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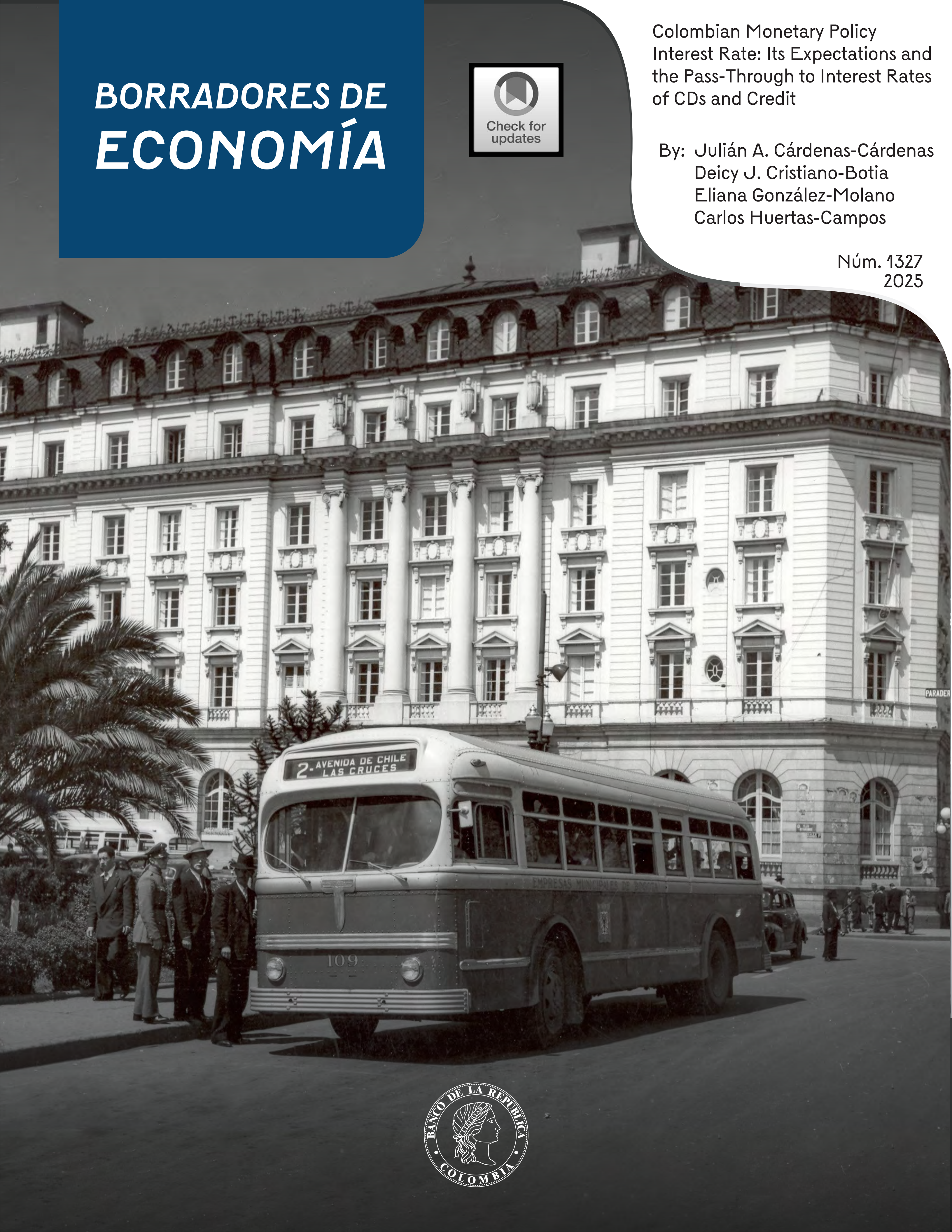

BANCO DE LA REPUBLICA
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Colombian Monetary Policy Interest Rate: Its Expectations and the Pass-Through to Interest Rates of CDs and Credit

Julián A. Cárdenas-Cárdenas* Deicy J. Cristiano-Botia† Eliana González-Molano‡
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Abstract

The credibility of a central bank is reflected in the agent's expectations of the monetary policy interest rate (MPR) and affects the behavior of interest rates in the economy. This document includes these expectations in various models that estimate the pass-through of monetary policy to CD and credit interest rates for the Colombian case. Compared with previous works that only include the observed MPR, the models that incorporate MPR expectations show stronger correlations with CD and credit rates, and faster transmission. It was also found that when analyzing periods of increases and decreases of the MPR, the transmission is asymmetric. However, it was found that the asymmetry in transmission between periods of MPR increases and decreases varies over time. In the short term, transmission tends to be more rapid during phases of MPR decline. Conversely, over longer horizons, transmission appears to be more pronounced during periods of MPR increase.

Keywords: Monetary policy, Interest rate pass-through, Expectations.
JEL Classification: E4, E5, D8.

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Tasa de interés de política monetaria de Colombia: Sus expectativas y el traspaso a las tasas de CDTs y de créditos

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Resumen

La credibilidad de un banco central se refleja en las expectativas de la tasa de interés de política monetaria (TPM) de los agentes y afecta el comportamiento de las tasas de interés de la economía. En este documento se incluyeron estas expectativas en varios modelos que estiman el traspaso de la política monetaria a las tasas de interés de CDTs y de crédito para el caso colombiano. Frente a trabajos anteriores que sólo incluían la TPM observada, los modelos que incluyen las expectativas de la TPM registran correlaciones más altas con las tasas de CDs y de crédito y menores tiempos de traspaso. También se encontró que, cuando la muestra se divide entre periodos de aumentos y descensos de la TPM, el traspaso es asimétrico. Sin embargo, se encontró que la asimetría en la transmisión entre períodos de aumento y disminución de la TPM varía con el tiempo. En el corto plazo, la transmisión tiende a ser más rápida durante las fases de disminución de la TPM. Por el contrario, a horizontes más largos la transmisión puede ser más acentuada durante periodos de incrementos de la TPM.

Palabras clave: Política monetaria, transmisión de tasas de interés, expectativas.
Clasificación JEL: E4, E5, D8.

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1 Introduction

In the monetary policy transmission channels, the pass-through of changes in the monetary policy interest rate (MPR) to long-term interest rates in the economy is crucial. This pass-through is supported by the theory of the term structure of interest rates, which posits that a long-term interest rate is determined by the sum of observed and expected short-term interest rates up until maturity, plus a risk premium[1]. For example, in the case of the interest rate channel, a change in the MPR is transmitted directly to short-term interest rates (money market interest rates)[2]. At the same time, the risk premium and expectations of future MPR changes initiate a process of propagation to longer-term interest rates in the economy. These shifts in interest rates at all maturities influence both consumption and investment decisions, thereby impacting overall price dynamics.

The effectiveness of the interest rate channel is strengthened when the bank lending channel is operating. The bank lending channel operates effectively when bank loans represent an important source of financing for economic agents[3] and when financial institutions face limited alternative assets to substitute for lending. Under such conditions, observed and anticipated changes in the MPR, influence not only short- and long-term interest rates on savings and loans, but also affect the supply of credit. Consequently, the impact of interest rate variations on loan rates is amplified, further affecting aggregate demand and inflation.

In both channels, the credibility of monetary policy plays an important role in transmitting changes in the MPR to market interest rates. A high level of credibility in the Central Bank (CB) encourages economic agents to place greater confidence in the CB's commitment to achieving its inflation target, and consequently, the market has strong incentives to accurately forecast the future path of the MPR consistent with inflation converging to the target. Furthermore, with high CB credibility, changes in the MPR are less likely to be perceived as temporary (Levieuge et al. (2018)). In this case, an unexpected change in the MPR can be transmitted to market interest rates (Cristiano-Botia et al. (2017)) since it would be perceived as a timely and optimal response by the CB to an unexpected shock that could divert inflation from its target. Therefore, CB credibility influences agent expectations (Anzoátegui-Zapata and Galvis-Ciro (2022)), facilitating a more accurate anticipation of potential changes in the

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[1] For example, a one-year interest rate would be equal to a risk premium plus the sum of the observed and expected daily interest rates for each day of the year, see Mandeno and Giles (1995)

[2] See Cardozo-Ortiz et al. (2011)

[3] Households and companies do not have a substitute funding for bank credit since other types of financing are more expensive or difficult to access.

future path of the MPR and its subsequent impact on the yield curve and market interest rates.

The pass-through of interest rates has been extensively analyzed in international studies, reinforcing the need to examine its duration, completeness, and heterogeneity to fully understand its dynamics. (Kho, 2023), (Mayordomo and Roibas, 2023), and (Beyer et al., 2024) investigate the pass-through in European countries, finding significant heterogeneity across euro area countries. They found differences in pass-through across sectors and rate types, influenced by financial market characteristics, banking concentration, and liquidity. (Kho, 2023) also analyzed the asymmetries in response to unexpected monetary policy changes and its relation to banking sector concentration, finding that this asymmetry leads to temporary divergences in deposit rates across the euro area, underscoring the importance of market concentration in the effectiveness of monetary policy transmission. Likewise, (Maravalle and González, 2022) found that in Mexico, while the transmission of monetary policy is heterogeneous between credit types, the average bank credit rate achieves a complete pass-through within three months. The authors also revealed that higher banking concentration and elevated risk in the country lead to higher lending rates. These international findings emphasize the importance of considering market structure, credit segmentation, economic conditions, and expectations when analyzing pass-through, supporting the approach taken in this paper to assess transmission dynamics in Colombia.

