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LECTURAS DE ECONOMÍA

Versión preliminar

Supply Shocks and Monetary Policy: The Case of the Colombian Economy (2003-2023)

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El presente artículo ha sido aprobado para ser publicado en Lecturas de Economía 104. Sin embargo, se trata de una versión preliminar, la cual está sujeta a cambios asociados al proceso editorial de la revista. Próximamente se contará con una versión definitiva.

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Supply Shocks and Monetary Policy: The Case of the Colombian Economy (2003-2023)

Carlos David Alape Gamez[1]

Abstract: This article aims to analyze the effects of a negative supply shock on expected inflation, the intervention rate, and gross domestic product during the period 2003 to 2023 in Colombia. A vector autoregressive multivariate time series model is employed as an empirical approach. The research indicates that after a negative supply shock, there is a misalignment in the formation of economic expectations, leading to an increase in the monetary policy rate. This, in turn, has a detrimental impact on the evolution of the gross domestic product, while failing to effectively anchor the expectations of economic agents.

Keywords: Supply shocks, monetary policy, econometrics.

JEL classification: E52, E43, E31, D84.

Choques de oferta y política monetaria: el caso de la economía colombiana (2003-2023)

Resumen: El objetivo de este artículo es analizar cómo un choque negativo de oferta impacta la inflación esperada, la tasa de intervención y el producto interno bruto, durante el periodo de 2003 al 2023 en Colombia. Como estrategia empírica, se emplea un modelo de series de tiempo multivariantes del tipo vectorial autorregresivo. Se encuentra que, tras este choque, se produce un desajuste en la formación de las expectativas económicas, conllevando a un aumento de la tasa de política monetaria, afectando negativamente la evolución del producto interno bruto, sin lograr anclar las expectativas de los agentes económicos eficientemente.
Palabras clave: Choques de oferta, política monetaria, econometría.

Chocs d'offre et politique monétaire : le cas de l'économie colombienne (2003-2023)

Résumé L'objectif de cette étude est d'analyser l'impact d'un choc d'offre négatif sur l'inflation attendue, le taux d'intervention et le produit intérieur brut, au cours de la période de 2003 à 2023 en Colombie. À titre de stratégie empirique, un modèle de série chronologique multivariée de type vecteur autorégressif est utilisé. L'étude constate qu'après ce choc, il y a un déséquilibre dans la formation des anticipations économiques, conduisant à une augmentation du taux directeur, affectant négativement l'évolution du produit intérieur brut, sans parvenir à ancrer efficacement les anticipations des agents économiques.

Mots-clés : Chocs d'offre, politique monétaire, économétrie.

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Introduction

The New Neoclassical Synthesis (NNS), or New Macroeconomic Consensus (NMC), emerged in the latter half of the 20th century as a cornerstone of contemporary macroeconomic analysis. This framework integrates key relationships between aggregate supply and demand, nominal and real interest rates, and inflation targeting, particularly through the application of the Taylor Rule (García & Perrotini, 2014). Several countries, including the United Kingdom, New Zealand, and Canada, have adopted inflation targeting as part of their stabilization programs, viewing it as an effective mechanism for maintaining low and sustainable inflation (Ramos-Francia & Torres, 2005). In this context, monetary policy serves as the primary instrument for ensuring inflation control.

When supply shocks occur, monetary authorities must navigate the trade-off between inflation and output (Bernanke et al., 2001). However, the central bank can influence inflation by addressing the second-round effects of these shocks, especially if they disrupt economic expectations. In Latin American countries, such as Colombia, price indexation and inflation inertia amplify the likelihood of inflation persistence (Vargas et al., 2010). Additionally, a lack of central bank credibility can lead to an increase in inflation expectations, as agents may doubt the bank's commitment to inflation control (Uribe, 2011).

A key element of inflation targeting is the increased credibility of monetary policy announcements, which reinforces central banks' commitment to price stability. This credibility makes policymakers more resilient to negative supply shocks, as the formation of economic expectations becomes less sensitive to these shocks, which are often viewed as temporary in advanced economies. Nevertheless, this may not hold the same validity in emerging economies, such as Colombia.

In Latin America, inflation expectations are more prone to negative supply shocks, often persisting due to second-round effects that misalign inflation expectations (Gómez & Julio, 2000). In response, monetary authorities may tighten intervention rates to align with inflation targeting. However, the effectiveness of this approach remains questionable, given the nature of these shocks (Angeriz, 2008).

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This research explores the role of monetary policy in managing negative supply shocks. It aims to offer an econometric analysis to assist central banks and policymakers in understanding the impact of these shocks on expected inflation, the intervention rate, and GDP. Specifically, the study estimates impulse-response functions using a vector autoregressive (VAR) model and identifies supply shocks by examining food and regulated product inflation in Colombia from the third quarter of 2003 to the fourth quarter of 2023, following Díaz Casas (2023).

This article is divided into five sections: an introduction, a literature review, a methodological framework outlining the data and econometric model, conclusions, and recommendations for policy actions.

I. Reference Framework

A. Theoretical literature

A subset of macroeconomic theorists has focused on advancing macroeconomic theory by analyzing business cycles through the lens of non-monetary factors that influence output, inflation, and employment. Within this framework, real business cycle (RBC) theory explicitly assumes the neutrality of money, meaning that monetary variables have no effect on real variables such as output, employment, or investment, either in the short or the long run. Instead, RBC theorists argue that fluctuations in economic output around its equilibrium growth path are driven primarily by technological innovations or real supply shocks, which directly affect productivity (Blanchard et al., 2012).

According to Romer (2006), RBC models are grounded in rigorous microeconomic foundations, involving representative agents—such as consumers and producers—who optimize utility and profits intertemporally. These models rely on assumptions such as perfect competition, flexible prices, complete information, and full factor mobility, which ensure that markets clear continuously and that monetary policy is irrelevant for real economic outcomes.

However, the universal applicability of these assumptions has been challenged, particularly in the context of small open economies like Colombia, which are highly sensitive to external shocks. In these economies, price rigidities and imperfect competition are prevalent, leading to deviations from the RBC framework. Under these conditions, money is no longer neutral, and monetary shocks can have persistent effects on real variables, highlighting the importance of monetary policy in macroeconomic stabilization (Lavoie, 2006).

The existence of market imperfections and monetary non-neutrality underpins the need for monetary policy to manage the economic cycle. Such policy is crucial in addressing deviations in output arising from both demand and supply shocks, as central banks may face a trade-off between inflation and output depending on the nature and magnitude of the disturbance. For instance, in the case of negative supply shocks, inflationary pressures increase while output contracts, intensifying this trade-off (Blanchard et al., 2012).

This forms part of the New Neoclassical Synthesis or New Macroeconomic Consensus (NMC), which integrates various economic theories into a single model. The NMC considers the role of the intervention interest rate, the temporal dynamics of shocks, and their impact on macroeconomic variables in economies with price rigidities, monetary non-neutrality, and market imperfections, like Colombia.

