lambda^x_{i1})(\Delta-\lambda^x_{i2}) = \Delta^2 - (\lambda^x_{i1}+\lambda^x_{i2})\Delta + \lambda^x_{i1}\lambda^x_{i2}} \mathbb{E}_{i\tau}(X_{it+1}). \end{aligned} \tag{B7}$$

The right hand side of (B7) is a lag polynomial with roots λ_{xij} ($j = 1, 2$) that solve

$$\begin{cases} \lambda_{xi1}\lambda_{xi2} = \beta \\ \lambda_{xi1} + \lambda_{xi2} = (1+\beta) + \theta_{x12}^{-1}(\theta_{xi1} - 2c_{x1}). \end{cases} \tag{B8}$$

Notice that $\lambda_{xij} > 0$ since their product equals the positive constant β and their sum results in a positive constant.[18] Without loss of generality $\lambda_{xi1} < 1$ and $\lambda_{xi2} > 1$.[19] Furthermore,

[18]The constant $(1+\beta) + \theta_{x12}^{-1}(\theta_{xi1} - 2c_{x1})$ is positive since $c_{x1} < 0$, and β, θ_{xi1}, and θ_{xi2} are positive.

[19]From the first equation in (B8) we can set $\lambda_{xi2} = \beta/\lambda_{xi1}$. Since $\lambda_{xi1} > 0$, $\lambda_{xi2} > 0$, $\theta_{xi2}^{-1}(\theta_{xi1} - 2c_{x1}) > 0$, the second equation in (B8) holds if and only if $(\lambda_{xi1} - 1)(\lambda_{xi1} - \beta) > 0$. This can only happens in two scenarios: (i) $\lambda_{xi1} > 1$, which implies that $\lambda_{xi2} < \beta$; or (ii) $\lambda_{xi1} < \beta$, which implies $\lambda_{xi2} > 1$.

since $\theta_{xi2}^{-1}(\theta_{xi1} - 2c_{x1}) > 0$, the second equation in (B8) implies $\lambda_{xi1} + \lambda_{xi2} > 1 + \beta > \beta$, so that

$$\nu_{ix} \equiv \frac{\beta}{\lambda_{xi1} + \lambda_{xi2}} \in (0, 1/2),$$

which is a quantity that will result useful in establishing a transversality condition.

Now rewrite Equation (B7) as

$$\begin{aligned}
&- \theta_{xi2}^{-1} c_{x0} - \theta_{xi2}^{-1}(\xi_x + c_{x2}) \mathbb{E}_{i\tau}(r_t^s) - \theta_{xi2}^{-1} c_{x1} \textstyle\sum_{j \in \mathcal{B}_i'} \mathbb{E}_{i\tau}(X_{jt}) \\
&= \mathbb{E}_{i\tau}(X_{it-1}) - (\lambda_{i1}^x + \lambda_{i2}^x) \mathbb{E}_{i\tau}(X_{it}) + \beta \mathbb{E}_{i\tau}(X_{it+1})
\end{aligned}$$

so clearing for $\mathbb{E}_{i\tau}(X_{it})$ results in

$$\begin{aligned}
\mathbb{E}_{i\tau}(X_{it}) = \frac{1}{\lambda_{xi1} + \lambda_{xi2}} \Bigg\{ & \mathbb{E}_{i\tau}(X_{it-1}) + \theta_{xi2}^{-1} c_{x1} \sum_{j \in \mathcal{B}_i'} \mathbb{E}_{i\tau}(X_{jt}) \\
& + \theta_{xi2}^{-1}(\xi_x + c_{x2}) \mathbb{E}_{i\tau}(r_t^s) + \theta_{xi2}^{-1} c_{x0} + \beta \mathbb{E}_{i\tau}(X_{it+1}) \Bigg\}.
\end{aligned} \tag{B9}$$

Notice that Equation (B9) is an iterative equation since it tells how to substitute $\mathbb{E}_{i\tau}(X_{it+1})$. Iterating $K \geq 2$ times we reach

$$\begin{aligned}
\mathbb{E}_{i\tau}(X_{it}) = (\lambda_{xi1} + \lambda_{xi2} - \nu_{ix})^{-1} \Bigg\{ & \mathbb{E}_{i\tau}(X_{it-1}) + \sum_{k=1}^{K-1} \nu_{ix}^{k+1} \mathbb{E}_{i\tau}(X_{it+k}) \\
& + \theta_{xi2}^{-1} c_{x1} \sum_{k=0}^{K} \sum_{j \in \mathcal{B}_i'} \left(\nu_{ix}^k \mathbb{E}_{i\tau}(X_{jt+k}) \right) + \theta_{xi2}^{-1}(\xi_x + c_{x2}) \sum_{k=0}^{K} \nu_{ix}^k \mathbb{E}_{i\tau}(r_{t+k}^s) \\
& + \theta_{xi2}^{-1} c_{x0} \sum_{k=0}^{K} \nu_{ix}^k + \nu_{ix}^K \beta \mathbb{E}_{i\tau}(X_{it+1+K}) \Bigg\}.
\end{aligned} \tag{B10}$$

Since X_{it+k} and r_{t+k}^s are bounded processes and $\nu_{ix} \in (0, 1/2)$, we can establish the transversality condition

$$\lim_{K \to \infty} \nu_{ix}^K \mathbb{E}_{i\tau}(X_{it+1+K}) = 0,$$

so taking $\tau = t - 1$, $K \to \infty$ and substituting ξ_x and c_{xj} ($j = 0, 1, 2$) into Equation (B10) for (x, X) results in $\mathbb{E}_{it-1}(X_{it})$. By definition $\gamma_{xit} = X_{it} - \mathbb{E}_{it-1}(X_{it})$, so Equations (9) and (10) of Proposition 1 follow. ∎

