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Inflation Expectations Measurement and its Effect on Inflation Dynamics in Colombia

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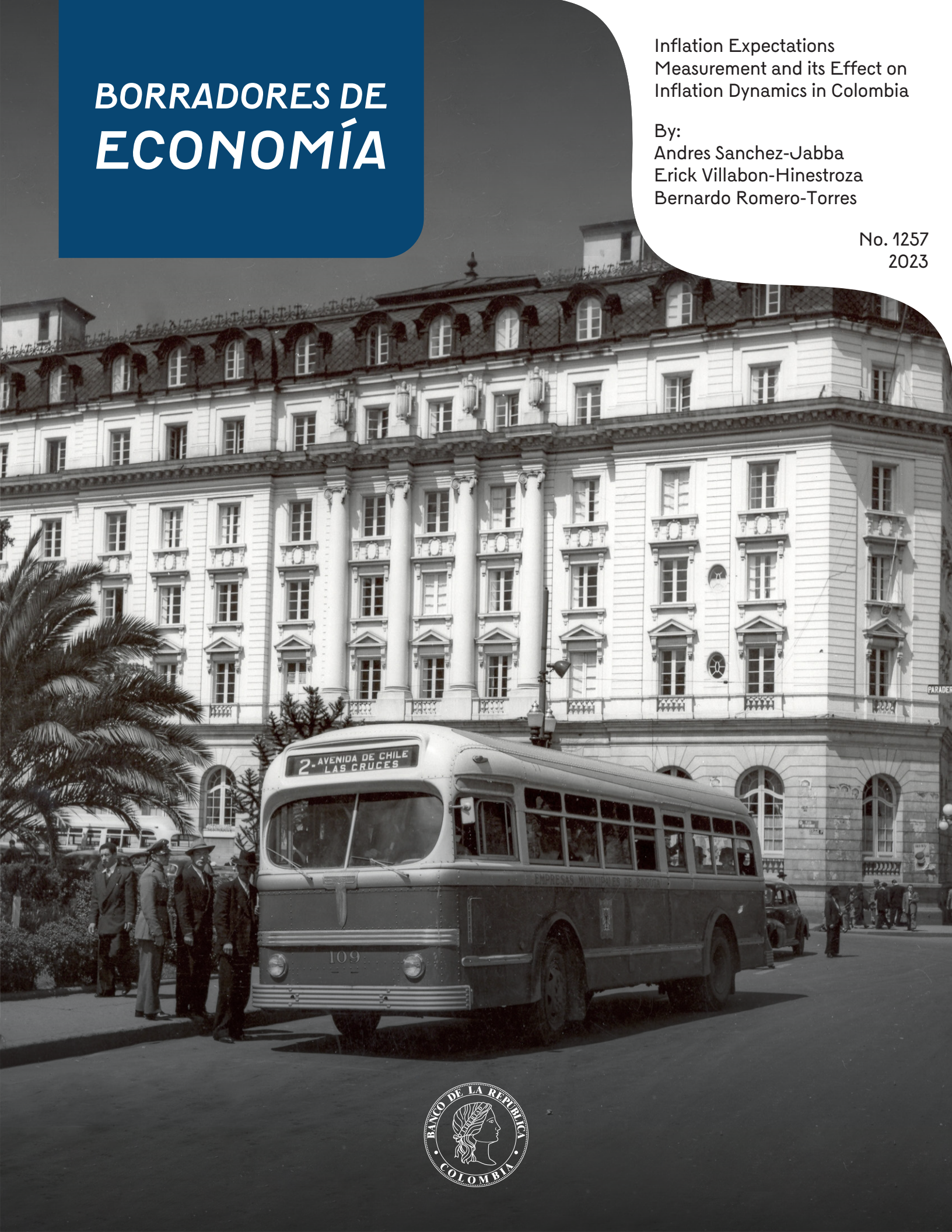

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COLOMBIA

Inflation Expectations Measurement and its Effect on Inflation Dynamics in Colombia

Andres Sanchez-Jabba[♦]; Erick Villabon-Hinestroza[♠]; Bernardo Romero-Torres[♣]

Abstract

The main objective of this study is to determine whether the effect of inflation expectations on inflation dynamics in Colombia depends on the measurement of this variable. For this purpose, we estimate New-Keynesian Phillips Curves measuring expectations with data from financial markets, economic surveys, and macroeconomic models. Our findings show that a one percentage point increase in financial market expectations (BEI) leads to a median increment in inflation of 0.96 percentage points, while economic survey (QSEE) and macroeconomic model (4GM) expectations yield median effects of 0.78 and 0.50 percentage points, respectively. Possible explanations for the differences in the effect of expectations on inflation relate to asymmetric losses in forecast errors, variations in forecasting costs, rigidities in information transmission, and economic modelling limitations.

JEL classification: C26, D84, E12, E31.

Keywords: Inflation expectations, inflation dynamics, New-Keynesian Phillips Curve, Generalized Method of Moments.

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Medición de las expectativas de inflación y su efecto sobre la dinámica de la inflación en Colombia

Andres Sanchez-Jabba♦; Erick Villabon-Hinestroza♠; Bernardo Romero-Torres♣

Resumen

El objetivo principal de este estudio es determinar si el efecto de las expectativas de inflación en la dinámica de la inflación en Colombia depende de la medición de esta variable. Para este propósito, estimamos Curvas de Phillips Neokeynesianas midiendo las expectativas con datos de mercados financieros, encuestas económicas y modelos macroeconómicos. Nuestros resultados muestran que un aumento de un punto porcentual en las expectativas del mercado financiero (BEI) conduce a un incremento medio en la inflación de 0.96 puntos porcentuales, mientras que las expectativas de encuestas económicas (QSEE) y de modelos macroeconómicos (4GM) producen efectos medios de 0.78 y 0.50 puntos porcentuales, respectivamente. Las posibles explicaciones de estas diferencias en el efecto de las expectativas en la inflación están relacionadas con pérdidas asimétricas en los errores de pronóstico, variaciones en los costos de pronóstico, rigideces en la transmisión de información y limitaciones en la modelización económica.

Códigos JEL: C26, D84, E12, E31.

Palabras clave: expectativas de inflación, dinámica inflacionaria, curva de Phillips neokeynesiana, método generalizado de momentos.

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1. Introduction

Inflation expectations represent a critical factor influencing monetary policy and economic stability, as they affect the decisions of households, businesses, and investors regarding consumption, investment, and pricing. Empirical studies, such as those by Mankiw *et al*. (2003), Svensson (1997), Gürkaynak *et al*. (2005), and Coibion and Gorodnichenko (2015), have emphasized the importance of inflation expectations in determining inflation rates, guiding central banks' policy decisions, and impacting the real economy. Given the significance of inflation expectations in monetary policy and economic stability, accurate measurement of this variable is essential, since employing different measurement methods can lead to biases that affect estimates of inflation dynamics (Lindé, 2005; Rudd and Whelan, 2005).

