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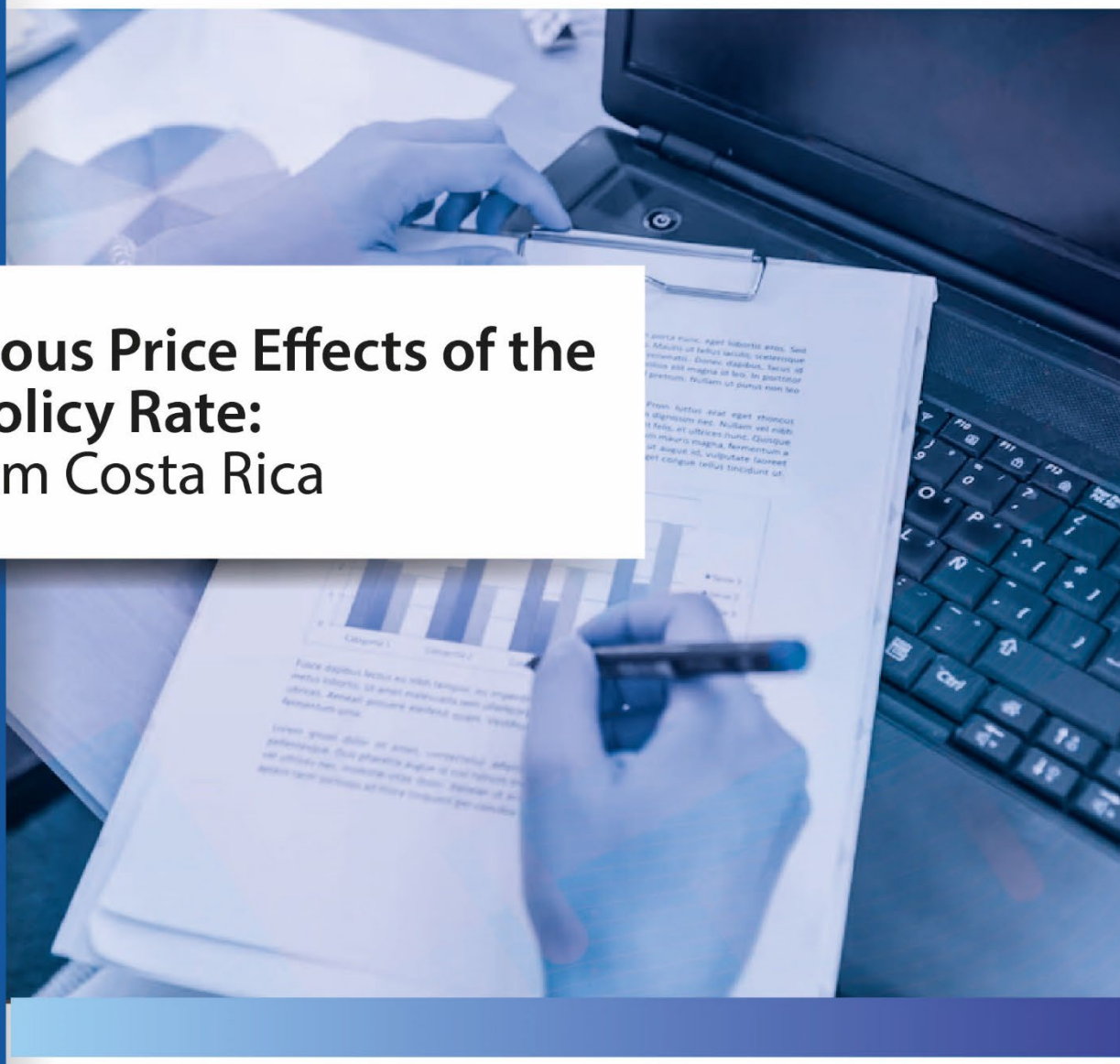

Heterogeneous Price Effects of the Monetary Policy Rate: Evidence from Costa Rica

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Octubre 2024

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Abstract:

We explore the effects of unanticipated monetary policy shocks on prices in an open and developing economy. We address endogeneity issues that arise given that policy makers consider current and expected changes in prices when setting the monetary policy rate by following Romer and Romer 2004 approach. We find that the monetary policy rate has a negative and statistically significant effect on the consumer price index. The effect becomes statistically significant after three quarters and reach a 2.84% reduction after six quarters. We also find that there is heterogeneity in the timing and the magnitude of the effects when we tested the different components of the index. Prices of regulated goods and prices of information and communication sector are not affected. But the prices of food and non-alcoholic beverages are affected within the first quarter and reach a 6% reduction after six quarters. These results can guide policy makers in order to conduct a more effective and less costly monetary policy.

[1] We would like to thank seminar participants at the School of Economics and Institute of Economics Research and the University of Costa Rica and at the Research Department of the Central Bank of Costa Rica. All errors are our own.

1. Introduction

The effectiveness of monetary policy has been extensively debated in economics. Lately, these discussions have focused on the empirical evidence and its challenges. Understanding the extent and the timing of the effects of monetary policy on prices can help decision makers control inflation while reducing the potential negative collateral consequences. This is especially important in highly open economies where price movements are dependent on external factors.

In this paper, we explore the effectiveness of monetary policy on prices of different types of goods in Costa Rica, a highly open economy. Using quarterly data, the period of analysis extends from 2006 to 2019, when the policy rate in Costa Rica was implemented as the main monetary policy tool.

Our estimation approach is based on Romer & Romer 2004 and Rojas et al. 2022. This approach allows us addressing endogeneity concerns that arise when policy makers set the monetary policy rate considering future price movements and economic conditions. The approach consists in using the exogenous component of the variation in the policy rate. The exogenous component is estimated by eliminating all potential sources of endogenous factors and information that might have been used by policy makers at the time of setting the rate (e.g. prior and forecasted inflation rates). Then, the exogenous component is used as an instrumental variable of the policy rate in order to estimate its effects on prices.

Our results suggest that changes in the monetary policy rate have negative effects on consumer price index (CPI). We also show that the influence on prices may differ between different types of goods and services. One reason is price regulations. We show that the monetary policy rate has a negative and significant impact on the prices of unregulated goods and services, while we do not find significant short-term effects on the prices of regulated goods and services. Furthermore, we find that the policy rate has instantaneous negative effect on the prices of food and beverages and personal care goods and services. Prices related to education react after one quarter. After three quarters, the negative effects on prices of alcoholic beverages and tobacco become statistically significant. The effects on the dining-out and accommodation services prices, the recreation, sports and culture prices, and the rents and housing service prices become statistically significant and negative after four quarters. After six quarters, the effects on clothing and footwear, healthcare, and household furniture and domestic services become statistically significant. But there are also prices such as those in the information and communication services that do not seem to be affected by the policy rate.

But the difference in the effect is not only related to timing. In terms of magnitude, after six quarters, the accumulated effect is stronger on prices of non-alcoholic food and beverages, which can reach up

to a 5.73% reduction, and for rents and housing can reach up to a 3.7% reduction. The effects on the dining-out and accommodation services prices reach a 2.93 reduction, on the healthcare prices reach a 2.85% reduction, and on the recreation, sports and culture prices reach a 2.83% reduction, after six quarters. The effects on prices of education services reach a 2.70% reduction, the effects on prices of personal care reach a 2.52% reduction, and the effects on prices of alcoholic beverages and tobacco reach a 2.03% reduction, after six quarters. Finally, for the same period, the effects on clothing and footwear prices reach a 0.71% reduction.