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The NMC emerged from dominant macroeconomic paradigms in the latter half of the twentieth century (Canzoneri et al., 2003). Its prominence in contemporary macroeconomics stems from its incorporation of three key elements: the rational expectations extension of the IS-LM model (Sargent & Wallace, 1976), nominal rigidities through Calvo-like prices (Calvo, 1983), and the classical RBC model's economic structure (Kydland & Prescott, 1982).

In essence, the NMC blends the RBC model with the concept of monopolistic competition and high price adjustment costs, drawn from the Keynesian tradition. It adds nominal rigidities, which the RBC model does not account for, creating a synthesis between classical and Keynesian ideas.

Moreover, a crucial theoretical implication of the NMC is the role of central bank credibility in shaping expectation formation. In forward-looking models, such as those incorporating rational expectations and Calvo pricing, agents' behavior is influenced not only by current economic conditions but also by their expectations about future policy. The credibility of the central bank enters implicitly into the expectation functions through parameters related to inflation inertia or perceived policy consistency. A highly credible central bank is more likely to anchor expectations, reducing the inflationary impact of adverse supply shocks, while a lack of credibility can lead to amplified responses in inflation expectations and output volatility (Clarida et al., 1999; Woodford, 2003).

A critical aspect of the NMC model is the monetary authority's credibility. When firms trust that the monetary authority will anchor inflation expectations around a long-term target, they are less likely to adjust prices in response to short-term shocks. This stability in prices means that, in the short run, output and employment are driven by aggregate demand (Goodfriend & King, 1997).

In the New Macroeconomic Consensus (NMC), fluctuations in output and employment are primarily explained by aggregate demand shocks, which may originate from exogenous factors—such as shifts in consumer confidence or investment sentiment—or from monetary disturbances, like unexpected changes in interest rates or money supply. These shocks cause the economy to deviate from its natural level of output in the short run due to the presence of nominal rigidities.

However, unlike in models with monetary neutrality, the central bank plays an active role in stabilizing the economy. Since firms do not continuously adjust their markups to maximize long-term profits, the intervention interest rate affects aggregate demand by influencing consumption and investment decisions. In this framework, the central bank does not generate the shocks but rather responds to them using interest rate adjustments to guide observed output back toward its potential level (Mankiw, 2006).

In this framework, the nominal interest rate becomes the central tool of the monetary authority. It regulates inflation and influences output and employment. In the short run, due to price rigidities, output is primarily determined by aggregate demand, and the effects of supply shocks on inflation are limited. During this phase, the role of the central bank may be less pronounced in response to supply disturbances, as the output does not immediately adjust to potential changes.

However, in the long run, as prices begin to adjust, supply shocks can lead to persistent inflationary pressures and misalignments between actual and potential output. At this stage, monetary policy becomes essential to stabilize the economy. By adjusting the intervention

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interest rate, the central bank can steer aggregate demand closer to the new potential output, thus guiding inflation back to target levels and reducing output volatility.

The Keynesian view of demand-driven output in the short term is thus complemented by the classical RBC perspective in the long run. The interest rate influences aggregate demand, wages, and firm markups (Kydland & Prescott, 1982). A reduction in the intervention rate boosts aggregate demand, raises firms' marginal costs, and reduces markups, stimulating production. This mechanism functions similarly to a fiscal stimulus in RBC models (Romer, 2006).

Consequently, the intervention rate serves as a key instrument for managing inflation and output, especially in the presence of price rigidities (Blanchard et al., 2012). The NMC's monetary policy framework is crucial for minimizing deviations in output and inflation from their equilibrium paths, aligning with the inflation targeting regime, which aims to maintain long-term price stability and reduce welfare losses from inflation-induced distortions (Goodfriend & King, 1997). Inflation targeting introduces the intervention rate as a critical tool for managing economic imbalances. This framework is supported by three factors: it enhances the credibility of the monetary authority, minimizes inflation's destabilizing effects, and grants the central bank discretionary power to stimulate or moderate real economic activity (Mishkin, 2000).

Understanding the NMC is crucial for appreciating its conceptual contributions to economic theory. It posits that when prices are rigid in the short term, a positive aggregate demand shock need not harm real economic activity. Nevertheless, a negative supply shock presents a different scenario. The monetary authority must navigate the trade-off between lower inflation and slower economic growth, potentially leading to stagflation—when economic activity contracts, and prices rise simultaneously (Canzoneri et al., 2003).

Models within this framework have proposed new perspectives on the temporary effects of monetary policy, such as changes in economic activity and the duration of those effects. These models assume that price, employment, and output adjustments occur with a lag.

The NMC has become a dominant framework in contemporary macroeconomic analysis, emphasizing the importance of monetary policy in managing aggregate demand and supply shocks. Its focus on price rigidities and short-term fluctuations makes monetary policy particularly relevant for stabilizing output and employment during economic imbalances. However, in the case of negative supply shocks, monetary policy has its limitations, and it is critical to consider its role when analyzing economic cycles (Blanchard et al., 2012).

In accordance with the NMC, monetary policy reactions to economic imbalances should stabilize the observed output near its potential, while focusing on managing aggregate demand. This holds particular significance considering the constraints of monetary policy in addressing supply-side shocks. The NMC model integrates classical and Keynesian macroeconomic principles, creating a comprehensive framework for understanding the role of monetary policy in small open economies like Colombia. Its emphasis on the non-neutrality of money, market imperfections, and price rigidities highlights the need for careful monetary interventions, particularly during periods of economic instability. The inflation targeting framework, supported by credible monetary authorities, provides a vital tool for maintaining economic stability, even in the face of challenging supply shocks.

B. Empirical literature

The academic literature examining the transmission of economic policy and supply shocks reveals some findings regarding their dynamics across various economies. Hence, the

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NMC approach has captured the attention of numerous theorists, making it a valuable contribution for this research.

Zuccardi (2002) considers how negative supply shocks affect output in Colombia and Peru, based on the estimation of a VAR model using the Blanchard and Quah (1988) restriction. As a proxy variable for these shocks, the author examines regulated and food inflation and the terms of trade, and concludes that these shocks generate inflationary pressures and output reductions.

Lindé (2003) studied the relationship between fluctuations in the cycle and changes in the stance of the intervention rate set by the monetary authority to validate whether changes in the intervention rate respond proportionally to changes in prices in the Swedish economy. For this purpose, the estimation of a VAR model was used, considering exogenous and endogenous shocks on the cycle. Among the main results, it is highlighted that external shocks to the performance of economic activity generate higher cycle volatilities, taking into consideration the actual short-term impact that monetary policy can have on a small economy that is open to the international market.

Quintero (2015) examines the influence of the intervention rate on five Latin American countries using a structural vector autoregressive (SVAR) model. The study reveals that a 0.01 increase in the intervention rate leads to a decline in real GDP, a statistically significant effect that materializes two years following a positive demand shock, but not in the case of supply shocks. Moreover, the findings underscore the effectiveness of monetary policy as a tool for controlling inflation in the presence of demand shocks—an effect not observed when inflation arises from supply-side disturbances.