The literature on inflation expectations consistently shows that this component matters when explaining inflation dynamics. Almost all empirical studies that have estimated inflation rates report a statistically significant effect for inflation expectations. However, and despite the conclusive evidence pointing towards the relevance of expectations, economists don’t really have a precise idea about the magnitude of this effect. Estimates for this variable vary considerably, with studies yielding effects that range from 0.1 to 1.3.

This variation poses significant challenges for central banks, who rely on an increasing number of measures of inflation expectations when conducting policy analysis (Sousa and Yetman, 2016). In considering the various measures, practitioners should ponder the potentially heterogeneous effects of expectations in inflation to avoid unintended policy effects. For example, excessive policy shocks resulting from assessments based on measures that overestimate the effect of expectations might create unnecessary contractions in economic activity and even generate financial risks. Conversely, modest policy responses when using measures that underestimate this effect might prove insufficient in containing episodes of elevated inflation.

In this study, we show that some of the variation in the effect of expectations on inflation dynamics is explained by differences in the measurement of this variable. We do so by estimating New Keynesian Phillips Curves (NKPC) using measures of expectations from different sources, including financial markets, economic surveys, and macroeconomic

models. We find a heterogeneous effect of expectations on inflation dynamics in Colombia which depends on the measurement of this variable. Particularly, when using financial market data, our results indicate that a one percentage-point (pp) increase in expectations leads to a median expected increment of 0.96 pp in inflation, which diminishes to 0.78 and 0.50 percentage points when using survey-based and model-based expectations, respectively.

These variations plausibly reflect fundamental differences in the formation of expectations that come from different sources, which we relate to asymmetric losses, differences in forecasting costs and information rigidities. Mainly, we argue that financial market participants overshoot their expectations to hedge against future losses resulting from underpredicting inflation. If expectations are anchored, as has been the case in Colombia during the last decades, this overstatement should translate into higher future inflation. We also postulate that, when selecting forecasting methods, not all agents face the same cost, with sophisticated predictors demanding more resources. As such, we expect the use of different forecasting methods across sources to produce varying estimates for expectations in estimations of inflation dynamics. Finally, we argue that staggered information updates about future economic activity leads to disagreements in inflation expectations.

Besides contributing to the literature on inflation dynamics, our paper offers valuable insights for central banks and policymakers. By recognizing the distinctive effect of the various measures of inflation expectations, central banks can implement policy responses to economic shocks that are consistent with the actual impact of expectations on inflation dynamics, thereby enhancing the effectiveness of monetary policy. Furthermore, we discuss possible explanations for the mediating mechanisms behind the differences in the effect of expectations on inflation dynamics, where evidence is quite limited.

The remainder of this study is organized as follows: Section two explains the different measures of inflation expectations used in our study. Section three describes the data. Section four outlines the empirical strategy. Section five presents our results. Section six discusses the differences in the effect of inflation expectations on inflation dynamics in Colombia. Finally, Section seven concludes and analyzes the implications of our findings for monetary policy.

2. Measures of Inflation Expectations in Colombia

The measures of inflation expectations used in our study consist of one-year-ahead expectations that come from financial markets, economic surveys, and macroeconomic models. The market-based measure of expectations is the Breakeven Inflation (BEI) rate, which is calculated as the difference between the yields of nominal and inflation-indexed bonds with equivalent maturities. The BEI rate indicates the expected inflation rate at which an investor is indifferent between holding nominal and inflation-indexed bonds and reflects the compensation that investors require for bearing inflation risk when holding fixed-rate bonds. To overcome limitations associated with separating market expectations from other factors that affect yield curves, our estimations use a BEI rate that filters out inflation and liquidity risk premia[1].

Survey-based expectations come from the Quarterly Survey of Economic Expectations (QSEE) of the Central Bank of Colombia (CBoC), where respondents provide forecasts for macroeconomic variables of interest. The use of surveys eliminates the need to rely on indirect measurements for expectations, such as market-based measures (Adam and Padula, 2011; Henzel and Wollmershäuser, 2008). Moreover, survey respondents usually represent various economic sectors, such as businesses, industry, and consumers. In particular, the QSEE polls agents from finance, retail, industry, transportation, communications, academia, and labor unions. However, relying on forecasts from a diverse group of economic agents leads to subjectivity that could create biases stemming from shocks that affect responses from a particular sector. This hinders the effectiveness of survey expectations in reflecting aggregate changes in inflation expectations (Clements, 2019; Pesaran and Weale, 2006)[2].

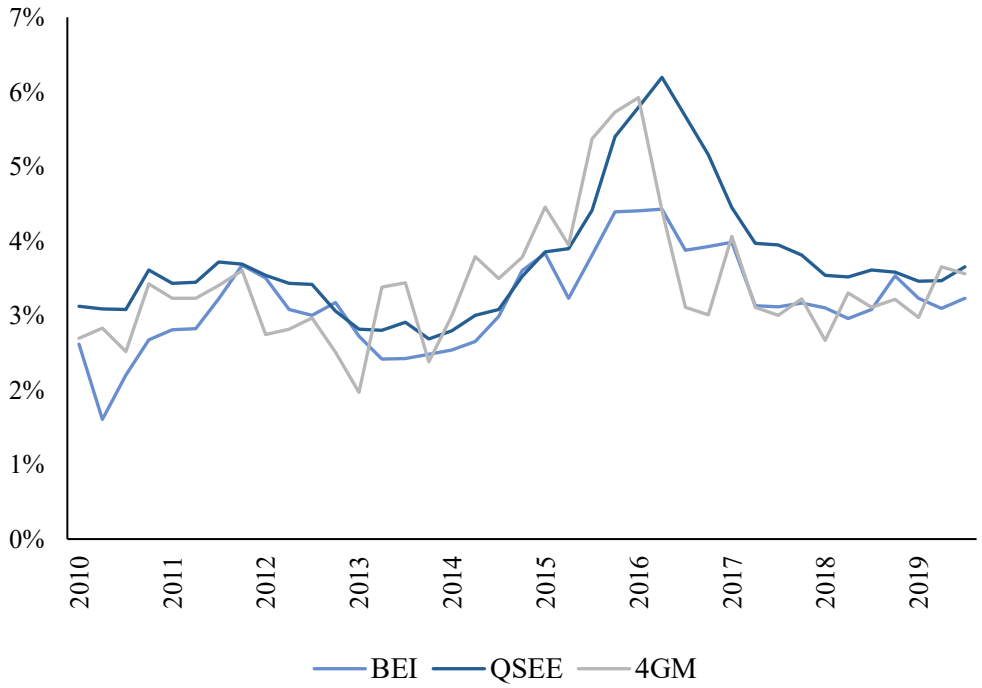
Model-based expectations are generated by the 4GM, a semi-structural economic model that reflects key features of the Colombian economy and supports monetary policy analysis at the CBoC. In this model, inflation expectations are endogenously determined by movements in relative prices and affect monetary policy through deviations from their

[1] Our estimations employ a BEI measure for Colombia proposed by Espinosa-Torres *et al.* (2017), which removes inflationary and liquidity risk premia.