These results are relevant for two important reasons. First, we show that the policy rate might have limitations controlling the prices of some of the goods and services. Our results show that, if prices of regulated goods (e.g. fuel in Costa Rica) or of unregulated goods not affected by the rate (e.g. information and communication services) are the direct reason that the CPI inter-annual growth rate is increasing, the Central Bank will have limited power to control it. Second, the timing of the policy effect is also a relevant factor. We find that for prices of some goods and services (e.g. food and non-alcoholic beverages) might be affected immediately by the policy rate. But, there are prices of other goods and services (e.g. housing and rents) for which the effect will only be seen after four quarters. This can have implications also on the speed of the reaction of the central bank depending on the source of the inflation.

As for the price puzzle, we do not find evidence that heterogeneous effects can explain price increases when the policy rate increase. However, we show that depending on what drives inflation, the policy rate might have a large, small or even statistically insignificant negative effect on prices. However, if we add up the heterogeneous effects, the results are remarkably similar to the total effect. This suggests that some of the previous research that find price puzzle might be explained by other reason, probably as the presence of unobserved covariates or reverse causality.

The paper is organized as follows. In the next section, we present the background. In section 3, we discuss the literature. In section 4, we describe the monetary policy in Costa Rica. We present the data and the methodology in section 5 and 6 respectively. In section 7, we discuss the results and in section 8 we present the concluding remarks.

2. Background

In 2005, the Central Bank of Costa Rica's Board of Directors approved the inflation-targeting scheme in response to more than 40 years of two-digit inflation rates (Barquero-Romero, 2014). The inflation

target was set at 8% for 2007 and 6% for 2008 (BCCR, 2008). However, reductions in inflation started to become evident until 2009 due to the inflationary pressures of the 2008 crisis. Between August 2009 and September 2012, general inflation remained within the target range of 5%, as established by the Central Bank (BCCR, 2012). Later, in 2016, this target range (or range of tolerance) was set at 3% (BCCR, 2017). Since 2020, the Central Bank announces its inflation target range every quarter.

Before 2020, Costa Rica had managed to stay within its inflation target range. However, like many other countries, its economy was severely affected by the COVID-19 pandemic. In the second quarter of that year, Gross Domestic Product fell 7.6% inter-annually, and the unemployment rate increased to 24.4%. In this context, the Central Bank lowered the monetary policy rate three times, resulting in a cumulative decrease of two percentage points (p.p), reaching a historic low of 0.75% (BCCR, 2021). In 2021, global inflation began to rise due to various factors, such as the recovery of demand (BCCR, 2023a) and, consequently the problems of the restoration of global supply chains (BCCR, 2023c). The inter-annual inflation reached 12.13% in August 2022. In response to these rising prices, the Central Bank of Costa Rica increased the monetary policy rate in an unprecedented 8.25 p.p, bringing it to 9% in less than a year (BCCR, 2023).

As a small and open economy, prices in Costa Rica are also highly influenced by international prices (COMEX, 2012). In particular, the country imports commodities such as fuels, basic grains, and metals. Consequently, increases in international prices lead to inflationary pressures in the country's economy (CEPAL, 2022). Therefore, the exchange rate is also an important determinant of domestic prices. If the exchange rate rises (colones per dollar), this increase is passed on to the unregulated prices of imported goods (see González et al., 2008; Goldberg & Campa, 2010; Capistran et al., 2012; Orane, 2015).

In Costa Rica, there have been different exchange rate regimes. From 1983 until 2006, the Central Bank maintained a mini-devaluation regimen, which aimed to keep the real exchange rate relatively stable. However, as pointed out by the monetary authority, the cost of maintaining this currency stability led to high inflation rates (Alfaro et al., 2016). In October 2006, the Central Bank adopted a system of exchange rate bands. Under this framework, the monetary authority made an explicit commitment to defend the exchange rate, ensuring that it remained within the established exchange rate bands (Alfaro et al., 2016). This system allowed for greater currency price variability compared to the previous period, providing more flexibility to control price levels by setting inflation targets. Then, in 2015, the Central Bank implemented a managed floating exchange rate regime with the same aim of improving the effectiveness of monetary policy in controlling inflation (BCCR, 2015).

Currently, the flexible exchange rate period operates in conjunction with the inflation-targeting scheme.

It is also important to note that there are goods with regulated prices that are not be affected by the monetary policy rate. Regulated prices are determined by the Public Services Regulatory Authority. Regulated prices weight 13.94% of the consumer price index in the base year. Given the way that the regulations is set up, these prices are affected by changes in international prices, such as international oil prices, and the exchange rate.

Within this context, the anecdotal evidence suggests that monetary policy has been effective in Costa Rica after 2009. However, it is critical to comprehend the true magnitude of the effects of monetary policy, particularly of the monetary policy rate, on prices. As we discussed in this section, there are different factors in play that affect causal channels in different ways for different markets. With adequate estimations of the effects of the monetary policy rate on prices, policymakers can then adjust their decisions to avoid incurring unnecessary costs in order to keep inflation under control.

3. Literature review

The effects of the changes in the monetary policy rate have been extensively studied in the context of inflation. Theoretically, increases in the interest rates will lead to reductions in investment and consumption, which could lead to reductions in prices. However, the empirical findings in the literature are diverse. In the case of the United States, there are studies that indicate the presence of a Price Puzzle effect, meaning that increases in interest rates lead to higher prices in the economy (Bernanke et al., 2005; Christiano et al., 1999). However, in other studies, a negative relationship between interest rate and inflation is observed. Others find that the effect on prices is small (Estrella, 2014; Krusec, 2010). All these studies are characterized by employing the VAR model as their base methodology and using the variability of the monetary policy rate as an independent variable.

Romer & Romer (2004) point out that conventional measures of monetary policy have obvious flaws and suggest that the accuracy of estimates of the effects of monetary policy depends on the validity of the monetary policy measure used for the estimations. This is because changes in the policy rate can influence price levels, but changes in current and forecasted prices can also be a factor considered by monetary authorities when adjusting the policy rate. In other words, there is a two-way causal relationship between these variables. Given that monetary authorities respond to changes in inflation that can affect their objectives, temporary fluctuations in production, or political influences, and the

pursuit of other goals, the decisions to change monetary policy are endogenous (Nakamura & Steinsson, 2018). In light of this endogeneity issue, Romer & Romer (2004) proposed a new measure for the federal funds rate in the United States. In their approach, the proposal is to estimate the exogenous component of interest rate changes that are unanticipated. This variable is then used as the monetary policy shock measure in their estimations. The authors found that a 1 percentage point increase in the policy rate reduces inflation by 6% 48 months later, and this effect is highly significant.

Following Romer & Romer (2004), various studies in developed countries have estimated the effects of monetary policy on inflation. Some examples are Coibion (2012), who updated Romer y Romer's estimates for the United States; Champagne & Sekkel (2018) who applied this method for Canada; Cloyne & Hürtgen (2016) who focused on the United Kingdom and Murgia (2020) on the Eurozone. They find that the change in monetary policy increases inflation at the time of the shock, followed by a subsequent decrease.

This methodology has also been applied to Latin American countries. Da Costa Filho (2017) used this method for Brazil and, more recently, Rojas et al. (2022) applied this methodology in Argentina, Brazil, and Uruguay. They find a fall in economic activity in response to a policy rate increase. Rojas et al. (2022) find that a one percentage-point increase in interest rate reduces output up by -0.25 p.p. after a year of the shock (see panel B of figure 9). Da Costa Filho (2017) estimates that in response to the changes of monetary policy shocks, output declines, with a maximum impact of 0.5% until the fifth month after the shock. For inflation, they find that after the shock, it initially increases but then falls.

