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Weather Shocks and Inflation Expectations in Semi-Structural Models

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Abstract

Colombia is particularly affected by the El Niño Southern Oscillation (ENSO) weather fluctuations. In this context, this study explores how the adverse weather events linked to ENSO affect the inflation expectations in Colombia and how to incorporate these second-round effects into a small open economy New Keynesian model. Using BVARx models we provide evidence that the inflation expectations obtained from surveys and break-even inflation measures are affected by weather supply shocks. Later, using this stylised fact, we modify one of the core forecasting models of the Banco de la República by incorporating the mechanisms in which weather-related shocks affect marginal costs and inflation expectations. We find that ENSO shocks had an important role in both inflation and the dynamics of inflation expectations, and that policymakers should consider this fact.

Keywords: Inflation, inflation expectations, inflation expectations anchoring, weather shocks.

JEL: D84, E31, E52, Q54

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1 Introduction

Inflation expectations and the central bank's ability to anchor them to the inflation target play a central role in monetary policy (Łyziak and Paloviita, 2017). Furthermore, the central bank's ability to affect inflation expectations is a direct measure of central bank credibility and has a central role in price and wage formation (Bernanke (2007); Belke et al. (2018)). Nonetheless, extreme supply-related shocks that increase inflation could make this task harder. These weather-related shocks can have a wider impact on price setting, beyond its direct effect on food prices and the cost of utilities. In addition, the El Niño Southern Oscillation (ENSO) fluctuations can also affect the inflation expectations that are anchored to the inflation target if the shocks are significantly pronounced and persistent.

Although there are many studies that have tackled the assessment of anchoring the inflation expectations, the impact of weather shocks on inflation expectations has not been studied in Colombia. This study provides the first approach to analyse how weather shocks, particularly those related with the ENSO fluctuations, can affect inflation expectations and how to incorporate this fact into a small open economy New Keynesian model.

In this context, this study involves three different areas of research. The first area covers the empirical literature regarding the inflation expectations that are anchored to the inflation target. In this literature, the anchoring of inflation expectations has been tested by assessing the persistence of headline inflation (Davis et al. (2013)), estimating the pass- through of either inflation or short-term inflation expectations to long-term inflation expectations (Gefang et al. (2012); Strohsal et al. (2016); Łyziak and Paloviita (2017)), measuring the variability and dispersion of inflation expectations (Bems et al. (2018)), evaluating the deviations of long-term inflation expectations from the inflation target (Demertzis et al. (2008); Demertzis et al. (2010)), and calculating the implicit inflation anchor (Demertzis et al. (2008); Mehrotra and Yetman (2018)). We contribute to this literature by showing that adverse weather may have statistically significant effects on inflation expectations and may affect the inflation expectations that are anchored to the inflation target.

The second area corresponds to the studies that have tackled the question of how weather shocks affect inflation in Colombia. Among the most relevant studies in this area, Abril-Salcedo et al. (2016) find that a strong El Niño shock has an important effect on the food inflation growth from six to nine months after the shock. In addition, they find evidence of a non-linear relationship between food inflation and ENSO shocks. Other important studies that have argued the significance between weather shocks and food inflation in Colombia include Caicedo (2007), Cano (2014) and Melo et al. (2017). In this area, we contribute by introducing simple mechanisms that allow for a better understanding of how inflation is affected directly and by second-round effects arising from adverse weather shocks.

The third area refers to small open economy New-Keynesian models that are usually used in central bank policy and forecasting exercises. These models are not completely micro-founded, and usually incorporate features that improve their fitting and forecasting abilities. [1] These models originated from the Quarterly Projection Model (QPM), which is used by several central banks in their forecasting and policy analysis. The QPM is based on the principles of New-Keynesian open economy models, with equations for output (IS curve), inflation (the Phillips curve), the shot-term interest rate (a policy reaction function), and the exchange rate (an uncovered interest rate parity condition). There are numerous references regarding the use of these models and its implementation in several emerging market economies (for example see Berg and Laxton (2006), Benes et al. (2017), and Gonzalez et al. (2020) among others).In addition, some of this models have tried to incorporate simple modifications to the food inflation Phillips curves, allowing for example, rain precipitations (Berg and Laxton (2006), Uribe et al. (2002), and Benes et al. (2017)). In this context, our work contributes to the literature by providing a theoretical framework that evaluates to what extent the central bank should react to these shocks to anchor inflation expectation.

This study is organised as follows. In section 2, we present a brief review about the importance of weather shocks and ENSO fluctuations in Colombia. In section 3, we discuss some stylised facts regarding inflation expectations and the ENSO fluctuations in Colombia. In section 4, using BVARx models for an ample set of inflation expectations series, we provide evidence that inflation expectations are affected by weather shocks. This approach allows the control of supply shocks, short-term inflation surprises, and macroeconomic fundamentals that could affect the anchoring of inflation expectations. In section 5 ,we modify a small open economy New- Keynesian model in which we include mechanisms that allow inflation and inflation expectations to be affected by weather shocks. Furthermore, we include a credibility mechanism that allow us to create simulations depending on the level of central bank credibility. For this purpose, we modify the 4GM model proposed by Gonzalez et al. (2020) for Colombia. The advantage of this model is that it closely matches the Colombian data and disentangles inflation in four baskets (food, regulated items, goods, and services), allowing for a better assessment of the origin of inflation pressures. In section 6, we show the dynamics of the model and historical decomposition of Colombian data during the 2015-2016 episode in which Colombia was affected by a severe El Niño event. In section 7,we provide some concluding remarks and further research areas regarding the impact of weather shocks on inflation and inflation expectations.

[1]These models are also known as semi-structural models.

2 The significance of weather shocks related to the ENSO in Colombia

The ENSO is a recurring climate pattern involving changes in the temperature of waters in the central and eastern tropical Pacific Ocean. The oscillations in the warming and cooling pattern directly affect the rainfall distribution in the tropics and can have a strong influence on weather. In fact, the ENSO is the Earth's strongest source of year-to-year climate variability (Santoso et al., 2017). This natural weather fluctuation oscillates between extreme events named El Niño and La Niña (Abril-Salcedo et al., 2016).The ENSO occurs in a quasi-oscillatory manner with an average period of approximately 4 years, owing to the tropical Pacific climate system's particularity. That is, the climatological elements of the tropical Pacific lead to the accumulation and lag times for their interaction that can take approximately 2 years for an El Nino to develop, peak, and decay, followed by a La Niña, and so forth in a quasi-cyclical fashion (Santoso et al., 2017).

Regarding its measurement, the estimates of ENSO fluctuation rely on the Oceanic Niño Index (ONI) which is calculated by the National Oceanic and Atmospheric Administration of the US (NOAA). The ONI tracks the running 3-month average sea surface temperatures in the east-central tropical Pacific between 120°-170°W, near the International Dateline, and whether these temperatures are warmer or cooler than average (Lindsey, 2009). For this study we use the ONI as our measure of ENSO fluctuations.

Although the impact of these fluctuations are heterogeneous in different areas of the world, in Colombia, the El Niño phase of the ENSO cycle is associated with a decrease in rainfall and droughts in majority of the country, while the La Niña phase is characterised by higher-than-average rain precipitations. Among the most intense occurrences of the El Niño, the 2015-2016 episode was particularly strong (NOAA, 2016) and had a severe effect on Colombia (figure 1).[2]

[2] The 2015-2016 event was a very strong El Niño event. It developed rapidly and had spectacular climatic impacts worldwide. It also followed the recent research which found that the frequency of extreme El Niños will likely double in the 21st century, if greenhouse gas emissions continue unabatedly Santoso et al. (2017).Other strong El Niño events include the 1982/83 and 1997/98 episodes.

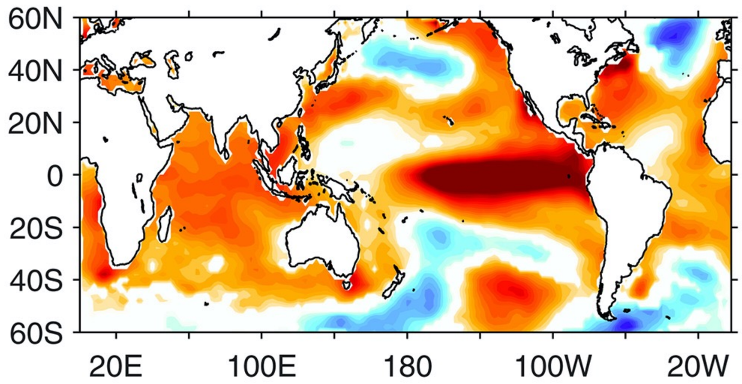


Figure 1: Sea Surface Temperature (SST) anomalies at the mature phase of the 2014 -2016 El Niño event.

Source:Santoso et al. (2017).

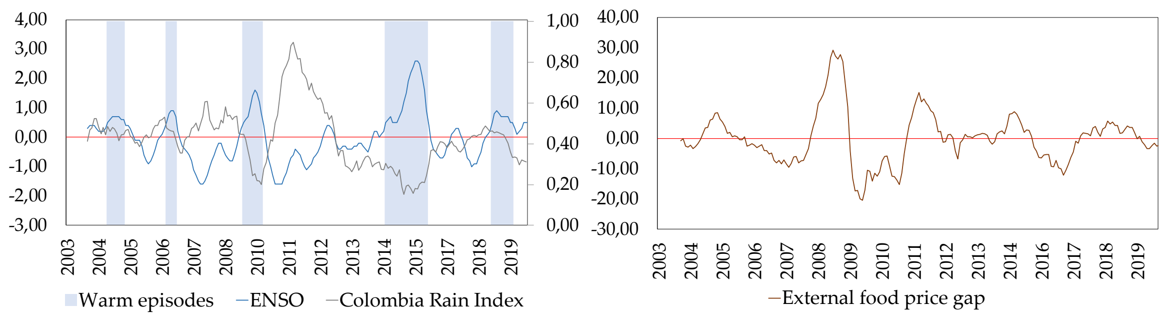
There are at least two channels through which the ENSO cycles can influence the inflation, and if these fluctuations are sufficiently strong and persistent, they can also drive inflation expectations. The first channel is associated with the relationship between the ENSO fluctuations and rain precipitation. As shown in the left- hand side graph of Figure 2, ENSO fluctuations have a strong negative correlation with rain precipitation in Colombia (high levels of the index are accompanied with lower precipitations). During extreme warm episodes that are linked to El Niño, lower rain precipitation has a direct impact on locally produced perishable food products and hydroelectric generation (the most important source of electricity generation in the country).[3]

Regarding the food inflation, the decrease in rain precipitation has a direct impact on the production of perishable food products and increasing the prices of these items, which has been extensively documented (Caicedo (2007), Cano (2014), Abril-Salcedo et al. (2016), Melo et al. (2017), and Abril-Salcedo et al. (2020)). Concerning the electric energy generation, lower rainfall translates into lower hydro-electric power generation which has to be replaced by more expensive sources of electric generation and affects the inflation print of regulated items through increases in the price of utilities. Thus, higher food and electricity prices affect the overall inflation print.

