Box 2
Measurement of Inflation Expectations and its Effect on Inflation Dynamics in Colombia

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This box shows estimates for New Keynesian Phillips Curves (NKPC) employing several measures of inflation expectations using information from financial markets and economic surveys. The coefficient properties (value, statistical significance, predictive capacity and goodness-of-fit) that result from varying these measurements within this variable are then analyzed. The latter is done to establish whether the incidence of inflation expectations on core inflation dynamics in Colombia depends on the measurement of this variable.

Market-based inflation expectations are calculated as the difference between real and nominal yields on domestic bonds (TES) with the same maturity term. This difference, known in the economic literature as breakeven inflation (BEI), reflects the minimum return required by an investor in order to hold these assets. Forward BEI (FBEI) controls for financial market effects and short-term inflationary shocks, reflecting expectations after certain time has elapsed. On the other hand, survey expectations are obtained from polls that reflect economic agents' forecasts of variables of interest (e.g., expected inflation). This eliminates the need to use additional instruments to approximate this variable (Adam and Padula, 2011; Henzel and Wollmershäuser, 2008).

Among the limitations of market-based measures of inflation expectations lies the difficulty in separating expectations from other factors that plausibly affect returns required by investors, such as inflationary risk and liquidity premium (Ríos and Girón, 2013; Melo-Velandia and Granados-Castro, 2012; Melo-Velandia and Moreno-Gutiérrez, 2010; Arias et al., 2005). Therefore, this exercise uses measures of BEI and FBEI that separates these components using the methodology outlined in Espinosa-Torres, et al. (2017).

Conversely, although surveys provide an explicit measure of expected inflation, they rely on methods and information specific polled agents, which can limit their effectiveness (Clements, 2019; Pesaran and Weale, 2006). To address this, the estimations conducted in this exercise include aggregate inflation expectations. The aim is to

mitigate respondent subjectivity and control for possible heterogeneity among agents.

Inflation dynamics are captured through an NKPC specification. In its hybrid version, which exhibits the best adjustment to the empirical evidence, the NKPC states that current inflation depends on past inflation, inflation expectations, and a measure of real economic activity, usually approximated through the output gap or based on real marginal costs. This can be expressed with the following equation:

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

Where π_t is inflation in period t; x_t approximates real economic activity[1]; and $E_t\{\pi_{t+1}\}$ denotes expected inflation.

Market-based expectations are obtained from *Banco de la República's* Operations and Financial Markets Analysis Department, while survey expectations come from the Bank's Quarterly Survey of Economic Expectations (ETE for its initials in Spanish). The use of quarterly data is determined by the availability of information for gross domestic product, which is necessary for the measurement of the output gap. Expectations reflect expected inflation in one year[2]. Estimates were derived for the period 2008-2020 using the generalized method of moments for the following inter-annual measures of inflation: core inflation; inflation excluding food; inflation excluding food and regulated goods[3]. The exercise using survey data included expectations from the financial, academic, industrial, and retail sectors[4].

The validity of models was assessed using Hansen's specification test[5] and by comparing estimated coefficients with those reported by the literature concerned with NKPC estimations[6]. For all measures, 85% (or more) of the proposed specifications were valid according to Hansen's criterion, the exception being FBEI models, for which only

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1   Real economic activity is measured through GDP and real marginal deviations with respect to their long-term trends; real marginal costs are calculated as the ratio between work income and nominal GDP, adjusted by the portion of output attributable to the labor factor.

2   BEI and FBEI are calculated as quarterly averages based on daily observations, although the results do not change when based on the median.

3   To focus the analysis on the influence of expectations on core inflation, the following inflation measures (which include volatile components) were discarded: headline inflation; food inflation; inflation for food and regulated goods. This helps minimize biases derived from possible correlation between expected inflation indicators and persistent shocks on headline inflation.

4   In addition to facilitating the estimation of non-linear models within these parameters, the generalized method of moments mitigates endogenous problems arising from measurement errors in expected inflation indicators.

5   The null hypothesis of Hansen's specification test establishes that the instruments employed in the estimation are jointly valid. The instruments included in the econometric exercise were: between three and six lags of inflation and real economic activity.