We adopt this methodology for the case of Costa Rica, a small and highly open economy, where prices are highly affected by international conditions. In Costa Rica, studies related to estimating the effects of monetary policy have primarily focused on production and transmission mechanisms, such as financial system interest rates and credit. The commonly used method is the VAR methodology, and as a measure of monetary policy, they have used the 6-month term stabilization bond rate (Flores et al., 2000; Mayorga & Torres, 2004; Durán & Esquivel, 2008; Castrillo et al., 2008; Barquero & Cendra, 2020), while others, like Barquero & Vásquez (2012) and Barquero & Mora (2015) utilize the passive basic rate or a monetary policy indicator constructed by Castro & Chaverri (2013). Flores et al. (2000) identify a price puzzle associated with the pass-through of exchange rate depreciation linked to the shock in interest rates. This was rectified by incorporating prices of primary goods into the model. Flores et al. (2010), Mayorga & Torres (2004), and Castrillo et al. (2008) find that an increase in the policy related interest rate is followed by a price puzzle, although not statistically significant. Barquero & Vásquez (2012) find that there is a credit transmission mechanism for private

banks; while Barquero & Mora (2015) and Barquero & Cendra (2020) find that changes in the policy related interest rate have an effect over the interest rates of the financial system in an eight- to twelve-month period. They also find that changes in the monetary policy rate are transmitted more intensely to savings rates than to loan rates.

Another issue that could explain the price puzzle and the different results in the empirical literature is that interest rates might have different effects in different markets and countries in terms of magnitude and timing. For instance, when facing higher interest rates, households might choose to reduce consumption of some of the goods and maintain consumption levels of others. Firms might react similarly in their investment decisions. We explore if this is the case in Costa Rica and discuss to what extent this could partially explain previous empirical results.

Additionally, having evidence about how the effects of monetary policy can vary across goods and services will be useful for the monetary authority. This can help understand if the policy rate can be useful as it might depend on what goods and services are driving the inflation shock. But it can also be useful to define timing of changes in the policy rate based on price increases expectations.

4. How the monetary policy rate works in Costa Rica

The transition to the inflation-targeting scheme led the Central Bank to consider the necessary steps for using the interest rate as the primary instrument of monetary policy. (Tenorio-Chaves, 2008). Between 2004 and 2006, the monetary policy rate was the 30-day investment rate within the Short-Term Investment System. From 2006 to 2007, the overnight investment rate became the monetary policy rate. In May 2008, the overnight interest rate started operating within a new system known as Central Direct. From May 2008 to June 2011, the active interbank market rate began to function as an indicator of the policy interest rate (Tenorio-Chaves, 2008). Currently, this indicator corresponds to the interest rate used by the Central Bank as a reference to guide the cost of one-day term operations in the liquidity market (BCCR, 2011).

The monetary policy rate guides the cost of operations in the integrated liquidity market within a corridor formed by the permanent credit and deposit facility rates (BCCR, 2011). These credit and deposit rates move simultaneously with the monetary policy rate. The purpose of this market is to provide the Central Bank a tool to stabilize the demand for liquidity by banking institutions at an interest rate level consistent with its objectives. This market is the mechanism through which permanent loans can be granted at a fixed interest rate (permanent credit facility rate). In addition, it

serves as the mechanism through which banking institutions can deposit funds with the Central Bank using the permanent deposit facility rate (Lankester, 2015). On average, during the period 2014-2019, transactions in the integrated liquidity market amounted to 239,816 million colones, while between 2020 and 2023, the average traded amount increased to 716,900 million colones. This demonstrates that there has been an increase in traded liquidity in this market in recent years, where the Central Bank rate guides the cost of the liquidity.

Currently, the permanent credit facility rate is 0.75 percentage points higher than the monetary policy rate, and the permanent deposit facility rate is 0.75 percentage points lower than the monetary policy rate. In this market, if there are entities willing to transact at rates higher or lower than the permanent facility rates, the Central Bank ensures that liquidity is offered or demanded at those rates. This ensures that the rates at which liquidity is transacted in the market remain within that specified limit. This is the way in which the monetary policy rate is transmitted to the rest of the rates in the financial system (Muñoz-Salas & Rodríguez-Vargas, 2017).

The Board of Directors of the Central Bank determines the monetary policy rate. This Board of Directors has seven members, including the President of the Central Bank, the Minister of Finance, and five directors, one of whom assumes the vice presidency of the bank. The Organic Law establishes that the Minister of Finance has a voice but no vote. His participation is not necessary to achieve the quorum for the meeting and typically does not actively participate in the Board of Directors meetings[2] (BCCR, 1995). The decision to change interest rates is a policy determined through a vote among the board members. The monetary policy rate is reviewed in accordance with a schedule approved by the Board of Directors at the beginning of each year, which is made public in advance (BCCR, 2023). The Board of Directors holds approximately eight meetings per year, dedicated to reviewing the monetary policy rate[3].

The Central Bank changes the monetary policy rate to achieve its objectives, primarily to maintain low and stable inflation, as stipulated in its Organic Law No. 7558 (BCCR, 1995). The Central Bank's monetary policy is forward-looking (BCCR, 2023). That is, since monetary policy measures take time to transmit to the economy and have the expected effect on inflation, they are based on the projected

[2] As an exception to the law, since February 28, 2019, the Minister of Finance maintains his right to vote and counts for quorum purposes until the appointment of the sixth additional member is ratified.
[3] Please refer to the following link for a comprehensive overview of the decisions made at each meeting. Additionally, the meeting schedule for the review of the monetary policy rate can be accessed at the following link.

evolution of inflation and its determinants. Monetary policy rate is adjusted so that the projected inflation aligns with the 3% target (BCCR, 2023).

The commitment to maintaining low and stable inflation by the Central Bank indicates that monetary policy contributes to the well-being of households (BCCR, 2017). Maintaining low inflation levels helps to minimize the loss of the national currency's purchasing power, especially among lower-income groups. This stability encourages decision-making regarding savings, investment, and consumption, in an environment with greater certainty, facilitating a more efficient allocation of productive resources. Consequently, it promotes economic growth and job creation (BCCR, 2017).

5. Data

Given the various policy regimes that Costa Rica has experienced, we concentrate our analysis on the period from the fourth quarter of 2006 to the second quarter of 2021. Inflation, GDP growth, and the monetary policy rate variables come from the Central Bank of Costa Rica (BCCR). We used inflation and growth forecasts from the World Economic Outlook (WEO). Additionally, we constructed an employment series using data from the Costa Rican Social Security Fund[4]. All our data is on a quarterly basis.

Our analysis starts in the fourth quarter of 2006 when the Central moved away from the mini-devaluation regime (a period of exchange rate parity adjustments) and transitioned to a more flexible exchange rate band regime (BCCR, 2007). During this period, the monetary policy rate played a significant role as it became the primary monetary policy tool employed by the Central Bank to achieve its inflation target.

In Costa Rica, inflation is measured through the Consumer Price Index (CPI), which is calculated by the National Institute of Statistics and Censuses (INEC, for its spanish acronym). The CPI allows us to measure the changes in the prices of a group of goods and services over time, which are representative of a typical household's final consumption basket. Currently, this basket includes 289 goods and services (INEC, 2021). INEC makes a distinction between prices of regulated and non-regulated goods and services. In total, there are 12 regulated good and services and 277 unregulated goods and services[5]. Goods and services with regulated prices are classified as such because their

[4] This employment series does not consider informal employment.
[5] The list of goods and their classification can be found in the following link.

prices are set by the Public Services Regulatory Authority[6]. These include fuel prices, public services like transportation, vehicle inspections, tolls, water, and electricity, among others. Unregulated prices include goods and services where the prices are collected in establishments (INEC, 2021).