[2] Our overall result does not change when we use expectations from specific agents polled in the QSEE, suggesting that there is no bias arising from specific sectors. In fact, Iregui *et al.* (2021) show that the effect of inflation expectations in Colombia resulting from NKPC estimations does not change when using expectations from different QSEE agents. To facilitate the comparison between measures of inflation expectations from various sources, we decided to show aggregate expectations for the QSEE.

long-term target (González-Gómez *et al*., 2020). These expectations are based on systematic empirical relationships and economic theory, constituting a consistent analytical approach toward forecasting inflation. Nonetheless, they are determined by model specifications and assumptions, limiting their ability to reflect changes in factors that affect inflation expectations, such as climate related shocks and variations in commodity prices.

Figure 1. Inflation Expectations in Colombia (2010-2019)



These three measures of expectations correctly predict changes in inflation in Colombia, attaining a forecasting accuracy that ranges from 72% to 77% (Iregui *et al*., 2021). Furthermore, each one has its own strengths and limitations, enhancing suitability for specific purposes. Market measures are generally available at a higher frequency, increasing responsiveness to macroeconomic developments. Additionally, their precision is favored by the fact that compensation of inflation-protected securities depends on the quality of the forecast. On the other hand, survey measures are more reliable when markets for inflation-protected securities are underdeveloped or display considerable liquidity risk. Finally, model measures facilitate the analysis of fundamental drivers of inflation, as they are based on systematic empirical relationships and reduce the incidence of transitory shocks that affect inflation dynamics (Sousa and Yetman, 2016).

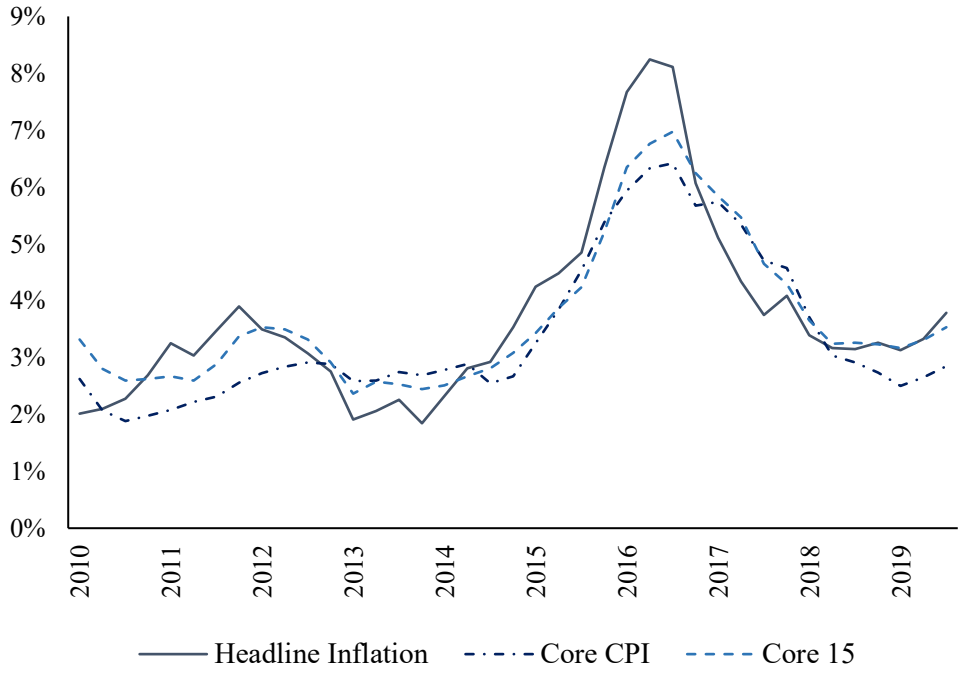
More noticeably, they employ distinct forecasting methods, which explains some of the variation in the effect of expectations on inflation dynamics. Market expectations are formulated by financial analysts, who have access to dedicated datasets and extensive experience in financial asset trading. Model expectations require economic modelling through time-series, structural models, and Bayesian models that involve specialized econometric methods. Conversely, survey expectations come from agents that lack access to the information and expertise of professional forecasters. Additionally, these measures may be influenced by changes in prices relevant to price-setters and consumers, such as food and energy prices and wages (Mankiw *et al*., 2003; Blanchflower and MacCoille, 2009; Coibion *et al.*, 2018).

3. Data

The data for inflation corresponds to annualized variation in two measures of core inflation routinely used by the CBoC for policy analysis. The first measure is the Core CPI, which consists of inflation excluding food and energy prices each period from the Consumer Price Index (CPI); the second measure is the Core 15, which consists of inflation excluding the 15% most volatile prices each period from the CPI using the root mean-squared-error (RMSE) as criterion for this procedure (González-Molano *et al*., 2020). Using these measures allows us to check if the effect of expectations on inflation dynamics varies according to the exclusion criteria used to remove volatile components from headline inflation (i.e., goods categories or percentage based on volatility). Additionally, it provides a better signal of the inflationary pressures driven by fundamental factors (Vargas-Herrera *et al*., 2009).

We examine the effect of expectations on core inflation instead of headline inflation for three reasons. First, it minimizes volatility related to the excluded components of headline inflation, which hinder the accuracy of inflation forecasts. Second, using core inflation limits biases arising from possible correlations between expectations and exogenous shocks (e.g., climate or commodity price shocks) that affect headline inflation (Vargas-Herrera, 2016). Lastly, these measures contribute with 68% (Core CPI) and 88% (Core 15), respectively, toward the CPI in Colombia, capturing a sizeable proportion of the variation in headline inflation and thus a significant share of the overall effect of expectations on inflation dynamics (González-Molano *et al*., 2020).

Figure 2. Headline Inflation and Core Inflation in Colombia (2010-2019)

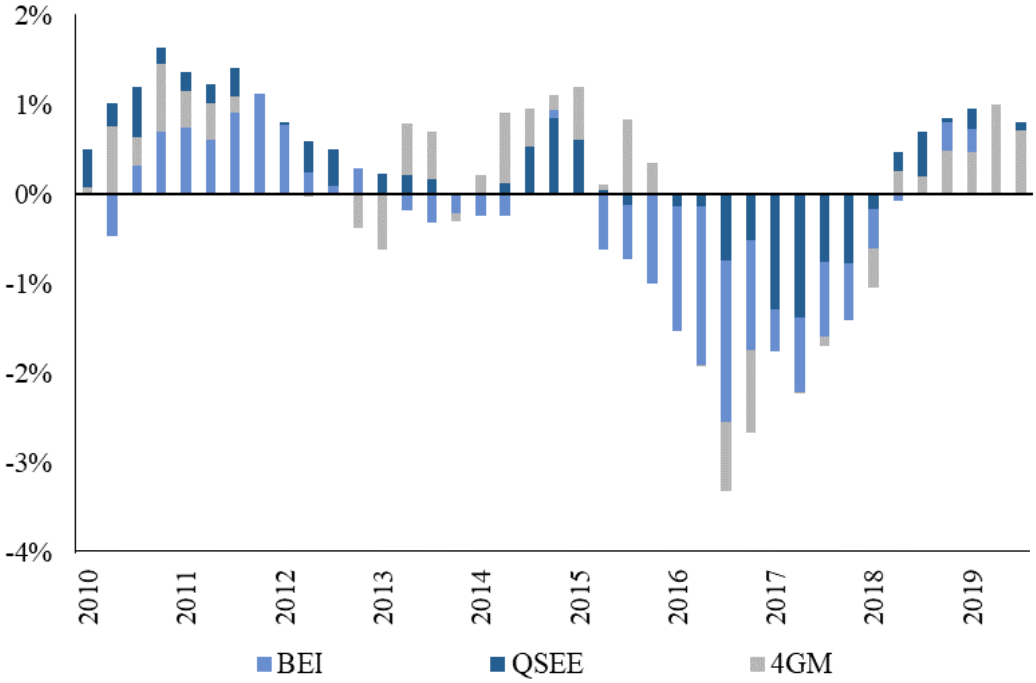


Core CPI consists of inflation excluding food and energy prices each period from the CPI; Core 15 consists of inflation excluding the 15% most volatile prices each period from the CPI.