B.3 Proof of Proposition 2

Proof. Let $(x, X) \in \{(d, D), (\ell, L)\}$. From Corollary 1 we know that

$$X_{it} = \alpha_{xi0} + \psi_{xi,-1} X_{it-1} + \sum_{k=1}^{\infty} \psi_{xik} \mathbb{E}_{it-1}(X_{it+k}) \\ + \sum_{k=0}^{\infty} \psi_{\hat{x}ik} \mathbb{E}_{it-1}(\hat{X}_{it+k}) + \sum_{k=0}^{\infty} \psi_{sxik} \mathbb{E}_{it-1}(r^s_{t+k}) + \gamma_{xit},$$

where $\gamma_{xit} = \mathbb{E}_{it-1}(X_{it})$. Since information is the same for every bank, at month $t-1$ every bank knows that bank i's share of the expected value of X is $q_{xi} \in (0,1)$ such that $\sum_{i \in \mathcal{B}_i} q_{xi} = 1$, so it follows

$$\mathbb{E}_{t-1}(q_{xi} X_t) = \alpha_{xi0} + \psi_{xi,-1} q_{xi} X_{t-1} + \sum_{k=1}^{\infty} \psi_{xik} \mathbb{E}_{t-1}(q_{xi} X_{t+k}) \\ + \sum_{k=0}^{\infty} \psi_{\hat{x}ik} \mathbb{E}_{t-1}((1-q_{xi}) X_{t+k}) + \sum_{k=0}^{\infty} \psi_{sxik} \mathbb{E}_{t-1}(r^s_{t+k}),$$

and clearing for $\mathbb{E}_{t-1}(X_t)$

$$\mathbb{E}_{t-1}(X_t) = A_{xi}^{-1} \Bigg\{ \alpha_{xi0} + \psi_{xi,-1} q_{xi} X_{t-1} + \sum_{k=1}^{\infty} \psi_{xik} q_{xi} \mathbb{E}_{t-1}(X_{t+k}) \\ + \sum_{k=1}^{\infty} \psi_{\hat{x}ik} (1-q_{xi}) \mathbb{E}_{t-1}(X_{t+k}) + \sum_{k=0}^{\infty} \psi_{sxik} \mathbb{E}_{t-1}(r^s_{t+k}) \Bigg\}, \tag{B11}$$

where $A_{xi} \equiv q_{xi} - (1-q_{xi}) \psi_{\hat{x}ik}$.

To simplify the analysis we do below, let

$$a_{\ell 0} = (1 + \varepsilon_\ell + \chi_\ell) \varepsilon_\ell^{-1} \bar{L}, \quad a_{\ell 1} = -(\varepsilon_\ell \bar{r}^\ell)^{-1} \bar{L}^{-1}, \quad a_{\ell 2} = -\chi_\ell (\varepsilon_\ell \bar{r}^s)^{-1},$$

$$a_{d0} = \varepsilon_d^{-1} (\varepsilon_d + \chi_d - 1) \bar{D}, \quad a_{d1} = (\varepsilon_d \bar{r}^d)^{-1} \bar{D}^{-1}, \quad a_{d2} = -\chi_d (\varepsilon_d \bar{r}^s)^{-1},$$

$$b_{\ell 0} = (1 + \varepsilon_\ell + \chi_\ell) \bar{r}^\ell, \quad b_{\ell 1} = -\varepsilon_\ell \bar{r}^\ell \bar{L}^{-1}, \quad b_{\ell 2} = -\chi_\ell \bar{r}^\ell (\bar{r}^s)^{-1},$$

$$b_{d0} = (1 - \varepsilon_d - \chi_d) \bar{r}^d, \quad b_{d1} = \varepsilon_d \bar{r}^d \bar{D}^{-1}, \quad b_{d2} = \chi_d \bar{r}^d (\bar{r}^s)^{-1},$$

so from Lemma 1, Equations (B2) and (B3) in its proof, and by taking expectations conditional on the information at month $t-1$ we have

$$\mathbb{E}_{t-1}(X_{t+k}) = a_{x0} + a_{x1} \mathbb{E}_{t-1}(r^x_{t+k}) + a_{x2} \mathbb{E}_{t-1}(r^s_{t+k}) \tag{B12}$$

$$\mathbb{E}_{t-1}(r_t^x) = b_{x0} + b_{x1}\mathbb{E}_{t-1}(X_t) + b_{x2}\mathbb{E}_{t-1}(r_t^s), \tag{B13}$$

and substituting Equation (B12) into (B11), and then its result into (B13) results in

$$\begin{aligned}
\mathbb{E}_{t-1}(r_t^x) = {} & \underbrace{\hat{b}_{x0} + B_{xi}^{-1}\left(\alpha_{xi0} + a_{x0}q_{xi}\psi_{xi,-1} + \sum_{k=1}^{\infty} q_{xi}\psi_{xik}a_{x0} + \sum_{k=0}^{\infty}(1-q_{xi})\psi_{\hat{x}ik}a_{x0}\right)}_{z_{x0}} \\
& + \underbrace{B_x^{-1}b_{x1}a_{x1}q_{xi}\psi_{xi,-1}}_{z_{xi,-1}}\mathbb{E}_{t-1}(r_{t-1}^x) + \underbrace{B_x^{-1}b_{x1}a_{x2}q_{xi}\psi_{xi,-1}}_{z_{xsi,-1}}\mathbb{E}_{t-1}(r_{t-1}^s) \\
& + \underbrace{(B_{xi}^{-1}b_{x1}((1-q_{xi})\psi_{\hat{x}i0}a_{x2} + \psi_{xsi0}) + \hat{b}_{x2})}_{z_{xs0}}\mathbb{E}_{t-1}(r_t^s) \\
& + \sum_{k=1}^{\infty}\underbrace{B_{xi}^{-1}b_{x1}(q_{xi}\psi_{xik}a_{x2} + (1-q_{xi})\psi_{\hat{x}ik}a_{x2} + \psi_{xsik})}_{z_{xsik}}\mathbb{E}_{t-1}(r_{t+k}^s) \\
& + \sum_{k=1}^{\infty}\underbrace{B_{xi}^{-1}b_{x1}(q_{xi}\psi_{xik}a_{x1} + (1-q_{\hat{x}ik})\psi_{\hat{x}ik}a_{x1})}_{z_{xxik}}\mathbb{E}_{t-1}(r_{t+k}^x),
\end{aligned} \tag{B14}$$

where $B_{xi} = A_{xi}(1 - b_{xi}A_{xi}(1-q_{xi})\psi_{\hat{x}ik}a_{x1})$ and $\hat{b}_{xj} = A_{xi}b_{xj}B_{xi}^{-1}$.