INEC also categorizes the prices included in the CPI into 13 groups of goods and services, which include: food and non-alcoholic beverages; alcoholic beverages and tobacco; clothing and footwear; rent and housing services; furniture, household goods, and domestic services; healthcare; transportation; information and communication; recreation, sports, and culture; education; dining out and accommodation services; financial services and insurance[7]; and personal care[8] (INEC, 2021). We will use these groups in order to test if monetary policy can have different effects in different markets.

6. Methodology

As we discussed previously, one of the most difficult challenges is addressing the potential endogeneity between changes in the policy rate and prices. Theoretically, the policy rate affects prices, but also changes in price levels or expected changes in prices might affect the policy rate. In order to address this issue, we use an instrumental variable technique. The instrumental variable is constructed using the method developed by Romer & Romer 2004, who propose using the exogenous component of the variation in the policy rate by eliminating all potential sources of endogenous factors and information that might have been used by policy makers at the time of setting the rate. Once the instrumental variable is constructed, we follow the standard VAR approach in order to estimate accumulative effects over time.

6.1. New measure of monetary policy rate shock

To construct the instrumental variable for the interest rate, we used the strategy proposed by Romer & Romer (2004). We extracted the exogenous component of the monetary policy rate (*ir*), which is unanticipated. In this case, we estimated a regression of the change in the interest rate against a lagged interest rate, one lag of inflation, GDP growth, and inflation and growth forecasts. The exogenous component of the interest rate corresponds to the residual μ_t. The estimated regression is as follows:

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[6] Not all goods and services are regulated by ARESEP; one example is municipal services

[7] In this study, we did not include the effects of monetary policy on this price index because we did not have enough observations to conduct the estimation.

[8] The original name of this index according to the classification by the INEC is "Different good and services". However, in our study, we have chosen to refer to it as "Personal Care" as the majority of items can be included in this category.

$$\Delta ir_t = \theta_0 + \theta_1 ir_{t-1} + \Theta_2 \Delta ir_{t-1}$$

$$+ \sum_{k=-1}^{2} (\omega_k \pi_{t+k} + \delta_k D\pi_{t+k} + \beta_K \Delta y_{t+k} + \gamma_k D\Delta y_{t+k}) + \underbrace{\mu_t}_{\Delta ir_t^{exog}} \qquad (1)$$

where π represents inflation, y denotes the logarithm of GDP, $D\pi t + k$ denotes $\pi t + k - \pi t + k - 2$, and $Dyt + k$ denotes $yt + k - yt + k - 2$. The independent variables in the regression are included to explain changes in the policy interest rate that respond to changes in the economic cycle. In other words, central bankers take the decision to change the reference interest rate either to control market prices or to stimulate economic activity[9]. Such events make it predictable for economic agents the direction of the change in the interest rate. Therefore, the component μ_t includes everything that we cannot explain by changes in the macroeconomic environment.

The results are reported in table 1. Both the individual coefficients associated with inflation and production are not statistically significant. However, this aligns with the findings of Romer & Romer (2004). It is important to note that the coefficient with the highest t-statistic (0.188/0.134=1,4) corresponds to the forecast of inflation at the end of the same year. The importance of estimating this regression is that with the residuals we obtain our instrumental variable.

Table 1. Determinants of monetary policy rate changes (Δir_t)

Variable	Coefficient	Standard error
Constant (θ_0)	0.085	1.232
Lag of the monetary policy rate (ir_{t-1})	-0.093***	0.038
Lag of the monetary policy rate change (Δir_{t-1})	0.393***	0.095
Inflation variables (π)		
Lag	-0.003	0.238
Contemporary value	0.135	0.230
Forescast at the end of the same year	0.188	0.134
Forecast at the end of the following year	-0.127	0.138
Changes in inflation variables		

[9] For example, you can view the legal agreements that the Central Bank publishes when it changes the monetary policy rate on the following link.

Lag	0.062	0.170
Contemporary value	-0.052	0.177
Forescast at the end of the same year	-0.191	0.127
Forecast at the end of the following year	0.215	0.170
Output variables (*y*)		
Lag	-0.146	0.201
Contemporary value	0.130	0.189
Forescast at the end of the same year	0.025	0.177
Forecast at the end of the following year	-0.003	0.383
Changes in output variables		
Lag	-0.074	0.125
Contemporary value	0.133	0.135
Forescast at the end of the same year	-0.036	0.171
Forecast at the end of the following year	-0.315	0.445

Note: R^2=0.23, F-statistic = 4.40. Significance: * p<0.10, ** p<0.05, *** p<0.01.

Figure 1 shows the changes in the monetary policy rate (*IR*) and the estimated changes in the exogenous rate. Throughout our study period, we have 59 observations, where the monetary policy rate increased 13 times, remained unchanged 21 times and decreased 25 times. The exogenous rate changes indicate 19 increases and 40 decreases. In the figure, we show changes in both rates. The difference between the rate and its exogenous component reflects variations in anticipated changes that are explained by the independent variables in Table 1.

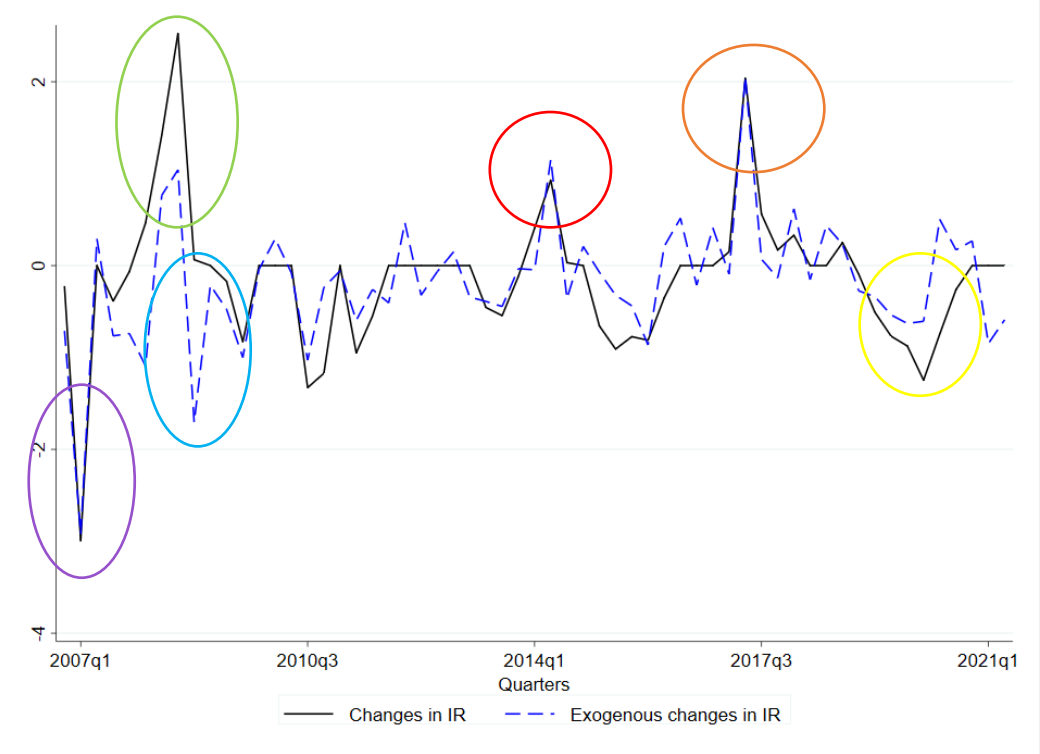
Sometimes t*he monetary policy rate increased in a similar way that the exogenous rate,* for instance in the second quarter of 2017 (orange circle). In this case, economic agents did not anticipate an increase in the monetary policy rate, so the entire change was unexpected, and therefore, exogenous. A similar change occurred in the first quarter of 2007 (purple circle), but in the opposite direction, where economic agents did not anticipate a reduction in the interest rate; thus, the entire change is also exogenous.

