Box 2
Inflation expectations and their degree of anchoring: what can be inferred from expectations obtained from Colombia's public debt market?

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The global economy experienced a substantial rise in inflation in the aftermath of the COVID-19 pandemic and ensuing disruptions in the international supply chain, in addition to the impact on international energy prices resulting from the war between Russia and Ukraine. In emerging economies, this inflationary phenomenon coincided with a devaluation of their currencies, resulting in increased costs for imported goods. This elicited a significant monetary policy reaction on a worldwide scale. Over the past year, numerous economies have shown a reduction in inflation; yet, despite some converging towards long-term targets, their inflation expectations continue to surpass the objectives. The Colombian case is no exception.

Consequently, because inflation expectations are a critical input to the decision-making process of the Board of Directors of *Banco de la República* (BDBR), it is necessary to continuously monitor the indicators that signal the probable future trajectory of inflation. Various sources of information exist to measure or estimate inflation expectations for Colombia, including surveys of economic analysts[1] or measures derived from public debt markets. The latter compares different term structures between nominal TES (bonds issued by the Colombian government and managed by *Banco de la República*) and UVR-denominated TES (real value unit for its Spanish acronym). Additionally, for this analysis break-even inflation (BEI) and forward BEI (FBEI) rates were used (see Appendix B2.1) because, relative to the surveys, they offer different terms for study, offer a greater number of observations over time, and are for longer horizons (vs. one to two years for the surveys). In addition, *Banco de la República* has compiled daily information on the yield curve of public debt securities since 2003, which can also be used to obtain the market's inflation expectations.

At the international level, inflation expectations and their degree of anchoring are evaluated by monitoring: 1) deviation from a specific target level, 2) uncertainty and distribution, and 3) the pass-through of short-term expectations changes to medium and long-term expectations. In the next three sections, we provide some sample events and econometric models that provide insight into the degree of anchoring.[2]

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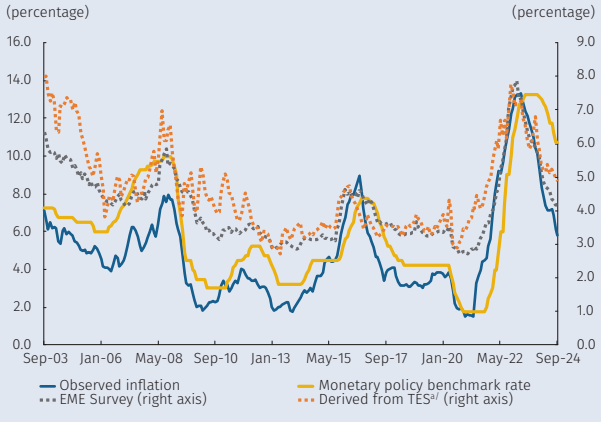
1 For example, in Colombia there are the Monthly Survey of Economic Analyst Expectations (EME for its Spanish acronym) and the Quarterly Survey of Economic Expectations (ETE), both conducted by *Banco de la República.*

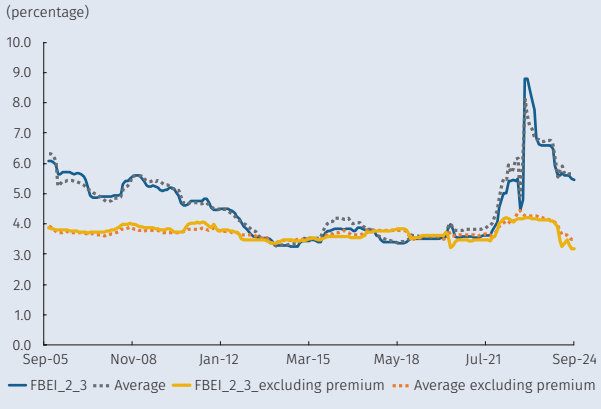
2 Economic literature has stressed the relevance of the degree of expectation anchoring to improve the ability of central banks to control inflation, along with the possibility of assessing the credibility of monetary policy (e.g., Haubrich et al., 2012; Autrup and Grothe, 2014; Strohsal et al., 2016).

Graph B2.1
Inflation expectations, observed inflation, and monetary policy interest rate



a/ The average 1- to 10-year BEI and FBEI (i, j) are computed where i = 1, 2, ... ,5 and j = 1, 2, ... , 5.
Sources: DANE; *Banco de la República*; own calculations.

Graph B2.2
Anchor perceived by the market ($\bar{\pi}_s^e$)a/



a/ The anchor averages are computed, considering the FBEI (i, j), where i = 1, 2, ... ,5 and j = 1, 2, ... , 5.
Sources: *Banco de la República*; own calculations.