Finally, substituting $\mathbb{E}_{t-1}(r_{t+k}^x)$ recursively into Equation (B14), allows to express retail rates as a linear function of its lag and of security rates because of the linearity of this recursive formula which depends only on one lag for any k. ■

C Summary of empirical evidence

Table C1: Unit root tests for deposit rates: Unit root presence

Test	Augmented Dickey-Fuller	Specification		
Currency	Interest rate	1	2	3
Local currency	All deposits	Yes	No	Yes
	Deposits for less than 1 month	Yes	Yes	Yes
	Deposits between 1 and 4 months	Yes	Yes	Yes
	Deposits between 4 and 7 months	No	No	Yes
	Deposits between 7 and 13 months	No	No	Yes
	Deposits for more than 13 months	No	No	Yes
	Monetary policy rate (TPM)	Yes	Yes	Yes
	Liquidity market rate (MIL)	Yes	Yes	Yes
Dollars	All deposits	Yes	No	Yes
	Deposits for less than 1 month	No	No	Yes
	Deposits between 1 and 4 months	Yes	Yes	Yes
	Deposits between 4 and 7 months	Yes	Yes	Yes
	Deposits between 7 and 13 months	Yes	Yes	Yes
	Deposits for more than 13 months	No	No	Yes
	Libor 3 months	Yes	Yes	Yes
	Libor 6 months	Yes	Yes	Yes
Test	Phillips-Perron	Specification		
Currency	Interest rate	1	2	3
Local currency	All deposits	No	No	Yes
	Deposits for less than 1 month	No	No	Yes
	Deposits between 1 and 4 months	Yes	Yes	Yes
	Deposits between 4 and 7 months	No	No	Yes
	Deposits between 7 and 13 months	No	No	Yes
	Deposits for more than 13 months	No	No	Yes
	Monetary policy rate (TPM)	Yes	Yes	Yes
	Liquidity market rate (MIL)	Yes	Yes	Yes
Dollars	All deposits	Yes	No	Yes
	Deposits for less than 1 month	No	No	No
	Deposits between 1 and 4 months	No	No	Yes
	Deposits between 4 and 7 months	No	No	Yes
	Deposits between 7 and 13 months	No	No	Yes
	Deposits for more than 13 months	No	No	Yes
	Libor 3 months	Yes	Yes	Yes
	Libor 6 months	Yes	Yes	Yes

Note: *1: Without intercept nor trend; 2: With intercept without trend; 3: With intercept and trend. The table reports if there is evidence of unit root presence. Source: Own elaboration with SUGEF data

Table C2: Unit root tests for loan rates: Unit root presence

Test	Augmented Dickey-Fuller	Specification		
Currency	Interest rate	1	2	3
Local currency	All loans	Yes	Yes	Yes
	Loans for less than 2 years	Yes	Yes	Yes
	Loans between 2 and 5 years	No	No	Yes
	Loans between 5 and 10 years	No	Yes	Yes
	Loans between 10 and 20 years	Yes	Yes	Yes
	Loans for more than 20 years	Yes	Yes	Yes
	Monetary policy rate (TPM)	Yes	No	Yes
	Liquidity market rate (MIL)	No	No	Yes
Dollars	All loans	Yes	Yes	Yes
	Loans for less than 2 years	Yes	Yes	Yes
	Loans between 2 and 5 years	Yes	Yes	Yes
	Loans between 5 and 10 years	Yes	Yes	Yes
	Loans between 10 and 20 years	No	Yes	Yes
	Loans for more than 20 years	Yes	Yes	Yes
	Libor 3 months	Yes	Yes	Yes
	Libor 6 months	Yes	Yes	Yes
Test	Phillips-Perron	Specification		
Currency	Interest rate	1	2	3
Local currency	All loans	Yes	Yes	Yes
	Loans for less than 2 years	Yes	Yes	Yes
	Loans between 2 and 5 years	No	No	Yes
	Loans between 5 and 10 years	No	No	Yes
	Loans between 10 and 20 years	Yes	No	Yes
	Loans for more than 20 years	Yes	Yes	Yes
	Monetary policy rate (TPM)	Yes	Yes	Yes
	Liquidity market rate (MIL)	No	No	Yes
Dollars	All loans	Yes	Yes	Yes
	Loans for less than 2 years	Yes	Yes	Yes
	Loans between 2 and 5 years	No	No	Yes
	Loans between 5 and 10 years	No	No	Yes
	Loans between 10 and 20 years	No	No	Yes
	Loans for more than 20 years	Yes	Yes	Yes
	Libor 3 months	No	Yes	No
	Libor 6 months	Yes	No	No

Note: *1: Without intercept nor trend; 2: With intercept without trend; 3: With intercept and trend. The table reports if there is evidence of unit root presence. Test for the TPM and MIL rates are reported again as the sample size is different. Source: Own elaboration with SUGEF data

Table C3: Cointegration tests for deposit rates

Currency	Interest rate	Cointegration with TPM	Cointegration with Libor 3 months
Local currency	All deposits	Yes	-
	Deposits for less than 1 month	Yes	-
	Deposits between 1 and 4 months	Yes	-
	Deposits between 4 and 7 months	Yes	-
	Deposits between 7 and 13 months	Yes	-
	Deposits for more than 13 months	Yes	-
Dollars	All deposits	No	Yes
	Deposits for less than 1 month	Yes	Yes
	Deposits between 1 and 4 months	Yes	Yes
	Deposits between 4 and 7 months	No	Yes
	Deposits between 7 and 13 months	No	No
	Deposits for more than 13 months	Yes	Yes
Currency	**Interest rate**	**Cointegration with MIL**	**Cointegration with Libor 6 months**
Local currency	All deposits	Yes	-
	Deposits for less than 1 month	Yes	-
	Deposits between 1 and 4 months	Yes	-
	Deposits between 4 and 7 months	Yes	-
	Deposits between 7 and 13 months	Yes	-
	Deposits for more than 13 months	Yes	-
Dollars	All deposits	No	Yes
	Deposits for less than 1 month	Yes	Yes
	Deposits between 1 and 4 months	Yes	Yes
	Deposits between 4 and 7 months	No	Yes
	Deposits between 7 and 13 months	No	No
	Deposits for more than 13 months	Yes	Yes