Frías et al. (2016) examine the impact of supply shocks on production levels, fluctuations in overall oil prices, the intervention rate, and output in Spain during the period 1981-2013. To this end, they used a multivariate time series model of the VAR type. Among the main results, it is highlighted that, in the presence of a 0.01 negative oil shock, a 0.25% reduction in output is observed in the fourth quarter, in addition to a positive impact on inflation.

Using the observed energy price inflation as a proxy, Parra et al. (2016) study the impact of negative aggregate supply shocks on output, the intervention rate, and the formation of economic expectations about expected inflation. They rely on the estimation of a VAR model during 2000-2016 and conclude that when the intervention rate contracts due to supply shocks, output decreases, raising agents' expectations of rising inflation, and significantly impacting the GDP of the economy.

Finally, Díaz Casas (2023) analyzes the impact that a supply shock in the Colombian economy may have on employment, the inflation-output gap, and monetary policy. He employs a VAR model as a proxy variable for these shocks in the international WTI benchmark oil prices. One of the key findings is that when supply shocks occur, the economy experiences actual and severe effects. This includes both a positive rise in the gap between inflation and employment and a negative impact on GDP. In turn, monetary policy exhibits a positive and strong reaction during various periods.

II. Data

The monetary authority's response to negative supply shocks is crucial, as it impacts key economic variables in Colombia. Inflation rises reduce household purchasing power, while high

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intervention rates used to control inflation affect overall welfare. According to Frías et al. (2016), inflation in recent years has been driven by supply shocks, which cannot be addressed solely through restrictive monetary policies.

Despite this, Colombia's central bank has maintained a policy aligned with the inflation targeting framework proposed by the NMC, consistently raising the intervention rate to bring observed and expected inflation toward the long-term 3% target. This reflects persistent inflation and difficulties in anchoring expectations.

This research conducts a descriptive and econometric analysis of key economic variables in Colombia from the third quarter of 2003 to the fourth quarter of 2023. It uses food and regulated product inflation as a proxy for aggregate supply shocks, as this measure is less influenced by the economy's endogenous behavior. Additionally, 12-month expected inflation, the intervention rate, and GDP growth are analyzed.

Colombia's economy is particularly relevant for this study, given the high levels of observed and expected inflation during the last two decades, especially in periods of crisis such as 2007-2008, 2015-2016, and 2021-2022. During these times, negative supply shocks, indicated by rising food and regulated product inflation, are closely linked to higher inflation expectations, increased intervention rates, and slower GDP growth.

The study uses data from Colombia's central bank (BanRep), including inflation figures for total and food prices, expected inflation, intervention rates, and real GDP at constant prices. Food and regulated product inflation serve as a proxy for negative supply shocks, as they reflect production costs that are affected by external factors such as pandemics, fiscal policies, supply chain disruptions, and weather conditions. While this measure may underestimate the full impact on headline inflation, it provides the best available approximation.

Lastly, year-on-year changes in Brent and West Texas Intermediate (WTI) oil prices were considered as potential exogenous factors, although they may not capture all relevant domestic or international factors that could affect supply shocks.

A. Description of data

Figure 1 illustrates that during the 2007-2008 period, food and regulated product inflation (FOOD_INFLATION) surpassed total inflation (TOTAL_INFLATION). FOOD_INFLATION rose from 8.55% in the first quarter of 2007 to 12.54% by the fourth quarter of 2008, while TOTAL_INFLATION increased from 5.78% to 7.67%. This rise in FOOD_INFLATION was driven by higher prices of primary and imported goods, exacerbated by the El Niño phenomenon, which affected supply, as well as growing demand for food from India and China.

Additionally, international oil price hikes increased transportation and agrochemical costs, while the depreciation of the Colombian peso raised the cost of importing corn and wheat. Adverse weather conditions and low agricultural sector elasticity further intensified these price pressures.

Between 2015 and 2016, FOOD_INFLATION surged from 5.03% in the second quarter of 2015 to 12.17% in the same quarter of 2016, while TOTAL_INFLATION rose from 4.42% to 8.6%. The El Niño phenomenon once again played a key role, reducing rainfall and causing a shortage in agricultural output, which led to price increases. The depreciation of the Colombian peso also raised the cost of imported inputs essential for farming. Additionally,

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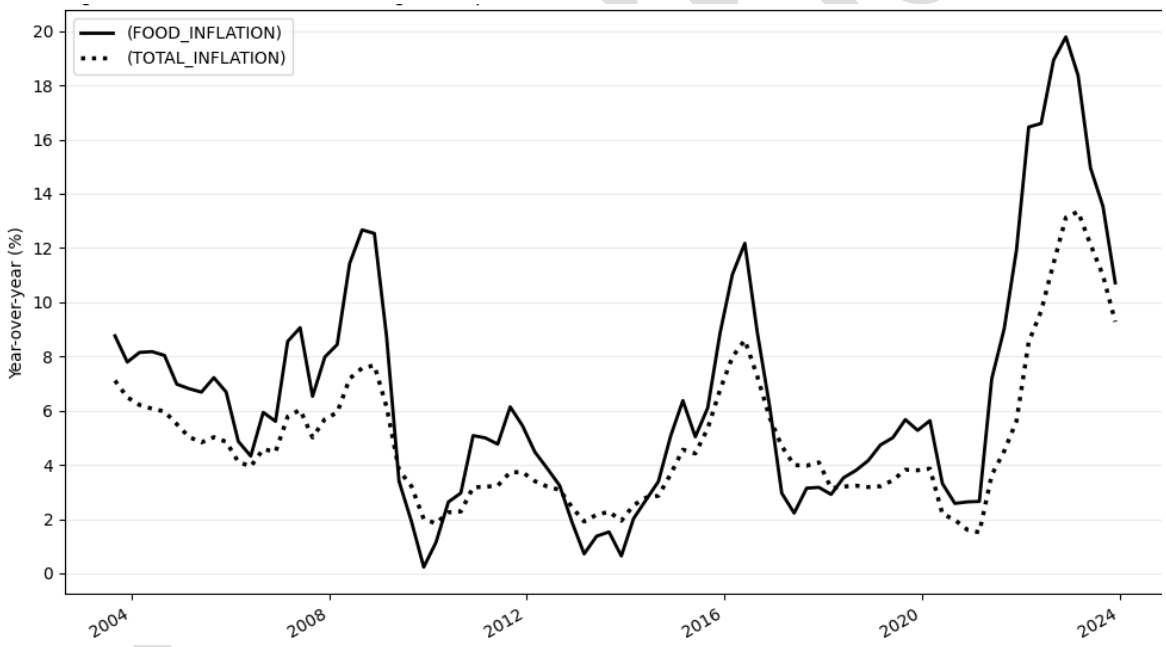
strikes in the transportation sector, especially a major truckers' strike, disrupted the supply chain and further contributed to the inflationary spike.