The second channel is associated with the impact that the ENSO can have on international food prices, which has been captured in the right-hand side graph of

[3]In Colombia, approximately 68% of electric energy generation comes from hydroelectric power Planas-Marti and Cárdenas (2019). Thus, severe droughts have a significant effect on electricity and utility prices.

Figure 1 by the international food price gap. Regarding this channel, Brunner (2002) finds that ENSO has economically important and statistically significant effects on world real commodity prices for the 1963-1998 period. His analysis further shows that the ENSO shocks explain 20% of the shifts in commodity price inflation movements. Cashin et al. (2017) show that the El Niño shock increases prices of both energy and non-energy commodities. One of the motivations of our empirical approach is to capture these channels by including international food prices in the empirical model as shown in Section 4.



(a) (b)

Figure 2: The ENSO Fluctuations Colombian rain index and external food prices: possible channels.

Source: NOAA, Banco de la República, World Bank and authors' calculations.
Notes: The Colombia rain index is constructed as the 12-month moving average of precipitations and it is normalized with the mean=0 and the standard deviation =1 and is displayed in the right-hand axis (RHA). The external food price gap is constructed as the cyclical component of the World Bank's nominal international food price index.

3 Inflation expectations in Colombia and some stylised facts

3.1 Inflation expectations data in Colombia

Majority of the literature regarding inflation expectations in Colombia analyses short-term measures (usually one or two years ahead). Contrarily, this study also analyse the behaviour of medium- and long-term inflation expectations from three sources.[4]First, we use the inflation expectations from FocusEconomics.[5]The advantages of this survey are the stability of its respondents (mainly local and international financial institutions), its monthly periodicity, and the availability of medium-term

[4]See Appendix A1 for a summary of the available inflation expectations indicators in Colombia.

[5]FocusEconomics provides economic analysis and forecasts. The inflation expectations obtained from this source corresponds to the median response of several local and international analysts surveyed in its monthly report.

expectations. In this survey, inflation expectations from one up to five years are available since the early 2000s, allowing us to capture the reduction of inflation and various inflation-shocks episodes in Colombia. Second, we use Banco de la Republica's monthly survey by economic and financial analysts. This source is a widely used reference for the inflation expectations in Colombia. Finally, we examine the inflation expectations obtained from local government bonds, namely Break-even inflation (BEI), Forward Break-even inflation (FBEI) expectations, and BEI measures that control for inflation risk and liquidity premium (E-BEI).[6] These measures are published periodically in several reports by Banco de la República.

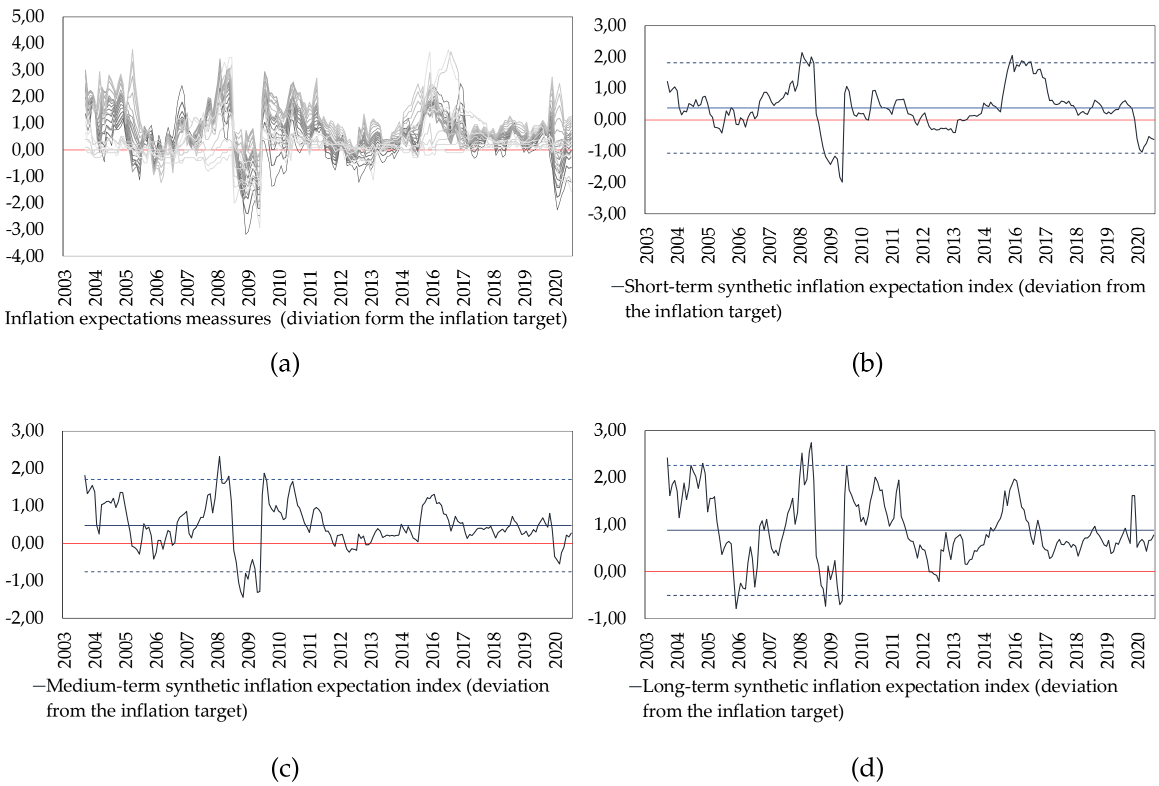


Figure 3: The inflation expectations dynamics in Colombia.

Source: Focus Economics, Banco de la República, and authors' calculations. Notes: The dotted blue lines represent 2-standard deviation intervals around the mean of the inflation expectations indicator.

Although we study the impact of weather shocks on each of the individual inflation expectations series, we also construct synthetic measures for short-, medium-,

[6]BEI inflation expectations are computed as the difference between the yields of fixed-rate and inflation-indexed government bonds. FBEI inflation expectations are computed using the term structure of BEI expectations. E-BEI are inflation expectations measures extracted from the BEI indicators, excluding the inflation risk and liquidity premium that is included in bonds' market yields.

and long-term inflation expectations.[7] These indicators were computed using the first principal component of the deviations in the inflation expectations measures to the inflation target for each term.[8] The evolution of the inflation expectations as deviations from the official inflation target,[9], along with the synthetic measure for each term, are shown in Figure 3.

3.2 Some stylised facts regarding the ENSO fluctuations and inflation expectations in Colombia

This section investigates whether the ENSO fluctuations are correlated with inflation expectations. If the ENSO fluctuations only affect short run inflation and if inflation expectations are fully anchored, it would be reasonable to expect a non-significant correlation between them.

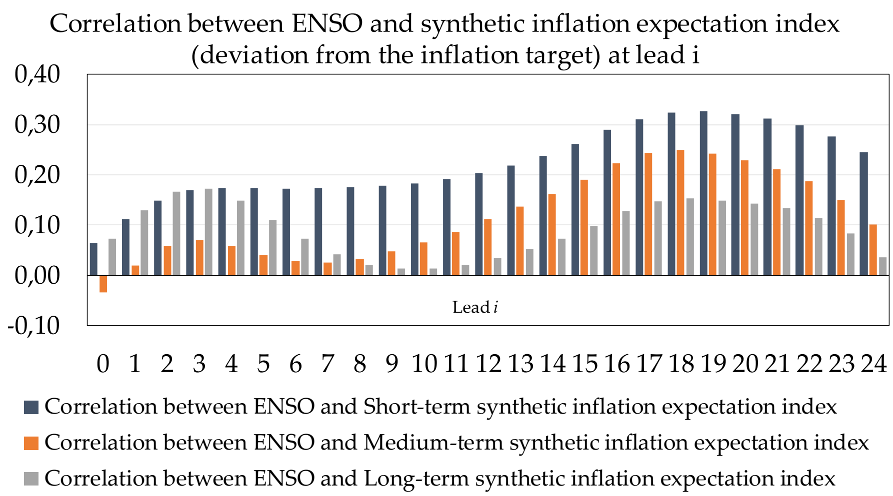


Figure 4: The ENSO index and inflation expectations cross-correlations.
Source: Authors' calculations

Figure 4 shows the correlation between the ENSO fluctuations and our synthetic measures of inflation expectations at different leads, providing evidence for a co-movement between these series. To further assess the impact of these shocks on

[7]For the synthetic indicators, short-term inflation expectations include one and two years ahead measures, medium-term inflation expectations that collect three-, four-, and five-year expectations, while long-term inflation expectations comprise all the expectation measures that are higher than five years ahead.

[8]See Appendix A2 for the estimation details of the synthetic indicators.

[9]In 2009, the inflation target was increased from 4% to 5%. In 2010 the inflation target was set to its long-term goal of 3%.

inflation expectations, we use an approach that allows us to control for other supply shocks and fundamentals that could affect the inflation expectations.