The monetary policy framework in Colombia during our study period (2010-2019) consisted of an inflation-targeting regime with flexible exchange rate, during which expectations mostly fluctuated around the CBoC's long-term target (3%). Although all measures of expectations closely comoved with core inflation, deviations emerged during episodes of elevated inflation between 2015 and 2017 that were caused by substantial drops in oil prices and climate-related shocks. These exogenous shocks deteriorated terms of trade and increased the relative price of food, which affected the anchoring of expectations and triggered disagreements among measures (González-Gómez *et al.*, 2020; Vargas-Hererra, 2016). Panels (a) and (b) of Figure 3 present the deviations of inflation expectations with respect to core inflation as well as disagreements among measures, with Table 1 showing that the QSEE and BEI exhibited greater accuracy (using the RMSE as forecast precision criteria) when predicting Core CPI and Core 15 inflation, respectively.

Figure 3. Deviations of Inflation Expectations from Core Inflation

Panel (a): Core CPI



Panel (b): Core 15

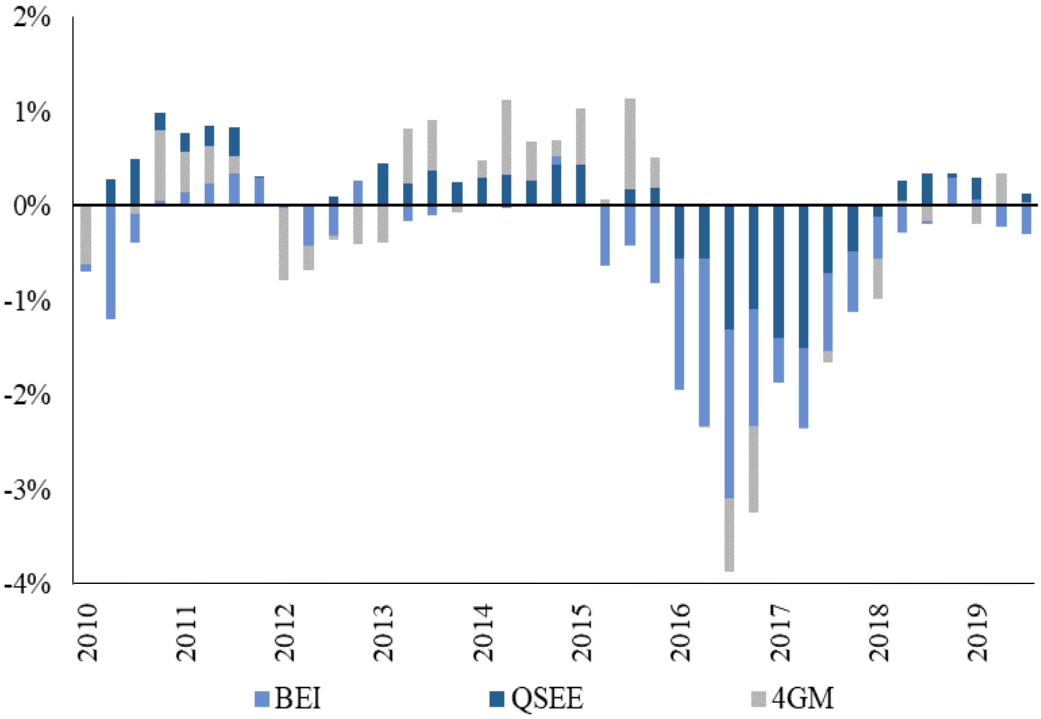


Table 1. Root Mean-Squared-Error of Inflation Expectations with respect to Core Inflation (2010-2019)

	Core CPI	Core 15
BEI	0.010	0.006
QSEE	0.008	0.010
4GM	0.012	0.012

4. Empirical Strategy

New-Keynesian Phillips Curve

We examine inflation dynamics using the hybrid NKPC proposed by Galí and Gertler (1999), which states that inflation in each period depends on past inflation[3], inflation expectations, and a measure of real economic activity approximated through real marginal costs or the output gap[4]. This relationship is expressed in Equation [1], where π_t is inflation in period t; x_t approximates real economic activity; $E_t\{\pi_{t+1}\}$ represents inflation expectations for the following period, and ε_t is an error-term.

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t\{\pi_{t+1}\} + \lambda x_t + \varepsilon_t \qquad [1]$$

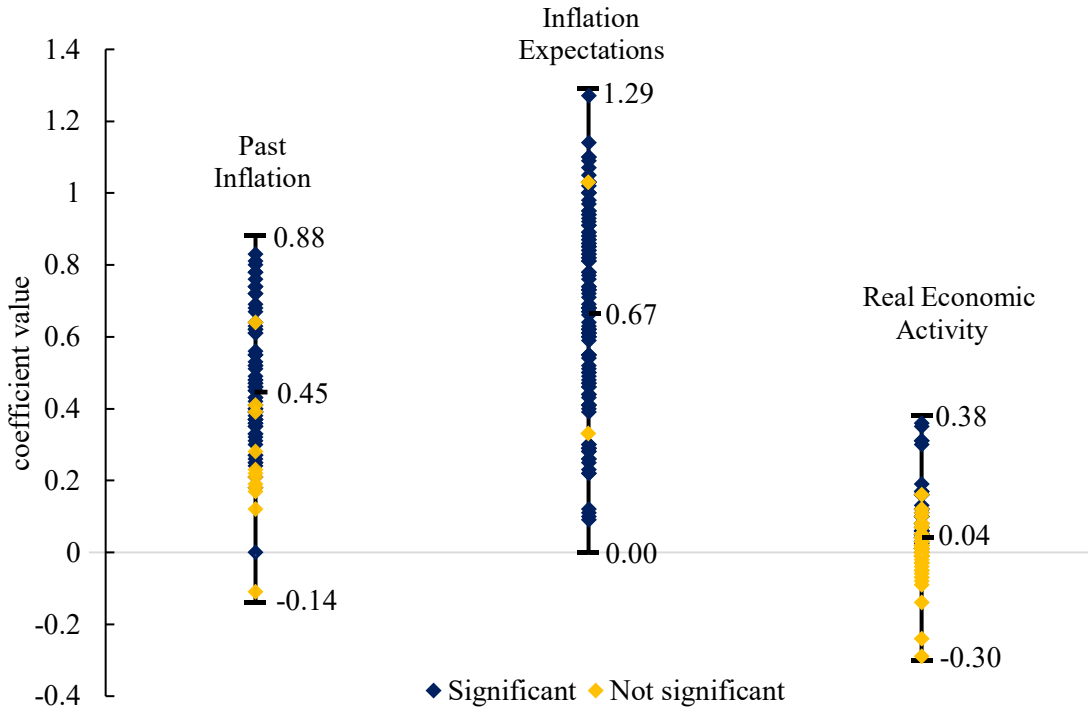
Previous estimates indicate that the NKPC constitutes a reasonable representation of inflation dynamics. Estimates for various countries yield a statistically significant coefficient for expectations and past inflation, with average effects of 0.67 and 0.45 percentage points, respectively[5]. Real economic activity mostly lacks statistical significance and exerts a negligible effect on inflation. Among the studies that have estimated the NKPC for Colombia are Gómez *et al*. (2002), Bejarano (2005), Galvis (2010), and Cháves (2011), which report estimates for inflation expectations ranging from 0.46 to 0.95.