Finally, from 2021 to 2022, FOOD_INFLATION increased sharply from 2.65% in the first quarter of 2021 to 19.79% in the fourth quarter of 2022, while TOTAL_INFLATION rose from 1.51% to 13.12%. This was driven by high international prices for agricultural inputs, a drop in meat and perishable goods supply, and the national strike in early 2021, which limited availability. The COVID-19 pandemic also contributed to higher freight and transportation costs due to global restrictions. In 2022, the surge in FOOD_INFLATION was further fueled by internal shocks, such as the truckers' strike that disrupted supply chains, and external shocks, including the Russia-Ukraine conflict, which strained logistics and reduced agrochemical supplies. Additionally, the peso's depreciation against the U.S. dollar further raised raw material and processed food costs.

Figure 1. *Evolution of food and regulated product inflation and total inflation*



Note. Food and regulated products inflation (FOOD_INFLATION, solid line) and total inflation as change in CPI (TOTAL_INFLATION, dotted line).
Source: Own elaboration based on data from BanRep (2024c).

Figure 2 shows a clear pattern in the formation of economic expectations related to expected inflation (EXP_INFLATION) during 2007-2008, a period marked by economic crises due to internal and external supply shocks. During this time, expected inflation rose, reflecting heightened uncertainty and market volatility.

In the first instance, EXP_INFLATION increased from 4.22% in the first quarter of 2007 to 5.84% by the third quarter of 2008, a rise of 0.06 percentage points. This increase was

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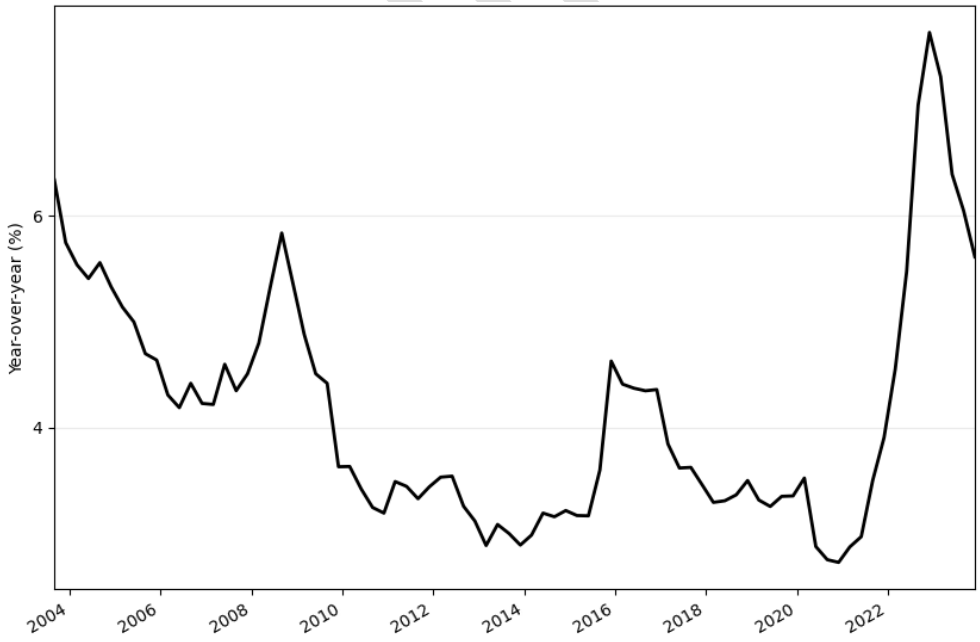
largely due to the global financial crisis, which altered relative prices in the goods and services market, particularly through rising input costs. This led to an increase in observed inflation, which shaped agents' expectations. According to the adaptive expectations theory, higher inflation today leads to expectations of further inflation tomorrow. BanRep (2007) noted that this rise in inflation expectations reflected doubts about the central bank's ability to meet its inflation target, as expectations were largely driven by supply shocks rather than monetary policy measures.

In the second period, between 2015 and 2016, EXP_INFLATION continued to rise from 3.17% in the first quarter of 2015 to 4.36% by the fourth quarter of 2016. This 0.04 percentage point increase was linked to rising prices for biofuels and oil on international markets, as well as uncertainty surrounding the peace negotiations between the FARC and the government. These factors, along with the revaluation of the Colombian peso, contributed to a de-anchoring of inflation expectations. BanRep (2016) attributed this prolonged inflationary misalignment to price and wage indexation, which further fueled inflationary pressures and caused the central bank to miss its inflation target.

Finally, in 2021, expected inflation surged from 2.87% in the first quarter to 7.74% by the fourth quarter, a 0.07 percentage point increase. This spike was driven by rising domestic prices in response to international increases in gas, oil, and coal prices, as well as the uncertainty caused by the pandemic. The central bank responded with contractionary policies to contain inflation expectations and steer inflation back toward its long-term target, as noted by BanRep (2022).

Figure 2. *Expected inflation trend*



Note: 12-month inflation expectations (EXP_INFLATION).
Source: Own elaboration based on data from BanRep (2024d).

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Figure 3 illustrates the impact of economic crises on Colombia's Gross Domestic Product (GDP) growth, which was hindered by internal and external supply shocks. During these periods, inflation rose, and the central bank maintained high intervention rates (MPR) to manage price stability.

In the first scenario, between the first quarter of 2007 and the fourth quarter of 2008, GDP fell from 6.56% to 0.33%, while the MPR increased from 8% to 10%. The global financial crisis of 2008 played a key role in this contraction, as foreign demand decreased, influenced by the appreciation of the nominal exchange rate. This diminished international incentives to import Colombian goods. Additionally, rising international prices raised local costs, particularly for critical imports, leading to "imported inflation." The central bank reacted by hiking interest rates to curb inflation, which ultimately dampened consumption and investment, causing both aggregate demand and supply to shrink. According to BanRep (2008), this decline was due to the financial crisis and reduced internal and external demand, driven by high lending rates that curbed investment and spending.

The second scenario, spanning from 2015 to 2016, saw GDP drop from 3.38% in the second quarter of 2015 to 1.43% by the third quarter of 2016, while the MPR rose from 4.5% to 7.75%. The slowdown was largely a consequence of falling international oil prices, worsened by an oversupply from leading producers. Additionally, the industrial sector faced heavy taxation—profits were taxed at a 75% rate—due to the 2016 tax reform. This led to reduced household consumption and private investment. Political uncertainty during the FARC peace negotiations and an increase in the cost of servicing foreign debt, due to the peso's revaluation, further contributed to this slowdown. BanRep (2016) confirmed that negative supply shocks and the rise in interest rates aimed at controlling inflation led to credit contractions in both consumption and commercial sectors.

Finally, during 2021-2022, GDP fell sharply from 17.435% in the second quarter of 2021 to 1.95% in the fourth quarter of 2022, while the MPR surged from 1.75% to 11%. Initially, the central bank lowered rates to stimulate consumption and investment, but inflationary pressures in 2022 required a shift to contractionary monetary policy. This led to reduced household consumption and postponed investments, resulting in a significant drop in aggregate demand and supply. BanRep (2022) highlighted that the economic downturn was further exacerbated by rising prices, which eroded household income, and by the Russia-Ukraine conflict, which drove up input costs and caused the peso to depreciate, making imports more expensive.