Based on these insights, this study proposes to include the MPR expectations in new and existing econometric models of interest rate pass-through for the Colombian case. This is important because previous econometric works only included the observed MPR and did not account for the effects of the central bank's credibility in the pass-through. To this end, Section 2 presents a simple theoretical model to illustrate the role of MPR expectations in determining interest rates on deposits and credit, assuming perfect competition in the banking market. Section 3 shows the MPR expectations that will be used, their high correlations with CDs, and how an unexpected shock of the MPR is transmitted to interest rates in that market. In Section 4, we specifically aim to understand: i) How long does it take for changes in the MPR to be transmitted to CDs and credit interest rates? ii) What factors affect this pass-through? and iii) Are there asymmetries in this pass-through? Finally, Section 5 concludes the analysis, summarizing the main results and their implications.

2 Banking market model with expectations of the MPR

When a central bank sets the level of the monetary policy rate (MPR) for a given period, its next operational step is to influence the short-term cost of money through open market operations (OMOs). Typically, these operations aim to align the money market interest rate with the MPR providing short-term liquidity (or absorb excess liquidity) at a rate equivalent to the MPR. Financial institutions, in turn, analyze past and present monetary policy actions, assess potential adjustments, examine financial market frictions, estimate variations in their non-financial costs, and, more broadly, evaluate macroeconomic conditions that could impact future financial dynamics.[4] Based on this analysis, they attempt to anticipate the transmission of MPR changes to short-term funding costs and other deposit interest rates. Thus, in the absence of unexpected shocks, short-term interest rates tend to converge to the MPR, providing financial institutions with greater certainty that they can secure funding at a cost aligned with the policy interest rate. This facilitates decision-making in the deposit market, and at the same time, when funding costs fluctuate, credit interest rates are also affected.

When setting the optimal levels for deposit demand and credit supply, financial institutions face uncertainty about the future value of the MPR over their operational horizon. Forecasts of the MPR are crucial, partly due to the maturity mismatch between the MPR, deposits, and loans. Typically, the term of a loan exceeds the duration of the deposits used to fund it, so each financial institution must estimate future changes in deposit costs. Additionally, current and expected changes in the MPR can influence the interest rates of assets on the financial institution's balance sheet (e.g., public and private bonds, loan portfolios, fixed assets, etc.), thus affecting their investment decisions. For these reasons, each financial institution has incentives to make the best forecast of the MPR and consider it when optimizing their deposit demand and credit supply.[5]

To illustrate the importance of MPR expectations on the behavior of deposit and loan credit rates, a simple model for the financial institution B in a competitive market will assume the next framework:

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[4] In this process, they monitor the MPR, the current economic conditions, the communication and the credibility of the CB, aiming to answer key questions: Where is the economy and where is it headed? What MPR path will achieve the inflation target and stabilize long-term output? What uncertainties does this path face?

[5] If a financial institution's forecast of the MPR is higher than the actual rate, it would likely end up paying a higher interest rate on deposits compared to the market rate. Conversely, if the forecast is significantly lower, the institution risks losing customers to competitors offering better rates.

- Central Bank decides that the monthly MPR for month 1 will be MPR_1 (nominal monthly rate).[6]
- A financial institution B can obtain liquidity M from the CB at cost MPR_1, also it can demand deposits D, and grant loans L. We assume a one-year duration and an annual cost i^D and i^L, both interest rates set by the market.[7]
- The only regulation is that a fixed percentage α of D must be sent to the CB (banking reserve).
- There are no financial frictions, no risk of bankruptcy or credit risk, and in general, B only faces an annual non-financial operating cost function that depends on the levels of credit, deposits, and liquidity, $C(L, M, D)$.

Taking the above conditions into account, the initial balance of B would be $L+\alpha D = D+M$. In terms of income and cost, at the end of the year, B would receive interest from the loan $\left(i^L L\right)$ and pay the costs of the deposits $\left(i^D D\right)$ and non-financial costs $C(L, M, D)$. During the first month, it would pay the interest rate on liquidity demanded from the Central Bank (MPR_1), and in the following 11 months, it would pay the expected rate at time 1 for each period j until the maturity, thus $E_1(MPR_j) \times M$. Therefore, B would choose the amounts of L, D, and M that maximize its expected profit function for the year:

$$\begin{aligned} \max_{\{L,D,M\}} \quad & i^L L - i^D D - \left[MPR_1 + \sum_{j=2}^{12} E_1\left(MPR_j\right)\right] M - C(L, M, D) \\ & \text{s.t. } L + \alpha D = D + M \\ & i^D \geq 0; i^L \geq 0; MPR_j \geq 0 \end{aligned} \tag{1}$$

By substituting the restriction and differentiating with respect to L and D, the first-order conditions that solve the maximization problem are obtained.

$$\begin{aligned} \max_{\{L,D\}} \quad & i^L L - i^D D - \left[MPR_1 + \textstyle\sum_{j=2}^{12} E_1\left(MPR_j\right)\right] [L + (\alpha - 1)D] - C(L, D) \\ \text{F.O.C:} \quad & i^D = (1-\alpha)\left[MPR_1 + \textstyle\sum_{j=2}^{12} E_1\left(MPR_j\right)\right] - C^D \\ & i^L = \left[MPR_1 + \textstyle\sum_{j=2}^{12} E_1\left(MPR_j\right)\right] + C^L \end{aligned} \tag{2}$$

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[6] It is assumed that this decision is made one day before the start of the first month.

[7] For simplicity, it is assumed that L and D, along with their respective interests, are paid at the end of the year.

According to this simple model, at the optimum, the monthly interest rates for deposits and loans depend on the policy interest rate, its expectations, and the marginal costs. Using the first-order conditions, the current loan rate can also be rewritten as.

$$i^L = \frac{1}{1-\alpha} i^D + \frac{1}{1-\alpha} C^D + C^L \tag{3}$$

In perfect competition and without regulation ($\alpha = 0$), the interest rate levels for deposits (D) and loans (L) depend, one-to-one, on the observed value and expectations of the MPR, and of the marginal costs $\left(C^L, C^D\right)$. The change in these variables and their transmission to the interest rates of the financial system is calculated. Assume a general case, where the deposit interest rate $\left(i_t^{D,m}\right)$ is set in the market in month t with a duration of m months, along with its marginal costs $\left(C_t^{D,m}\right)$. The MPR (MPR_t) has a duration of 1 month and is set by the Central Bank in month $t-1$, with $E_t\left(MPR_t\right) = MPR_t$. This general case is shown in 4 and, subsequently, the change is calculated: $\Delta i_t^{D,m} = i_t^{D,m} - i_{t-1}^{D,m}$.

$$i_t^{D,m} = (1-\alpha)\left[MPR_t + \sum_{j=1}^{m-1} E_t\left(MPR_{t+j}\right)\right] - C_t^{D,m} \tag{4}$$

$$\Delta i_t^{D,m} = (1-\alpha)\overbrace{\left[\underbrace{\Delta MPR_t}_{\substack{\text{Change in}\\ \text{the MPR}}} + \underbrace{\left[E_t\left(MPR_{t+m-1}\right) - MPR_t\right]}_{\substack{\text{Expected change for the}\\ \text{end of the n month}}} + \underbrace{\sum_{j=1}^{m-2}\left[E_t\left(MPR_{t+j}\right) - E_{t-1}\left(MPR_{t+j}\right)\right]}_{\substack{\text{Adjustments in whole period}\\ \text{until maturity of the deposits}}}\right]}^{\text{Total effect of the changes in the MPR and its expectations}} - \underbrace{\Delta C_t^{D,m}}_{\substack{\text{Change in the}\\ \text{marginal cost}}} \tag{5}$$

This shows, in theory, that the most recent monthly change observed in the MPR, the expected variation of MPR by the end of the m month, along with the adjustment of MPR expectations for each of the following m months, are transmitted to the deposit interest rates. In the absence of bank reserves ($\alpha = 0$) and changes in marginal costs $\left(\Delta C_{D,t}^n = \Delta C_{L,t}^n = 0\right)$, the transmission would be one-to-one. However, other frictions in the financial market make this pass-through slower. Some of these frictions are related to the regulation of the financial system, such as credit interest rates limits, liquidity and capital requirements, forced investments, etc. For instance, (Estrada et al., 2008) show that, in response to a reduction in the expected return on loans due to a decrease in the credit interest rate limits, banks tend to reduce their funding needs and their deposit interest rates. In this scenario, in addition to lower financial deepening, banks have incentives to reduce monitoring of their riskier clients and to offer the maximum rate to loans with lower risk than that implied by this rate.[8] These factors can alter the transmission of changes in the MPR to savings rates and credit rates in certain sectors of the economy.[9] Other frictions result in non-competitive markets, where some banks hold a larger share of deposits and credit, and do not simply accept the prevailing interest rates in those markets. Thus, they may have some power to alter the degree of pass-through of the MPR to market interest rates. For example, given an increase in the MPR from an already high level, financial institutions with market power may not fully transmit the increase to charge higher margins on deposits or to mitigate the effects of restrictive monetary policy on loan demand. Another friction is the difference in levels of access to external financing between large and small financial institutions, which can differently affect their balance of sources and uses of liquidity and explain differences in the sensitivity of deposit and credit rates to changes in the MPR. See Wang et al. (2022) who discuss these frictions and their effects over the interest rates.