4 Assessing the impact of weather shocks on inflation expectations: a BVARx approach

This section proposes an empirical approach to assess the impact of ENSO shocks on the inflation expectations. Particularly, our BVARx model takes the following form:

$$y_t = A_t y_{t-1} + B_t x_t + \mu_t \tag{1}$$

The residuals are distributed according to:

$$\mu_t \sim \mathcal{N}(0, \sum) \tag{2}$$

In our empirical model, we assume that inflation expectations deviations from the inflation target is affected by external variables, internal supply shocks, short-term inflation surprises, and demand shocks. Additionally, we incorporate weather fluctuations as an exogenous driver that affects the anchoring of inflation expectations to the target. These variables are intended to capture the channels that have been described in Section 2 and to control for several fundamentals that may have an impact on the inflation expectations. Thus, in our specification the vector y_t is given by:

$$y_t = \begin{pmatrix} pf_t^* \\ RER_t \\ \pi_t^s \\ RP_t \\ IP_t \\ \pi_{i,t^e} - \overline{\pi_t} \end{pmatrix} \tag{3}$$

where pf_t^*, RER_t ,RP_t, and IP_t, denote the log-deviations of the World Bank's international food price index, the real exchange rate, the relative price of local food prices, and industrial production from the HP filter trend, respectively.[10]

π_t^s represents the short-term monthly inflation surprises that are obtained from Banco de la República's monthly survey [11], and $\pi_{i,t^e} - \overline{\pi_t}$ refers to each of the

[10]Similar qualitative results are obtained using alternative trend measures.

[11]11 Similar results are obtained using Bloomberg's monthly survey, which includes a similar set of analysts, although the period to answer this survey is higher

inflation measures that we use in this study as a deviation from the inflation target. In x_t, we include the ENSO index.

In this setting, the external food price gap is included to control external cost-push shocks that could translate into higher inflation expectations. Furthermore, the real exchange rate gap is included to capture the pressures arising from higher FX pressures. The monthly inflation surprises capture the forecast errors in the monthly inflation that is printed by analyst which can lead to revisions in inflation expectations. The relative food price gap is considered to be the cyclical component of the relative price between the food price index and CPI excluding the food index. It is intended to capture supply shocks. This variable allows us to capture the impact of supply shocks on inflation expectations and also how these shocks are reversed (i.e. after a strong increase in supply-side-related shocks, food prices increase but they also tend to revert rapidly). The industrial production gap is included to account for any remaining business cycle effect that could affect the deviations of expectations from the inflation target.

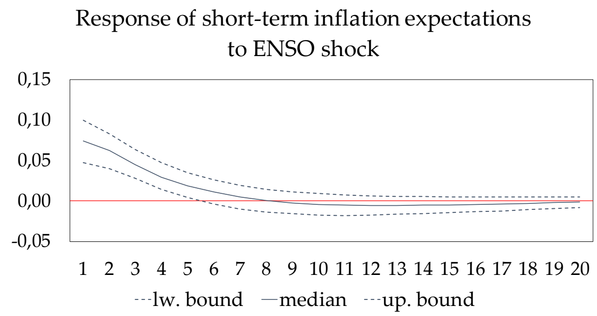
Importantly this specification implies that inflation expectations are partially anchored and that there are known macroeconomic and weather variables can explain the deviations of the inflation expectations from its target. Finally, for the identification of the shocks we use the Cholesky decomposition, setting the deviations of the inflation expectations from the target as the most contemporaneously endogenous variable [12] . This specification also recognises that the ENSO fluctuations may have an impact on the external food price gap, but external food prices are not affected by the other variables in the system.

The models are estimated using monthly data from October 2003 to December 2020 for the individual expectations series, except for the E-BEI and synthetic indicators of BVARx models that are estimated from June 2004 to December 2020. Reducing the sample to exclude the COVID-19 period does not seem to alter the impulse response results. To select the lag structure, we use standard information criteria, which in most cases stood at four lags. To estimate the BVARx models we use the independent normal-Wishart prior which assumes that Σ is unknown. A brief description of the estimation procedure is shown in Appendix A4.

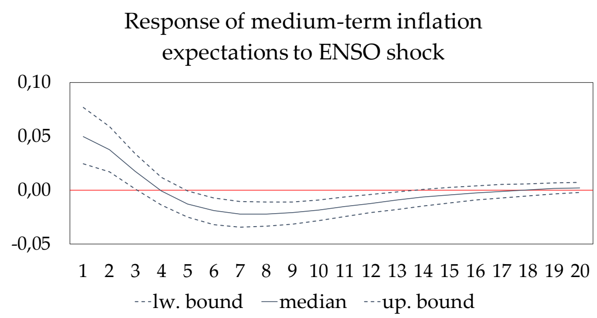
Figure 5 shows the response of our synthetic inflation expectations indicators (as deviations from the inflation target) after one standard deviation shock in the ENSO index. The weather shock associated with droughts in Colombia increase the deviation of inflation expectations from the inflation target. In the case of the short-term measure the effect dilutes in about six months, while in the medium and long -term measures the effect seems to vanish in about 4 months. For the medium- and long-term indicators, it seems that there are some small corrections (probably

[12]The impulse responses of the endogenous variables are shown in Appendix A3

for the reversion of the supply shock) between the 5th and 12th month after the shock.



(a)



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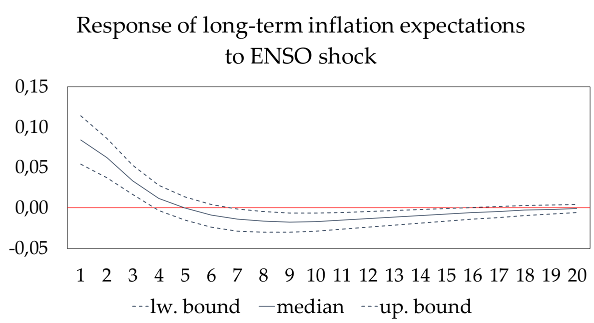

(c)

Figure 5: Response of the inflation expectations (deviations from the inflation target) to a one-standard deviation ENSO shock (68% confidence interval) in the BVAR model.

Source: Authors' calculations

Table 1 summarises the responses of the individual inflation expectations series to a one standard deviation ENSO shock. As a reference, the table also shows the average deviation of the inflation expectation measure from the inflation target. The impact of the one standard deviation ENSO shock ranges from 4bp to 13bp during the first period, with short term measures being the most affected. Focus Economics expectations for 3, 4 and 5 years seems to be practically unaffected by these shocks.Additionally, in most cases, it seems that the effect dilutes after 6 months. It is important to note that the ENSO shocks have displayed extreme readings,that are significantly higher than one standard deviation such as the 2015-2016 episode. To better assess the accumulated impact on inflation expectations measures, the next section presents the historical decomposition of the BVARx model for the three synthetic indicators.

Table 1: Inflation expectations response to the ENSO shocks

Inflation expectation measure (deviation from the inflation target)	**Classification**	**Sample average (Deviation from the inflation target)**	**ENSO Shocks (1 SD shock)**					
			Contemporaneous effect			**At t=6**		
			lw. bound	median	up. bound	lw. bound	median	up. bound
Synthetic inflation expectation index								
Short -term inflation expectations		0.27	0.05	0.07	0.10	0.00	0.01	0.03
Medium- term inflation expectations		0.40	0.02	0.05	0.08	-0.03	-0.02	-0.01
Long- term inflation expectations		0.84	0.05	0.08	0.11	-0.02	-0.01	0.00
Central Bank Survey								
1-year ahead	short-term	0.51	0.04	0.06	0.08	0.00	0.01	0.03
End of the current year	short-term	0.33	0.09	0.13	0.17	0.01	0.04	0.06
Focus Economics Survey								
End current year	short-term	0.51	0.09	0.12	0.16	0.01	0.03	0.05
End second year	short-term	0.21	0.03	0.05	0.07	-0.01	0.00	0.01
End third year	medium-term	0.11	-0.02	0.01	0.05	-0.04	0.00	0.04
End fourth year	medium-term	(0.02)	-0.03	0.01	0.04	-0.05	-0.01	0.03
End fifth year	medium-term	(0.09)	0.02	0.04	0.06	-0.01	0.00	0.01
Break-even Inflation								
1Y - BEI	short-term	0.21	0.03	0.07	0.11	0.00	0.02	0.04
2Y - BEI	short-term	0.30	0.03	0.06	0.10	-0.02	0.00	0.02
3Y - BEI	medium-term	0.39	-0.04	0.02	0.07	0.00	0.17	0.33
4Y - BEI	medium-term	0.48	0.03	0.06	0.09	-0.03	-0.02	0.00
5Y - BEI	medium-term	0.56	0.03	0.06	0.09	-0.03	-0.02	-0.01
6Y - BEI	long-term	0.63	0.03	0.06	0.10	-0.03	-0.02	-0.01
7Y - BEI	long-term	0.69	0.04	0.07	0.10	-0.03	-0.02	-0.01
8Y - BEI	long-term	0.73	0.05	0.07	0.10	-0.03	-0.02	0.00
9Y - BEI	long-term	0.77	0.05	0.08	0.11	-0.03	-0.01	0.00
10Y - BEI	long-term	0.81	0.05	0.08	0.11	-0.02	-0.01	0.00
E-BEI (correcting for liquidity)								
1Y - EBEI	short-term	0.01	0.03	0.07	0.10	-0.01	0.00	0.02
2Y - EBEI	short-term	0.02	0.03	0.05	0.08	-0.01	0.00	0.02
3Y -EBEI	medium-term	0.08	0.02	0.05	0.07	-0.01	0.00	0.02
5Y - EBEI	medium-term	0.20	0.02	0.04	0.06	-0.01	0.01	0.02
8Y -EBEI	long-term	0.33	0.02	0.04	0.06	0.00	0.01	0.02
Forward Break-even Inflation								
FBEI_1_1	short-term	0.39	0.02	0.05	0.09	-0.03	-0.02	0.00
FBEI_2_1	medium-term	0.58	0.01	0.05	0.08	-0.05	-0.03	-0.02
FBEI_3_1	medium-term	0.75	0.02	0.06	0.09	-0.05	-0.03	-0.02
FBEI_4_1	medium-term	0.88	0.03	0.07	0.10	-0.04	-0.03	-0.01
FBEI_5_1	long-term	0.97	0.05	0.08	0.12	-0.03	-0.02	0.00
FBEI_6_1	long-term	1.03	0.06	0.10	0.13	-0.02	-0.01	0.01
FBEI_7_1	long-term	1.07	0.07	0.11	0.15	-0.01	0.00	0.02
FBEI_8_1	long-term	1.09	-0.03	0.01	0.05	-0.06	-0.02	0.03
FBEI_9_1	long-term	1.10	0.09	0.13	0.17	-0.01	0.01	0.03

5 A semi-structural New Keynesian model incorporating the ENSO weather shocks

The previous section showed that the inflation expectations are affected by weather-related shocks in Colombia, even after controlling for other supply-related shocks and fundamentals. This implies that there can be a second round of effects on inflation arising from weather shocks that should be considered by the monetary authority. In this context, disentangling this particular shock, and assessing its magnitude and persistence from other cost-push shocks is important to evaluate the policy response.