Figure 3. *Evolution of the real gross domestic product growth rate and the central bank's intervention rate*

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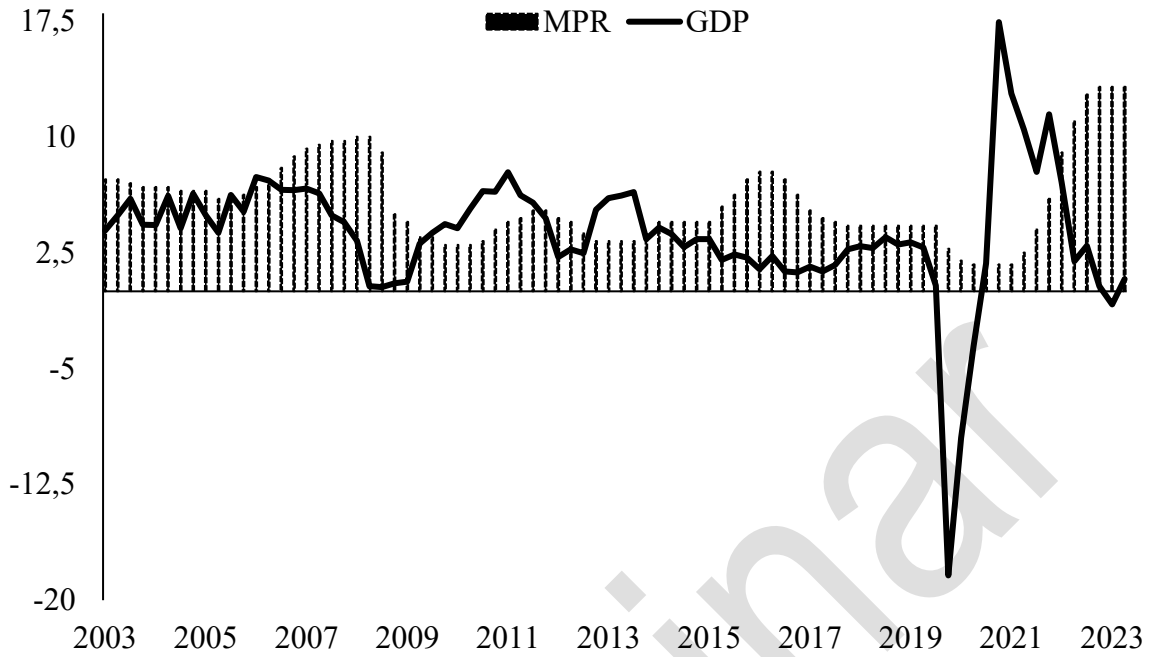

Note. Gross Domestic Product (GDP, solid line) and policy intervention rate (MPR, bars). *Source*: Own elaboration based on data from BanRep (2024a, b).

Finally, an exhaustive description of the impact and summary of the variables under study can be seen in Table 1. First, it is expected that, in the face of a negative supply shock, the inflation expected by economic agents will respond positively. Frías et al. (2016) indicate that the Colombian economy, similar to other Latin American economies, reacts strongly to increases in observed inflation. This not only prolongs the effect of price increases but also negatively impacts the welfare of the population.

Furthermore, the shock is expected to have a positive effect on the monetary authority's intervention rate. Díaz (2023) has argued that, in the presence of such shocks, the monetary authority will strengthen this mechanism, following the principles of the inflation scheme proposed by the NMC, seeking to make inflation converge towards the long-term target.

Also, as a result of this shock, a negative GDP reaction is expected. Following the monetary transmission mechanism outlined by Zuccardi (2002), a generalized increase in prices will lead the monetary authority to raise the intervention rate to anchor economic agents' inflation expectations. Nevertheless, this measure will not only contract consumption and aggregate investment but may also lead to negative GDP growth rates across several periods.

Table 1. *Summary and expected impact of variables*

VARIABLE	DESCRIPTION	EXPECTED IMPACT	SOURCE
FOOD_INFLATION	Represents the year-over-year change in the price index of food and regulated products.	Proxy for negative aggregate supply shocks.	BanRep

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EXP_INFLATION	Represents the inflation expected by economic agents 12 months ahead.	Positive impact in response to a negative aggregate supply shock.	BanRep
MPR	The intervention rate set by the monetary authority at the end of each quarter.	Positive impact in response to a negative aggregate supply shock.	BanRep
GDP	Refers to the growth rate of real gross domestic product in 2003 and 2005 prices.	Negative impact in response to a negative aggregate supply shock.	BanRep

Source: Own elaboration.

III. Econometric Model and Results

To analyze the impact and dynamics resulting from a negative supply shock on economic expectations and economic activity and to ultimately observe the response of monetary policy, we follow the framework established by Díaz Casas (2023). The present research expands on that study by identifying the impact that a negative supply shock - expressed through the proxy variable of food inflation and regulated products - generates on expected inflation, the intervention rate, and GDP, between the third quarter of 2003 and the fourth quarter of 2023.

A. *Econometric model*

The VAR (Vector Autoregression) models are a class of multivariate time series models widely used to analyze systems affected by unanticipated shocks, as they allow for endogeneity among variables. This endogeneity arises from the inherent simultaneity in the system, in which the dynamic effect of an unexpected innovation in one variable on the rest of the variables in the system is explicitly modeled.

For this reason, the empirical structure of the VAR model employed in this research incorporates a vector of endogenous variables to empirically evaluate the incidence of a negative supply shock on GDP and to analyze the role of the Colombian central bank in anchoring the formation of agents' expected inflation expectations around the long-term target. The vector autoregressive model (VAR) used in this paper is expressed in equation (1):

$$Y_t = \alpha + \sum_{i=1}^{n} A_i(Y_{t-1}) + B(Z_t) + \epsilon_t \quad (1)$$

where Y_t on the left-hand side of the equality represents the vector of endogenous variables of the system at time t. On the right side, α is a vector of constants, A_i are coefficient matrices from subscript i that multiply the lagged vector of endogenous variables $t-i$, composed by $FOOD\_INFLATION_t$, which refers to the inflation of food and regulated products, $EXP\_INFLATION_t$, which represents the inflation expected by economic agents 12 months

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ahead, MPR_t, which corresponds to the intervention rate, and GDP_t , which is the year-on-year growth rate of gross domestic product. The coefficient matrix $B(Z_t)$ involves dichotomous variables that can model seasonal effects, in particular, to control for the effects of extreme outliers[2], and finally, ϵ_t , refers to the vector of innovations or unanticipated shocks.

However, since the coefficients associated with VAR models can report a range of high values, a joint analysis is required to quantify the short- and long-term impact of random shocks on the endogenous explanatory variables, while elucidating how these stochastic shocks affect the evolution of the system's variables. To achieve the latter, it is necessary to estimate the impulse-response functions and subsequently apply the variance decomposition method of the system.