3 MPR expectations indicators and unexpected interest rate shocks

To incorporate the expectations of equation 5 into the analysis, we use the following indicator of expected cumulative rate for m months of the MPR, constructed by applying the term structure of interest rates:

$$E_t\left[MPR^*_{t+m}\right] = \left[\prod_{j=0}^{m-1}\left(1 + E_t\left[MPR_{t+j}\right]\right)\right]^{\frac{12}{m}} - 1 \tag{6}$$

$E_t\left[MPR^*_{t+m}\right]$: expected cumulative MPR from 1 to m months ahead (in terms of annual effective rate)

$E_t\left[MPR_{t+j}\right]$: expected monthly effective MPR at t for j months ahead.

It is important to note that in Colombia, the central bank's board sets the MPR at the end of

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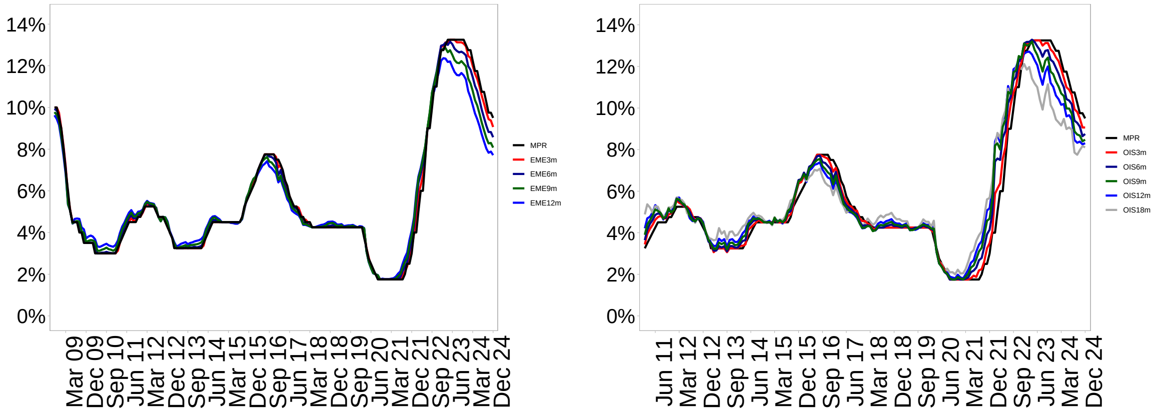
[8] A possible explanation for this behavior is to prevent future losses for banks due to new reductions in the maximum loan rate.

[9] In Colombia, an example of this behavior is the interest rates applied to credit cards, which are often very close to the maximum remunerative rate regardless of the customer's credit risk level. See Gomez-Gonzalez et al. (2016) who analyzed the *Partial R-squared* to evaluated the percentage of the market interest rates variability explicated by the MPR and the limit interest rates.

each month, with the decision taking effect since the beginning of the following month. Additionally, the CDs and credit interest rate data used in this document correspond to monthly averages; that is, the interest rates were determined throughout the month. Therefore, this document assumes that agents take the policy rate observed in the middle of the month $(MPR_{t(15th)})$ into account when setting market interest rates; that is why in equation 6 was included the observed term $E_{1(15th)}[MPR] = MPR_{1(15th)}$ for $j = 0$.

Based on the previous equation we calculate a series of indicators of expected cumulative MPR for different periods (m) using the following sources: *i)* the median of expectations of the MPR from the Monthly Survey of Economic Analyst Expectations (EME) available from October 2008 and *ii)* median market-based expectations derived from the Overnight Indexed Swaps (OIS) available from February 2011. For each source, we calculate expected cumulative indicators for 3, 6, 9, 12, and 18 months (except for 18 months in the case of the EME), where MPR expectations are set before the 15th of the current month. These indicators and the MPR observed are shown in Figure 1.

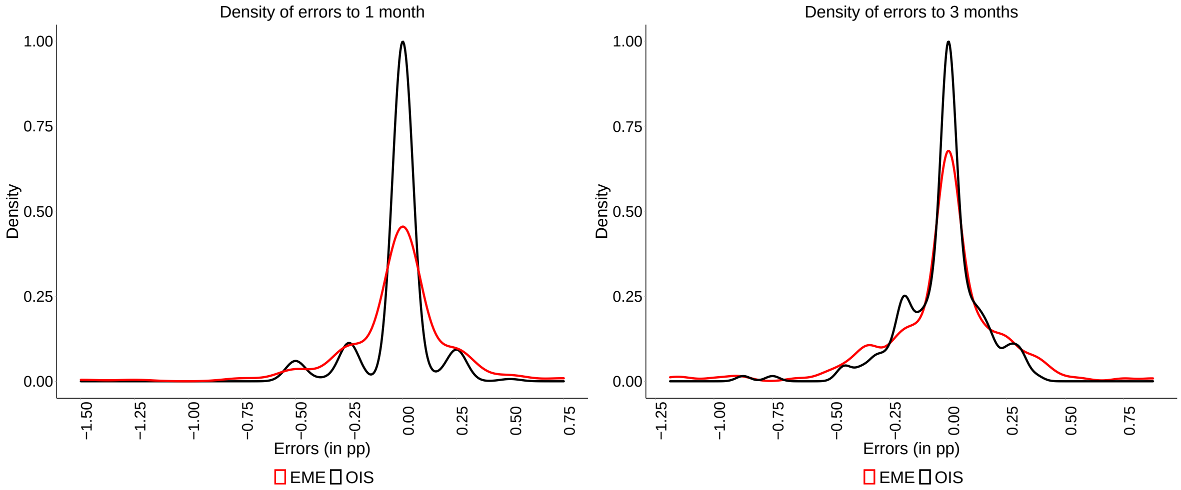


(a) EME

(b) OIS

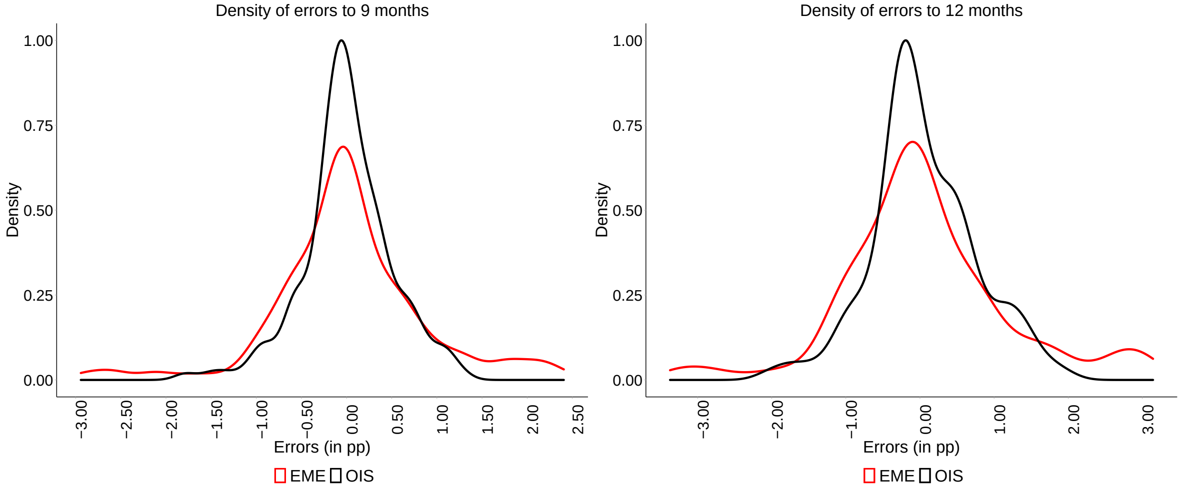
Figure 1: Monetary policy interest rate (MPR) and expected cumulative indicators by maturity. For example, EME3m in Panel a) indicates the expected cumulative from day 15th of month t to 3 months ahead according to the survey.

The indicators in Figure 1 show how economic agents anticipate future movements in MPR, reflecting, in part, the credibility in the central bank's future actions. Furthermore, Figure 2 shows the low forecast errors between the observed MPR and the expected indicator for the one-month horizon, as well as between the cumulative MPR and expected cumulative MPR over 3-, 9-, and 12-month horizons for each expectation indicator (EME or OIS). The differences of density functions of the forecast errors across horizons are minimal, with measures of central tendency and standard deviations close to zero. This suggests that the forecasting indicators tend to align closely with the actual path of the MPR.



(a) 1 month

(b) 3 months



(c) 9 months

(d) 12 months

Figure 2: Density of the errors to different maturities.