There are other events when *the monetary policy rate increased more than the change in the exogenous rate,* for instance in the third quarter of 2008 (green circle). In this case, economic agents expected an increase in the monetary policy rate, but not to such a significant extent. During that period, the Central Bank implemented a restrictive monetary policy by raising the policy interest rate

(BCCR, 2009). This year was marked by inflationary pressures, driven in part by larger-than-anticipated increases in the prices of commodities, including grains and fuels (BCCR, 2009b). A similar change occurred in the second quarter of 2020 (yellow circle), where Central Bank reduced the interest rate more that economic agents expected.

In other occasions, *the monetary policy rate increased less than the change in the exogenous rate.* These changes occurred in the second quarter of 2014 (red circle). In this case, economic agents were anticipating a reduction in the monetary policy rate, but instead, there was an increase. Another similar change but in the opposite direction was in the fourth quarter of 2008 (blue circle). In this case, individuals were anticipating the monetary policy rate to rise, but it did not.

Figure 1. Total and exogenous changes in the monetary policy rate



6.2. Empirical strategy

In this section, we present the empirical strategy to estimate the impacts of the monetary policy rate on prices. We first discuss the validity of the instrumental variables derived in the previous section. Then, we present the econometric specification.

6.2.1. Validity of the instrumental variable

An adequate instrumental variable should meet two conditions: relevance (association with the endogenous independent variable) and exogeneity (uncorrelated with the error term of the price regression). When estimating the effective F-statistic in the first stage of the regressions, we find that our instrumental variable is relevant. Table 2 presents the effective F-value following Montiel & Pflueger (2013) along with critical values for each horizon. We observe that the effective F-value is significantly larger than its critical value, indicating that our instrument is relevant. This is evidence that the instrumental variable (Δir_t^{exog}) is correlated with changes in the monetary policy rate. This correlation is intuitive because it is a construction of the instrumented variable itself.

Table 2. First stage indicators for the instrumental variable of the interest rate

Horizon	Montiel-Pflueger Effective F	Critical F value 5%
0	252.981	37.418
1	242.417	37.418
2	221.100	37.418
3	213.159	37.418
4	231.434	37.418
5	185.356	37.418
6	171.594	37.418

Note: Montiel-Pflueger's (2013) robust weak instruments test calculated for the instrumental variable of the interest rate.

Furthermore, according with Stock & Watson (2018), to demonstrate that our instrument meets the condition of intertemporal exogeneity, this instrument must be unpredictable. In line with the authors' perspective, the instrumental variable is considered exogenous if it cannot be explained by the lags of the model's variables. In our case, we conduct a regression where the instrumental variable is the dependent variable explained through lags of system variables (a lag of inflation, GDP growth and monetary policy rate). Table 3 presents the results of this regression. It is found that the coefficients are not statistically significant, and the R-squared value is very low, suggesting that our instrumental variable is not predictably (linearly) influenced by lags of system variables. Therefore, there is no evidence that our instrumental variable does not meets the condition of exogeneity.

Table 3. Linear predictability for the instrumental variable of the interest rate

	Coefficient	P value
Output growth (y_{t-1})	-0.031	0.358
Inflation (π_{t-1})	-0.105	0.326
Interest rate (i_{t-1})	-0.035	0.777
Constant (α)	-0.028	0.116
Observations	58	
R^2	0.052	
R^2 adjusted	-0.000	
Test F	0.574	
Prob > F	0.635	

Note: The table presents the F statistics and the R^2 of a linear regression of our instrument variable on lag of GDP growth, inflation and interest rate.

6.2.2. Econometric specification

Equation 2 presents the second stage of the regression:

$$\Delta Y_{t+h} = \alpha_h + \beta_h \widehat{\Delta ir_t} + \theta_{1,h} \widehat{\Delta ir_{t-1}}$$

$$\theta_{1,h} \Delta Y_{t-1} + \lambda_{1,h} \Delta X_{t-1} + \sum_l \gamma_{lh} \Delta ir_{t+h-l}^{exog} + \mu_{t+h} \qquad (2)$$

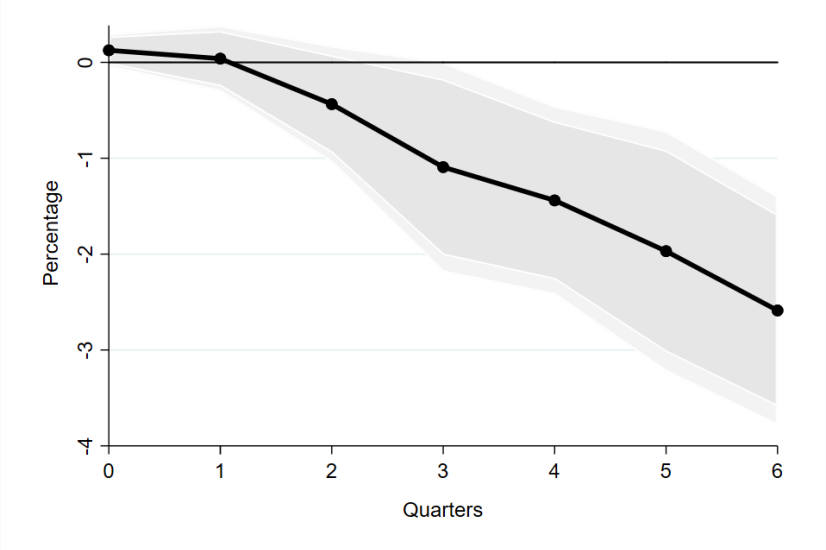
Where ΔY_{t+h} represents the accumulated change in the response variable for which we want to estimate the effect of the monetary policy rate. In this case, the variable Y represents the logarithm of Consumer Prices Index $\{ln(cpi)\}$. The variable $\widehat{\Delta ir_t}$ represents changes in the monetary policy rate, which has already been instrumentalized by its exogenous component. The coefficient β_h corresponds to the effect of the monetary policy rate on the response variable. These coefficients are used to construct impulse response functions that will be shown in the results. ΔY_{t-1} represents a lag of the response variable, ΔX_{t-1} is a vector of control variables that includes a lag of inflation, GDP, and employment. Additionally, Δir_{t+h-l}^{exog} is included in the regression. This variable is included to control for changes in monetary policy between time t and $t+h$, to avoid attributing an effect to the β_h coefficient that is not associated with changes in monetary policy at time t.

Finally, it is important to mention that regression 2 is estimated for each horizon h in which the effect of the monetary policy rate on the outcome variable is to be observed. For example, if the horizon is $h = 2, \beta_2$ would indicate the effect of a 1 percentage point (p.p) increase in the monetary policy rate on inflation two quarters after the change in monetary policy.

7. Results

Figure 2 shows the impulse responses to a 1 percentage point (p.p) contractionary monetary policy rate shock. We found that a 1 percentage point increase in the monetary policy rate has a negative effect on inflation. This result is significant two quarters after the change in the monetary policy rate. The effect is persistent up to 6 quarters later and reaches up to 2.84%.