This section incorporates these considerations into a small, open economy New Keynesian model, by recognising that weather shocks have direct impact on inflation and inflation expectations. We modify one of Banco de la República's core forecasting models, where inflation can be divided into several baskets. Namely, CPI inflation is separated into goods, services, regulated items, and food. In this classification, weather shocks impact directly regulated items (which includes electricity prices) and the food basket (which includes perishable food products). Furthermore, we incorporate a mechanism in which the inflation expectations are affected by these shocks depending on the credibility level of the central bank.

5.1 Model structure

To incorporate the effect of weather shocks on a small open economy New-Keynesian model we modify the 4GM model proposed by Gonzalez et al. (2020). This model is a modification of the IMF's quarterly projection model that incorporates several features of the Colombian economy. The advantage of this model is that it has a good empirical fit and allows to better disentangle the sources of inflation pressures, as it decomposes inflation in several baskets. The structure of the model consists of the following blocks (i) IS curve and potential output, (ii) Phillips curve and inflation expectations, (iii) monetary policy credibility process, (iv) Taylor rule and interest rates, and (v) determination of the exchange rate. The complete set of equations for the model is given in Appendix A5.

IS curve and potential output

Following Gonzalez et al (2020), the output level in logarithmic terms y_t is defined in terms of a cyclical component $\hat{y}_t$ (output gap), and a trend $\overline{y}_t$ (potential output):

$$y_t = \overline{y}_t + \hat{y}_t \tag{4}$$

The output gap is modelled using a modified IS curve in the following way:

$$\hat{y}_t = \beta_1 \hat{y}_{t-1} + \beta_2 E_t \hat{y}_{t+1} - \beta_\phi \phi_t + \beta_{\hat{y}^*} \hat{y}_t^* + \beta_{r\hat{p}_t{}^{oil}} r\hat{p}_t^{oil} + \eta_t^{\hat{y}_t} \tag{5}$$

where $\hat{y}_{t-1}$ captures the persistence of the economic cycle, and $E_t \hat{y}_{t+1}$ is the forward-looking component. In this specification, the output gap $\hat{y}_t$ depends on a real monetary condition index that is defined as $\phi_t = \beta_{\hat{r}_t} \hat{r}_t + (1 - \beta_{\hat{r}t}) \hat{z}_t$. This real monetary condition index captures the effect of the real interest rate gap $\hat{r}_t$ and the real exchange rate gap $\hat{z}_t$. The IS curve also depends on the foreign output gap $\hat{y}_t^*$ and the real oil price gap $r\hat{p}^o il_t$ which reflect the effects of these variables on domestic demand. The IS equation includes a demand shock $\epsilon_t^{\hat{y}_t}$ that follows an AR(1) process given by $\eta_t^{\hat{y}} = \beta_{\eta^{\hat{y}}} \eta_{t-1}^{\hat{y}} + \epsilon_t^{\hat{y}}$.

The annualised potential output growth and the quarterly output level can be expressed as:

$$\Delta\overline{y}_t = \rho_{\Delta y} \Delta\overline{y}_{t-1} + (1 - \rho_{\Delta y})(\Delta\overline{y}_{ss} + \kappa_{\Delta\overline{y}}(\Delta\overline{rp}_t^{oil} - \Delta\overline{rp}_s^{oil} s)) + \epsilon_t^{\Delta\overline{y}} \tag{6}$$

This equation describes the law of motion of potential growth. It depends on its lagged value $\Delta\overline{y}_{t-1}$, the long-term growth rate (steady state) $\Delta\overline{y}_{ss}$, deviations of the trend growth of the real oil price from its steady-state rate $(\Delta\overline{rp}_t^{oil} - \Delta\overline{rp}_s^{oil} s)$ and shocks to potential growth $\epsilon_t^{\Delta\overline{y}}$.

The output gap reflects the dynamic of the aggregate demand and it is an indicator of the business cycle. Thus, a negative gap indicates economic slack, while a positive one signals an overheating economy. It is worth noting that together, equations 4 and 5, imply that the output gap summarises the net balance between supply and demand shocks.

Phillips Curve and inflation expectations including ENSO

In this model specification the inflation rates of the food and regulated, goods, and services are modelled as a hybrid form of the Phillips curves:

$$\pi_t^j = \alpha_{\pi^j} \pi_{t-1}^j - (1 - \alpha_{\pi^j}) \pi_t^{e,j} + \alpha_{rmc^j}^{\pi^j} rmc_t^j + \epsilon_t^{\pi^j} \tag{7}$$

For j = Goods (g), Services (s), Regulated (r), and Food (f).

where π_t^j is the annualised quarterly inflation, and depends on its inertia π_{t-1}^j, expected value π_{t+1}^j, the real marginal cost rmc_t^j, and a basket-specific cost push shock $\epsilon_t^{\pi^j}$.In this setting the real marginal cost is given by:

$$rmc_t^j = \begin{pmatrix} \alpha_{\hat{y}}^{rmc^j}\hat{y} + (1-\alpha_{\hat{y}}^{rmc^j})(\hat{z}_t - \hat{rp}_t^j) for j = g, s \\ \alpha_{\hat{y}}^{rmc^j}\hat{y} + (1-\alpha_{\hat{y}}^{rmc^j})(-\hat{rp}_t^{F*} + \hat{z}_t + \lambda^f ENSO_t - \hat{rp}_t^j) for j = f \\ \alpha_{\hat{y}}^{rmc^j}\hat{y} + (1-\alpha_{\hat{y}}^{rmc^j})(-\hat{rp}_t^{oil} + \hat{z}_t + \lambda^f ENSO_t - \hat{rp}_t^j) for j = r \end{pmatrix} \tag{8}$$

In equation 8 the real marginal cost rmc_t^j depends positively on the output gap $\hat{y}$ and the real exchange rate gap $\hat{z}_t$. For all baskets, and following Gonzalez et al. (2020), the rmc_t^j includes the basket relative price $\hat{rp}_t^j$ gap. Furthermore, the rmc_t^j for food and regulated items include the real relative price gaps of world food prices $\hat{rp}_t^{F*}$ and oil $\hat{rp}_t^{oil}$, respectively. Furthermore, we include weather-related shocks $\lambda^f ENSO_t$ as a variable that affects marginal costs for food and regulated prices. The rational for including this variable is straight forward. Food prices include perishable food products that are highly sensitive to adverse weather while regulated items includes electric energy, which is mostly based on hydro-electric generation and is affected by rainfall. Finally, $\pi_t^{e,j}$ stands for inflation expectations for the basket j, following these processes:

$$\pi_t^{e,j} = c_t\pi_{t+1}^j + (1-c_t)(\pi_{t-1}^j + \psi Enso_t) + \epsilon_t^{\pi^{e,j}} for j = f, r \tag{9}$$

$$\pi_t^{e,j} = c_t\pi_{t+1}^j + (1-c_t)(\pi_{t-1}^j) + \epsilon_t^{\pi^{e,j}} for j = g, s \tag{10}$$

In equations 9 and 10 π_{t-1}^j correspond to a backward-looking (inertial) component while π_{t+1}^j represents the forward-looking rational expectations. Accordingly, and based with the empirical evidence shown in the previous section, we allow the inflation expectations to be affected by weather-related shocks. Specifically, we include $ENSO_t$ in the formation of inflation expectations for food and regulated items. The process c_t represents the stock of credibility of the monetary authority which we discuss in the next block of the model. For the food and regulated inflation prints if the credibility stock c_t is lower than one, the inflation expectations for these baskets are going to be affected by both the backward-looking component π_{t-1}^j and by $ENSO$ fluctuations. For the case of goods and services inflation, a credibility stock lower than one implies that expectations have an inertial component. If credibility is perfect ($c_t = 1$), the inflation expectations in all four baskets are completely forward-looking.

Credibility of the monetary authority:

An additional feature that we include in our model is a process for the stock of credibility of the monetary authority as presented by Benes et al. (2017). Credibility is modelled as a stock (c_t) measured between 0 and 1 that affects the way inflation expectations are formed in equation (5). The inflation expectations are more backward-looking with lower credibility. If the monetary authority is fully credible the inflation expectations are fully forward-looking. Furthermore, the specification of the process by which credibility changes is non-linear. This implies that at a lower level of credibility, monetary policy needs to be sufficiently aggressive to achieve disinflation. However, as credibility stock increases, the policy reactions need not do much to achieve the same quantum of disinflation (Benes et al. (2017)).

Credibility can only improve gradually over time, thus, it has a large AR coefficient (0.95). Credibility responds to a signal (ξ_t) that is good if inflation has been converging to the target (π^{good}), and is bad if rising towards a high-inflation state (π^{bad}).

$$c_t = \rho^c c_{t-1} + (1 - \rho^c)\xi_t \tag{11}$$

The credibility signal weighs the relative likelihood of the inflation converging to the target versus it being unanchored. It is higher if the current realised inflation is closer to the target. The forecasting error under the bad (good) regime is defined as the difference between the realised inflation and the expected inflation under the bad (good) regime.

$$\xi_t = \frac{(\epsilon_t^{bad})^2}{(\epsilon_t^{bad})^2 + (\epsilon_t^{good})^2} \tag{12}$$

$$\epsilon_t^{bad} = \pi_t - [\rho^\epsilon \pi_{t-1} + (1 - \rho^\epsilon)\pi^{bad}] \tag{13}$$

$$\epsilon_t^{good} = \pi_t - [\rho^\epsilon \pi_{t-1} + (1 - \rho^\epsilon)\pi^{good}] \tag{14}$$

To control for boundary conditions, we set $\xi_t = 0$ if $\epsilon_t^{bad} > 0$ and $\xi_t = 0$ if $\epsilon_t^{good} < 0$.