However, we are interested in analyzing the immediate deviations between expected and actual values of the MPR. Below, we analyze the presence of these unobserved monetary policy shocks and whether the market has transmitted these deviations to short-term interest rates ($i_t^D =$ 90-day CDs). In equation 8, we evaluate for CDs (i_t^D), the impact of: unanticipated monetary policy shocks (α_1), the expectation adjustments (α_2), and the total change in expectation at the end of maturity (α_3).

$$i_t^D = \sum_{j=0}^{2} E_t \left[MPR_{t+j} \right] \tag{7}$$

Upon implementing the change and incorporating the error, the resulting model to be estimated would be:

$$\Delta i_t^D = \alpha_1 \left(MPR_t - E_{t-1} \left[MPR_t \right] \right) + \alpha_2 \left(E_t \left[MPR_{t+1} \right] - E_{t-1} \left[MPR_{t+1} \right] \right) + \alpha_3 \left(E_t \left[MPR_{t+2} \right] - MPR_{t-1} \right) + \epsilon_t \tag{8}$$

We named the next variables:

α_1 : Unexpected shock $= MPR_t - E_{t-1} \left[MPR_t \right]$
α_2 : Expectation adjustment $= E_t \left[MPR_{t+1} \right] - E_{t-1} \left[MPR_{t+1} \right]$
α_3 : Total expectation $= E_t \left[MPR_{t+2} - MPR_{t-1} \right]$
ϵ_t : Error

We consider the unanticipated shock of the MPR defined under the two alternatives, OIS and EME.[10] The empirical findings indicate that the unanticipated shock (α_1) does not exhibit statistical significance under either estimation methodology. However, the total effect (α_3) is found to be significant. Moreover, in both approaches, the sum of the three coefficients is positive, suggesting that upward revisions in expectations regarding the MPR are effectively transmitted to the 90-day interest rate, see Table 1.

	OIS	p-value	EME	p-value
Unexpected shock	-0.207	0.14	0.269	0.12
Expectation adjustment	0.163*	0.07	-0.146	0.24
Total expectation	0.226***	0.00	0.384***	0.00

Table 1: Results for the models under the two alternatives, OIS and EME.

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[10] Dickey-Fuller Unit Root Test was calculated for both shocks and the results show that there is no unit root.

4 The pass-through of MPR to the market interest rates

In this section, we present three models that assess the pass-through of the MPR and its expectations to interest rates of CDs and credits. As a proxy for MPR expectations, we use the expected cumulative rate (considering a maturity of twelve months) based on a path derived from the overnight indexed swaps (OIS) shown in Section 3. We outline the estimation approach, discuss the key assumptions underlying each model, and present the main results. Although these models conceptually reinforce each other, they do not necessarily yield identical results. The following subsections detail specific methodologies employed, beginning with the vector autoregression (VAR) model.

4.1 VAR Model

One of our goals is to measure how agents anticipate changes in the monetary policy rate and how these expectations are transmitted to deposit interest rates, subsequently influencing credit interest rates through this channel. Using the VAR models with the OIS cumulative indicator as a proxy for expectations of the MPR, we analyze the transmission mechanism of the MPR to the market interest rates. Three VAR models were evaluated, one for each type of credit: consumer, commercial, and housing. In all of them, the deposit interest rate (total CD) was considered in the models as saving interest rate.[11] The proposed model is the following:

$$\begin{aligned} i_t^D &= \sum_{k=1}^{p} \Big(\alpha_{1k}\, i_{t-k}^D + \alpha_{2k}\, i_{t-k}^L + \alpha_{3k}\, MPR_{t-k}^{OIS} \Big) + RR_t + gap_t + \varepsilon_{2t}, \\ i_t^L &= \sum_{k=1}^{p} \Big(\alpha_{4k}\, i_{t-k}^L + \alpha_{5k}\, i_{t-k}^D + \alpha_{6k}\, MPR_{t-k}^{OIS} \Big) + RR_t + gap_t + \varepsilon_{1t}. \end{aligned} \tag{9}$$

where i_t^D and i_t^L are the interest rates of deposit rate and loans (consumer, commercial, or housing), MPR_t^{OIS} is the MPR cumulative expectations obtained from the OIS for 12-month horizon. All of them are effective annual rates. RR_t correspond to liabilities under statutory reserve requirements and gap_t is the output gap. The exogenous variables RR and the gap are used as proxy indicators of Colombia's liquidity and economy activity, respectively.

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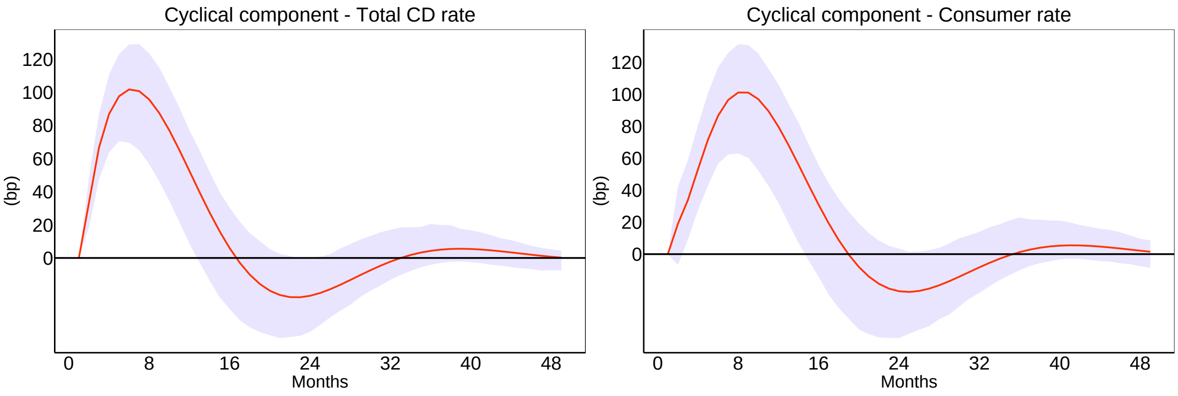
[11] Tests for cointegration using the Johansen methodology show that the series are cointegrated.

	Consumer ($p = 2$)		Commercial ($p = 1$)		Housing ($p = 2$)	
Coef.	Deposit rate	Loans	Deposit rate	Loans	Deposit rate	Loans
Deposit rate	0.694*	0.307*	0.906*	0.351*	0.873*	0.195*
Loan rate	0	0.642*	-0.21*	0.485*	-0.265*	0.679*
MPR^{OIS}	0.340*	0.111*	0.394*	0.293	0.679*	0.073*
RR	0.048*	-0.037	0.063*	0.012	0.057*	0.004
gap	-0.019	0.009	-0.013	-0.021	-0.022	-0.015*

Table 2: VAR models for different credit types. Columns represent the equations for each model, and Deposit and Loans rows show the sum of coefficients of all lags. The variable p indicates the number of lags included.

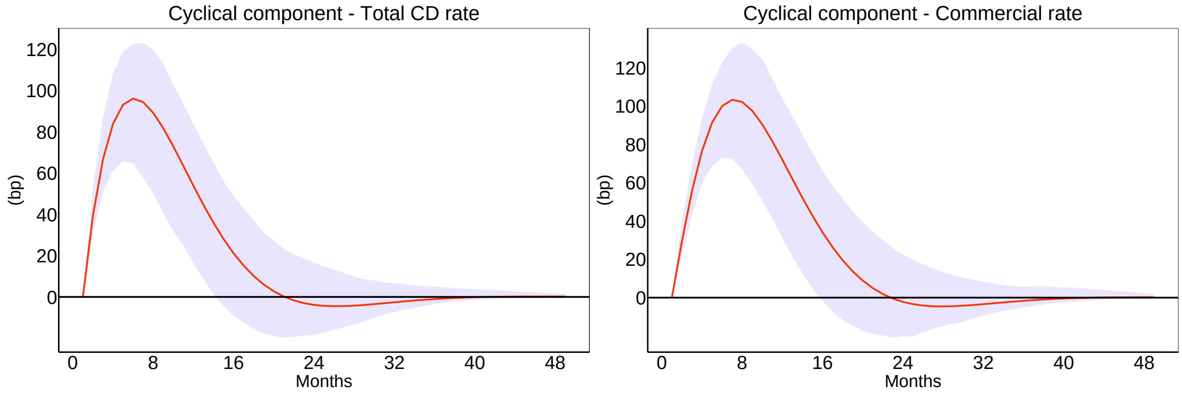
Table 2 presents the results of the VAR model for deposits and loans (consumer, commercial, and housing). These models aim to understand the pass-through mechanism of the monetary policy interest rate. The findings suggest that changes in the monetary policy interest rate impact the cost of deposits, which subsequently affect loan interest rates. This indicates that the transmission mechanism operates initially through deposits, which are then spread to loans. In all models i_t^D and MPR_t^{OIS} are significant (except MPR_t^{OIS} for commercial model), and its coefficients for the CD models are larger than that for the credit models. The impulse response demonstrates that the effect of the MPR_t^{OIS} initial shock is strong in the first few months but has a diminished influence after a year (see Figures 3,4,5). This finding is consistent with results obtained from other methodologies.