Figure 2. Effect of the interest rate on total CPI



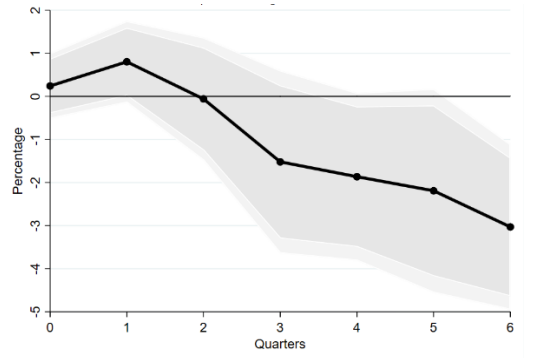
7.1. Regulated versus non-regulated goods and services

The Consumer Price Index contains regulated and non-regulated goods and services. One might expect that prices of regulated goods and services would not be affected by changes in the monetary policy rate. We estimate the effects of the policy rate on these two different types of goods and services. On one hand, Panel A of Figure 3 shows that there is no effect of the monetary policy rate on the prices of regulated goods and services. This result is intuitive and expected, as these prices are regulated by public institutions in the country.

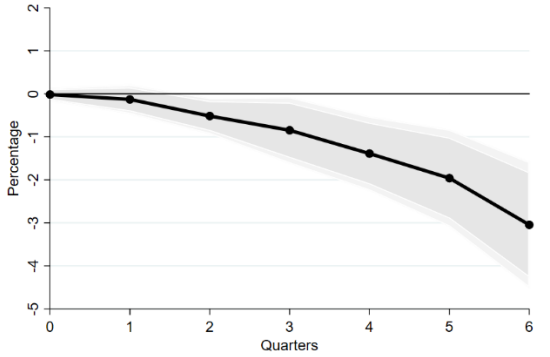
On the other hand, Panel B of Figure 3 shows the monetary policy rate affects prices of non-regulated goods and services, which are set by market forces. The response of inflation calculated with the index of prices for non-regulated goods and services is significant from the second quarter onwards, and its effect is persistent. When the monetary policy rate is changed by one percentage point, we find a negative effect of up to 3 percentage points on the sixth quarter.

Figure 3. Effect of the interest rate on the CPI of regulated and non-regulated goods and services

Panel A. Effect of interest rate on the CPI of regulated goods and services



Panel B. Effect of the interest rate on the CPI of no-regulated good and services



7.2. Results on prices of unregulated goods and services by groups

Considering that the monetary policy rate has no significant effects on the prices of regulated goods and services, we focus on the effects on the different components of the Consumer Price Index for unregulated goods and services (see Figure 4). We observe that the monetary policy rate affects prices of some groups of goods and services but, for other groups, prices remain unaffected. Within the group of prices that change the most due to variations in the monetary policy rate are those related to food and non-alcoholic beverages (Panel A), alcoholic beverages and tobacco (Panel B), and dining out and accommodation services (Panel C). The cumulative effects reach 5.73%, 2.03%, and 2.93% reductions, respectively, 6 quarters after a 1 p.p increase in the monetary policy rate.

These effects are substantial in magnitude. These indexes consider prices of cereals (oats, flour, wheat), pasta, meat, milk, beer, prepared rice, soft drinks, accommodation services, among others. As one would expect, the demand of these goods is sensitive to income shocks. So, an increase in the monetary policy rate discourages household consumption, leading to a deceleration in the demand for these goods, causing a decrease in prices.

Increases in the monetary policy rate also have negative effects on the price index of education (Panel D) and the price index of recreation, sports, and culture (Panel E). The cumulative effect 6 quarters after the change in the monetary policy rate is 2.70% and 2.83%, respectively. In the case of education, the effect on the price index becomes significant from the first quarter after the change in the monetary policy rate. In the country's education sector, the periodicity of enrollment in language courses and universities (mainly private) allows for adjustments in prices in the short term. For the recreation, sports, and culture price index, we can observe significant effects from the second quarter after the change in the monetary policy rate. This index includes prices for gym services, cinema and theater tickets, vacation packages, and products such as books, newspapers, office materials, among others, also highly affected by income shocks.

The effects of the monetary policy rate on the consumer price index for rents are also negative (Panel F). This effect becomes negative and significant by the fourth quarter, i.e., one year after the change in the policy rate. This result is intuitive as rental prices typically have a lag until contract renegotiations. The effect can reach -3.70% six quarters after the change in the policy rate. Also, the effects of the monetary policy rate on personal care reach -2.52% six quarters after the rate change (Panel G). However, the effects can be observed from the first quarter in prices. This index includes prices for personal care goods such as deodorants, makeup, facial cream, among others, making them goods that can relatively easily adjust to changes in the rate.

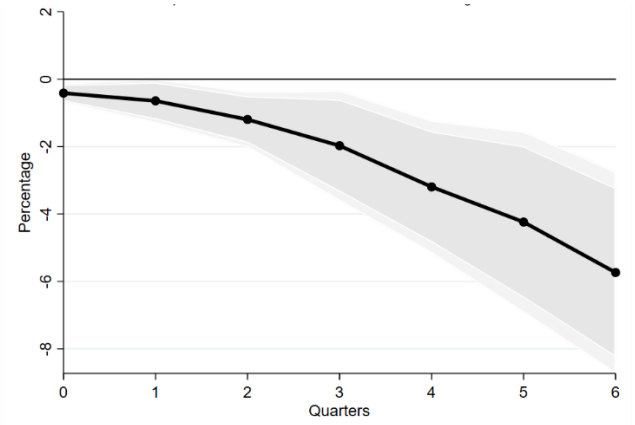
There are price indices such as the clothing and footwear price index (Panel H) and the healthcare price index (Panel I) where the effects of the monetary policy rate can be observed 5 quarters later (one and a half years after). The effects are -0.71% and -2.85%, respectively. The clothing and footwear price index includes prices of items such as shirts, shoes, among others, while the healthcare price index includes prices of medications, vitamins, surgery services, X-rays, among others. Based on our results, it appears that the prices of these goods take some time to adjust.

A similar finding indicates that changes in the monetary policy rate have a significant impact on the prices of furniture, household goods, and domestic services 6 quarters after the rate change (Panel J). The effect can reach up to -1.98% a year and a half later.

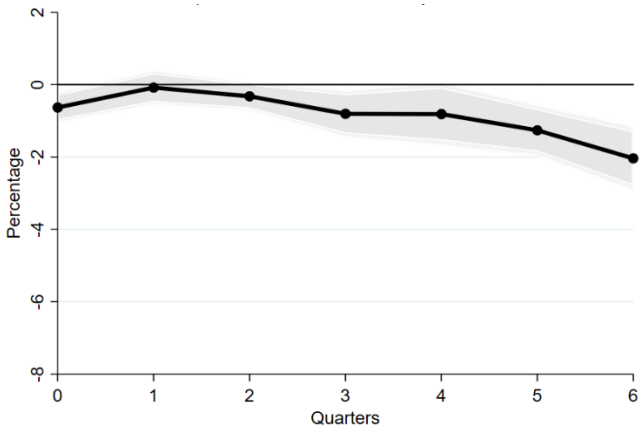
Lastly, the information and communication price index does not respond to changes in the monetary policy rate (Panel K). The effects are negative but not significant.