For the exercises carried out, we 1) estimated a 250-day (one-year) rolling window, 2) conducted estimates for each term and component of the BEI and FBEI, and 3) averaged and standardized the results[3] to measure the anchoring perception between zero and one (Graphs B2.2, B2.3 and B2.6), where a value close to zero indicates a higher degree of anchoring.

1. Level

Any economy that faces shocks from diverse origins may experience short-term inflation deviations from a target. In these situations, and according to the nature of the shock (supply or demand/ permanent or transitory), economic agents expect the central bank to react so as to revert inflation back to the target. In Colombia, it is widely acknowledged that the recent inflationary surge has resulted in significant price changes and remains above the inflation target (Graph B2.1). At its peak, expectations derived from debt securities exceeded the inflation target and the historical average of inflation since 2000 by over two standard deviations.

In this context, it is important to have some measure that indicates the variations in the persistence of inflation expectation deviations vis-a-vis a specific level, as well as some measure reflecting the anchor perceived by the market. For this purpose, the methodology of Winkelmann (2014) was implemented, which allows estimating for each time window (s), both the anchor perceived by the market ($\bar{\pi}_s^e$) as well as the degree of anchoring, measured as the pace of the convergence to the anchor perceived by the market ($\frac{1}{\gamma_s}$). The model developed is based on the following equation, where the two parameters ($\bar{\pi}_s$ and γ_s) are estimated for each rolling window of 250 days (s):

Equation 1:

$$\pi_t^e = \bar{\pi}_s^e + exp(-\gamma_s\ (\pi_{t-1}^e - \bar{\pi}_s^e)^2)\left(\sum_{i=1}^{p} \alpha_i \pi_{t-i}^e - \bar{\pi}_s^e\right) + \varepsilon_t$$

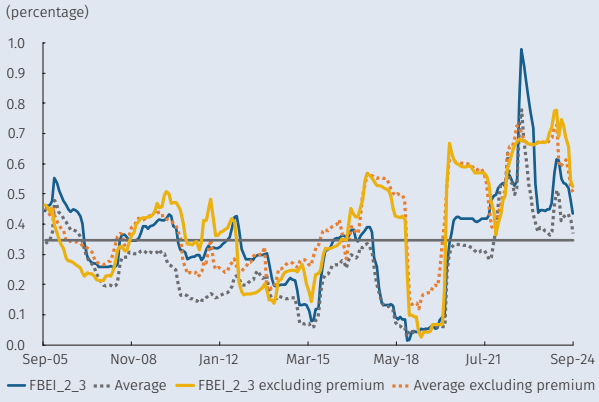
Equation 1 provides estimates for different terms of both BEI and FBEI,[4] although these were aggregated for the sake of simplicity. Most of the findings apply to all terms.[5] Graph B2.2 presents the anchor perceived by the market, which had been gradually declining since 2010 as inflation approached the Bank's long-term target. However, this downward trajectory was marred by certain exceptions when significant but transitory shocks occurred, as was the case in 2015 and 2016 when the effects of the international oil shock that occurred at yearend 2014 were felt, with repercussions on the exchange rate,

3 It is important to note that a 3-year BEI of x% indicates that the average inflation expectation over the next three years will have to be x. Thus, starting in 2024, the 3-year BEI indicates that inflation is expected to average x% for 2025-2027. Alternatively, an FBEI of y% represents the one-year-ahead inflation expectation for two years into the future. Consequently, if our start point is 2024, the FBEI suggests that the inflation expectation for 2027 positioning ourselves in 2026 would be y%).

4 Assuming terms of two to ten years. It should be noted that sections of the yield curve may be more prone to market volatility and liquidity premium changes, which are not covered in this analysis.

5 Additionally, the resulting inflation expectation measure can be "cleaned up" by discounting the inflationary risk premium. To construct the inflationary risk premium, the methodology of Espinosa-Torres et al. (2017) was followed. The results are similar, although they tend to show a lower anchor perceived by the market versus that of the original series, because, by definition, the longer the term, the higher the inflationary risk premium.

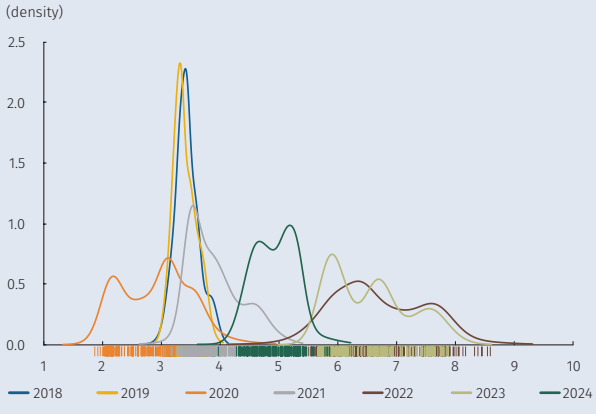
Graph B2.3
Degree of anchoring $(\frac{1}{\gamma_s})$ measured as the pace of convergence to the perceived anchor $(\bar{\pi}_s^e)$[a/]