B. Tests performed

When estimating multivariate time series models, it is essential to verify a series of assumptions through statistical tests to ensure their robustness. First, the order of integration of the variables must be determined, which is crucial to specify whether the variables should be estimated at levels with intercept or trend, in first or second differences. This involves determining whether the variables are stationary or have no unit root. In this research, we apply the Augmented Dickey-Fuller test[3] to confirm that the variables are stationary at levels with intercept.

Once it is confirmed that the series does not have a unit root, it is necessary to determine the optimal number of lags for the VAR model. This is achieved using lag length tests, in which statistical criteria such as the Bayesian Information Criterion (BIC), the Forecast Prediction Error Criterion (FPE), and the Hannan-Quinn Information Criterion (HQ) are used to define the optimal number of lags for the model. In the present investigation, five lags suggested by the FPE criterion were selected. Although other criteria suggested one and four lags according to Gujarati and Porter (2010), when using quarterly frequency time series models, it is advisable to estimate the model with lags greater than or equal to four.

We then tested whether the system variables are caused by an unanticipated negative supply shock, following Granger (1969), who built the following simple two-variable causality model:

$$X_t = \sum_{j=1}^{m} a_j X_{t-j} + \sum_{j=1}^{m} b_j Y_{t-j} + \varepsilon_t \quad (2)$$

$$Y_t = \sum_{j=1}^{m} c_j X_{t-j} + \sum_{j=1}^{m} d_j Y_{t-j} + \eta_t \quad (3)$$

[2] With this, the variance-covariance matrices of the error terms are smaller, providing greater efficiency to the estimations.

[3] See the Appendix: Augmented Dickey-Fuller test, where the null hypothesis points to a unit root, Lag length tests: Information criteria, Test inverted roots of the autoregressive polynomial: The roots of the model must not be greater than unity, Heteroscedasticity test, Serial Correlation test, Normality test.

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where, X_t and Y_t are stationary time series variables, ε_t and η_t are uncorrelated white noise series and m is finite and smaller than the given time series. According to the above equations, Granger (1969) postulates the following causality implications:

1. Y_t causes X_t if any coefficient b_j is different from zero.
2. X_t causes Y_t if any coefficient c_j is different from zero.
3. Y_t causes X_t, and in turn, X_t causes Y_t, if the above events occur.

Subsequently, the dynamic stability of the model is verified, ensuring that the variables return to their previous dynamic equilibrium levels after identifying variations in the vector of innovations. In our research, we estimate the inverse roots of the autoregressive polynomial to confirm the stability of the VAR model.

First, we evaluate whether the variance of the residuals is constant by applying White's heteroscedasticity test without cross terms, concluding that the residuals are homoscedastic. Second, the absence of serial correlation is verified using the Lagrange Multiplier test, confirming that there is no autocorrelation between the lags applied in the model.

Next, two additional assumptions of the VAR model are reviewed. Finally, the normality test was performed on the residuals of the model, which evaluates their asymptotic distribution in the estimated VAR model. This step is based on the premise of complying with the assumptions of uncorrelated errors and homoscedasticity, as suggested by Johansen (1988), who points out the importance of verifying that the residuals do not deviate significantly from the white noise assumption. To meet this assumption, this research performed a detailed review of the outliers in the residuals of the VAR model to create the dichotomous exogenous normality variables that are included in the model. Likewise, the test is performed to confirm the fulfillment of this assumption and validate the normality of the residuals.

IV. Analysis of Results

Once the corresponding tests have been carried out to verify the consistency of the proposed model, we proceed to analyze the impact of an unanticipated negative supply shock - expressed as an increase in the inflation of food and regulated products as a proxy for the supply shocks- on each of the previously explained variables. In this sense, we present an argument based on the graphical evidence resulting from the impulse-response functions, considering the existence of causality in the sense of Granger (1969) and the impact of this shock 20 quarters ahead.

A negative aggregate supply shock leads to an increase in the formation of agents' economic expectations regarding expected inflation in the Colombian economy. This pattern persists over time and is consistent with the occurrence of imported inflation, wherein the increase in international prices is transferred to domestic prices, directly influencing the formation of expectations and generating lasting effects in the economy.

Figure 4. *Impulse-response function of a negative supply shock on expected inflation by economic agents*

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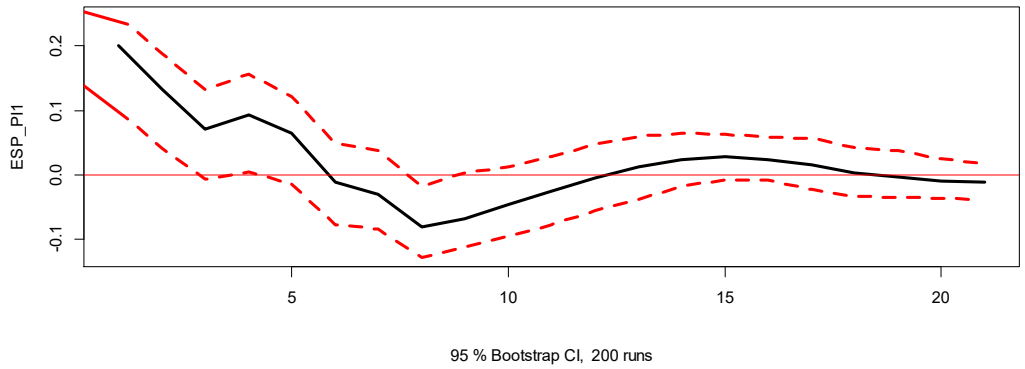
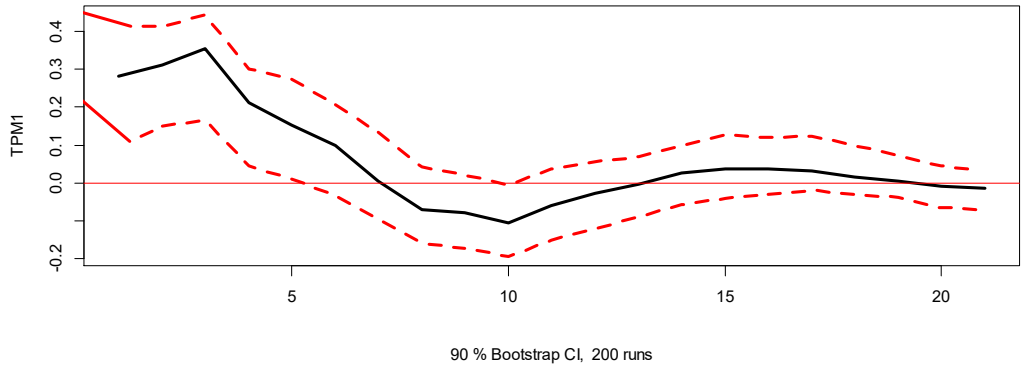


Source: Own elaboration.