Note: The null hypothesis is the error correction term does not have unit root. Cointegration means this null hypothesis is rejected. Source: Own elaboration with SUGEF data

Table C4: Cointegration tests for loan rates

Currency	Interest rate	Cointegration with TPM	Cointegration with Libor 3 months
Local currency	All loans	Yes	-
	Loans for less than 2 years	Yes	-
	Loans between 2 and 5 years	Yes	-
	Loans between 5 and 10 years	Yes	-
	Loans between 10 and 20 years	Yes	-
	Loans for more than 20 years	Yes	-
Dollars	All loans	Yes	Yes
	Loans for less than 2 years	Yes	Yes
	Loans between 2 and 5 years	Yes	Yes
	Loans between 5 and 10 years	Yes	Yes
	Loans between 10 and 20 years	Yes	Yes
	Loans for more than 20 years	Yes	Yes
Currency	Interest rate	Cointegration with MIL	Cointegration with Libor 6 months
Local currency	All loans	Yes	-
	Loans for less than 2 years	Yes	-
	Loans between 2 and 5 years	Yes	-
	Loans between 5 and 10 years	Yes	-
	Loans between 10 and 20 years	Yes	-
	Loans for more than 20 years	Yes	-
Dollars	All loans	Yes	Yes
	Loans for less than 2 years	Yes	Yes
	Loans between 2 and 5 years	Yes	Yes
	Loans between 5 and 10 years	Yes	No
	Loans between 10 and 20 years	Yes	Yes
	Loans for more than 20 years	Yes	Yes

Note: The null hypothesis is the error correction term does not have unit root. Cointegration means this null hypothesis is rejected. Source: Own elaboration with SUGEF data

Table C5: Estimates of pass-through coefficient for deposit rates

Currency	Interest rate	With TPM/Banks			With Libor 3 months/Banks		
		All	State-owned	Private	All	State-owned	Private
Local currency	All	0.61***	0.64***	0.57***	-	-	-
		(0.09)	(0.11)	(0.07)			
	Less than 1 month	0.74***	0.76***	0.27	-	-	-
		(0.06)	(0.06)	(0.21)			
	Between 1 and 4 months	0.77***	0.77***	0.73***	-	-	-
		(0.09)	(0.09)	(0.09)			
	Between 4 and 7 months	0.53***	0.53***	0.55***	-	-	-
		(0.09)	(0.10)	(0.08)			
	Between 7 and 13 months	0.64***	0.62***	0.67***	-	-	-
		(0.10)	(0.12)	(0.10)			
	More than 13 months	0.56***	0.60***	0.39***	-	-	-
		(0.16)	(0.19)	(0.15)			
Dollars	All	0.04	0.03	0.09**	0.46***	0.50***	0.30***
		(0.06)	(0.07)	(0.04)	(0.04)	(0.06)	(0.04)
	Less than 1 month	0.09**	0.08**	0.09	0.06	0.00	0.04
		(0.04)	(0.04)	(0.06)	(0.06)	(0.06)	(0.10)
	Between 1 and 4 months	0.09***	0.12**	0.09***	0.09*	0.16**	0.00
		(0.03)	(0.05)	(0.02)	(0.05)	(0.07)	(0.05)
	Between 4 and 7 months	0.00	0.00	0.06*	0.41***	0.47***	0.19***
		(0.06)	(0.07)	(0.04)	(0.05)	(0.07)	(0.04)
	Between 7 and 13 months	0.02	0.00	0.06*	0.30***	0.59***	0.20***
		(0.04)	(0.08)	(0.03)	(0.04)	(0.07)	(0.04)
	More than 13 months	0.05	0.00	0.04	0.23***	0.99***	0.24***
		(0.05)	(0.14)	(0.05)	(0.05)	(0.13)	(0.06)

Note: Coefficient of securities interest rate from long-run equation. *** means statistical significance to 1%, ** to 5%, * to 10%. Standard errors in parenthesis. Source: Own elaboration with SUGEF data

Table C5: Estimates of pass-through coefficient for deposit rates (continuation)

Currency	Interest rate	With MIL/Banks			With Libor 6 months/Banks		
		All	State-owned	Private	All	State-owned	Private
Local currency	All	0.61***	0.64***	0.53***	-	-	-
		(0.07)	(0.09)	(0.06)			
	Less than 1 month	0.71***	0.72***	0.31*	-	-	-
		(0.05)	(0.05)	(0.18)			
	Between 1 and 4 months	0.75***	0.76***	(0.70***	-	-	-
		(0.07)	(0.07)	(0.08)			
	Between 4 and 7 months	0.51***	0.51***	0.49***	-	-	-
		(0.08)	(0.08)	(0.07)			
	Between 7 and 13 months	0.62***	0.61***	0.64***	-	-	-
		(0.08)	(0.10)	(0.08)			
	More than 13 months	0.46***	0.52***	0.29*	-	-	-
		(0.15)	(0.19)	(0.16)			
Dollars	All	0.07	0.07	0.10***	0.45***	0.48***	0.29***
		(0.05)	(0.07)	(0.04)	(0.04)	(0.06)	(0.04)
	Less than 1 month	0.08**	0.07**	0.08	0.07	0.00	0.04
		(0.04)	(0.03)	(0.06)	(0.06)	(0.06)	(0.09)
	Between 1 and 4 months	0.08***	0.11**	0.08***	0.10*	0.16**	0.01
		(0.02)	(0.04)	(0.02)	(0.05)	(0.07)	(0.05)
	Between 4 and 7 months	0.04	0.04	0.07**	0.38***	0.44***	0.18***
		(0.06)	(0.07)	(0.03)	(0.05)	(0.07)	(0.04)
	Between 7 and 13 months	0.05	0.00	0.08**	0.28***	0.54***	0.19***
		(0.04)	(0.09)	(0.03)	(0.04)	(0.07)	(0.04)
	More than 13 months	0.06	0.00	0.05	0.21***	0.91***	0.22***
		(0.05)	(0.15)	(0.05)	(0.05)	(0.12)	(0.06)

Note: Coefficient of securities interest rate from long-run equation. *** means statistical significance to 1%, ** to 5%, * to 10%. Standard errors in parenthesis. Source: Own elaboration with SUGEF data