Figure 4. Effects of the interest rate on the CPI across different goods and services of consumption

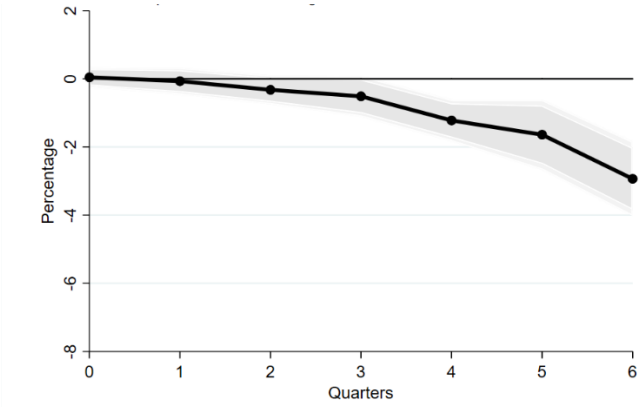
Panel A. Response of the CPI for food and non-alcoholic beverages



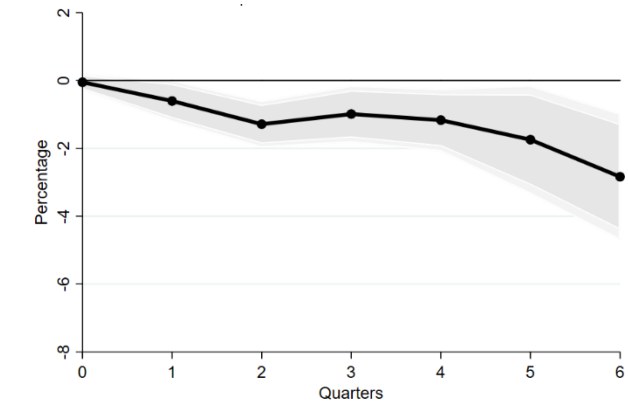
Panel B. Response of the CPI for alcoholic beverages and tobacco



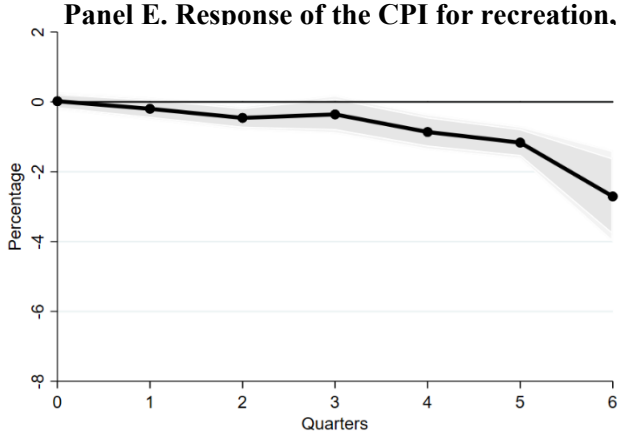
Panel C. Response of the CPI for dining out and accommodation services



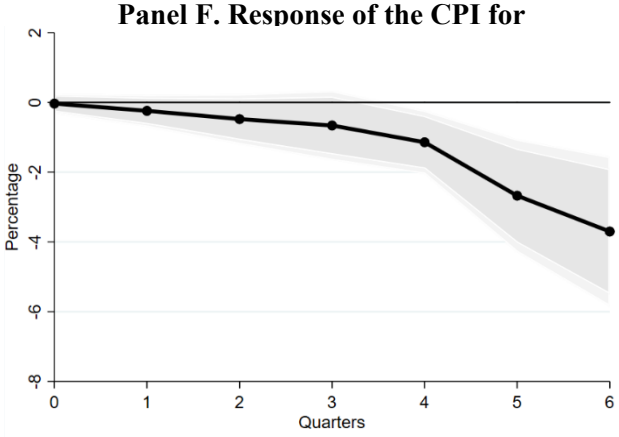
Panel D. Response of the CPI for education



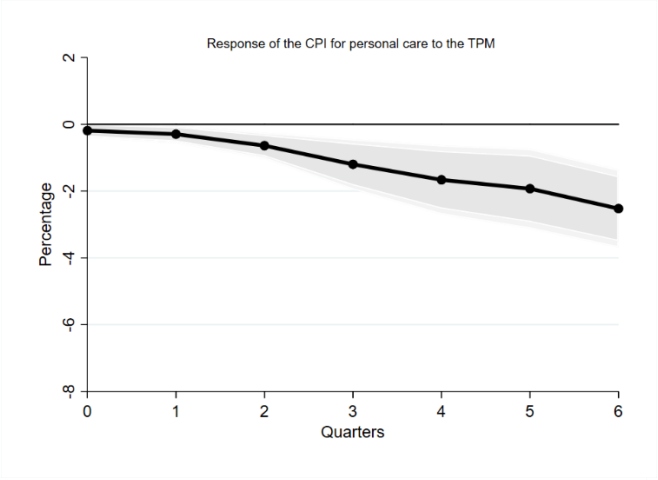
Panel E. Response of the CPI for recreation,



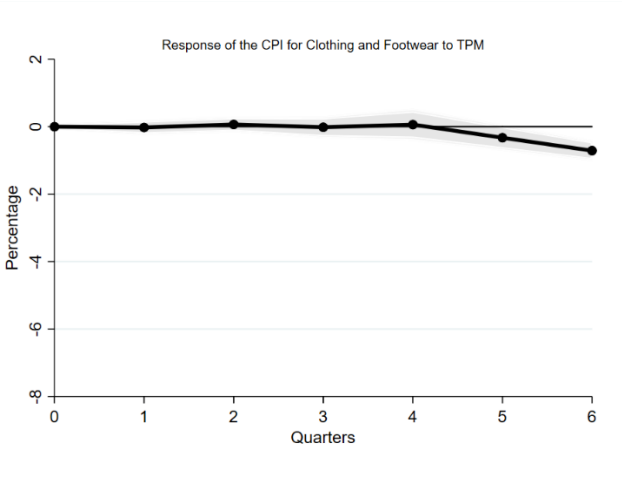
Panel F. Response of the CPI for



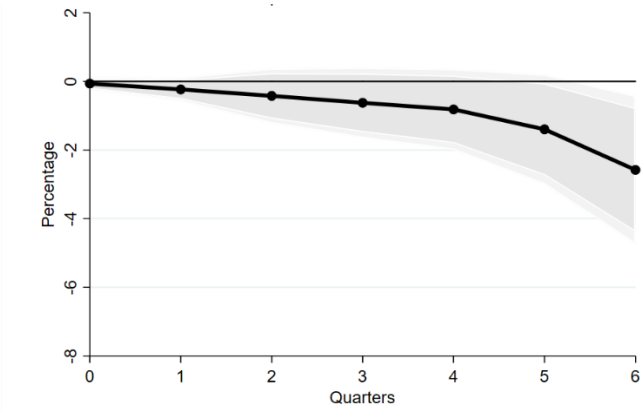
Panel G. Response of the CPI for personal care



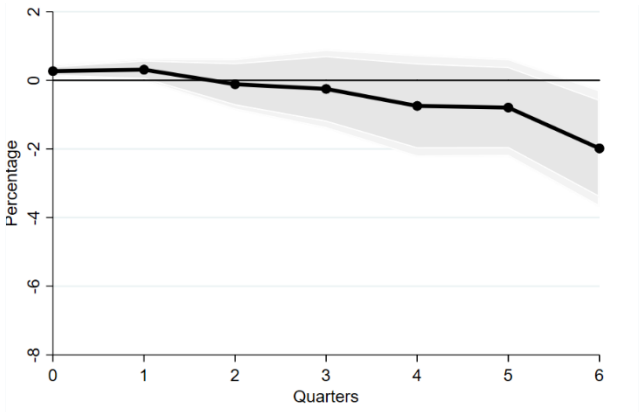
Panel H. Response of the CPI for clothing and footwear

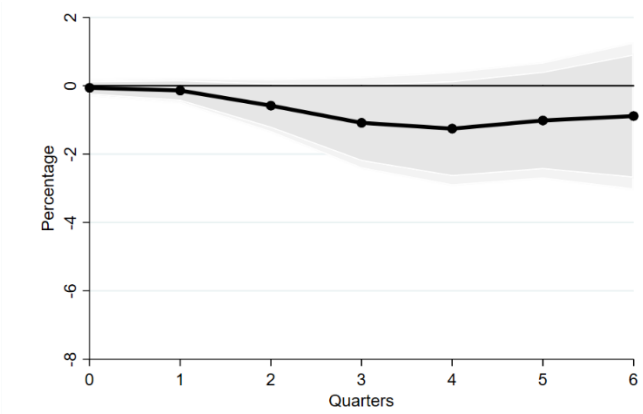


Panel I. Response of the CPI for healthcare



Panel J. Response of the CPI for furniture, household goods, and domestic services





As a summary of the effects, we present Table 4. Food and beverages not only have the largest accumulated effect over six quarters but also the reaction to the change of the policy rate is instantons. Personal care and education react also almost instantaneously and the impacts are above 2% after six quarters. However, rents and housing and dining and accommodations only react after four quarters but the magnitude of the accumulated effect after six quarters is around 3%. However, clothing and footwear and information and communication services are barely or not affected and, only, after six quarters.