Figure 4 illustrates that following a negative supply shock, inflation expectations rise by 0.2 percentage points (p.p.) in the first quarter. Although this increase gradually becomes less pronounced, it remains positive until the fourth quarter, when expected inflation reaches 0.1 p.p. before fully declining by the sixth quarter, converging to zero. However, the anchoring of inflation expectations is only significant by the eighth quarter. This effect is confirmed by the Granger causality test, which shows that negative supply shocks cause inflation expectations from the second lag onwards with 95% confidence.

Additionally, in response to a negative supply shock, the central bank's intervention rate increases, aligning with the inflation targeting framework of the New Macroeconomic Consensus. As economic expectations become misaligned, the monetary authority reacts to prevent second-round effects, leading to a persistent rise in the intervention rate over time.

Figure 5. *Impulse-response function of a negative supply shock on the monetary authority's intervention rate*



Source: Own elaboration.

Figure 5 shows that the intervention rate initially rises from 0.29 percentage points (p.p.) in the first quarter to 0.35 p.p. by the third quarter in response to a negative supply shock. This rate remains positive until the eighth quarter but is significant only through the sixth quarter. The Granger causality test confirms that the intervention rate is influenced by the shock at the 95% confidence level from the third lag onwards. This aligns with the New Macroeconomic

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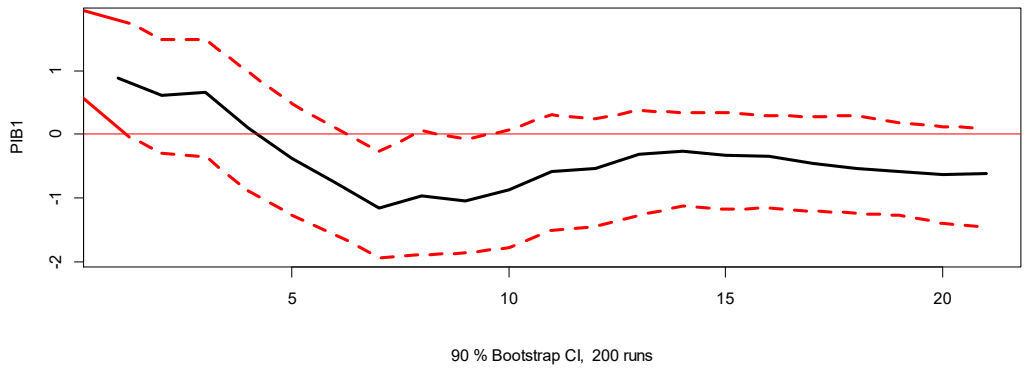
Consensus, wherein the central bank raises the policy rate to manage inflation expectations, which become anchored one year after the shock.

Additionally, the negative supply shock impacts economic activity, reducing GDP growth. As the central bank raises rates to curb inflation, consumption and investment decline, further compounded by rising prices, leading to a persistent drop in economic output.

Figure 6. *Impulse-response function of a negative supply shock on the gross domestic product at constant prices*



Source: Own elaboration.

Figure 6 shows that real GDP contracted by 2.9 percentage points (p.p.) after a negative supply shock, reaching its lowest point by the seventh quarter. This contraction remains persistent over the 20 estimated quarters, but is statistically significant only until the tenth quarter. The Granger causality test supports that GDP is influenced by negative supply shocks with 95% confidence starting from the seventh quarter. This aligns with the monetary transmission mechanism, where rising prices misalign expectations, prompting the central bank to raise the intervention rate to anchor them, at the expense of economic output.

These findings are supported by the Cholesky variance decomposition in the VAR model, revealing that changes in expected inflation are driven 78.6% by the shock, 10.5% by inflation expectations themselves, 4.7% by GDP fluctuations, and only 6.1% by the intervention rate. This highlights that the policy rate, while crucial in controlling inflation, has a limited impact when responding to unanticipated supply shocks. The formation of expectations is largely explained by the shock itself, suggesting that the Taylor rule, which balances inflation and output, is not sufficient to stabilize the economy following such a shock.

Additionally, the decomposition reveals that changes in the intervention rate are influenced 80.7% by the shock, 10.2% by the rate itself, 5.6% by GDP, and 3.4% by inflation expectations. This aligns with the New Macroeconomic Consensus, wherein the central bank primarily reacts to price increases caused by supply shocks, focusing on inflation stabilization. Nevertheless, its ability to anchor inflation expectations remains limited, achieving significant results only after one year.

Finally, variations in GDP are explained 10.7% by the shock, 61.7% by its own historical changes, 11.1% by the intervention rate, and 16.5% by inflation expectations. This indicates that GDP is heavily self-influenced, with changes persisting over time. As the monetary authority raises the intervention rate to combat inflation, the economy enters a recession, delaying

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recovery. This underscores the painful and prolonged impact of negative supply shocks on GDP, especially when the central bank is committed to inflation targeting.

V. Policy Recommendations

The recommendations derived from this research are closely aligned with the findings reported therein. It is essential that economic decision-makers, particularly Banco de la República, consider the stabilizing potential of additional tools—especially complementary fiscal policies—in the face of unanticipated negative supply shocks. In such scenarios, monetary policy could be supported by fiscal interventions that help prevent inflation expectations from becoming unanchored.

Understanding the complementarity between fiscal and monetary policy is crucial to managing the effects of price indexation and inertial inflation. The proposed approach involves two key components:

First, a public savings fund for macroeconomic stabilization should be created and managed by the Ministry of Finance and Public Credit. This fund would aim to stabilize prices in the primary sector, which is especially vulnerable to supply shocks, by providing compensation to producers facing rising input costs. However, given that subsidies can lead to net welfare losses due to the distortions introduced by taxation (as microeconomic theory suggests), it is important to consider how the fund is financed. To preserve social equity, the financial burden of the fund should fall primarily on higher-income economic agents, ensuring that low-income households are not adversely affected by the fiscal adjustment required to sustain price stabilization efforts.

Second, government intervention through targeted trade policies is recommended. In addition to the savings fund, the state should incentivize both domestic and foreign producers to maintain the supply of goods and services, even under adverse conditions. This could involve lowering tariffs or transportation costs and offering compensatory subsidies to domestic producers negatively impacted by events like natural disasters or supply chain disruptions.

Together, these fiscal tools, when properly financed and coordinated with monetary policy, could shorten the adjustment period for inflation expectations. Nonetheless, it remains crucial to assess the distributional consequences of these measures, especially their impact on the most vulnerable sectors of the population, and to ensure that fiscal policy design supports macroeconomic stabilization without undermining equity or long-term efficiency.

Conclusions

The research validated the hypothesis that during the period from 2003 to 2023, when the Colombian economy experienced negative supply shocks, there was a mismatch in the formation of expected inflation expectations. This led to an increase in the intervention rate by the central bank, adversely impacting the gross domestic product, while failing to anchor the expectations of economic agents around the expected inflation efficiently. The empirical results obtained through a VAR model revealed substantial responses in the endogenous variables, which are supported both theoretically by previous economic research and empirically through Granger causality tests and variance decomposition.