Monetary Policy Rule and Interest Rates

The monetary policy rate i_t follows an inflation-forecast-based reaction function. The equation is as follows:

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left[\bar{i}_t + \psi_\pi (E_t \pi^A_{t+3} - E\overline{\pi}^A_{t+3}) + \psi_{\hat{y}}\ \hat{y}_t\right] + \epsilon^i_t\,. \tag{15}$$

Where i_{t-1} refers to an interest rate smoothing term, $\bar{i}_t$ is the neutral nominal interest rate and ϵ^i_t are monetary policy shocks. The reaction function also depends on the output gap $\hat{y}$ and the deviation of annual inflation expectations from the three periods ahead target $E_t \pi^A_{t+3} - E\overline{\pi}^A_{t+3}$.The three-quarter-ahead inflation-forecast-based reaction function ensures more robustness as policy is reacting to a mix of current data, near-term forecast, and model-based projection in the initial periods (see Benes et al, 2017).

The neutral nominal interest rate is defined by the Fisher equation $\bar{i}_t = \bar{r} + \pi_{t+1}$, where $\bar{r}$ is the neutral real interest rate and π_{t+1} is the inflation expectations. Therefore, the long depreciation will be constant and given by:

$$\Delta\bar{z} = \bar{r} - \bar{r}^* + \overline{prem}$$

Where $\bar{r}^*$ and $\Delta\bar{z}_t$ are the US neutral real interest rate, and the depreciation of the real exchange rate trend, respectively.

Modified Risk-Adjusted Uncovered Interest Parity (UIP)

The risk adjusted Uncovered Interest Parity (UIP) condition is given by:

$$\Delta s_{t+1} = i^*_t - i_t + prem + \varepsilon^{ls}_t \tag{16}$$

Where Δs_t is the nominal depreciation, i^*_t is the FED funds rate, i_t is the monetary policy interest rate, $prem$ is a constant risk premium, and ε^{ls}_t is an idiosyncratic shock to the UIP condition.

Regarding the real exchange rate, z_t is where one can identify a trend $\bar{z}_t$ and a cyclical component $\hat{z}_t$ which follows: $z_t = s_t + \pi^*_t - \pi_t$

$$z_t = \bar{z}_t + \hat{z}_t \tag{17}$$

$$\Delta\bar{z}_t = \rho_{\Delta z}\Delta\bar{z}_{t-1} + (1-\rho_{\Delta z})(\Delta\bar{z}_{ss} - \varepsilon_{\Delta\bar{z}}(\Delta\overline{rp}^{oil}_t - \Delta\overline{rp}^{oil}_{ss})) + \epsilon^{\Delta\bar{z}}_t \tag{18}$$

Lastly, the nominal and real depreciation are related through $\Delta z_t = \Delta s_t + \pi^*_t - \pi_t$.

5.2 Calibration and Estimation

The parameters of the model are divided into two groups: calibrated and estimated parameters. Among the first group, there are parameters related to the steady state, the credibility block and the ENSO shock. The calibrated parameters for the steady state of the model include the long-run GDP growth rate, the inflation target and the convergence of each basket to its long-term value,where the persistence of some of the exogenous processes were taken from Gonzalez et al. (2020).The parameters regarding the credibility process were taken from Benes et al. (2017) and the inflation regimes correspond to the tolerance band around the long-term inflation target.

Table 2: Calibrated Parameters Values and Description

Parameter	Value	Description
Steady State		
$\Delta\bar{y}$	3.3%	Long run Potential Output Growth
$\overline{\pi}$	3%	Long run inflation
$\bar{r}$	2%	Long run neutral real interest rate
$\overline{\pi}^{\star}$	2%	Long run US inflation
$\bar{r}^{\star}$	0.5%	Long run US neutral real interest rate
$\Delta\bar{z}$	0%	Long run depreciation
$\overline{\omega}$	1.5%	Long run risk premium
$\overline{\delta p^{oil}_t}$	0%	Trend growth, of real oil prices
$\overline{\delta p^{F*}_t}$	0%	Trend growth, of real foreign food prices
Credibility		
$\bar{c}$	1	Long run credibility
ρ^c	0.8	Backward component
π^{bad}	4	Bad regime inflation
π^{good}	3	Good regime inflation
ENSO		
λ^f	1.7	Sensibility of food inflation to ENSO shocks
λ^r	3.7	Sensibility of regulated inflation to ENSO shocks
ψ	0.5	Effect of ENSO into inflation expectations
ρ_{Enso}	0.78	ENSO Backward component
σ_{Enso}	0.8	Standard Deviation of ENSO fluctuations

The parameters related to the ENSO shock were calibrated to match the impulse responses showed in Section 4 and time series estimations to capture the persistence and variance of the ENSO series. The values for these parameters are presented in Table 2.

Table 3: Estimated Parameters Description

Parameter	Value	Description
Phillips Curve (Food)		
α_{π^F}	0.3062	Backward component weight
$\alpha^{\pi^A}_{rmc}$	0.1212	Real marginal cost weight
$\alpha^{rmc^A}_{\hat{y}}$	0.6424	Output gap weight
Phillips Curve (Regulated)		
α_{π^R}	0.271	Backward component weight
$\alpha^{\pi^R}_{rmc}$	0.0209	Real marginal cost weight
$\alpha^{rmc^R}_{\hat{y}}$	0.8523	Output gap weight
Phillips Curve (Goods)		
α_{π^G}	0.3061	Backward component weight
$\alpha^{\pi^G}_{rmc}$	0.1432	Real marginal cost weight
$\alpha^{rmc^G}_{\hat{y}}$	0.2598	Output gap weight
Phillips Curve (Services)		
α_{π^S}	0.3462	Backward component weight
$\alpha^{\pi^S}_{rmc}$	0.0783	Real marginal cost weight
$\alpha^{rmc^S}_{\hat{y}}$	0.6397	Output gap weight
IS Curve		
β_1	0.5773	Backward component weight
β_2	0.0505	Forward component weight
β_{phi}	0.1400	MCI weight
$\beta_{\hat{y}^*}$	0.0956	Foreign output gap weight
$\beta_{\hat{rp}^{oil}}$	0.0157	Oil gap weight
$\beta_{\hat{r}}$	0.7500	Real interest rate gap weight
Taylor rule		
ρ_i	0.7	Backward component weight
ψ_π	1.5	MCI weight
$\psi_{\hat{y}}$	0.375	Foreign output gap weight

The second group of parameters were estimated using a Bayesian technique, following the model specification proposed in Gonzalez et al. (2020). For the estimation we use quarterly data containing 19 domestic variables and 9 foreign variables from 2003Q1 to 2019Q4. The first set of variables includes the real GDP y_t, in millions of Colombian Pesos, monetary policy rate i_t, annual inflation target $\overline{\pi_t}$, nominal exchange rate s_t, CPI p_t, core CPI p_t^c, and the price index for the baskets of goods p_t^b, services p_t^s, food p_t^f, and regulated items p_t^r.

This data set also includes the trend components of relative prices of the goods basket $\overline{p_t^b}$, food basket $\overline{p_t^f}$, and regulated goods basket $\overline{p_t^r}$. The set of foreign variables consists of the US CPI p_t, the US monetary policy rate i_t^*, proxied by the 1-Year US FED rate, the Colombian risk premium $prem_t$ measured through the 5-year CDS spread on sovereign Colombian bonds, and the real oil price pr_t^{Oil} in US dollars. We also include estimates of the US neutral real interest rate $\overline{r_t^*}$, gaps for the foreign output y_t^*, relative price of world food p_t^{F*}, trend components of the risk premium $\overline{prem}$,and real oil price $\overline{p_t^{oil}}$. Trends and gaps of external variables correspond to off-model estimates that combine satellite models and judgments as proposed by Gonzalez et al. (2020). Table 3 summarises the estimation results.

6 Results

6.1 Impulse – responses of the model to an ENSO shock

This section shows the dynamics of the model to a transitory ENSO shock in the model presented in Section 5[13]. As shown in Figure 6, the transitory ENSO shock increases food and regulated inflation. The increase in these baskets is a consequence of the direct effect that adverse weather has on marginal costs for these baskets and for the effect on inflation expectations which also increases in response to this shock. In the case of food inflation, the initial increase is close to 30 b.p., while the increase in regulated inflation is about 7 b.p.

As a result of higher food and regulated inflation and its expectations, headline inflation and total inflation expectations increase accordingly. With our proposed parametrisation, headline inflation and total inflation expectations increased approximately 5 b.p initially as a consequence of the shock. In these setting the monetary policy authority has to react to this shock to anchor the inflation expectations by increasing the interest rates between 4 to 6 b.p. In this model, there are no direct effects of the ENSO shocks on activity, so the decrease in the output gap is a result of the increase in monetary policy. Nonetheless, this impact is moderate in this parametrisation.

[13]That corresponds to 100 basis points or equivalently to a one standard deviation shock in ENSO's historical series.