[3] Galí and Gertler (1999) incorporate past inflation into the NKPC to account for the high degree of inflation persistence observed in inflation dynamics (Galí *et al*., 2005; Stock and Watson, 2007; Pivetta and Reis, 2007; Nason and Smith, 2008).

[4] According to Galí and Gertler (1999), using the output gap to approximate real economic activity results in measurement error because potential output is unobservable. Instead, they propose using real marginal costs arguing that this variable can be directly measured and reflects inflationary pressures in the economy by considering the markup set by firms operating in a monopolistically competitive market. This allows for more accurate measurement of the relationship between real economic activity and inflation.

[5] These values correspond to the average of estimates reported by empirical studies that estimate the NKPC.

Figure 4. Estimates for the NKPC (1949-2016).



Note: this figure summarizes a literature review regarding estimations of the NKPC between 1949 and 2016. For each component of the NKPC (e.g., past inflation, inflation expectations, and real economic activity) we indicate the median value of the coefficient and its statistical significance at a 95% confidence level. We examined 19 studies which report a total of 121 estimates for inflation expectations, 83 for past inflation, and 120 for real economic activity. These vary according to the estimation method, country sample, measurement of inflation expectations and real economic activity, and empirical specification (see Annex 1).

Generalized Method of Moments (GMM)

We perform our estimations for the period 2010-2019 using the GMM with quarterly data. GMM mitigates endogeneity that potentially arises from measurement error or reverse causality by including instruments that are highly correlated with inflation expectations but lack correlation with the error term. Measurement error could arise because inflation expectations are difficult to measure or not directly observable (Pesaran and Weale, 2006). Reverse causality is attributable to persistent shocks that affect inflation, leading to changes in expectations regarding future inflation. Our choice of instruments consists of 2-6 lags of inflation, the output gap, and interest rates, including combinations of these instruments.

The rationale for choosing these instruments is that inflation in Colombia displays a high degree of persistence and expectations remained anchored around the CBoC's long-term target during most of our study period, such that past values of inflation constitute a good

predictor of inflation expectations (Vargas *et al*., 2009; Echavarría *et al*., 2011; González *et al*. 2011; López *et al*., 2016). On the other hand, past values of the output gap indicate whether the economy was producing above or below its potential level, with positive values signaling excess demand that triggers expectations of increments in future prices. Finally, the transmission lag of changes in the central bank policy rate toward inflation in Colombia is of 6-8 months (Melo, 2008; Rocío, 2008; Bandera *et al.*, 2023), such that past values of this variable help predict current inflation and consequently inflation expectations. Table 2 describes the variables and instruments used in our empirical analysis.

Table 2. Variables Description.

Variable	Measure	Frequency	Calculation
Inflation*	Annualized core inflation	Monthly	i) Inflation excluding food and energy prices each period. ii) Inflation excluding the 15% most volatile prices each period.
Market-based expectations	Breakeven Inflation (BEI)	Daily	BEI: difference between the price of fixed nominal rate government bonds and inflation-indexed government bonds with equivalent maturities.
Survey-based expectations	Inflation expectations in the QSEE	Quarterly	One-year-ahead forecast for inflation among respondents of a quarterly economic survey.
Model-based expectations	Inflation expectations from the 4GM	Quarterly	Inflation expectations endogenously determined in a macroeconomic model for the Colombian economy.
Real marginal costs	Labor share of income	Quarterly	Ratio of real total wages to GDP, multiplied by the marginal product of labor.
Output gap*	Deviation of quarterly real GDP from its long-term trend	Quarterly	Cyclical component of real GDP using the Hodrick-Prescott filter.
Interest rate*	Central Bank Policy Rate	Daily	Interest rate on short-term loans between commercial banks.

1) *Indicates variables used as instruments in GMM estimations.
2) Daily and monthly data are converted into quarterly variables using the mean value for each quarter.

Specification Checks

We performed several checks to ensure that any differences we detect in the effect of expectations are not related to the validity of instruments, differences in the explanatory

power of empirical specifications, or variations in the forecast precision across measures. Our first check consisted of Hansen's Over-Identification (OI) test, which tests for correlation between regressors and the error term. Second, we compared the goodness-of-fit by analyzing the median r-squared and median RMSE of our estimations. Finally, we examined forecast precision through Fisher's Test (FT) and Pesaran-Timmerman's Test (PT). In total, we performed 360 checks using the abovementioned criteria: 120 for each measure of expectations using two measures of core inflation, two measures of real economic activity, and 2-6 lags for six different sets of instruments.

Table 3. Specification Checks Using Different Measures of Inflation Expectations.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
BEI	95.8%	0.936	0.334	0.000	0.000	115
QSEE	90.0%	0.952	0.265	0.000	0.000	108
4GM	98.3%	0.961	0.261	0.000	0.000	118
Mean/Total	**94.7%**	**0.952**	**0.286**	**0.000**	**0.000**	**341**

(1) Specifications that fail to reject null hypothesis in Hansen's OI test

(2) Median r-squared

(3) Median RMSE

(4) p-value FT test

(5) p-value PT test

(6) Specifications with valid instruments

1) The null hypothesis for Hansen's OI test establishes that there is no correlation between regressors and the error term. Failure to reject the null hypothesis indicates that the proposed empirical specification uses valid instruments.
2) The FT test examines if inflation expectations and actual inflation series are independent. The PT test establishes if the sign of changes in inflation expectations corresponds to the sign of changes in actual inflation. A rejection of the null hypothesis in either test implies that the measure of expectations being tested correctly predicts changes in inflation.