Table C6: Estimates of pass-through coefficient for loan rates

Currency	Interest rate	With TPM/Banks			With Libor 3 months/Banks		
		All	State-owned	Private	All	State-owned	Private
Local currency	All	0.74***	0.70***	1.00***	-	-	-
		(0.10)	(0.09)	(0.17)			
	Less than 2 years	1.00***	0.81***	1.46***	-	-	-
		(0.11)	(0.09)	(0.18)			
	Between 2 and 5 years	0.37***	0.64***	0.73***	-	-	-
		(0.09)	(0.08)	(0.15)			
	Between 5 and 10 years	0.36***	0.54***	0.79***	-	-	-
		(0.12)	(0.10)	(0.25)			
	Between 10 and 20 years	0.64***	0.62***	0.74***	-	-	-
		(0.08)	(0.08)	(0.11)			
	More than 20 years	0.50***	0.56***	0.40***	-	-	-
		(0.12)	(0.13)	(0.09)			
Dollars	All	0.31***	0.29***	0.31***	0.43***	0.43***	0.42***
		(0.07)	(0.04)	(0.08)	(0.14)	(0.12)	(0.14)
	Less than 2 years	0.38***	0.34***	0.38***	0.45**	0.56***	0.43***
		(0.08)	(0.05)	(0.10)	(0.18)	(0.15)	(0.20)
	Between 2 and 5 years	0.24***	0.27***	0.24***	0.33***	0.64***	0.22***
		(0.07)	(0.07)	(0.08)	(0.11)	(0.11)	(0.11)
	Between 5 and 10 years	0.23***	0.22***	0.25***	0.51***	0.60***	0.46***
		(0.05)	(0.06)	(0.06)	(0.09)	(0.13)	(0.10)
	Between 10 and 20 years	0.20***	0.20***	0.23***	0.57***	0.80***	0.38***
		(0.07)	(0.09)	(0.07)	(0.10)	(0.15)	(0.09)
	More than 20 years	0.14***	0.00	0.15***	0.43***	0.18***	0.43***
		(0.05)	(0.05)	(0.05)	(0.09)	(0.09)	(0.10)

Note: Coefficient of securities interest rate from long-run equation. *** means statistical significance to 1%, ** to 5%, * to 10%. Standard errors in parenthesis. Source: Own elaboration with SUGEF data

Table C6: Estimates of pass-through coefficient for loan rates (continuation)

Currency	Interest rate	With MIL/Banks			With Libor 6 months/Banks		
		All	State-owned	Private	All	State-owned	Private
Local currency	All	0.75***	0.68***	1.00***	-	-	-
		(0.13)	(0.13)	(0.22)			
	Less than 2 years	0.97***	0.74***	1.31***	-	-	-
		(0.17)	(0.15)	(0.24)			
	Between 2 and 5 years	0.46***	0.64***	0.91***	-	-	-
		(0.11)	(0.14)	(0.16)			
	Between 5 and 10 years	0.61***	0.66***	1.00***	-	-	-
		(0.14)	(0.12)	(0.16)			
	Between 10 and 20 years	0.63***	0.62***	0.64***	-	-	-
		(0.11)	(0.11)	(0.14)			
	More than 20 years	0.51***	0.55***	0.38***	-	-	-
		(0.13)	(0.14)	(0.13)			
Dollars	All	0.23***	0.23***	0.23***	0.35***	0.37***	0.33***
		(0.06)	(0.06)	(0.07)	(0.12)	(0.12)	(0.12)
	Less than 2 years	0.26***	0.26***	0.26***	0.35**	0.48***	0.33***
		(0.06)	(0.06)	(0.07)	(0.17)	(0.15)	(0.18)
	Between 2 and 5 years	0.20***	0.21***	0.20***	0.26***	0.56***	0.16***
		(0.07)	(0.09)	(0.07)	(0.09)	(0.12)	(0.09)
	Between 5 and 10 years	0.22***	0.24***	0.23***	0.45***	0.55***	0.39***
		(0.06)	(0.07)	(0.07)	(0.09)	(0.13)	(0.10)
	Between 10 and 20 years	0.17***	0.14**	0.23***	0.49***	0.71***	0.31***
		(0.06)	(0.07)	(0.07)	(0.09)	(0.15)	(0.07)
	More than 20 years	0.15***	0.00	0.15***	0.37***	0.17***	0.37***
		(0.05)	(0.07)	(0.05)	(0.08)	(0.08)	(0.09)

Note: Coefficient of securities interest rate from long-run equation. *** means statistical significance to 1%, ** to 5%, * to 10%. Standard errors in parenthesis. Source: Own elaboration with SUGEF data

Table C7: Estimates of speed of adjustment coefficient for deposit rates

Currency	Interest rate	With TPM/Banks			With Libor 3 months/Banks		
		All	State-owned	Private	All	State-owned	Private
Local currency	All	-0.15***	-0.14***	-0.35***	-	-	-
		(0.05)	(0.05)	(0.09)			
	Less than 1 month	-0.62***	-0.67***	-0.24**	-	-	-
		(0.15)	(0.15)	(0.11)			
	Between 1 and 4 months	-0.16***	-0.25***	-0.16***	-	-	-
		(0.06)	(0.09)	(0.05)			
	Between 4 and 7 months	-0.27***	-0.27***	-0.31***	-	-	-
		(0.03)	(0.04)	(0.09)			
	Between 7 and 13 months	-0.32***	-0.31***	-0.29***	-	-	-
		(0.08)	(0.09)	(0.07)			
	More than 13 months	-1.00***	-0.99***	-0.68***	-	-	-
		(0.16)	(0.16)	(0.15)			
Dollars	All	-0.07	-0.15***	-0.23***	-0.57***	-0.42***	-0.65***
		(0.06)	(0.06)	(0.11)	(0.11)	(0.10)	(0.14)
	Less than 1 month	-0.59***	-0.54***	-0.77***	-0.51***	-0.58***	-0.72***
		(0.14)	(0.14)	(0.10)	(0.13)	(0.15)	(0.10)
	Between 1 and 4 months	-0.47***	-0.84***	-0.35***	-0.63***	0.91***	-0.40***
		(0.14)	(0.24)	(0.08)	(0.21)	(0.30)	(0.08)
	Between 4 and 7 months	-0.18***	-0.25***	-0.24***	-0.52***	-0.54***	-0.47***
		(0.06)	(0.08)	(0.09)	(0.11)	(0.13)	(0.12)
	Between 7 and 13 months	-0.15*	-0.09**	-0.33***	-0.40***	-0.17***	-0.61***
		(0.08)	(0.05)	(0.15)	(0.11)	(0.07)	(0.15)
	More than 13 months	-0.73***	-0.24***	-0.71***	-0.97***	-0.44***	-1.00***
		(0.15)	(0.09)	(0.16)	(0.14)	(0.15)	(0.17)