(a)

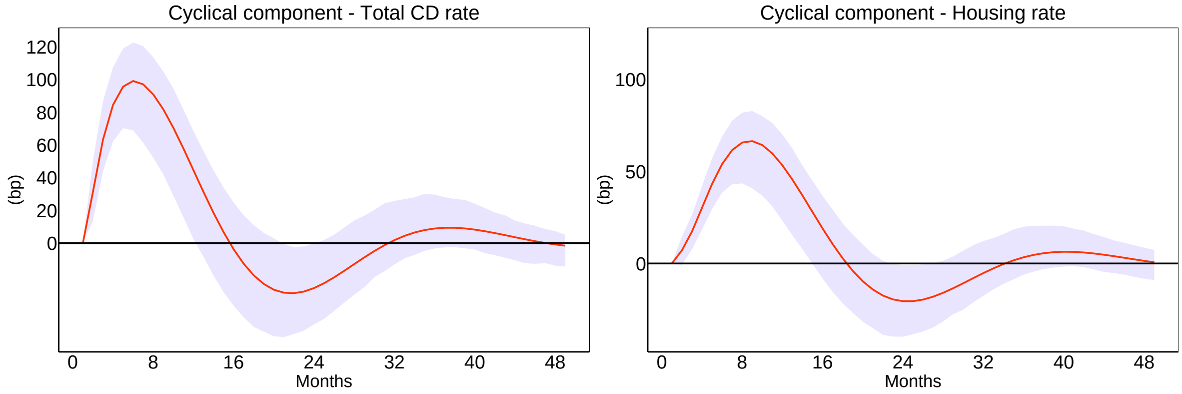
(b)

Figure 3: Impulse response of cyclical components for consumer rates VAR model



(a) (b)

Figure 4: Impulse response for commercial rates VAR model



(a) (b)

Figure 5: Impulse response of cyclical components for housing rates VAR model

4.2 NARDL Model

The pass-through of monetary policy is a complex mechanism influenced by numerous factors. Interest rates often do not adjust symmetrically in response to monetary policy actions, presenting significant challenges for policymakers. The duration or speed at which these policy changes translate into adjustments in interest rates can vary considerably, influenced by macroeconomic conditions and the types of credits in the financial market. Additionally, the pass-through process is not always complete; it can be slower and less predictable under certain conditions. Understanding these asymmetries and the temporal dynamics of the pass-through is crucial for designing effective monetary policy. It enables policymakers to anticipate a range of responses and adapt strategies accordingly. This subsection provides an analysis of these asymmetries and the temporal dynamics of the pass-through with Colombian data.

The nonlinear autoregressive distributed lag model (NARDL) is a robust methodology that allows the modeling of both short-term and long-term asymmetries. In our analysis, we adapt the same model as the one used by (Galindo and Steiner, 2022), which provides a comprehensive review of the NARDL framework to better understand the pass-through and asymmetries of interest rates in Colombia. Additionally, we included the expectation factor using the OIS series instead of MPR series for comparison purposes.

$$i_t = \theta^+ MPRt^+ + \theta^- MPR_t^- + \varepsilon_t \tag{10}$$

$MPR_t = MPR_0 + MPR_t^+ + MPR_t^-$. Where MPR_0 represents the MPR in the first period of time considered, MPR_t^+ represents the cumulative positive changes of MPR to t, and MPR_t^- represents the cumulative negative changes of MPR to t. This can be represented as a NARDL(p,q) model as follows:

$$\begin{aligned}\Delta i_t = {} & c + \alpha i_{t-1} + \beta^+ MPR_{t-1}^+ + \beta^- MPR_{t-1}^- \\ & + \sum_{k=1}^{p-1} \psi_k \Delta i_{t-k} + \sum_{k=0}^{q-1} \varphi_k^+ \Delta MPR_{t-k}^+ + \sum_{k=0}^{q-1} \varphi_k^- \Delta MPR_{t-k}^- + \varepsilon_t\end{aligned} \tag{11}$$

where α is the adjustment speed. $\hat{\theta}^+ = -\hat{\beta}^+/\hat{\alpha}$ and $\hat{\theta}^- = -\hat{\beta}^-/\hat{\alpha}$ the long-term transmission coefficients for positive and negative scenarios. This model has the capacity to evaluate the relationships from short and long term between the monetary policy rate and the market interest rates, providing an understanding of dynamic relationships by capturing both immediate and delayed effects. By considering non-linearity, the NARDL model allows us to analyze asymmetries in interest rates in response to increases or decreases in the monetary policy rate.

To estimate the importance of MPR expectations, two models were estimated for deposit rate and for each lending rate (commercial, consumer and housing); one using the observed MPR and another with the cumulative expectations obtained from the OIS for 12-month horizon (MPR^{OIS}). Table 3 shows a faster transmission when using the OIS expectation indicator compared to the MPR, with the effect being more pronounced in lending rates. In all cases, the fastest transmission occurs in deposit rates, followed by commercial, consumer and housing rates.

	Adjustment 50%		Adjustment 90%	
Interest Rate	MPR	MPR^{OIS}	MPR	MPR^{OIS}
Deposits	4	3	13	9
Consumer	12	3	39	12
Commercial	4	3	14	9
Housing	24	19	81	65

Table 3: Number of months requires to absorb 50% and 90% of the shock.

Monetary policy rate				
Variable	Deposits	Consumer	Commercial	Housing
MPR	0.869***			0.286
MPR+		0.832***	1.071***	
MPR-		1.143***	1.25***	

Table 4: Estimation result by type of credit using MPR as explanatory variable. The coefficient indicates how much of a long-run deviation is absorbed in one period.

MPR^{OIS}				
Variable	Deposits	Consumer	Commercial	Housing
OIS12	1.125***			0.77***
OIS12+		1.442***	1.373***	
OIS12-		1.643***	1.516***	

Table 5: Results using the cumulative expectations for the MPR obtained from the OIS. The coefficient indicates how much of a long-run deviation is absorbed in one period.

Tables 4 and 5 compare the parameter values for each model type, using both the observed MPR and the expectation-based OIS. The inclusion of expectations results in higher coefficients, which are significant in all cases and reflect complete pass-through for the deposit interest rate. Asymmetries were found in consumer and commercial interest rates. While these asymmetries do not show large differences, they are still statistically significant. Furthermore, the large magnitude of the estimates for the parameters associated with commercial and consumer rates indicates that pass-through is faster than for housing interest rates.

4.3 Survival analysis

The survival analysis methodology applied to the pass-through context was initially presented in Gomez-Gonzalez et al. (2016) as an innovative way to quantify the probability of pass-through from the MPR to market interest rates. First, to account for the effect of expectations on the transmission of monetary policy, we use the cumulative expectations indicator of the MPR (MPR^{OIS}) instead of the MPR. Second, we disaggregate the analysis by instrument type and maturity: for certificates of deposit (CDs), we examine different maturities, while for credit interest rates, we differentiate by loan type (commercial, consumer, and housing). Third, the use of institution-level data allows us to incorporate heterogeneity by including institutional size as a categorical variable. Furthermore, the methodology was expanded to identify potential asymmetries in monetary policy transmission across different economic states (e.g., periods of increasing or decreasing MPRs). Finally, some important variables that may affect the transmission was included, such as output, inflation, and credit gaps.

In survival analysis, an event occurs when the observation is at risk of contagion, which means that it is exposed to a phenomenon that could change its state to *non-surviving*.[12] In this exercise, the risk event is the pass-through of the monetary policy, which occurs when the interest rate (of CD or loan) of a financial institution reaches the same variation in basis points (bp) as indicated by the last change in the MPR^{OIS}. The goal is to identify the number of months that a financial institution needs to reach the change in bp indicated by MPR^{OIS}, considering the accumulated changes during a period of consecutive changes in the same direction.

To analyze the pass-through, we employ the Cox proportional hazards model, a semi-parametric approach widely used in survival analysis. The hazard function is central to this framework, and the formulation allows for modeling covariate effects; considering the next function.

$$h(t|X) \quad = \quad h_o(t)\exp\left(X^t\beta\right) \tag{12}$$

Where X includes variables that could affect the pass-through, such as output, credit, and inflation gaps. In this paper output gap is the official series published in the Monetary Policy Report, estimated for a monthly frequency. The inflation gap is the difference between observed inflation and the target, and the credit gap was calculated using a HP filter. Financial institutions were classified based on risk profiles and sizes into four groups: large institutions,

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[12] The details of the survival model exercise for pass-through is presented in Appendix B. Additionally, the process of building the observations associated with the described schema has certain particularities, which are also described in the same Appendix.

medium-sized institutions, small institutions, and other types of institutions. Additionally, we include a variable to distinguish between periods of increasing and falling of the MPR. This model captures both short- and long-term relationships through the constructed risk functions. We built two models: one for term deposit interest rates (CD) and another for loans interest rates.

We begin the survival analysis by identifying the time at which the estimated pass-through reaches 50% and 90% of the cumulative change in the MPR or MPR^{OIS}. These duration statistics are reported in Table 6, showing that the months required to absorb 90% of the accumulated change in the MPR^{OIS} are less than those required in the case of the accumulated MPR, aligns with the results obtained from the NARDL model (except in the case of housing loans).[13]. To complement this, Figure 6 shows the probability of the pass-through changes over time depending on the stance of monetary policy. A statistical test for the equality of the curves confirms significant differences in the transmission dynamics between periods of increasing and decreasing of the MPR^{OIS}. In this market, initially, the pass-through is more pronounced during periods of declines in the MPR^{OIS}; however, this dynamic shifts over time, with the pass-through becoming more responsive during periods of MPR^{OIS} increases. Appendix B presents the pass-through curves disaggregated by maturity and by institutional size. Figure 14 illustrates the evolution of the pass-through probability over time for certificates of deposit (CDs) with maturities of 90, 180, and 360 days. Figure 15 displays the corresponding curves by financial institution size. As there are no statistically significant differences in the transmission dynamics across CD maturities or institutional size, these variables are excluded from the model specification.

	Adjustment 50%		Adjustment 90%	
Interest Rate	MPR	MPR^{OIS}	MPR	MPR^{OIS}
Deposits	2	3	19	9
Consumer	3	3	16	13
Commercial	1	2	13	9
Housing	7	6	-	15

Table 6: Number of months requires to absorb 50% and 90% of the shock.