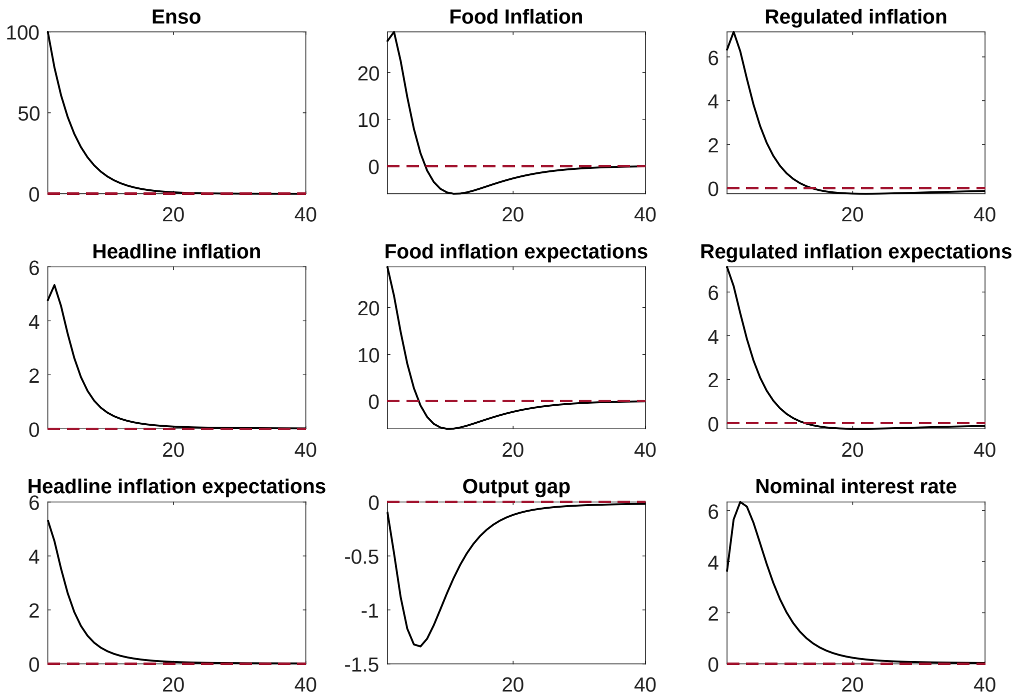

Figure 6: Response of selected variables(deviation from the steady state to a one-unit (b.p.) ENSO shock. The responses of the endogenous variables are in basis points (b.p).

Source: Authors' calculations

It is important to highlight that these quantitative results correspond to a transitory, one standard deviation shock in the ENSO series. As we have seen, extreme weather events could be higher and more persistent as the episode in 2014 - 2016. Thus, in the next sub-section we study this episode using the model's historical shock decomposition. This approach gives a better assessment of how persistent shocks affect inflation, inflation expectations and monetary policy.

6.2 Disentangling the underlying shocks during an adverse weather event

This section discusses the contribution of the ENSO shocks during the most intense El Niño phase in recent history: the 2015-2016 event. As discussed by Abril-Salcedo et al. (2016) and Abril-Salcedo et al. (2020) El Niño in 2015-2016 was particularly strong and had a significant effect on inflation in Colombia. To understand this event, and how the ENSO affected inflation and inflation expectations, we use our proposed model to disentangle the underlying shocks during this period.To do this we use the historical shock decomposition.[14]

Figure 7 illustrates, for the period 2014-2019, the historical shock decomposition of five macroeconomic variables: food inflation, regulated inflation, headline inflation, inflation expectations, and the monetary policy rate.

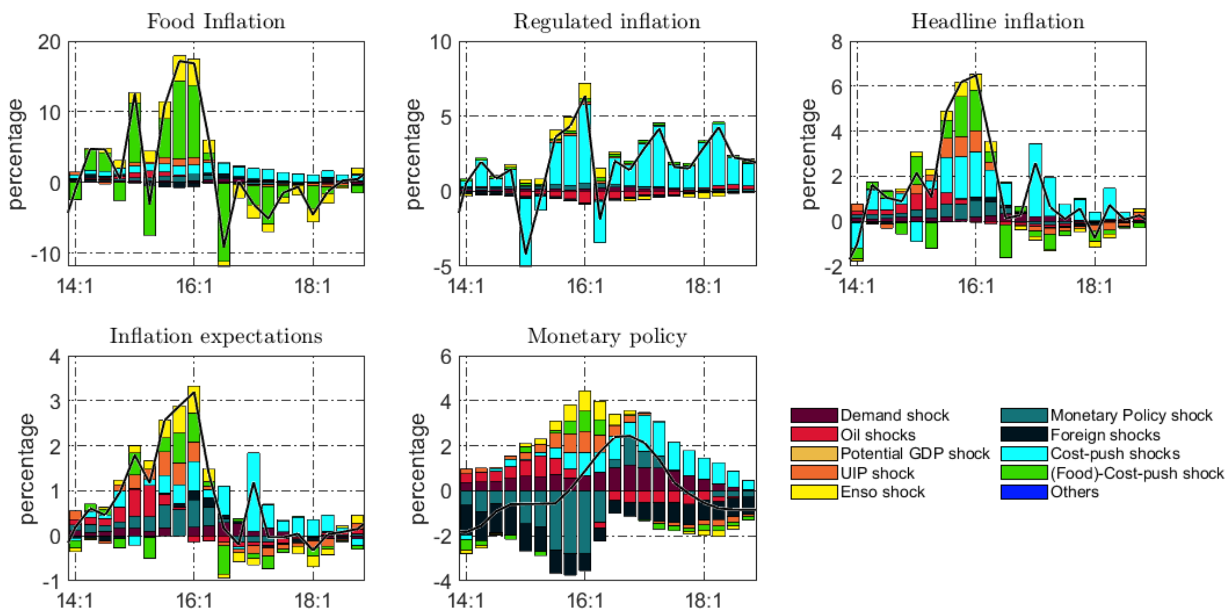

Figure 7: 2014-2019 Historical Decomposition as the deviation from the steady state.
Source: Author's calculations. Note: Inflation series correspond to quarterly annualized changes.

Disentangling the different shocks that affected the Colombian economy during 2015-2016 is not an easy task. During this time, the economy experienced several strong and persistent shocks. Among these, the Colombian economy was affected by a severe fall in its terms of trade, strong exchange rate depreciation (as a result of a dramatic drop in oil prices), local supply disruptions in transportation, and adverse weather related to the El Niño phenomenon.

As shown in Figure 7, food and regulated inflation prints are mostly affected by different kinds of cost push shocks. Nonetheless, the inclusion of ENSO fluctuations in the model helps to further assess their drivers. Particularly, it is clear that the ENSO affected these baskets in 2015 and early 2016. Regarding headline inflation, the shock decomposition shows the relevance of cost-push shocks arising from food inflation. This food cost push shock was particularly relevant from the second quarter of 2015 to the first quarter of 2016. Furthermore, using our proposed model, we can distinguish the specific contribution that the ENSO fluctuations had during this episode. This result is in line with anecdotal evidence and the published Inflation Reports produced

[14]The historical shock decomposition represents the estimated latent variables in terms of contributions of the estimated structural shocks of the model and is estimated using a Kalman smoother.

by Banco de la República during this time. We can also quantitatively distinguish how the ENSO shocks affected inflation expectations during this period, which relates to the BVARx evidence shown in Section 4. Furthermore, our decomposition allows for a better assessment of the multiple shocks that affected inflation and inflation expectations. Finally, the model suggest that the impact of weather shocks should have been considered earlier in the monetary response to the inflationary pressures arising in 2015 and 2016.

7 Concluding Remarks

In this study we find evidence of second-round effects of weather-related cost-push shocks on inflation. The mechanism appears to be related to the fact that inflation expectations are partially anchored to the inflation target and can be affected by the ENSO fluctuations. Using BVARx models, we provide evidence for this fact using a broad set of Colombian inflation expectations. We incorporate this finding in a semi-structural model that captures different sources of inflationary pressures and the dynamics of different CPI baskets. In our model, we allow the ENSO shocks to affect the marginal costs of regulated goods and food prices in the Phillips curves and inflation expectations. The results in terms of impulse-response function and historical shock decomposition illustrate the properties of the model, and allow us to better assess episodes of extreme weather shocks such as the strong El Niño event of 2015-2016.

Regarding policy implications, identifying the ENSO-shocks and incorporating them the specific models that are usually used for forecasting and policy analysis could be an important tool to construct scenarios of extreme weather fluctuations in countries that are affected by the ENSO fluctuations. Additionally, we find that these shocks had an important role in the dynamics of both inflation and inflation expectations, and that this fact should be considered by the central bank when assessing its monetary policy stance.

Nonetheless, this study is just an initial approximation on how to include weather shocks into such models and hence, further research is required on this issue. In particular, it is important to work incorporating the impact that weather shocks have on different sectors, evaluating alternative mitigation policies, and how to simulate scenarios. Finally, as shown in the literature, there could be non-linear features related to weather shocks that should be incorporated in the analysis and into models with economic content.

References

Abril-Salcedo, D. S., Melo-Velandia, L. F., and Parra-Amado, D. (2016). Impactos de los fenómenos climáticos sobre el precio de los alimentos en colombia. *Ensayos sobre política económica*, 34(80):146–158.

Abril-Salcedo, D. S., Melo-Velandia, L. F., and Parra-Amado, D. (2020). Nonlinear relationship between the weather phenomenon el niño and colombian food prices. *Australian Journal of Agricultural and Resource Economics*, 64(4):1059–1086.

Atems, B. and Sardar, N. (2021). Exploring asymmetries in the effects of el niño-southern oscillation on us food and agricultural stock prices. *The Quarterly Review of Economics and Finance*, 81:1–14.

Belke, A., Beckmann, J., and Dubova, I. (2018). What drives updates of inflation expectations? a bayesian var analysis for the g-7 countries. VfS Annual Conference 2018.

Bems, M. R., Caselli, F. G., Grigoli, F., Gruss, B., and Lian, W. (2018). *Expectations' Anchoring and Inflation Persistence*. International Monetary Fund.

Benes, J., Clinton, K., Asish, G., Gupta, P., Joice, J., Ondra, K., and Laxton, D. (2017). Quarterly projection model for india: Key elements and properties. Technical report, International Monetary Fund.

Berg, A.and Karam, P. and Laxton, D. (2006). A practical model-based approach to monetary policy analysis—overview. Technical report, International Monetary Fund.

Bernanke, B. (2007). Inflation expectations and inflation forecasting. Technical report, Board of Governors of the Federal Reserve System (US).

Berry, B. J. and Okulicz-Kozaryn, A. (2008). Are there enso signals in the macroeconomy? *Ecological Economics*, 64(3):625–633.

Brunner, A. D. (2002). El nino and world primary commodity prices: warm water or hot air? *Review of Economics and statistics*, 84(1):176–183.