6   A total of 19 studies of the Phillips Curve, which reported 121 coefficients for expected inflation, were consulted.

21% passed the specification test[7]. The literature suggests that the effect of inflation expectations on inflation dynamics should be statistically significant and that the value of the estimated coefficient should lie between 0.1 and 1.2 (or between 0.46 and 0.95 under Colombian data) with an expected value of 0.67. The predictive capacity of inflation expectations was evaluated through Fisher's and Pesaran and Timmerman's tests, whose results suggest that the measures used in this exercise correctly predict the direction of changes in core inflation (Chart B2.1).

Graph B2.1 summarizes the results, which include 336 estimations. In general, these assert the statistical significance of the effect associated with inflation expectations, as well as their goodness-of-fit. This is reflected in the root-mean-square error and the R-squared. As expected, the value of the coefficient shows minor variations across measurements and economic agents, attributable to the measurement differences and heterogeneities mentioned above. However, these remain relatively bounded around values reported in the literature, without significant deviations between models. This indicates that the effect of inflation expectations on inflation dynamics in Colombia is highly robust, as said effect exhibits consistent patterns when employing different measures for this variable.

Chart B2.1
P-value from Fisher and Pesaran-Timmerman (P-T) directionality tests for expected inflation [a/]

Source	Core inflation					
	excluding food		excluding food and regulated items		Core 15	
	Fisher	P-T	Fisher	P-T	Fisher	P-T
Finance	0.000	0.000	0.000	0.000	0.000	0.000
Academia	0.000	0.000	0.000	0.000	0.000	0.000
Industry	0.000	0.000	0.000	0.000	0.000	0.000
Retail	0.000	0.000	0.000	0.000	0.000	0.000
ETE	0.000	0.000	0.000	0.000	0.000	0.000
BEI	0.000	0.000	0.000	0.000	0.000	0.000
FBEI	0.000	0.000	0.000	0.000	0.000	0.000

a/ The null hypothesis of the Fisher (Pesaran-Timmerman) test establishes that the series of expected inflation and observed inflation are independent (they come from independent distributions). At 95% statistical confidence, the null hypothesis is rejected when the p-value is less than 0.05. In this context, the rejection of the null hypothesis indicates that the measure of inflation expectations being analyzed in the test correctly predicts the direction of the changes observed in core inflation.
Source: calculations by the author.

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Pesaran, H. M.; Weale, M. (2006). "Survey Expectations" [online], en G. Elliot; C. W. J. Granger y A. Timmermann (eds.), *Handbook of Economic Forecasting*, Elsevier, vol. 1, ch. 14, pp. 715-776, available at: https://doi. org/10.1016/ S1574-0706(05)01014-1
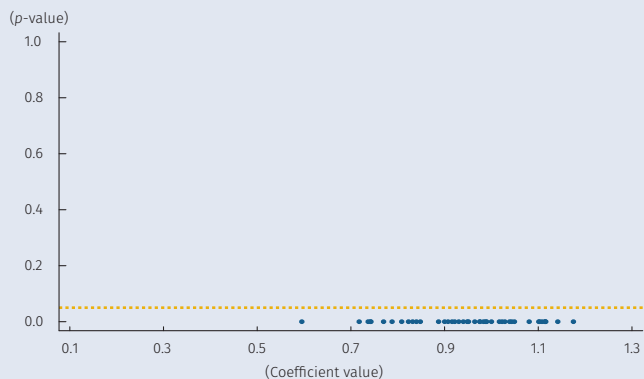
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7   A possible explanation for this relates to the time horizon, as the FBEI is formulated after a year has passed, which can affect the precision of this variable on a Phillips Curve. Equally, it could indicate that short-term shocks on headline inflation affect the formation of expectations relevant for price formation gathered by the measures of core inflation.
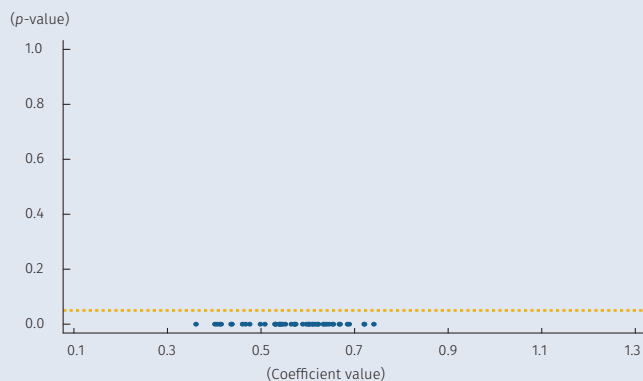
Graph B2.1
Effect of inflation expectations on inflation dynamics in Colombia using market and measures indicators (2008-2020)[a]
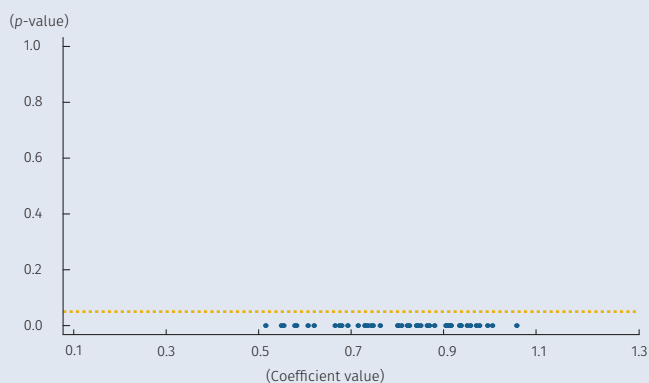
A. p-value (vertical) and coefficient value (horizontal)[b]