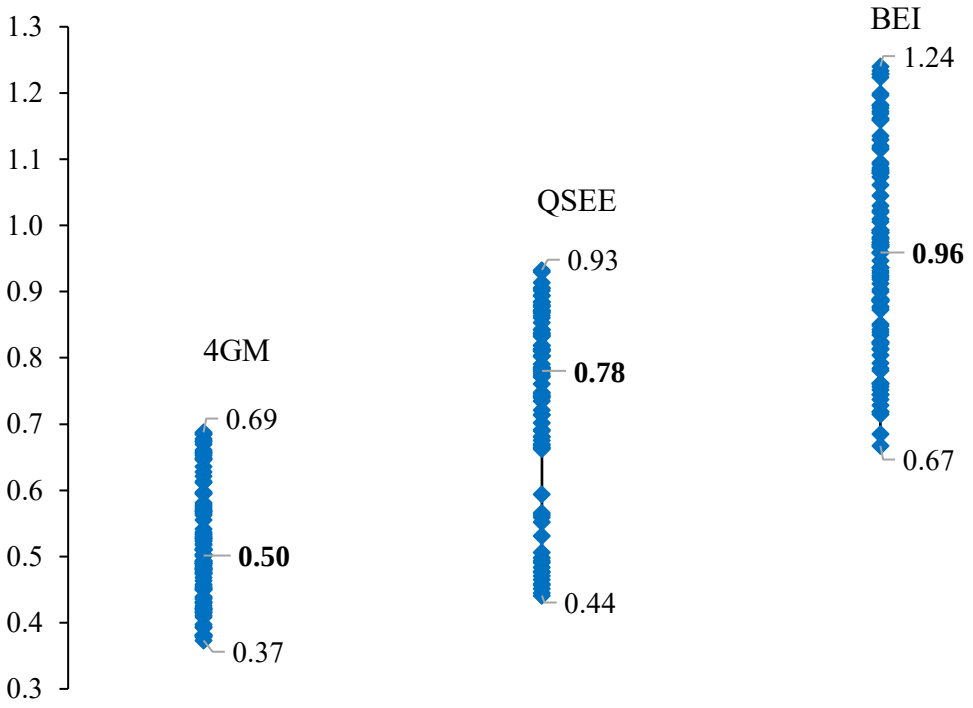
According to the results of these checks, most empirical specifications used valid instruments, attained high explanatory capacity, and exhibited equivalent forecast precision. As shown in column (1) of Table 3, we accepted the null hypothesis of joint validity of instruments in 95% of cases. Moreover, columns (2) and (3) show that all measures achieved a median r-squared of 93% or above and similar RMSE. Likewise, in columns (4) and (5) we rejected the null hypothesis of the FT and PT tests across measures. Hence, we conclude that any variations we observe in the magnitude of estimates plausibly reflect fundamental differences in the formation of expectations from

different sources. Upon discarding specifications that lack valid instruments, we have a total of 341 specifications to be estimated, as indicated in column (6).

5. Results

To simplify our results, we removed extreme values representing 8% of our valid specifications. Specifically, we trimmed two symmetric tails (4% on each side) of the distributions corresponding to the estimates of inflation expectations using the BEI, QSEE, and 4GM. Additionally, we discarded estimates (7 in total) that lacked statistical significance. Hence, our sample of estimates dropped from 341 to 304, still accounting for 89% of the initial estimate distribution[6]. Figure 5 presents our findings.

Figure 5. NKPC Estimates of Inflation Expectations in Colombia (2010-2019)



Each point in this figure represents an estimate for inflation expectations using different measures of core inflation, real economic activity, and instrumental variables. There are a total of 304 estimates: 105 for BEI; 91 for QSEE; 108 for 4GM. For each measure of expectations, this figure indicates the maximum, minimum and median value of the distribution of estimates. All estimates for inflation expectations in this figure exhibit statistical significance at a 95% confidence level.

Our findings indicate that inflation expectations exert a statistically significant effect on inflation dynamics in Colombia and that estimates for this variable range from 0.37 to

[6] Our findings do not change due to this restriction, and we have included the results using the initial estimate distribution in Annex 2.

1.24, consistent with the empirical evidence pertaining to NKPC estimations[7]. Noticeably, the size of the effect depends on the measurement of this variable: when we consider financial market expectations (BEI), a one percentage point increase in expectations leads to a median increment in inflation of 0.96 percentage points, while economic survey (QSEE) and macroeconomic model (4GM) expectations yield median effects of 0.78 and 0.50 percentage points, respectively. This result does not change significantly when we examine the mean of the effect instead of the median.

Table 4. Distribution of Estimates of Inflation Expectations in Colombia (2010-2019)

	Max	**Min**	**Median**	**Mean**	**Std. Dev.**	**t-stat**
BEI	1.24	0.67	0.96	0.96	0.148	6.50
QSEE	0.93	0.44	0.78	0.73	0.143	5.46
4GM	0.69	0.37	0.50	0.52	0.086	5.83

These differences in estimates are statistically significant according to the results of a Kolmogorov-Smirnov (KS) test, which examines the equivalence of the distributions of estimates of inflation expectations using the different measures analyzed in this study[8].

Table 5. KS Test for Equivalence of Distribution of Estimates of Inflation Expectations

	4GM	**BEI**
BEI	0.981 (0.000)	
QSEE	0.715 (0.000)	0.607 (0.000)

Note: the null hypothesis of the Kolmogorov-Smirnov (KS) test states that the two samples being tested belong to the same distribution. Failure to accept the null hypothesis indicates that the two samples being tested belong to different distributions. Table 5 shows the KS statistic above and the p-value in parenthesis below. At a 95% confidence level, the null hypothesis is rejected when the p-value is lower than 0.05.

[7] According to the information shown in Figure 4, the coefficient for inflation expectations should lie between 0.1 and 1.3 and should be statistically significant.
[8] The KS test calculates the difference between the cumulative distribution functions (CDFs) of two samples to determine whether their data belong to the same distribution.

6. Possible Explanations

The statistical differences in the effect of inflation expectations on inflation dynamics in Colombia among various sources could be explained by asymmetric losses from forecasting errors, differences in forecasting costs, lags in information dissemination across economic agents, and modelling limitations.

Financial market analysts are compensated based on the quality of their forecasts since real returns on government bonds depend on uncertain values of future inflation (Schuh, 2001). Given that higher than anticipated inflation can result in negative real returns, these agents bear a higher cost of underpredicting inflation. To hedge against inflationary risk, investors overshoot their expectations, which creates an upward bias when using market-based measures (Capistran and Timmerman, 2009).

When selecting forecasting methods, not all agents face the same cost, with specialized predictors demanding more resources (Brock and Hommes, 1997). Economic modelling requires dedicated staff and training, while trading of financial assets involves access to specialized data. Consumers and firms typically lack the extensive knowledge and expertise that professional forecasters and economists have (Sousa and Yetman, 2016). These agents predominantly form their expectations based on price indexation –to past inflation– or forecasts from specialized agents, albeit with a certain lag (Caroll, 2003). These cost variations prompt agents to select distinct forecasting methods (Branch, 2004), producing varying effects for expectations.