Buono, I. and Formai, S. (2018). New evidence on the evolution of the anchoring of inflation expectations. *Journal of Macroeconomics*, 57:39–54.

Caicedo, E. (2007). El fenómeno de el niño y su posible impacto en colombia. *Reportes del Emisor*, 92.

Cano, G. (2014). Carestía e inflación:qué esperar de la política agrícola y los gravámenes a la tierra y el carbono. *Borradores de Economía*, 836.

Cashin, P., Mohaddes, K., and Raissi, M. (2017). Fair weather or foul? the macroeconomic effects of el niño. *Journal of International Economics*, 106:37–54.

Davis, S., Mack, A., et al. (2013). Cross-country variation in the anchoring of inflation expectations. *Staff Papers*, (Oct).

de Mendonça, H. F. (2018). Credibility and inflation expectations: What we can tell from seven emerging economies? *Journal of Policy Modeling*, 40(6):1165–1181.

Demertzis, M., Marcellino, M., and Viegi, N. (2010). Anchors for inflation expectations.

Demertzis, M., Marcellino, M. G., and Viegi, N. (2008). A measure for credibility: tracking us monetary developments. *Available at SSRN 1311160*.

Dieppe, A., Legrand, R., and Van Roye, B. (2016). The bear toolbox.

Espinosa-Torres, J. A., Melo-Velandia, L. F., and Moreno-Gutiérrez, J. F. (2017). Expectativas de inflación, prima de riesgo inflacionario y prima de liquidez: una descomposición del break-even inflation para los bonos del gobierno colombiano. *Revista Desarrollo y Sociedad*, (78):315–365.

Gamba, S., González-Molano, E., and Melo-Velandia, L. (2016). ¿ están ancladas las expectativas de inflación en colombia? Technical report, Banco de la Republica de Colombia.

Gefang, D., Koop, G., and Potter, S. M. (2012). The dynamics of uk and us inflation expectations. *Computational Statistics & Data Analysis*, 56(11):3120–3133.

Gonzalez, A., Guarin, A., Rodriguez-Guzman, D. A., Vargas-Herrera, H., et al. (2020). 4gm: A new model for the monetary policy analysis in colombia. Technical report, Banco de la Republica de Colombia.

González-Molano, E. R., Jalil-Barney, M. A., and Romero-Chamorro, J. V. (2011). Inflación y expectativas de inflación en colombia. *Capítulo 13. Inflación y expectativas de inflación en Colombia. Pág.: 491-519*.

Guarín, A., Hamann, F., and Rodríguez, D. (2015). De-anchoring of inflation expectations. Technical report, mimeo, Bank of the Republic.

Hattori, M. and Yetman, J. (2017). The evolution of inflation expectations in japan. *Journal of the Japanese and International Economies*, 46:53–68.

Huertas-Campos, C. A., González-Molano, E. R., and Ruiz-Cardozo, C. (2015). La formación de expectativas de inflación en colombia. *Borradores de Economía; No. 880*.

Iregui-Bohórquez, A. M., Anzola-Bravo, C., Ballén-Rubio, L. F., Bejarano-Salcedo, V., González-Molano, E., Grajales-Olarte, A., Guarín-López, A., Hernández-Montes, M. A., Hernández-Ortega, R., Julio-Román, J. M., et al. (2021). ¿ qué nos dicen las encuestas sobre la formación de expectativas de inflación? *Revista Ensayos Sobre Política Económica; No. 100, septiembre, 2021. Pág.: 1-95*.

Kapetanios, G., Maule, B., and Young, G. (2016). A new summary measure of inflation expectations. *Economics Letters*, 149:83–85.

King, M. (2005). Monetary policy: Practice ahead of theory (mais lecture 2005). *Bank of England Quarterly Bulletin*, 45(2):226–36.

Lindsey, R. (2009). Climate variability: Oceanic niño index. *News and Features, retrieved from https://www.climate.gov/news-features/understanding-climate/climate-variability-oceanic-niño-index.*

Łyziak, T. and Paloviita, M. (2017). Anchoring of inflation expectations in the euro area: recent evidence based on survey data. *European Journal of Political Economy*, 46:52–73.

Mavroeidis, S., Plagborg-Møller, M., and Stock, J. H. (2014). Empirical evidence on inflation expectations in the new keynesian phillips curve. *Journal of Economic Literature*, 52(1):124–88.

Medel, V. et al. (2018). An econometric analysis on survey-data-based anchoring of inflation expectations in chile. *Economía chilena, vol. 21, no. 2*.

Mehrotra, A. and Yetman, J. (2018). Decaying expectations: What inflation forecasts tell us about the anchoring of inflation expectations. *56th issue (December 2018) of the International Journal of Central Banking*.

Melo, S., Riveros, L., Romero, G., Álvarez, A., Diaz, C., and Calderón, S. (2017). Efectos económicos de futuras sequías en colombia: Estimación a partir del fenómeno el niño 2015. *Archivos de Economía*, 466:1–34.

Melo-Velandia, L. F. (2016). ¿ están ancladas las expectativas de inflación en colombia? *Borradores de Economía; No. 940*.

NOAA (2016). Monthly global climate report for annual 2016. *National Centers for Environmental Information Reports, retrieved from https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/201613.*

Planas-Marti, M. and Cárdenas, J. (2019). La matriz energética de colombia se renueva. Technical report, Inter-American Development Bank.

Santoso, A., Mcphaden, M. J., and Cai, W. (2017). The defining characteristics of enso extremes and the strong 2015/2016 el niño. *Reviews of Geophysics*, 55(4):1079–1129.

Sousa, R. and Yetman, J. (2016). Inflation expectations and monetary policy. *BIS Paper*, (89d).

Strohsal, T., Melnick, R., and Nautz, D. (2016). The time-varying degree of inflation expectations anchoring. *Journal of Macroeconomics*, 48:62–71.

Strohsal, T. and Winkelmann, L. (2015). Assessing the anchoring of inflation expectations. *Journal of International Money and Finance*, 50:33–48.

Trehan, B. (2015). Survey measures of expected inflation and the inflation process. *Journal of Money, Credit and Banking*, 47(1):207–222.

Uribe, J. D., Vargas, H., and Gómez, J. (2002). The implementation of inflation targeting in colombia. *Borradores Semanales de Economía*, (202).

Vargas, H., González, A., González, E., Romero, J. V., and Rojas, L. E. (2009). Assessing inflationary pressures in colombia. In *Participants in the meeting*, page 129.

Vargas-Herrera, H. et al. (2016). Inflation expectations and a model-based core inflation measure in colombia. *Horacio Aguirre, Mauro Alessandro and Lucas Llach (Central Bank of Argentina).. 69 Why is inflation so high and volatile in Brazil? A primer*, page 123.

A Appendix

A.1 Inflation expectations availability in Colombia

Over the last two decades there has been an important increase in the availability and diversity of inflation expectations measures in Colombia. The oldest surveys on record were collected by private institutions (Consensus Economics and Focus Economics) with information that dates to the 1990s. Although these surveys mostly focused on one- or two-year ahead expectations, they also included some sort of long-term inflation expectations. Citibank's survey focused on short-term inflation expectations (month-ahead and year-end) and gradually started to include two-year ahead inflation forecasts.

Fedesarrollo's survey began in 2005, but originally was focused on inflation perceptions, reporting the balance of survey respondents who thought that the inflation was going to increase/decrease. In 2014, Fedesarrollo started to ask for the expected point inflation forecast by the respondents. Since 2000, Banco de la República (Central Bank of Colombia – CB) has published a quarterly survey on a broad set of agents. Three years later, it started to publish a monthly survey of professional forecasters, and bond-derived break-even (BI) and forward break-even (FBEI) inflation rates. Most of the CB's surveys incorporate year-end and one-year ahead expectations, and it started to include two-year-ahead expectations in 2015. Market based expectations (BEI and FBEI) have information since 2003.

Break-even inflation measures are extracted from the prices of government bonds indexed to inflation (TES UVR) and fixed nominal rate bonds (TES fixed rate) at different terms (one to ten years). FBEI measures are constructed using the same market information than BEI expectations but considering its time structure. For simplicity, when we mention the FBEI at period n, we refer to the expected inflation one year after n-1 years that are extracted from the prices of fixed nominal rate bonds and bonds indexed to inflation . In synthesis, we selected these measures as they are available for a relatively long-time span, they are computed at different terms, and they are widely used by both analysts and policy makers. Table A.1 summarises the main characteristics of inflation expectations series available for Colombia.

Table 4: Inflation expectations measures ad related inflation indicators in Colombia

Inflation expectations	**Available inflation expectations measures**	**Entity in charge of its release**	**Periodicity and availability**	**Included in this study**
Monthly financial sector survey	Monthly inflation expectation; yearend, two-year ahead, 12-month and 24-month expectations. Core-inflation expectations.	Banco de la República	Monthly since 2003. Headline and core inflation expectation for the end of next year and 24-month expectations started to be collected in 2015.	Yes
Quarterly inflation survey	Four-quarter ahead inflation expectations. Eight-quarter ahead inflation expectations. Next year and two year ahead wage-inflation expectations.	Banco de la República.	Quarterly since 2000. Eight quarter ahead inflation expectations started to be collected in 2015.	No
BEI, Forward BEI and Expected BEI	These measures range from one to ten years ahead.	Banco de la República	Daily and monthly since 2003. FBEI is presented in the annex report of the CB's minutes.	Yes
Consensus Economics Survey	Yearend and next year inflation expectations. Long term inflation expectations.	Consensus Economics	Bi-monthly (alternate months) between March 1993 and April 2001 and monthly thereafter.	No
Focus Economics Survey	Yearend and next year inflation expectations. Yearend inflation expectations up to five years.	Focus Economics	Monthly since 1999.	Yes
Fedesarrollo-BVC survey	Inflation expectations balance. Yearend inflation expectations.	Fedesarrollo	Monthly since 2005. In 2014 Fedesarrollo started to ask for point forecasts.	No
Citibank survey	Monthly inflation expectation; yearend, two-year ahead, 12-month and 24-month expectations. Core-inflation expectations.	Citi Research	Monthly since 2003. Inflation expectation for the end of next year started to be collected in 2015.	No

Source: Author's compilation.
Notes: Financial information providers such as Bloomberg and Reuters also have monthly and year end inflation forecasts from market analysts.