i. Finance

(p-value)
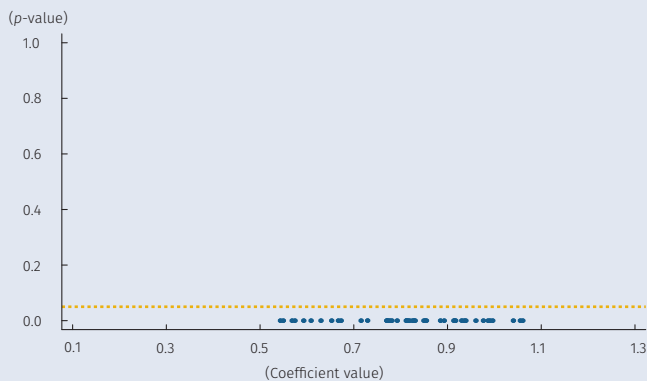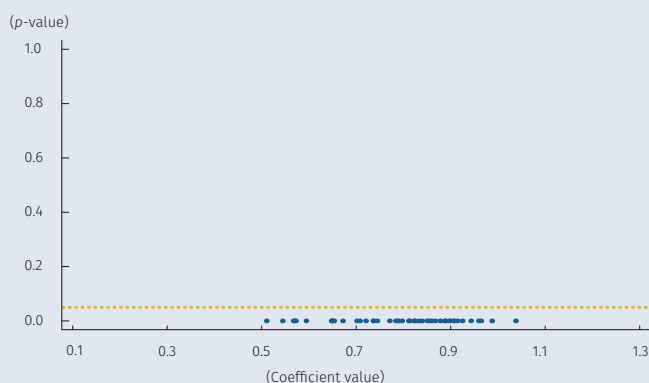
iii. Industry

(p-value)

v. ETE

(p-value)

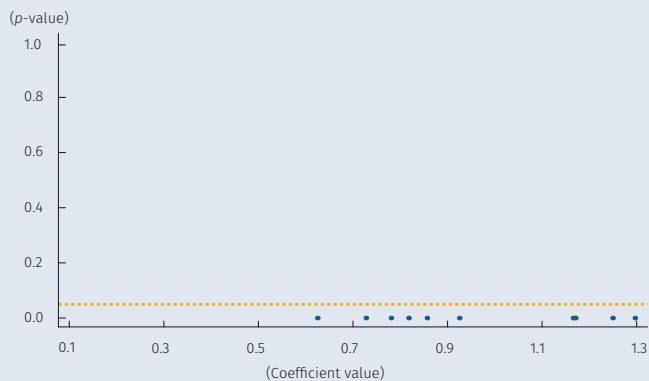vii. FBEI

(p-value)