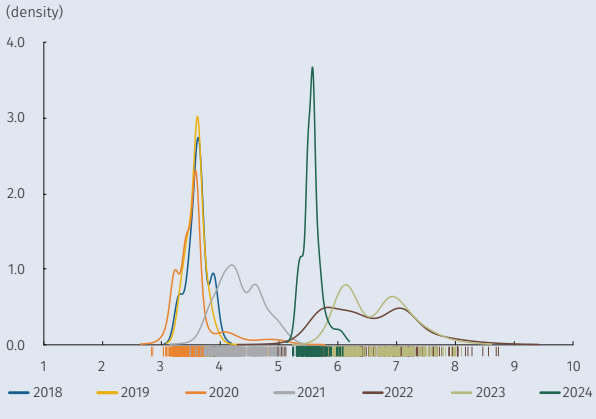
a/ The anchor averages are computed, considering the FBEI (i, j), where i = 1, 2, ... ,5 and j = 1, 2, ... , 5.
Sources: *Banco de la República*; own calculations.

Graph B2.4
Annual densities for BEI to 5 and 10 years

A. 5-year BEI



B. 10-year BEI



Sources: *Banco de la República*; own calculations.

exacerbated by a strong El Niño phenomenon that impacted food prices. Recently, after the peak observed in 2023, the market-perceived anchor has shown a significant reduction. Nevertheless, this level remains above the historical average, the pre-COVID levels, and *Banco de la República's* target. When discounting for the inflationary risk premium, something similar occurs, although here the levels fall closer to the 3% target.

For its part, γ_s is used as a proxy measure of the speed of convergence to $\bar{\pi}_s$. Here the concept of degree of anchoring is related to the persistence of the inflation expectation response to a shock and the swiftness of its reversion to the mean (perceived anchor). In this sense, the lower the persistence of the response of expectations to shocks, the more anchored the inflation expectations will be. Graph B2.3 shows how the recent inflationary shock generated pressures on the degree of anchoring, which, although these have gradually dissipated, remain above pre-pandemic levels.

2. Uncertainty and distribution

When the agents are unclear about the timing and persistence of the shocks affecting observed inflation, this uncertainty is reflected in changes in the variation and asymmetry of the distribution of inflation expectations.

Panels A and B of Graph B2.4 show the evolution of the probability densities for five- and ten-year inflation expectations using BEI rates discounted by the inflation risk premium. It can be seen that, in 2018 and 2019 before the COVID crisis, most of the probability mass was between 3% and 4%. During the COVID-19 period (2020-2021) the density of these expectations shifted significantly to the left, leveling off with downward biases. Subsequently, in 2023, expectations shifted significantly to the right, with a large amplitude reflecting the high uncertainty detected. Recently, the situation has improved, but these expectations are still far from "normal".

3. Transfer of short-term expectations to the medium- and long-term

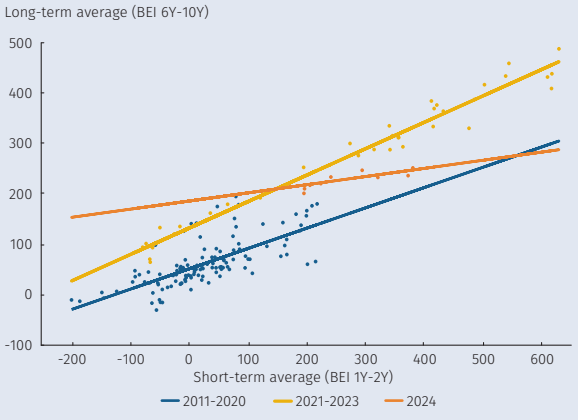
Finally, another way to monitor the degree of anchoring is by measuring the response or pass-through of shocks of short-term expectations to the dynamics of medium- and long-term expectations. In other words, under this concept of anchoring, if expectations are perfectly anchored, medium- and long-term expectations should be insensitive to short-term expectations and to current unforeseen inflationary shocks.[6]

Graph B2.5 shows a positive relationship between the short- and long-term expectation deviations from the target.

In the inflationary outbreak period between 2021 and 2023 (post-COVID-19), a greater slope is evident than in the previous decade. Recent improvements have been observed, with a lower slope than the previous period; however, the level of the deviations continues to be high.

6 This line of reasoning also includes the notion of codependence among these variables: the greater the codependence, the greater the transmission of shocks from short to medium and long terms.

Graph B2.5
Relationship between deviations from the target of short and long-term expectations



Sources: *Banco de la República*; own calculations.

The following are two econometric applications to measure the degree of anchoring under the notion of pass-through or codependence between short-term expectations and medium and long-term expectations.