Note: Coefficient of error correction term from short-run equation. *** means statistical significance to 1%, ** to 5%, * to 10%. Standard errors in parenthesis. Source: Own elaboration with SUGEF data

Table C7: Estimates of speed of adjustment coefficient for deposit rates (continuation)

Currency	Interest rate	With MIL/Banks			With Libor 6 months/Banks		
		All	State-owned	Private	All	State-owned	Private
Local currency	All	-0.17***	-0.16***	-0.37***	-	-	-
		(0.05)	(0.05)	(0.10)			
	Less than 1 month	-0.75***	-0.78***	-0.25***	-	-	-
		(0.19)	(0.20)	(0.11)			
	Between 1 and 4 months	-0.19***	-0.28***	-0.19***	-	-	-
		(0.06)	(0.09)	(0.05)			
	Between 4 and 7 months	-0.28***	-0.28***	-0.33***	-	-	-
		(0.03)	(0.04)	(0.09)			
	Between 7 and 13 months	-0.37***	-0.35***	-0.33***	-	-	-
		(0.07)	(0.08)	(0.08)			
	More than 13 months	-0.98***	-0.94***	-0.66***	-	-	-
		(0.16)	(0.17)	(0.15)			
Dollars	All	-0.07	-0.14***	-0.24***	-0.49***	-0.35***	-0.63***
		(0.06)	(0.05)	(0.11)	(0.11)	(0.09)	(0.14)
	Less than 1 month	-0.56***	-0.52***	-0.77***	-0.49***	-0.50***	-0.71***
		(0.14)	(0.13)	(0.10)	(0.13)	(0.14)	(0.09)
	Between 1 and 4 months	-0.51***	-0.88***	-0.36***	-0.51**	-0.83**	-0.29***
		(0.15)	(0.25)	(0.09)	(0.21)	(0.30)	(0.08)
	Between 4 and 7 months	-0.18***	-0.24***	-0.29***	-0.46***	-0.49***	-0.44***
		(0.06)	(0.08)	(0.08)	(0.10)	(0.12)	(0.11)
	Between 7 and 13 months	-0.16**	-0.07**	-0.35***	-0.36***	-0.14***	-0.57***
		(0.07)	(0.04)	(0.13)	(0.10)	(0.06)	(0.15)
	More than 13 months	-0.76***	-0.21***	-0.75***	-0.95***	-0.41***	-0.97***
		(0.15)	(0.08)	(0.16)	(0.13)	(0.14)	(0.16)

Note: Coefficient of error correction term from short-run equation. *** means statistical significance to 1%, ** to 5%, * to 10%. Standard errors in parenthesis. Source: Own elaboration with SUGEF data

Table C8: Estimates of speed of adjustment coefficient for loan rates

Currency	Interest rate	With TPM/Banks			With Libor 3 months/Banks		
		All	State-owned	Private	All	State-owned	Private
Local currency	All	-0.16***	-0.13**	-0.27***	-	-	-
		(0.06)	(0.05)	(0.08)			
	Less than 2 years	-0.22***	-0.17***	-0.23***	-	-	-
		(0.07)	(0.05)	(0.07)			
	Between 2 and 5 years	-0.49***	-0.34***	-0.66***	-	-	-
		(0.11)	(0.08)	(0.13)			
	Between 5 and 10 years	-0.21***	-0.15***	-0.34***	-	-	-
		(0.05)	(0.04)	(0.08)			
	Between 10 and 20 years	-0.16**	-0.16***	-0.48***	-	-	-
		(0.06)	(0.07)	(0.11)			
	More than 20 years	-0.08*	-0.06*	-0.43***	-	-	-
		(0.04)	(0.03)	(0.14)			
Dollars	All	-0.08	-0.12*	-0.11	-0.10*	-0.21***	-0.10
		(0.07)	(0.07)	(0.08)	(0.06)	(0.03)	(0.08)
	Less than 2 years	-0.08	-0.13**	-0.10	-0.10*	-0.18***	-0.09
		(0.06)	(0.05)	(0.08)	(0.05)	(0.03)	(0.08)
	Between 2 and 5 years	-0.36***	-0.31***	-0.41***	-0.30***	-0.40***	-0.31***
		(0.09)	(0.07)	(0.11)	(0.11)	(0.08)	(0.12)
	Between 5 and 10 years	-0.14**	-0.19**	-0.21***	-0.21***	-0.28***	-0.22***
		(0.06)	(0.08)	(0.06)	(0.04)	(0.08)	(0.04)
	Between 10 and 20 years	-0.20***	-0.17***	-0.49***	-0.27**	-0.38***	-0.40**
		(0.05)	(0.05)	(0.07)	(0.11)	(0.09)[3]	(0.13)
	More than 20 years	-0.13**	-0.46***	-0.12**	-0.18***	-0.42***	-0.16***
		(0.05)	(0.11)	(0.05)	(0.04)	(0.13)	(0.04)

Note: Coefficient of error correction term from short-run equation. *** means statistical significance to 1%, ** to 5%, * to 10%. Standard errors in parenthesis. Source: Own elaboration with SUGEF data

Table C8: Estimates of speed of adjustment coefficient for loan rates (continuation)