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[13] As it is evaluated in other papers, this interest rates are affected by other factors, see for example Gomez-Gonzalez et al. (2016)

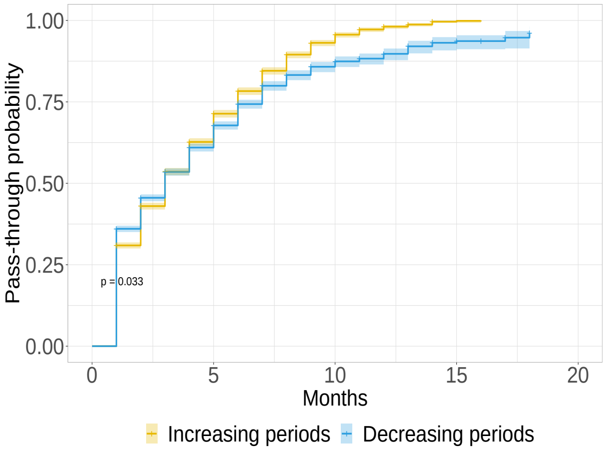

Figure 6: Probability of the pass-through for CDs. The y-axis represents the probability, and the x-axis shows time in months. The blue lines represent periods of decreasing MPR^{OIS}, while the yellow lines represent periods of increasing MPR^{OIS}. These lines indicate the probability of pass-through during periods of increasing and decreasing of the MPR^{OIS}.

Building on these preliminary results, we now turn to the analysis of the hazard functions. Figure 7 provides visual evidence of non-proportionality in the hazard curves, challenging the assumption of constant hazard ratios over time. This is particularly relevant given that the validity of Cox proportional hazards regression relies on the assumption that the hazard ratios between individuals with different covariate values remain constant. To formally assess this, we conduct the Schoenfeld Residuals Test. As reported in the appendix B, Table 12, the small p-value indicates that this assumption is not met.

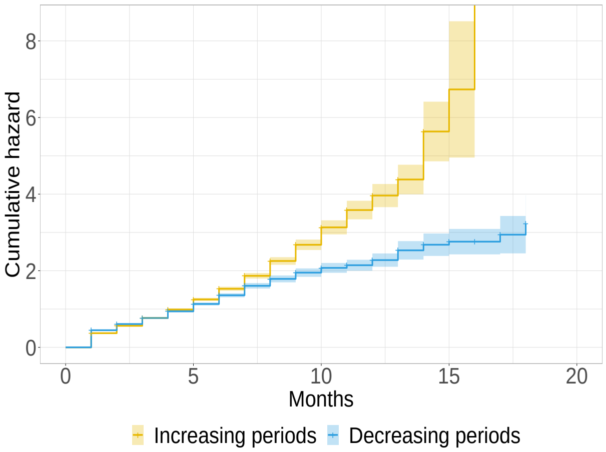

Figure 7: Cumulative hazard for increasing and decreasing periods - CD.

Taking into account the previuos analysis, we propose a model specification that incorporates time-varying covariate effects through interaction terms for variables that violate the proportional hazards assumption. This approach allows the hazard ratios to evolve over time, addressing the non-proportionality identified earlier, (see Appendix B.2). The resulting estimates are presented in Table 7. In interpreting these results, it is important to note that the Cox model estimates effects relative to a reference category. In our specification, periods of increasing monetary policy rates are set as the baseline, allowing the estimated coefficients to capture the relative change. Table 7 shows that the risk of transmission is greater during periods of decline (exp(coef) = 47) than during periods of increase. However, this risk decreases over time (exp(coef) = -14), potentially to the point of reversal.[14] Similarly, transmission risk is higher during periods of positive output and inflation gaps, and lower during periods of positive credit gaps. In all these cases, the associated risks diminish over time and may be reversed in the medium term.

		coef.	exp(coef)	p-value
Period Baseline: Increasing	Decreasing	0.38	47	0.00
	Decreasing * time	-0.15	-14	0.00
Macroeconomic variables	Inflation gap*	0.33	39	0.00
	Inflation gap * time	-0.03	-3	0.00
	Output gap*	0.03	3	0.07
	Inflation gap * time	-0.01	-1	0.00
	Credit gap*	-0.20	-18	0.00
	Credit gap * time	0.07	7	0.00

Table 7: Cox model for CDs. For each variable, a specific category is used as a baseline for comparison. The exp(coef) column reports the relative risk of pass-through for each category versus its baseline, based on the estimated coefficient β in the equation 12. In the case of the variable *time, it indicates whether the effect increases or decreases over time. Values above 1 indicate a higher risk than the reference group, while values below 1 reflect a lower risk. For each variable we include the interaction term with the time t.

To extend the analysis to credit interest rates, we begin by comparing the survival curves corresponding to periods of increasing and decreasing of the MPR^{OIS}. These curves display differences, and the statistical test for equality confirms that the survival functions are signif-

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[14] The total effect of decreasing periods at time t is: log(hazard ratio) = $\beta_{Decreasing} + \beta_{Decreasing*time}$.

icantly distinct, see Figure 8. Additionally, we extend the analysis by disaggregating the data by loan type across monetary policy phases. Figure 9 shows the pass-through probabilities for the types of credit interest rates considered: commercial, consumer, and housing. Across all types, the pass-through is initially stronger during decreasing MPR^{OIS} periods. Nevertheless, as time progresses, the pass-through in increasing MPR^{OIS} periods overtakes that of the decreasing periods, indicating a shift in the relative speed of adjustment. The figure also shows that the transmission in the commercial group is faster than in the other rates, while housing rates have a lower probability of pass-through.

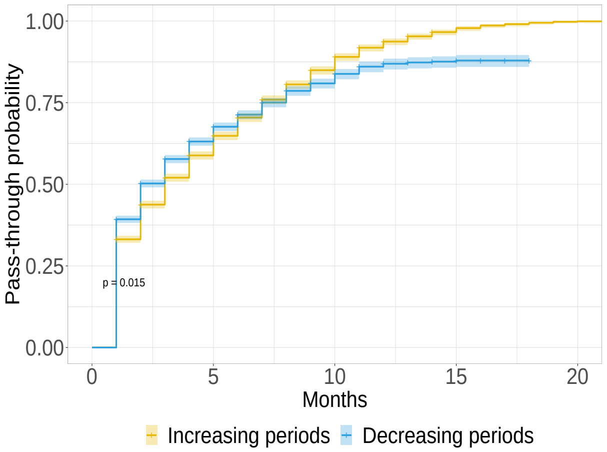

Figure 8: Probability of the pass-through over time - credit interest rates. The y-axis represents the probability, and the x-axis shows time in months. The blue lines represent periods of decreasing MPR, while the yellow lines represent periods of increasing MPR. These lines indicate the probability during periods of increasing and decreasing MPR.

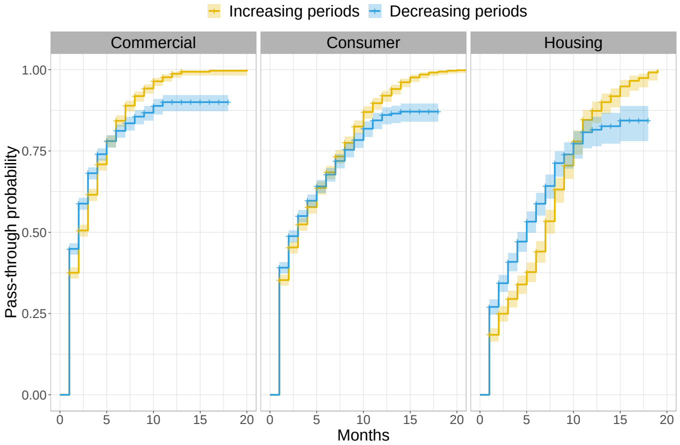

Figure 9: Probability of the pass-through over time - credit interest rates. The y-axis represents the probability, and the x-axis shows time in months. The blue lines represent periods of decreasing MPR, while the yellow lines represent periods of increasing MPR. These lines indicate the probability during periods of increasing and decreasing MPR by type of credit.

The analysis of the hazard functions suggest non-proportionality, challenging the assumption of constant hazard ratios, see Figures 10 and 11.

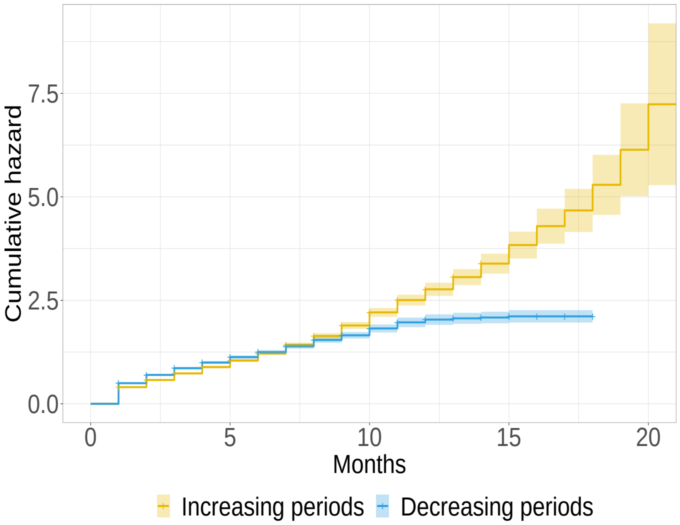

Figure 10: Cumulative hazard for increasing and decreasing periods - credit interest rates.