The first, by Antunes (2015), uses a copula analysis to estimate the codependence between the tails of the distribution of short- to medium- and long-term expectations. In the case where the extreme movements of short-term and of longer-term expectations are independent, expectations are perfectly anchored. On the contrary, if there is codependence between these variables, the dynamics of the degree of anchoring alters and can be analyzed through the following equations:

Equation 2:

$$\lambda_U = \lim_{k \to 1} Pr\left\{\pi^e_{MP} > \pi^e_{MP\,(k)} | \, \pi^e_{CP} > \pi^e_{CP\,(k)}\right\}$$

Equation 3:

$$\lambda_L = \lim_{k \to O} Pr\left\{\pi^e_{MP} \leq \pi^e_{MP\,(k)} | \pi^e_{CP} \leq \pi^e_{CP\,(k)}\right\}$$

Where λ_U is the upper tail and λ_L is the lower tail of the distributions of the medium (long) term expectations (π^e_{MP}) conditional on the value of the short-term expectations (π^e_{CP}) being located at the quantile *k*.

The second, from Gefang (2012), uses the following regression model:

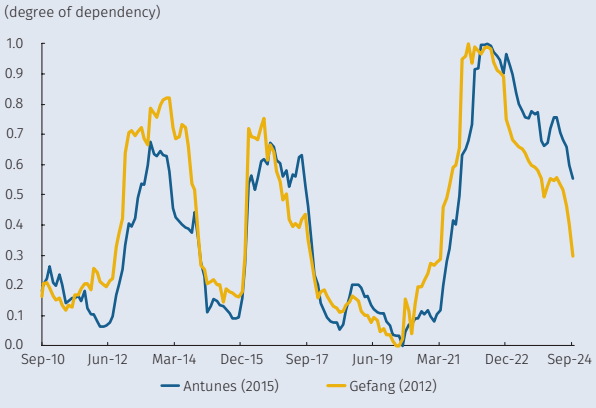
Equation 4:

$$\Delta\pi^e_{MP,t} = \beta\Delta\pi^e_{CP,t} + \varepsilon_t$$

Where Δ is the difference operator and β is a coefficient that captures the pass-through of short-term movements (π^e_{CP}) to medium-term movements (π^e_{MP}), which can be associated with a degree of deanchoring of inflation expectations in the concept of transfer.

Graph B2.6 shows the results of Antunes (2015) and Gefang (2012) estimates using 250-day (one year) rolling windows for short term (one to two years) BEI rates relative to medium-term (three to five years) BEI rates.7 Under this concept of anchoring, a value close to zero is desirable, which would indicate low codependence or pass-through, implying more anchored expectations. As can be seen, the degree of anchoring has improved significantly after the deterioration observed in 2023. Nevertheless, the levels of codependence and/or pass-through indicate a need for caution. Consequently, it is recommended that expectations be closely monitored so that the values may progressively converge closer to the Bank's inflation target.

Graph B2.6
Codependency and/or pass-through of short- and long-term expectations (BEI 3-5 years)



Note: The data reported corresponds to the main component of the 3- and 5-year BEI.
Sources: *Banco de la República*; own calculations.

Concluding remarks

The level and volatility of the various inflation expectations measures derived from debt securities (BEI and FBEI) increased significantly during 2023, as evidenced by the previous exercises. However, they have progressively exhibited a more favorable trend in the current

7 The results remain the same when comparing short-term with long-term (six to ten years).

year. Even so, the market's perception of the anchor's levels and the varying definitions of the degree of anchoring have not yet returned to values that are more consistent with the 3% inflation target set by *Banco de la República*.

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Appendix B2.1

This appendix provides the technical details of the EIB and FBEI rate calculation:

A. Break-even inflation rate (BEI):

The BEI $\pi_t^{e,n}$ rate over time *t* for a period of *n* years, is defined as:

$$\pi_t^{e,m} = \frac{\left(1+i_t^{Nom,\,m}\right)}{\left(1+i_t^{UVR,m}\right)} - 1$$

Where i_t^n and r_t^n are the returns of a bond with a nominal rate (ex. TES pesos) and a bond with a real rate (ex. TES UVR), respectively. The bonds have the same maturity of n years and the same credit rating. The BEIT rate $\pi_t^{e,n}$ reflects the average inflation expected over the following *n* years.

B. Forward break-even inflation rate (FBEI)

The FBEI $\pi_t^{e,a-b}$ rate over time t for a period of a-b years, represents the average inflation expectation over a period of b years that begins after a years. The FBEI rate $\pi_t^{e,a-b}$ is provided by:

$$\pi_t^{e,m-a} = \left[\frac{\left(1+\pi_t^{e,b}\right)}{\left(1+\pi_t^{e,a}\right)}\right]^{1/b} - 1$$

Where $\pi_t^{e,a}$ and $\pi_t^{e,n}$ are the BEIT rate over the terms of *a* and *n* years, where $n = a + b$.