Currency	Interest rate	With MIL/Banks			With Libor 6 months/Banks		
Local currency	All	-0.11***	-0.08*	-0.14***	-	-	-
		(0.05)	(0.04)	(0.07)			
	Less than 2 years	-0.12***	-0.11***	-0.08*	-	-	-
		(0.04)	(0.04)	(0.04)			
	Between 2 and 5 years	-0.45***	-0.23***	-0.47***	-	-	-
		(0.11)	(0.06)	(0.18)			
	Between 5 and 10 years	-0.28***	-0.16***	-0.32***	-	-	-
		(0.05)	(0.05)	(0.07)			
	Between 10 and 20 years	-0.07*	-0.07	-0.31***	-	-	-
		(0.04)	(0.05)	(0.10)			
	More than 20 years	-0.06	-0.04	-0.35***	-	-	-
		(0.04)	(0.03)	(0.12)			
Dollars	All	-0.05	-0.08*	-0.06	-0.08	-0.18***	-0.08
		(0.06)	(0.05)	(0.08)	(0.06)	(0.04)	(0.08)
	Less than 2 years	-0.06	-0.09**	-0.06	-0.08	-0.15***	-0.07
		(0.05)	(0.04)	(0.07)	(0.06)	(0.03)	(0.08)
	Between 2 and 5 years	-0.23**	-0.22***	-0.27*	-0.27**	-0.34***	-0.28**
		(0.11)	(0.07)	(0.15)	(0.10)	(0.07)	(0.12)
	Between 5 and 10 years	-0.11**	-0.15**	-0.14***	-0.17***	-0.25***	-0.19***
		(0.04)	(0.07)	(0.04)	(0.04)	(0.08)	(0.04)
	Between 10 and 20 years	-0.15*	-0.15**	-0.34***	-0.25***	-0.34***	-0.38***
		(0.08)	(0.06)	(0.14)	(0.09)	(0.09)	(0.13)
	More than 20 years	-0.08*	-0.41***	-0.06	-0.15***	-0.43***	-0.14***
		(0.04)	(0.12)	(0.04)	(0.04)	(0.13)	(0.04)

Note: Coefficient of error correction term from short-run equation. *** means statistical significance to 1%, ** to 5%, * to 10%. Standard errors in parenthesis. Source: Own elaboration with SUGEF data

Table C9: Wald tests for speed of adjustment sign asymmetry

Currency	Interest rate	Asymmetry evidence		
		All	State-owned	Private
Local currency	All loans	No	No	Yes (+)
	Loans for less than 2 years	No	No	Yes (+)
	Loans between 2 and 5 years	No	No	Yes (+)
	Loans between 5 and 10 years	No	No	No
	Loans between 10 and 20 years	No	No	Yes (+)
	Loans for more than 20 years	No	No	Yes (+)
Dollars	All loans	No	Yes (+)	No
	Loans for less than 2 years	No	No	No
	Loans between 2 and 5 years	No	Yes (+)	No
	Loans between 5 and 10 years	No	Yes (+)	Yes (+)
	Loans between 10 and 20 years	No	No	Yes (+)
	Loans for more than 20 years	No	No	No
Currency	Interest rate	Asymmetry evidence		
		All	State-owned	Private
Local currency	All deposits	No	No	Yes (+)
	Deposits for less than 1 month	No	No	No
	Deposits between 1 and 4 months	No	No	No
	Deposits between 4 and 7 months	No	Yes (+)	Yes (+)
	Deposits between 7 and 13 months	No	No	Yes (+)
	Deposits for more than 13 months	No	No	Yes (+)
Dollars	All deposits	No	Yes (+)	No
	Deposits for less than 1 month	No	No	Yes (-)
	Deposits between 1 and 4 months	No	Yes (-)	No
	Deposits between 4 and 7 months	No	No	No
	Deposits between 7 and 13 months	No	No	Yes (+)
	Deposits for more than 13 months	No	No	Yes (+)

Note: The null hypothesis is the coefficient of the error correction term relative to increases in the benchmark interest rate is equal to the respective coefficient relative to decreases. In other words, there is no asymmetry in the pass-through. For local currency the benchmark is the monetary policy rate, for dollars it is the 3 month Libor rate. (+) means there is strong evidence of positive asymmetry, i.e. banks react faster to increases relative to decreases with respect to the benchmark respective movement; (-) banks react faster to decreases relative to increases. Source: Own elaboration with SUGEF data

Table C10: Tests for the null hypothesis of expected securities rate adequacy and importance on pass-through to deposit rates.

Currency	Interest rate	Rejected/TPM			Rejected/Libor 3 months		
		All	State-owned	Private	All	State-owned	Private
Local currency	All	No	No	No	-	-	-
	Less than 1 month	No	No	No	-	-	-
	Between 1 and 4 months	No	No	No	-	-	-
	Between 4 and 7 months	No	No	No	-	-	-
	Between 7 and 13 months	No	No	No	-	-	-
	more than 13 months	No	No	No	-	-	-
Dollars	All	No	No	No	No	Yes	No
	Less than 1 month	No	No	No	No	No	No
	Between 1 and 4 months	Yes	No	Yes	Yes	No	Yes
	between 4 and 7 months	No	No	No	Yes	No	Yes
	Between 7 and 13 months	No	No	No	No	No	No
	More than 13 months	No	No	No	No	No	No
Currency	Interest rate	Rejected/MIL			Rejected/Libor 6 months		
		All	State-owned	Private	All	State-owned	Private
Local currency	All	No	No	No	-	-	-
	Less than 1 month	No	Yes	No	-	-	-
	Between 1 and 4 months	No	No	No	-	-	-
	Between 4 and 7 months	No	No	No	-	-	-
	between 7 and 13 months	Yes	Yes	No	-	-	-
	More than 13 months	Yes	Yes	No	-	-	-
Dollars	All	No	Yes	No	No	Yes	No
	Less than 1 month	No	No	No	No	No	No
	Between 1 and 4 months	No	Yes	No	Yes	Yes	Yes
	Between 4 and 7 months	No	Yes	No	No	No	No
	Between 7 and 13 months	No	Yes	No	No	No	No
	more than 13 months	No	No	No	No	No	No

Note: The effect of the expected securities rate on the respective retail rate is consistent with only one speed of adjustment. The null hypothesis is: $\vartheta = -\alpha * \kappa$ from Equation (17). Source: Own elaboration with SUGEF data

Table C11: Tests for the null hypothesis of expected securities rate adequacy and importance on pass-through to loan rates.