ii. Academia

(p-value)

iv. Retail

(p-value)

vi. BEI
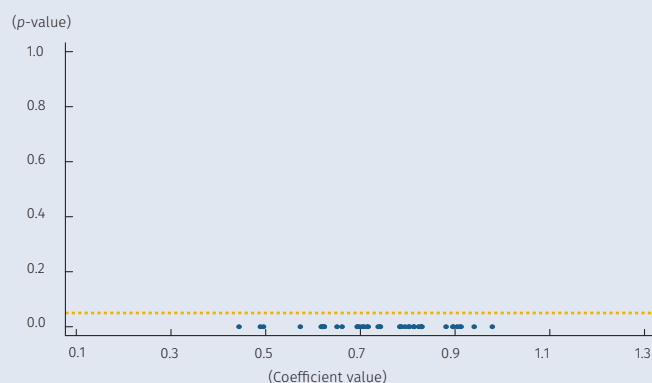
(p-value)

a/ This graph summarizes the results of the estimations for Colombia off the New Keynesian Phillips Curve using various measures of inflation expectations.
b/ The y-axis indicates the p-value of the effect associated with expected inflation, the x-axis shows the value of the estimated coefficient. The horizontal yellow line marks the threshold for statistical significance with 95% confidence. If the p-value is below the yellow line, it is concluded that the effect of the expected inflation indicator is statistically significant
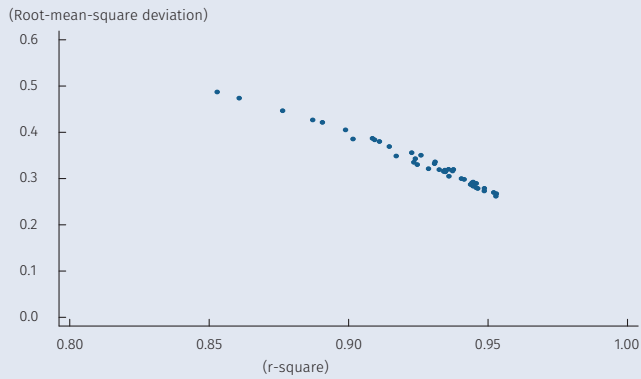Source: calculations by the author.
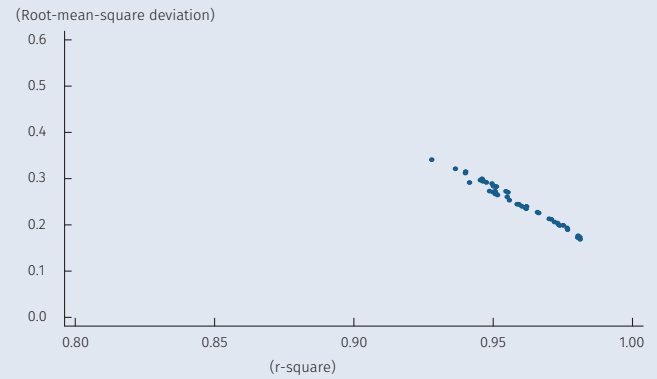
Graph B2.1 (continued)
Effect of inflation expectations on inflation dynamics in Colombia using market and measures indicators (2008-2020)