Disagreement in expectations could also be explained by staggered information updates regarding future economic activity (Mankiw *et al*., 2003). According to Mankiw and Reis (2002), these information rigidities arise due to costs of collecting and processing information, such that certain agents employ outdated information when forming expectations. Not surprisingly, especially considering their access to specialized datasets, financial analysts constantly monitor and update their expectations based on macroeconomic developments (Sousa and Yetman, 2016). Conversely, less sophisticated agents gradually acquire information from specialized forecasters by occasionally reading news reports (Carroll, 2003).

Finally, model-based expectations are determined by specifications and assumptions derived from economic theory and systematic empirical relationships. In Colombia, the 4GM assumes a monetary policy regime where the central bank reacts to deviations of inflation expectations from their long-term target. However, economic shocks that cause these deviations are limited in their ability to reflect changes in economic factors that affect inflation expectations, such as changes in commodity prices and climate-related shocks (see Figure 1). This limitation reduces the correlation between inflation and expectations, resulting in comparatively smaller estimates in NKPC.

7. Conclusion

Our study provides empirical evidence showing that the effect of inflation expectations on inflation dynamics in Colombia depends on the measurement of this variable. We found varying effects of expectations in NKPC estimations, with the size of the coefficient ranging between 0.37 and 1.24. Market-based measures exhibit comparatively greater effects on inflation dynamics: a one percentage point increase in financial market expectations (BEI) leads to a median increment in inflation of 0.96 percentage points, while economic survey (QSEE) and macroeconomic model (4GM) expectations yield median effects of 0.78 and 0.50 percentage points, respectively. Our findings are consistent with the existing empirical evidence regarding the effect of expectations in NKPC estimations and our results are robust to the use of alternative measures of core inflation, real economic activity, and instrumental variables. Possible explanations for the statistical differences in the effect of expectations on inflation relate to asymmetric losses in forecast errors, variations in forecasting costs, rigidities in information transmission, and economic modelling limitations.

Inflation expectations play a crucial role in determining inflation dynamics. Therefore, it is critical that central banks consider their varying effect when conducting policy analysis. By doing so, they can implement policy responses that are consistent with the actual effect of expectations on inflation rates, thereby enhancing the effectiveness of monetary policy.

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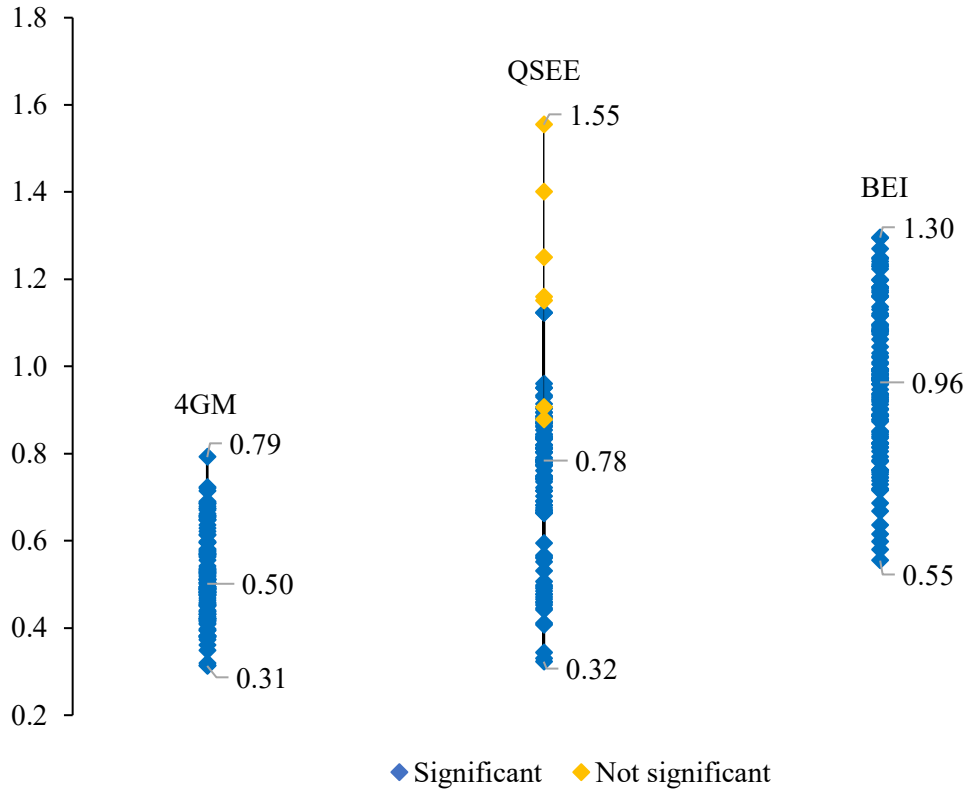
Annex 1. New-Keynesian Phillips Curve Estimations (1946-2016).

Country	Period	Measures of Expectations	Real Economic Activity	Estimation Method	NKPC	Study
Germany	1993-2004	Survey	Output gap	OLS	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	OLS	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	OLS	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	OLS	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	GMM	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	GMM	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	GMM	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	GMM	Hybrid	Henzel and Wollmershaeuser (2006)
	1970-1999	Survey	Output gap	GMM	Hybrid	Jondeau and Le Bihan (2005)
	1970-1999	Survey	Real marginal costs	GMM	Hybrid	Jondeau and Le Bihan (2005)
Eurozone	1993-2004	Survey	Real marginal costs	OLS	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	OLS	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	OLS	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	OLS	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	GMM	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	GMM	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	GMM	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	GMM	Hybrid	Henzel and Wollmershaeuser (2006)
	1970-1999	Survey	Real marginal costs	GMM	Hybrid	Jondeau and Le Bihan (2005)
	1970-1999	Survey	Output gap	GMM	Hybrid	Jondeau and Le Bihan (2005)
Argentina	1993-2003	Model	Output gap	GMM	Hybrid	D'Amato and Garegnani (2009)
	1993-2003	Model	Output gap	GMM	Hybrid	D'Amato and Garegnani (2009)
	1993-2003	Model	Output gap	GMM	Hybrid	D'Amato and Garegnani (2009)
Bolivia	2006-2014	Survey	Output gap	GMM	Hybrid	Murillo (2014)
Brazil	2002-2012	Model	Real marginal costs	GMM	Standard	Arruda *et al.* (2018)
	2002-2012	Model	Real marginal costs	GMM	Hybrid	Arruda *et al.* (2018)
	2002-2012	Survey	Real marginal costs	GMM	Standard	Arruda *et al.* (2018)
	2002-2012	Survey	Real marginal costs	GMM	Hybrid	Arruda *et al.* (2018)
	2002-2012	Model	Output gap	GMM	Standard	Arruda *et al.* (2018)
	2002-2012	Model	Output gap	GMM	Hybrid	Arruda *et al.* (2018)
	2002-2012	Survey	Output gap	GMM	Standard	Arruda *et al.* (2018)
	2002-2012	Survey	Output gap	GMM	Hybrid	Arruda *et al.* (2018)
Canada	1963-2000	Survey	Real marginal costs	GMM	Hybrid	Nason and Smith (2008)
	1963-2000	Survey	Real marginal costs	OLS	Hybrid	Nason and Smith (2008)
Chile	2002-2006	Survey	Output gap	GMM	Hybrid	Medel (2015)
	2002-2006	Survey	Output gap	GMM	Hybrid	Medel (2015)
Colombia	1984-2002	Model	Real marginal costs	GMM	Standard	Bejarano (2005)
	1984-2002	Model	Real marginal costs	GMM	Hybrid	Bejarano (2005)