Currency	Interest rate	Rejected/TPM			Rejected/Libor 3 months		
		All	State-owned	Private	All	State-owned	Private
Local currency	All	No	No	No	-	-	-
	Less than 2 years	No	No	No	-	-	-
	Between 2 and 5 years	No	Yes	No	-	-	-
	Between 5 and 10 years	No	No	No	-	-	-
	Between 10 and 20 years	No	No	No	-	-	-
	More than 20 years	No	No	No	-	-	-
Dollars	All	Yes	No	Yes	No	Yes	No
	Less than 2 years	Yes	No	Yes	No	Yes	No
	Between 2 and 5 years	No	No	No	No	No	No
	Between 5 and 10 years	No	No	No	No	No	No
	Between 10 and 20 years	No	No	No	No	No	No
	More than 20 years	Yes	Yes	Yes	No	No	No
Currency	Interest rate	Rejected/MIL			Rejected/Libor 6 months		
		All	State-owned	Private	All	State-owned	Private
Local currency	All	No	No	No	-	-	-
	Less than 2 years	No	No	No	-	-	-
	Between 2 and 5 years	No	No	No	-	-	-
	Between 5 and 10 years	Yes	No	Yes	-	-	-
	Between 10 and 20 years	No	No	No	-	-	-
	More than 20 years	No	No	No	-	-	-
Dollars	All	No	No	No	No	Yes	No
	Less than 2 years	No	No	No	No	Yes	No
	Between 2 and 5 years	No	No	No	Yes	Yes	No
	Between 5 and 10 years	No	No	No	No	No	No
	Between 10 and 20 years	No	No	No	No	No	No
	More than 20 years	No	No	No	No	Yes	No

Note: The effect of the expected securities rate on the respective retail rate is consistent with only one speed of adjustment. Also if there is cointegration, the expected securities rate matters for the pass-through process. The null hypothesis is: $\vartheta = -\alpha * \kappa$ from Equation (17). Source: Own elaboration with SUGEF data

Table C12: Comparison of estimates with and without expected securities rate for the pass-through to deposit rates

Currency	Interest rate	BIC with expected TPM	BIC without expected TPM	BIC with expected Libor 3 months	BIC without expected Libor 3 months
Local currency	All deposits	0.97	0.95	-	-
	Deposits for less than 1 month	1.96	1.95	-	-
	Deposits between 1 and 4 months	1.06	1.07	-	-
	Deposits between 4 and 7 months	0.86	0.77	-	-
	Deposits between 7 and 13 months	1.72	1.69	-	-
	Deposits for more than 13 months	3.95	3.89	-	-
Dollars	All deposits	-0.11	-0.10	-0.33	-0.36
	Deposits for less than 1 month	1.28	1.23	1.30	1.25
	Deposits between 1 and 4 months	0.33	0.31	0.26	0.29
	Deposits between 4 and 7 months	0.37	0.30	0.15	0.11
	Deposits between 7 and 13 months	-0.05	-0.09	-0.16	-0.20
	Deposits for more than 13 months	1.56	1.50	1.44	1.37

Currency	Interest rate	BIC with expected MIL	BIC without expected MIL	BIC with expected Libor 6 months	BIC without expected Libor 6 months
Local currency	All deposits	1.00	0.94	-	-
	Deposits for less than 1 month	1.87	1.86	-	-
	Deposits between 1 and 4 months	1.05	1.00	-	-
	Deposits between 4 and 7 months	0.80	0.73	-	-
	Deposits between 7 and 13 months	1.69	1.63	-	-
	Deposits for more than 13 months	3.99	3.97	-	-
Dollars	All deposits	-0.11	-0.08	-0.28	-0.29
	Deposits for less than 1 month	1.27	1.23	1.30	1.25
	Deposits between 1 and 4 months	0.33	0.29	0.25	0.28
	Deposits between 4 and 7 months	0.34	0.31	0.19	0.14
	Deposits between 7 and 13 months	-0.05	-0.09	-0.14	-0.18
	Deposits for more than 13 months	1.48	1.51	1.45	1.39

Note: BIC stands for Bayesian Information Criterion. The lower the value the less information is lost with the specification. Comparison should be made only between the same specification with and without the respective expected securities rate.
Source: Own elaboration with SUGEF data

Table C13: Comparison of estimates with and without expected securities rate for the pass-through to loan rates

Currency	Interest rate	BIC with expected TPM	BIC without expected TPM	BIC with expected Libor 3 months	BIC without expected Libor 3 months
Local currency	All loans	2.29	2.25	-	-
	Loans for less than 2 years	2.79	2.76	-	-
	Loans between 2 and 5 years	2.93	3.89	-	-
	Loans between 5 and 10 years	3.64	3.61	-	-
	Loans between 10 and 20 years	2.14	2.11	-	-
	Loans for more than 20 years	1.50	1.47	-	-
Dollars	All loans	0.71	0.73	0.70	0.63
	Loans for less than 2 years	0.90	0.92	0.87	0.81
	Loans between 2 and 5 years	2.25	2.25	2.28	2.25
	Loans between 5 and 10 years	1.48	1.57	1.43	1.53
	Loans between 10 and 20 years	1.97	1.96	1.87	1.89
	Loans for more than 20 years	0.64	0.63	0.57	0.51

Currency	Interest rate	BIC with expected MIL	BIC without expected MIL	BIC with expected Libor 6 months	BIC without expected Libor 6 months
Local currency	All loans	2.39	2.36	-	-
	Loans for less than 2 years	2.87	2.84	-	-
	Loans between 2 and 5 years	3.95	3.96	-	-
	Loans between 5 and 10 years	3.65	3.62	-	-
	Loans between 10 and 20 years	2.19	2.18	-	-
	Loans for more than 20 years	1.64	1.62	-	-
Dollars	All loans	0.66	0.69	0.69	0.61
	Loans for less than 2 years	0.90	0.91	0.84	0.79
	Loans between 2 and 5 years	2.23	2.30	2.28	2.26
	Loans between 5 and 10 years	1.37	1.62	1.45	1.55
	Loans between 10 and 20 years	2.02	2.04	1.90	1.91
	Loans for more than 20 years	0.58	0.57	0.55	0.49

Note: BIC stands for Bayesian Information Criterion. The lower the value the less information is lost with the specification. Comparison should be made only between the same specification with and without the respective expected securities rate.
Source: Own elaboration with SUGEF data