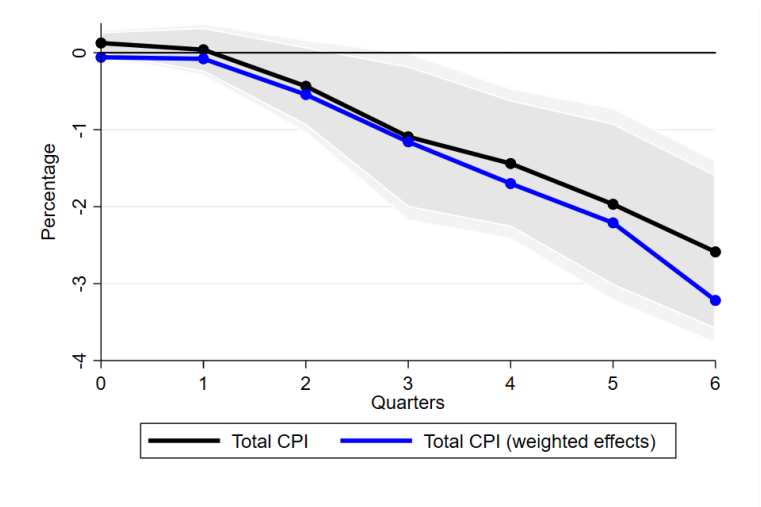
Table 4: Ranks of the effects by period when it becomes statistically significant and by magnitude of the accumulated effect after six months

Rank by timing of the effect		Rank by magnitude of the effect after six quarters	
CPI	Number of quarters after shock when CPI becomes statistically significant	CPI	Magnitude of the effect of the shock after six quarters
Food and beverages	0	Food and beverages	-5.73%
Personal care	0	Rents and housing	-3.70%
Education	1	Dining and accommodation	-2.93%
Alcoholic beverages and tobacco	3	Healthcare	-2.85%
Dining out and accommodation	4	Recreation, sports and culture	-2.83%
Recreation, sports and culture	4	Education	-2.70%
Rents and Housing	4	Personal care	-2.52%
Clothing and footwear	6	Alcoholic beverages & tobacco	-2.03%
Healthcare	6	Furniture and domestic services	-1.98%
Furniture and domestic services	6	Clothing and footwear	-0.71%
Information and communication	Insignificant	Information and communication	Insignificant

7.3. Considering heterogeneous effects on headline inflation

Figure 5 shows that our estimation of heterogeneous effects for each of the consumer price indices is consistent with the estimation of the effect of the monetary policy rate on total consumer price index. We can see that the estimation of the weighted heterogeneous effects using the weights of each of the CPI indices (blue line) falls within the confidence intervals of the estimated effects for the total consumer price index (black line).

Figure 5. Effects of the interest rate on the total CPI and total CPI (as the weighting of heterogeneous effects).



8. Conclusions

The estimation of the effects of monetary policy on different economic indicators has been an extensively studied topic in the literature. More recently, the focus in the literature has been on making these estimations as unbiased as possible. To do so correctly, we proposed applying the method suggested by Romer & Romer (2004), estimating exogenous changes in the monetary policy rate that cannot be explained by the economic context (whether inflation or economic growth). We use this exogenous component as an instrumental variable in our regressions, following the method of Rojas et al. (2022).

Our main findings show that changes in the monetary policy rate have negative effects on inflation. These effects are larger than those documented in previous research for Costa Rica using other methodologies, similar to what Romer & Romer (2004) find for the US. We also explore that the effects on prices might be different for different types of goods and services. One reason is price regulations. We show that the monetary policy rate has a negative and significant impact on the prices of unregulated goods and services, while we do not find significant short-term effects on the prices of regulated goods and services. This implies that if regulated prices are the main source of variation in the consumer price index, the monetary policy rate will have limited effects controlling them. This result is not only relevant for Costa Rica but also for other countries with price regulation policies.

Furthermore, even when focusing on unregulated prices, the monetary policy rate can have different impacts, in terms of magnitude and timing, on prices of different goods and services. The policy rate has instantaneous negative effect on the prices of food and beverages and personal care goods and services. Prices related to education react after one quarter. After three quarters, the negative effects on prices of alcoholic beverages and tobacco become statistically significant. The effects on the CPI for dining out and accommodation services, the CPI for recreation, sports and culture, and the CPI for rents and housing services become statistically significant and negative after four quarters. After six quarters, the effects of the CPIs for clothing and footwear, the CPI for healthcare, and the CPI for furniture household goods and domestic services become significant. But there are also prices such as those for information and communication services that do not seem to be affected by the policy rate.

But the difference in the effect is not only related to timing. In terms of magnitude, after six quarters, the accumulated effect is stronger on the prices of non-alcoholic food and beverages, which can reach up to -5.73%, and for rents and housing can reach up to -3.7%. The effects on the CPI of dining out and accommodation services reach -2.93, on the CPI of healthcare reach -2.85% and on the CPI for recreation, sports and culture reach -2.83% respectively, after six quarters. The effects on prices of education services reach -2.70%, the effects on prices of personal care reach -2.52%, and the effects on prices of alcoholic beverages and tobacco reach -.2.03%, after six quarters. Finally, for the same period, the effects on clothing and footwear prices reach -0.71%.

These results are relevant for two important reasons. First, in terms of the Central Bank's objective of controlling inflation, we show that the policy rate might have limitations controlling the prices of some of the goods and services. Our results show that, if prices of regulated goods (e.g. fuel in Costa Rica) or of unregulated goods not affected by the rate (e.g. information and communication services) are the direct reason that the CPI inter-annual growth rate is increasing, the Central Bank will have limited power to control it. But, the timing of the policy effect is also a relevant factor. This paper shows that for some goods and services (e.g. food and non-alcoholic beverages) might be affected immediately by the policy rate. But, there are other goods and services (e.g. housing and rents) for which the effect will only be seen after four quarters. Therefore, the authority can plan in advance depending on what can drive inflation in the future.

Second, the monetary authority can plan better the movements in the policy rate such that the effects on production and employment are minimized. If for instance, the monetary authority expects that food and non-alcoholic beverages will be driving inflation in the future, it can wait until prices actually increase as the effect of the policy will be instantaneous. So, rates can be kept lower for a

longer period of time. However, if they expect that future inflation will be driven by housing and rents, then the policy will have to be affected before the increases in prices are seen.

As for the price puzzle, we do not find evidence that heterogeneous effects can explain price increases when the policy rate increase. However, we show that depending on what drives inflation, the policy rate might a large, small or even statistically insignificant effect on prices. This suggests that some of the previous research that find price puzzle might be explained by other reason, probably something that might be linked to the presence of unobserved covariates or reverse causality.

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