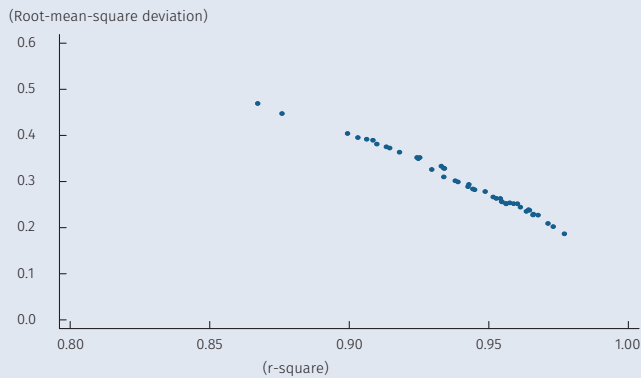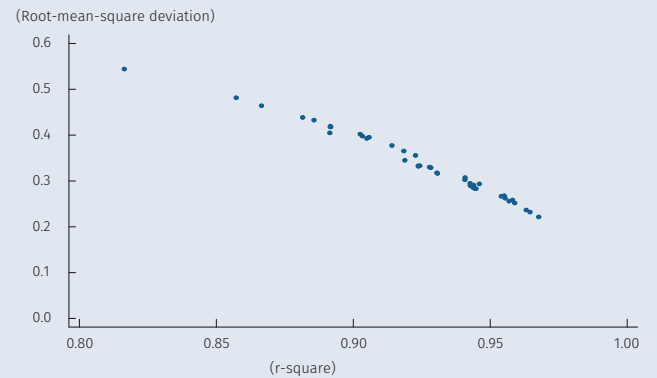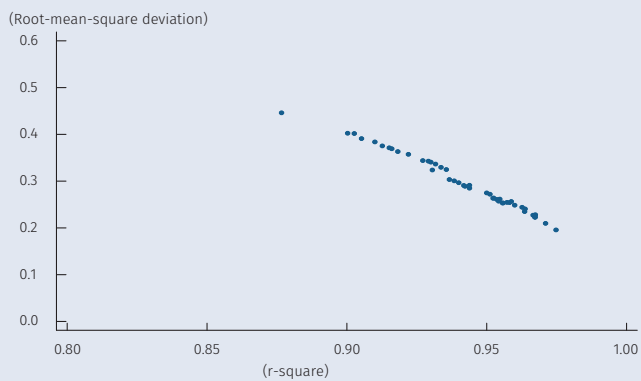B. Root-mean-square deviation (vertical) and R-squared (horizontal) [c/]

i. Finance

(Root-mean-square deviation)

(r-square)

ii. Academia

(Root-mean-square deviation)

(r-square)

iii. Industry

(Root-mean-square deviation)

(r-square)

iv. Retail

(Root-mean-square deviation)

(r-square)

v. ETE

(Root-mean-square deviation)

(r-square)

vi. BEI

(Root-mean-square deviation)

(r-square)

vii. FBEI

(Root-mean-square deviation)

(r-square)
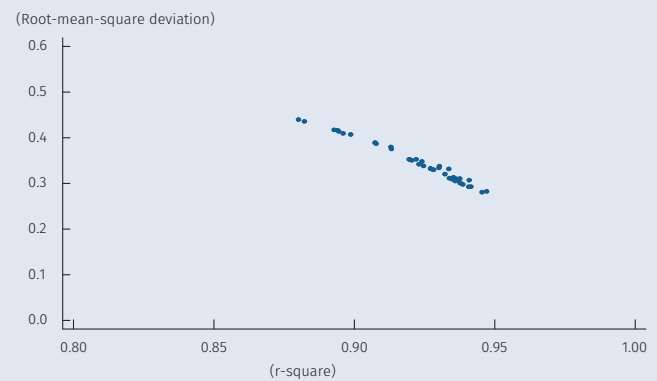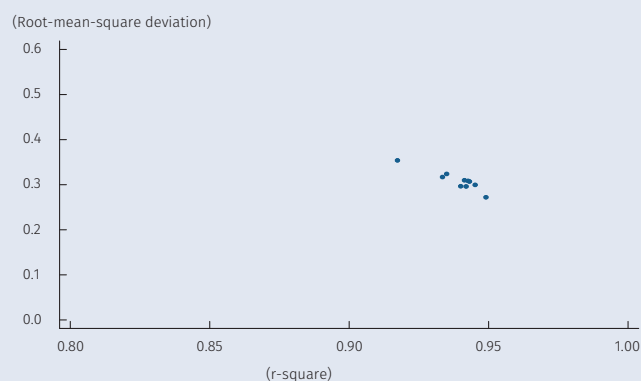
c/ The y-axis indicates the root-mean-square deviation; the x-axis denotes the R-squared of the estimated model. The lower (larger) the value of the root-mean-square deviation (R-squared), the better the goodness-of-fit of the estimated model.
Source: calculations by the author.