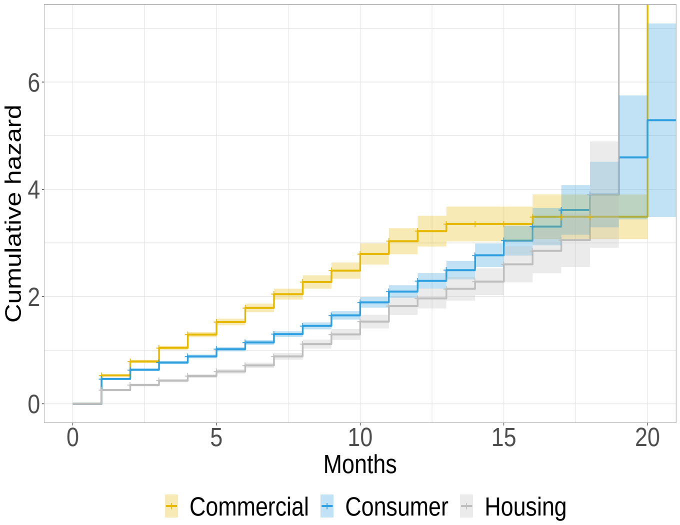

Figure 11: Cumulative hazard for type of credit interest rates.

Given the non-fulfillment of the assumption of the proportional hazards assumption according to the Schoenfeld Residuals Test, we extend the model by including interaction terms between the covariates and time.[15]. The estimation results are presented in Table 8. Coefficients are interpreted relative to a reference category; a positive coefficient indicates a higher hazard rate of the event occurring—while a negative coefficient suggests a lower hazard rate, compared to the baseline. In our specification, periods of increasing monetary policy rates serve as the reference category for the stance of monetary policy, and consumer interest rates are used as the baseline for loan type, allowing for comparisons across different credit modalities.

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[15] The initial model specification and the validation of the proportional hazards assumption are presented in Appendix B.3

		coef.	exp(coef)	p-value
Period Baseline: Increasing	Decreasing	0.42	52	0.00
	Decreasing * time	-0.12	-11	0.00
Type of credit Baseline: Consumer	Commercial	0.19	21	0.00
	Commercial * time	0.05	5	0.00
	Housing	-0.68	-49	0.00
	Housing * time	0.07	7	0.00
Macroeconomic variables	Inflation gap*	0.17	18	0.00
	Inflation gap * time	-0.01	-1	0.05
	Output gap	0.02	2	0.27
	Output gap * time	0.01	1	0.13
	Credit gap*	-0.17	-16	0.00
	Credit gap * time	0.02	2	0.00

Table 8: Cox model for loans. For each variable, a specific category is used as a baseline for comparison. The exp(coef) column reports the relative risk of pass-through for each category versus its baseline. Values above 1 indicate a higher risk than the reference group, while values below 1 reflect a lower risk. For each variable we include the interaction term.

Table 8 presents the estimation results for loan model, incorporating time interactions to account for non-proportional effects. The model includes variables grouped into three categories: monetary policy stance (Period), type of credit, and macroeconomic conditions. First, the coefficient for the period with decreasing MPR^{OIS} is positive and statistically significant, indicating a higher initial hazard for decreasing periods (faster pass-through), while its negative interaction with time suggests a deceleration in the pass-through rate over time, consistent with the observed graphs, where at some point, periods of increasing MPR^{OIS} exhibit a higher pass-through than decreasing ones. Commercial credit shows both a positive and significant main effect and time interaction, implying a higher initial pass-through probability and an increasing effect over time relative to consumer credit. In contrast, housing credit has a negative and significant coefficient, indicating a lower initial pass-through probability, with a positive time interaction that reduces this negative effect over time. Additionally, regarding the macroeconomic variables, the inflation gap exhibits a positive and significant impact on pass-through, though its slightly negative time interaction suggests a weakening influence as time progresses. Conversely, the credit gap has a negative effect that also diminishes over time. And finally, the output gap has not significant effect.

5 Conclusions

The credibility of monetary policy is crucial for the pass-through of changes in the MPR to the market interest rate. With an elevated level of central bank credibility, the market has strong incentives to accurately forecast the future path of the MPR, consistent with the convergence of inflation toward the target. Furthermore, agents are less likely to perceive unexpected changes in MPR as temporary. For these reasons, in addition to the observed MPR, this paper included MPR expectations in the monetary policy transmission models, improving correlations with market interest rates and finding faster pass-through compared to previous works for Colombia.

From the models that incorporate the expectation of the MPR, the following conclusions can be drawn: *i)* The pass-through is neither immediate nor uniform, with a more pronounced effect on deposits compared to loans; *ii)* Unanticipated changes in the MPR are transmitted to the CD interest rate and, through this channel, also affect credit rates; *iii)* The pass-through is asymmetric between periods of rising and falling MPR; however, it was found that the asymmetry in transmission between periods of MPR^{OIS} increases and decreases varies over time. In the short term, transmission tends to be more rapid during phases of MPR^{OIS} decline. Conversely, over longer horizons, transmission appears to be more pronounced during periods of MPR^{OIS} increase, and *iv)* approximately 90% of the transmission of changes in the MPR^{OIS} occurs within 9 months for the CD interest rate, 9 months for the commercial lending rate, 12 months for the consumer interest rate, and over 1 year or even over 5 years for the housing interest rate, depending on the methodology used.

A Data

In some models, we incorporate macroeconomic variables to capture economic dynamics and their influence on the pass-through, as well as microeconomic variables that account for financial system characteristics may affect the transmission process. Table 9 provides a detailed description of the variables used in this analysis. Our variable selection is guided by theoretical considerations and empirical evidence.

Variable	**Description**	**Source**
MPR	Monetary Policy Rate	Banco de la República
i_t^L	Interest rate of loans	Financial Superintendency
i_t^D	Interest rates of deposit	Financial Superintendency
$MPR_t^{OIS}(**)$	OIS rate	Bloomberg
gap or $\hat{y}_t^*$	Output gap	Banco de la República
Credit gap*	Credit gap	Banco de la República
Inflation gap*	Inflation gap	Banco de la República
ROA	Return on total assets	Financial Superintendency
ICM	Risk indicator	Financial Superintendency
RR	Liabilities subject to reserve requirement	Financial Superintendency

Table 9: The table shows the description of the variables used in our econometric models. The first column lists the variable names in the models, the second column provides a brief description of each variable, and the third column indicates the source of the data. The variables with * are non-observed. Those were provided by the BR Technical Team and were obtained by econometric techniques. (**) MPR_t^{OIS} indicator is calculated by BR.

B Asymmetries and duration of the pass-through

B.1 Implementation of Survival Models to our data

To better understand the survival model applied for the pass-through of MPR to the market interest rate, the details presented in this appendix provide a comprehensive explanation. The structure shown in Table 10 and Figure 12 offers an example of how to build the data for applying this methodology, referencing the variables defined. Imagine a scenario where the

Date	Fin. Inst.(m)	Δ OIS	$\Delta^c i_m$	Time (x_m)	Pass-through (δ)
t	1	100	50	1	0
$t+1$	1	100	80	2	0
$t+2$	1	100	100	3	1
t	2	100	70	1	0
$t+1$	2	100	110	2	1
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
t	n	100	70	1	0
$t+1$	n	100	80	2	0
$t+2$	n	100	105	3	1

Table 10: Example - Data structure for survival model

OIS rate increases by 100 basis points (bp) at some time t, then, we need to gather the next variables: *(i)* the time it takes for any financial institution to increase its interest rates by 100 bp, represented by (x), *(ii)* a dummy variable indicating whether the market rate of i_m reaches the change in bp shown by the OIS, noted as *Transmission* (δ). If the same amount of change as the OIS is not reached for a financial institution, this observation is considered *censored*.

Additionally, we must consider two important factors: First, if the OIS changes its behavior to increase after a decrease (or vice versa), we stop the counting in time. This ensures we consider the change of stance of the monetary policy. Second, after a period of continuous increase or decrease in the MPR, we establish a *tolerance window* to reach the pass-through. These windows are set at 3, 6, 9, 12, 15, and 18 months, representing periods when the MPR remains constant until the next change. These criteria establish the *cycle* during which a financial institution can reach the changes shown by the OIS.

The Figure 13 shows all of these cycles and the tolerance window for the case 12 months, each blue period in the figure represents a different cycle and the OIS changes only can be reached by the market interest rates in these periods. Finally, for the methodology, each financial institution and each observation generated by this schema has the same importance despite the period of time considered.

Now, with the data generated. We suppose that the financial institutions number does not change during the whole period analyzed. Let be $N \in \mathbb{N}$ the number of financial institutions considered and $M \in \mathbb{N}$ the number of risk events, we have a $M \times N$ survival times to study.