Country	Period	Measures of Expectations	Real Economic Activity	Estimation Method	NKPC	Study
	2003-2009	Survey	Output gap	GMM	Hybrid	Cháves (2011)
	2003-2009	Model	Output gap	GMM	Hybrid	Cháves (2011)
	1990-2006	Model	Real marginal costs	GMM	Standard	Galvis (2010)
	1982-2001	Model	Output gap	GMM	Hybrid	Gómez *et al.* (2002)
United States	1968-2003	Survey	Output gap	OLS	Hybrid	Adam and Padula (2011)
	1968-2003	Survey	Marginal costs	OLS	Hybrid	Adam and Padula (2011)
	1968-2003	Survey	Output gap	OLS	Standard	Adam and Padula (2011)
	1968-2003	Survey	Marginal costs	OLS	Standard	Adam and Padula (2011)
	1968-2000	Survey	Real marginal costs	GMM	Standard	Brissimis and Magginas (2008)
	1968-2000	Survey	Real marginal costs	GMM	Hybrid	Brissimis and Magginas (2008)
	1968-2000	Survey	Real marginal costs	GMM	Standard	Brissimis and Magginas (2008)
	1968-2000	Survey	Real marginal costs	GMM	Hybrid	Brissimis and Magginas (2008)
	1968-2006	Survey	Real marginal costs	GMM	Standard	Brissimis and Magginas (2008)
	1968-2006	Survey	Real marginal costs	GMM	Hybrid	Brissimis and Magginas (2008)
	1960-1997	Survey	Real marginal costs	GMM	Hybrid	Galí and Gertler (1999)
	1960-1997	Survey	Real marginal costs	GMM	Standard	Galí and Gertler (1999)
	1960-1997	Survey	Output gap	GMM	Hybrid	Galí, Gertler and López-Salido (2005)
	1960-1997	Survey	Real marginal costs	GMM	Hybrid	Galí, Gertler and López-Salido (2005)
	1960-1997	Model	Real marginal costs	GMM	Hybrid	Galí, Gertler and López-Salido (2005)
	1960-1997	Model	Output gap	GMM	Hybrid	Galí, Gertler and López-Salido (2005)
	1960-1997	Model	Real marginal costs	GMM	Hybrid	Galí, Gertler and López-Salido (2005)
	1960-1997	Model	Output gap	GMM	Hybrid	Galí, Gertler and López-Salido (2005)
	1993-2004	Survey	Output gap	OLS	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	OLS	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	OLS	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	OLS	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	GMM	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	GMM	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	GMM	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	GMM	Hybrid	Henzel and Wollmershaeuser (2006)
	1970-1999	Survey	Output gap	GMM	Hybrid	Jondeau and Le Bihan (2005)
	1970-1999	Survey	Real marginal costs	GMM	Hybrid	Jondeau and Le Bihan (2005)
	1967-2009	Model	Real marginal costs	GMM	Standard	Mazumder (2011)
	1967-2009	Survey	Real marginal costs	GMM	Standard	Mazumder (2011)
	1967-2009	Model	Real marginal costs	GMM	Hybrid	Mazumder (2011)
	1967-2009	Survey	Real marginal costs	GMM	Hybrid	Mazumder (2011)
	1949-2001	Survey	Real marginal costs	GMM	Hybrid	Nason and Smith (2008)
	1949-2001	Survey	Real marginal costs	OLS	Hybrid	Nason and Smith (2008)
	1968-2005	Survey	Output gap	OLS	Hybrid	Zhang *et al.* (2009)
	1968-2005	Model	Output gap	GMM	Hybrid	Zhang *et al.* (2009)
	1998-2005	Survey	Output gap	GMM	Hybrid	Zhang *et al.* (2009)
	1968-1999	Survey	Output gap	GMM	Hybrid	Zhang *et al.* (2009)
	1960-2005	Survey	Output gap	GMM	Hybrid	Zhang *et al.* (2009)
France	1993-2004	Survey	Output gap	OLS	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	OLS	Hybrid	Henzel and Wollmershaeuser (2006)

Country	Period	Measures of Expectations	Real Economic Activity	Estimation Method	NKPC	Study
	1993-2004	Survey	Real marginal costs	OLS	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	OLS	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	GMM	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	GMM	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	GMM	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	GMM	Hybrid	Henzel and Wollmershaeuser (2006)
	1970-1999	Model	Output gap	GMM	Hybrid	Jondeau and Le Bihan (2005)
	1970-1999	Model	Real marginal costs	GMM	Hybrid	Jondeau and Le Bihan (2005)
Italy	1993-2004	Survey	Output gap	OLS	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	OLS	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	OLS	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	OLS	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	GMM	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	GMM	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	GMM	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	GMM	Hybrid	Henzel and Wollmershaeuser (2006)
	1970-1999	Model	Output gap	GMM	Hybrid	Jondeau and Le Bihan (2005)
	1970-1999	Model	Real marginal costs	GMM	Hybrid	Jondeau and Le Bihan (2005)
Peru	2004-2016	Model	Output gap	OLS	Hybrid	Mendoza and Perea (2017)
United Kingdom	1993-2004	Survey	Output gap	OLS	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	OLS	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	OLS	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	OLS	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	GMM	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	GMM	Standard	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Real marginal costs	GMM	Hybrid	Henzel and Wollmershaeuser (2006)
	1993-2004	Survey	Output gap	GMM	Hybrid	Henzel and Wollmershaeuser (2006)
	1987-2007	Survey	Output gap	OLS	Hybrid	Jean-Baptiste (2012)
	1987-2007	Survey	Real marginal costs	OLS	Hybrid	Jean-Baptiste (2012)
	1987-2007	Survey	Real marginal costs	GMM	Hybrid	Jean-Baptiste (2012)
	1987-2007	Survey	Real marginal costs	GMM	Hybrid	Jean-Baptiste (2012)
	1970-1999	Survey	Output gap	GMM	Hybrid	Jondeau and Le Bihan (2005)
	1970-1999	Survey	Real marginal costs	GMM	Hybrid	Jondeau and Le Bihan (2005)
	1961-2000	Survey	Real marginal costs	GMM	Hybrid	Nason and Smith (2008)
	1961-2000	Survey	Real marginal costs	OLS	Hybrid	Nason and Smith (2008)

Annex 2. NKPC Estimates of Inflation Expectations in Colombia (2010-2019)



Each point in this figure represents an estimate for inflation expectations using different measures of core inflation, real economic activity, and instrumental variables. There are a total of 341 estimates: 115 for BEI; 108 for QSEE; 118 for 4GM. For each measure of expectations, this figure indicates the maximum, minimum and median value of the distribution of estimates. 98% of estimates for inflation expectations in this figure exhibit statistical significance at a 95% confidence level.