The stylized facts indicate that price increases in primary and imported goods, natural phenomena such as El Niño, national strikes, as well as international conflicts can lead to higher

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prices. These factors not only produce an increase in the observed inflation but also in the inflation expectations and the monetary policy rate. Additionally, this affects the positive growth of the GDP in the Colombian economy during the specified period.

Regarding the Granger causality test, it was observed that an unanticipated negative supply shock individually predicts an increase in expected inflation from the second quarter, as well as in the intervention rate and gross domestic product across different time lags, specifically in the third and seventh lags, respectively.

Therefore, it was concluded that a negative supply shock leads to an increase in expected inflation during the following six quarters, together with an increase in the intervention rate set by Banco de la República during the same period. Concerning gross domestic product, a significant cumulative decline is observed four quarters later.

Among the most outstanding results of the analyzed periods, the Cholesky variance decomposition revealed that the impact of an unanticipated negative supply shock is distributed as follows: expected inflation explains 78.6% of the variability, the intervention rate 80.7%, and gross domestic product 10.7%.

These findings suggest that Banco de la República de Colombia, in its effort to maintain low and stable inflation, tends to prioritize inflationary control over economic growth in the short and medium term, mainly using the intervention interest rate as a monetary policy tool. However, in the face of unanticipated shocks to the aggregate supply, the effectiveness of this contractionary monetary policy to control inflation expectations is limited; it stabilizes the inflation expected by agents only one year after the shock.

Appendix

Table A1. *Unit root test on levels with intercept*

Variable	Statistic t	Probability	Decision
FOOD_INFLATION	-3,086482	0,0316**	RH_0
GDP	-3,925641	0,0029***	RH_0
MPR	-3,294359	0,0184**	RH_0
EXP_INFLATION	-2,643466	0,0887*	RH_0

Note. The Augmented Dickey Fuller test considers the existence of a unit root as the null hypothesis. **NRH_0** means No Rejection of the Null Hypothesis. Significant values: ***p<0,01; **p<0,05; *p<0,1*.

Source: Own calculations performed in EViews 14.

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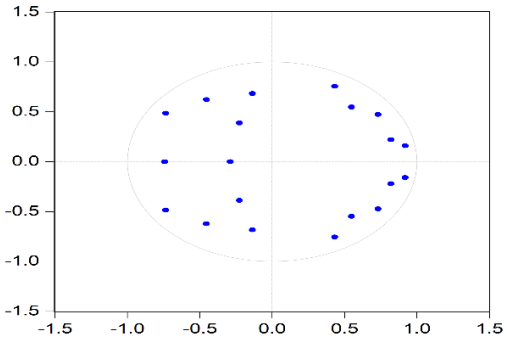
Table A2. *Lag length tests*

Lags	LogL	LR	FPE	AIC	SC	HQ
0	-557,9730	NA	110,4093	16,05481	16,68721	16,30657
1	-328,4121	401,7316	0,294142	10,12256	11,26089*	10,57573*
2	-317,4135	18,02547	0,341635	10,26149	11,90575	10,91607
3	-302,9777	22,05465	0,364129	10,30494	12,45512	11,16093
4	-269,0430	48,07424*	0,228780	9,806750	12,46286	10,86416
5	-250,3608	24,39066	0,223401*	9,732244*	12,89428	10,99106

Note. * indicates the number of lags relevant for estimating the VAR model.

Source: Own calculations performed in EViews 14.

Figure A1. *Inverted roots test of the autoregressive polynomial*



Source: Own calculations performed in EViews 14.

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Table A3. *Multivariate Serial Correlation Test: Lagrange Multiplier Test*

Lags	Df	Probability	Decision
1	16	0,0024*	RH₀
2	16	0,1998***	NRH₀
3	16	0,1986***	NRH₀
4	16	0,1145***	NRH₀
5	16	0,1426***	NRH₀

Note. The Lagrange Multiplier test considers as null hypothesis the non-existence of serial correlation. ***NRH_0*** *means No Rejection of the Null Hypothesis. Significant values: ***p<0,01; **p<0,05; p<0,1.*

Source: Own calculations performed in EViews 14.

Table A4. *Heteroscedasticity test*

Chi-sq	Df	Probability	Decision
476,0716	440	0,1138***	NRH₀

Note. The heteroscedasticity test considers as null hypothesis the non-existence of heteroscedasticity. **NRH_0** means No Rejection of the Null Hypothesis.

Table A5. *Asymmetry test (multivariate)*

Component	Chi-sq	Probability	Decision
1	0,029181	0,8644***	NRH₀
2	0,847585	0,3572***	NRH₀
3	0,789257	0,3743***	NRH₀
4	1,507370	0,2195***	NRH₀
Aggregate	3,173393	0,5292***	NRH₀

Note. The asymmetry test considers as null hypothesis the non-existence of asymmetry.

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Table A6. *Kurtosis test (multivariate)*

Component	Chi-sq	Probability	Decision
1	0,056140	0,8127***	NRH₀
2	0,288100	0,5914***	NRH₀
3	2,235976	0,1348***	NRH₀
4	0,044286	0,8333***	NRH₀
Aggregate	2,624501	0,6225***	NRH₀

Note. The kurtosis test considers as null hypothesis that kurtosis is equal to three.
Source: Own calculations performed in EViews 14.

Table A7. *Jarque-Bera test (multivariate)*

Component	Jarque-Bera	Probability	Decision
1	0,085321	0,9582***	NRH₀
2	1,135685	0,5667***	NRH₀
3	3,025233	0,2203***	NRH₀
4	1,551656	0,4603***	NRH₀
Aggregate	5,797894	0,6699***	NRH₀

Note. The Jarque-Bera test considers the existence of normality as the null hypothesis.
Source: Own calculations performed in EViews 14.

Table A8. *Granger causality test*

Null hypothesis	***Obs/Lags***	***Probability***	***Decision***
EXP_INFLATION does not cause FOOD_INFLATION	*78 / 2*	*0,1356*	NRH_0
FOOD_INFLATION does not cause EXP_INFLATION	*78 / 2*	*0,0029***	RH_0
MPR does not cause FOOD_INFLATION	*79 / 3*	*0,2912*	NRH_0
FOOD_INFLATION does not cause MPR	*79 / 3*	*0,0362***	RH_0
GDP does not cause FOOD_INFLATION	*75 / 7*	*0,9314*	NRH_0
FOOD_INFLATION does not cause GDP	*75 / 7*	*0,0552****	RH_0

Note. The Granger causality test considers as null hypothesis the non-causality between variables. ***NRH_0*** *means No Rejection of the Null Hypothesis, and* ***RH_0*** *means Rejection of the Null Hypothesis.*
Source: Own calculations performed in EViews 14.

Ethics Statement

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This research article did not work with a person or groups of persons to generate the data used in the methodology; therefore, it did not require the endorsement of an Ethics Committee for its realization.

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