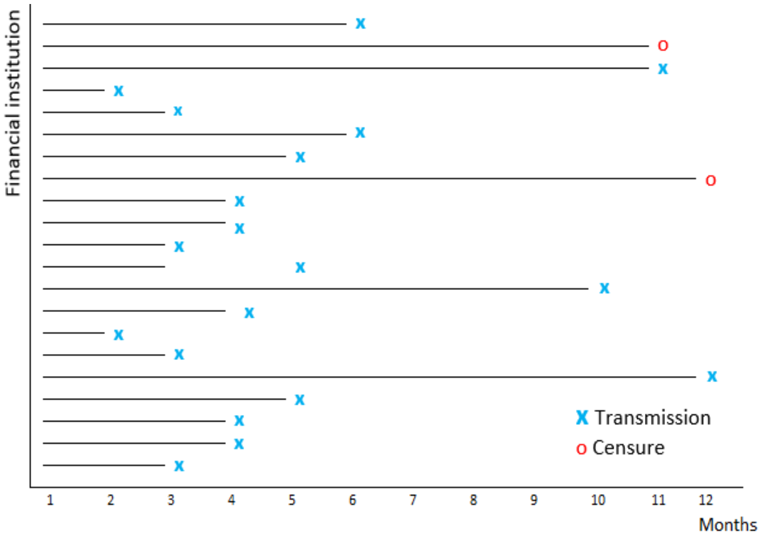

Figure 12: Example - How to follow a financial institution for a tolerance window of 12 months

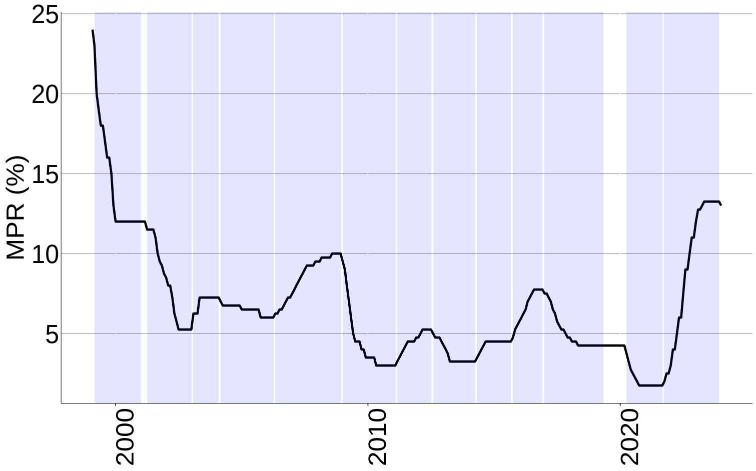

Figure 13: Tolerance window - 12 months

In addition, we have, $(x_1, \delta_1), \cdots, (x_n, \delta_n)$ the times (x_i) until we observe the interest rate reaches the changes observed by OIS or is considered as a censored data point. If an interest rate j of a specific financial institution i overcome the changes of the OIS rate in a certain period considered k regardless if its an increase or a reduction period, we have $(\delta_{ijk} = 1)$ and $(\delta_{ijk} = 0)$ in any other case.

B.2 Some results for CD model

We present the estimated pass-through probabilities of certificates of deposit (CDs) over time, disaggregated by maturity. Each panel displays two trajectories: one corresponding to periods of monetary policy rate (MPR) increases (yellow), and the other to periods of MPR decreases (blue). Initially, the pass-through is generally more pronounced during MPR-decreasing episodes across all maturities. However, the dynamics evolve over time, with the pass-through under MPR-increasing conditions eventually overtaking that of the decreasing periods. These patterns shows the asymmetries in the transmission of monetary policy. On the other hand, the curves across different maturities exhibit similar dynamics. This suggests that maturity may not be a key determinant in shaping the pass-through behavior. This finding implies that controlling for maturity may be unnecessary when analyzing the responsiveness of CD rates to policy changes in this survival models.

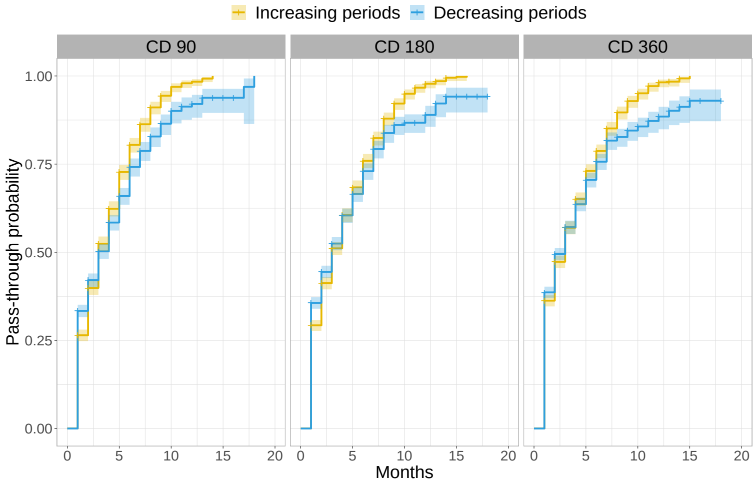

Figure 14: Probability of the pass-through over time - CD by maturity. The y-axis represents the probability, and the x-axis shows time in months. The blue lines represent periods of decreasing MPR, while the yellow lines represent periods of increasing MPR. These lines indicate the probability of the pass-through during periods of increasing and decreasing MPR.

Another factor we consider in the analysis is the financial institution size: Big, Medium, Little, and Others. We find that larger institutions exhibit a slightly faster and more pronounced pass-through in the initial months, indicating a higher short-term responsiveness. However, the magnitude of these differences across size categories remains modest throughout the observation period. Moreover, the convergence of pass-through in the later months suggests that institutional size does not show a persistent influence on long-run transmission dynamics. These findings support the decision to exclude size as a covariate in the baseline survival model specification.

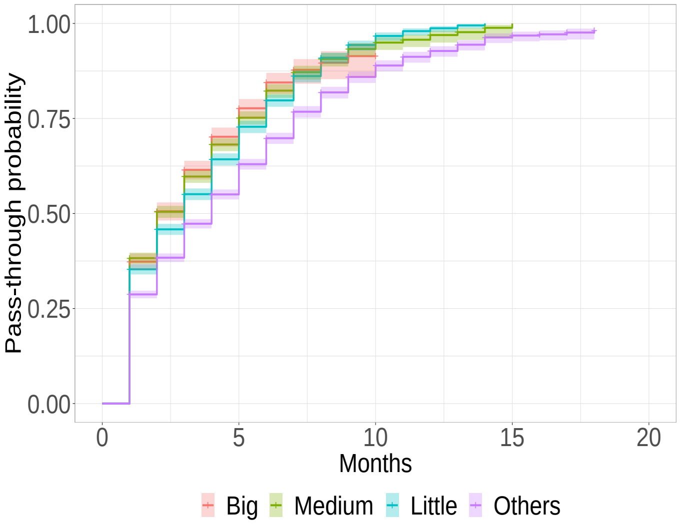

Figure 15: The y-axis represents the probability, and the x-axis shows time in months. The curves represents the probability of the pass-through for each size category.

Taking into account this, our initial Cox proportional hazards model incorporates the following covariates, with the corresponding estimation results presented in Table 11:

		coef.	exp(coef)	p-value
Period (ref=Increasing)	Decreasing	0.02	2	0.33
Fin. Inst. size (ref=Big size)	Medium size	-0.03	-3	0.36
	Little size	-0.09	-9	0.00
	Others	-0.36	-31	0.00
Macroeconomic variables	Output gap*	-0.11	-1	0.25
	Inflation gap*	0.25	29	0.00
	Credit gap*	-0.07	-7	0.00

Table 11: Cox model for CDs. For each variable, a specific category is used as a baseline for comparison (e.g. Period ref=Increasing). The exp(coef) column reports the relative risk of pass-through for each category versus its baseline. Values above 1 indicate a higher risk than the reference group, while values below 1 reflect a lower risk.

For the previous model, we include the results of Schoenfeld Residuals Test, as we see in table 12, the small p-value suggests that the proportionality assumption is violated.

	chi-sq	df	p-value
Period	261.63	1.00	0.00
Size	30.03	3.00	0.00
Output gap	0.37	1.00	0.54
Inflation gap	12.96	1.00	0.00
Credit gap	96.88	1.00	0.00

Table 12: Test the Proportional Hazard Assumption of a Cox Regression for the model of CD

B.3 Some results for loan interest rates

Table 13 presents the estimation results for the loan model without consider the interaction of variables with time

		coef.	probability	p-value
Period (ref=Increasing)	Decreasing	0.14	15	0.00
Type (ref=Consumer)	Commercial	0.31	37	0.00
	Housing	-0.50	39	0.00
Fin. Inst. size (ref=Big size)	Medium size	-0.14	-13	0.00
	Little size	-0.34	-29	0.00
	Others	-0.24	-21	0.00
Macroeconomic variables	Output gap*	0.04	4	0.00
	Inflation gap*	0.14	15	0.00
	Credit gap*	-0.13	12	0.00

Table 13: Cox model for loans. For each variable, a specific category is used as a baseline for comparison (e.g. Period ref=Increasing). The exp(coef) column reports the relative risk of pass-through for each category versus its baseline. Values above 1 indicate a higher risk than the reference group, while values below 1 reflect a lower risk Survival model for loans.

As we see in table 14, the small p-value suggests that the proportionality assumption is violated, so, we include the interactions wiht time in the final model.

	chi-sq	df	p-value
Period	122.14	1.00	0.00
Type of credit	101.26	2.00	0.00
Size	57.54	3.00	0.00
Output gap	19.89	1.00	0.00
Inflation gap	0.10	1.00	0.76
Credit gap	64.00	1.00	0.00

Table 14: Test the Proportional Hazard Assumption of a Cox Regression for the model of credit interest rates

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