A.2 Synthetic inflation expectations measures

Table 5: Inflation expectations principal component- short- term expectations

Principal Components Analysis
Sample (adjusted): 2004M06 2020M12
Included observations: 207 after adjustments
Balanced sample (listwise missing value deletion)
Computed using: Ordinary correlations

Eigenvalues: (Sum = 8, Average = 1)

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	7.09	6.17	0.79	7.09	0.79
2	0.92	0.52	0.10	8.01	0.89
3	0.40	0.04	0.04	8.41	0.93
4	0.35	0.21	0.04	8.76	0.97
5	0.15	0.08	0.02	8.91	0.99
6	0.07	0.05	0.01	8.98	1.00
7	0.01	0.00	0.00	8.99	1.00
8	0.01	0.01	0.00	9.00	1.00
9	0.00	—	0.00	9.00	1.00

Eigenvectors (loadings):

Variable	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9
BEI_1	0.33	-0.39	-0.33	0.05	0.49	-0.38	0.07	-0.04	0.48
BEI_2	0.35	-0.34	-0.14	0.30	0.09	-0.08	0.05	0.01	-0.80
EBEI1	0.34	-0.27	0.26	-0.41	0.07	0.24	-0.71	0.04	0.00
EBEI2	0.34	-0.16	0.43	-0.47	-0.08	0.05	0.67	0.04	0.00
FBEI_1_1	0.33	-0.23	0.14	0.60	-0.46	0.33	0.03	0.07	0.36
FOCUS_1	0.33	0.41	-0.40	-0.09	0.14	0.34	0.08	0.64	0.00
FOCUS_2	0.28	0.50	0.54	0.35	0.47	-0.08	-0.05	-0.14	0.00
BR_1	0.35	0.28	-0.02	-0.10	-0.51	-0.69	-0.17	0.12	0.00
BR_DIC1	0.35	0.28	-0.39	-0.15	-0.12	0.27	0.04	-0.74	0.00

Ordinary correlations:

	BEI_1	BEI_2	EBEI1	EBEI2	FBEI_1_1	FOCUS_1	FOCUS_2	BR_1	BR_DIC1
BEI_1	1.00								
BEI_2	0.96	1.00							
EBEI1	0.85	0.87	1.00						
EBEI2	0.78	0.81	0.97	1.00					
FBEI_1_1	0.81	0.93	0.79	0.76	1.00				
FOCUS_1	0.67	0.69	0.68	0.68	0.64	1.00			
FOCUS_2	0.45	0.56	0.57	0.64	0.63	0.76	1.00		
BR_1	0.69	0.75	0.77	0.81	0.75	0.89	0.78	1.00	
BR_DIC1	0.74	0.77	0.75	0.75	0.71	0.98	0.72	0.93	1.00

Source: Author's calculations

Table 6: Inflation expectations principal component- medium-term expectations

Principal Components Analysis
Sample (adjusted): 2004M06 2020M12
Included observations: 207 after adjustments
Balanced sample (listwise missing value deletion)
Computed using: Ordinary correlations

Eigenvalues: (Sum = 8, Average = 1)

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	6.99	4.62	0.64	6.99	0.64
2	2.36	1.13	0.21	9.35	0.85
3	1.23	0.98	0.11	10.59	0.96
4	0.26	0.16	0.02	10.84	0.99
5	0.10	0.06	0.01	10.94	0.99
6	0.03	0.02	0.00	10.98	1.00
7	0.02	0.01	0.00	10.99	1.00
8	0.01	0.01	0.00	11.00	1.00
9	0.00	0.00	0.00	11.00	1.00
10	0.00	0.00	0.00	11.00	1.00
11	0.00	—	0.00	11.00	1.00

Eigenvectors (loadings):

Variable	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10	PC 11
BEI_3	0.34	-0.15	-0.23	-0.53	0.13	0.11	0.01	0.13	-0.04	0.45	0.52
BEI_4	0.35	-0.19	-0.12	-0.33	0.09	0.03	0.01	0.09	0.14	0.12	-0.82
BEI_5	0.36	-0.21	-0.02	-0.18	0.07	0.16	0.01	0.07	0.04	-0.85	0.18
EBEI3	0.28	0.19	-0.53	0.24	0.03	0.17	0.09	-0.72	0.03	0.01	0.00
EBEI5	0.26	0.27	-0.49	0.43	-0.03	-0.10	-0.09	0.64	-0.02	-0.01	0.00
FBEI_2_1	0.35	-0.23	0.11	0.10	-0.02	-0.71	-0.07	-0.17	-0.52	0.01	0.01
FBEI_3_1	0.32	-0.26	0.27	0.32	-0.06	-0.21	0.00	-0.04	0.75	0.14	0.16
FBEI_4_1	0.30	-0.26	0.34	0.41	-0.02	0.61	0.01	0.06	-0.38	0.19	-0.03
FOCUS_3	0.28	0.39	0.19	-0.20	-0.77	0.01	0.33	0.02	-0.02	0.00	0.00
FOCUS_4	0.23	0.47	0.27	-0.12	0.08	0.07	-0.79	-0.10	0.03	0.00	0.00
FOCUS_5	0.20	0.48	0.32	0.01	0.61	-0.08	0.50	0.05	-0.01	0.00	0.00

Ordinary correlations:

	BEI_3	BEI_4	BEI_5	EBEI3	EBEI5	FBEI_2_1	FBEI_3_1	FBEI_4_1	FOCUS_3	FOCUS_4	FOCUS_5
BEI_3	1.00										
BEI_4	0.98	1.00									
BEI_5	0.95	0.99	1.00								
EBEI3	0.72	0.67	0.61	1.00							
EBEI5	0.61	0.56	0.51	0.98	1.00						
FBEI_2_1	0.86	0.93	0.96	0.52	0.44	1.00					
FBEI_3_1	0.74	0.84	0.91	0.37	0.30	0.97	1.00				
FBEI_4_1	0.66	0.78	0.85	0.28	0.22	0.91	0.98	1.00			
FOCUS_3	0.47	0.49	0.49	0.58	0.61	0.48	0.43	0.40	1.00		
FOCUS_4	0.32	0.34	0.34	0.49	0.55	0.35	0.31	0.30	0.94	1.00	
FOCUS_5	0.22	0.24	0.26	0.41	0.48	0.28	0.27	0.26	0.86	0.96	1.00

Source: Author's calculations

Table 7: Inflation expectations principal component- Long-term expectations

Principal Components Analysis
Sample (adjusted): 2004M06 2020M12
Included observations: 207 after adjustments
Balanced sample (listwise missing value deletion)
Computed using: Ordinary correlations

Eigenvalues: (Sum = 10, Average = 1)

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	8.81	7.55	0.80	8.81	0.80
2	1.26	0.43	0.11	10.06	0.91
3	0.83	0.72	0.08	10.89	0.99
4	0.11	0.11	0.01	11.00	1.00
5	0.00	0.00	0.00	11.00	1.00
6	0.00	0.00	0.00	11.00	1.00
7	0.00	0.00	0.00	11.00	1.00
8	0.00	0.00	0.00	11.00	1.00
9	0.00	0.00	0.00	11.00	1.00
10	0.00	0.00	0.00	11.00	1.00
11	0.00	—	0.00	11.00	1.00

Eigenvectors (loadings):

Variable	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10	PC 11
BEI_6	0.30	0.34	-0.21	-0.27	0.07	0.32	0.24	0.27	0.49	0.44	0.08
BEI_7	0.32	0.27	-0.19	-0.17	0.01	0.24	-0.10	0.43	-0.44	-0.54	0.15
BEI_8	0.32	0.20	-0.16	-0.13	-0.07	0.29	-0.01	-0.80	-0.05	-0.14	-0.23
BEI_9	0.33	0.14	-0.10	-0.13	-0.08	-0.68	0.47	-0.07	-0.34	0.18	0.08
BEI_10	0.34	0.07	-0.04	-0.17	0.00	-0.45	-0.74	0.05	0.26	0.03	-0.15
EBEI8	0.09	0.60	0.75	0.26	-0.02	0.00	0.00	0.00	0.00	0.00	0.00
FBEI_5_1	0.32	-0.05	-0.20	0.64	0.60	-0.08	0.10	-0.03	0.19	-0.17	0.06
FBEI_6_1	0.33	-0.18	-0.05	0.43	-0.31	0.26	-0.24	0.08	-0.41	0.53	0.02
FBEI_7_1	0.32	-0.28	0.12	0.15	-0.50	-0.01	0.29	0.21	0.32	-0.32	-0.45
FBEI_8_1	0.30	-0.35	0.28	-0.13	-0.14	0.04	-0.02	-0.18	0.20	-0.13	0.76
FBEI_9_1	0.27	-0.39	0.42	-0.37	0.51	0.14	0.06	0.08	-0.22	0.13	-0.32

Ordinary correlations:

	BEI_6	BEI_7	BEI_8	BEI_9	BEI_10	EBEI8	FBEI_5_1	FBEI_6_1	FBEI_7_1	FBEI_8_1	FBEI_9_1
BEI_6	1.00										
BEI_7	1.00	1.00									
BEI_8	0.98	1.00	1.00								
BEI_9	0.97	0.98	1.00	1.00							
BEI_10	0.94	0.97	0.98	1.00	1.00						
EBEI8	0.36	0.33	0.31	0.30	0.29	1.00					
FBEI_5_1	0.86	0.90	0.93	0.94	0.94	0.11	1.00				
FBEI_6_1	0.80	0.85	0.89	0.92	0.94	0.11	0.98	1.00			
FBEI_7_1	0.71	0.77	0.82	0.86	0.90	0.12	0.91	0.98	1.00		
FBEI_8_1	0.60	0.66	0.72	0.78	0.83	0.15	0.81	0.91	0.98	1.00	
FBEI_9_1	0.49	0.56	0.62	0.69	0.75	0.17	0.70	0.83	0.93	0.98	1.00

Source: Author's calculations

A.3 BVARx Impulse response for the synthetic inflation expectations measures

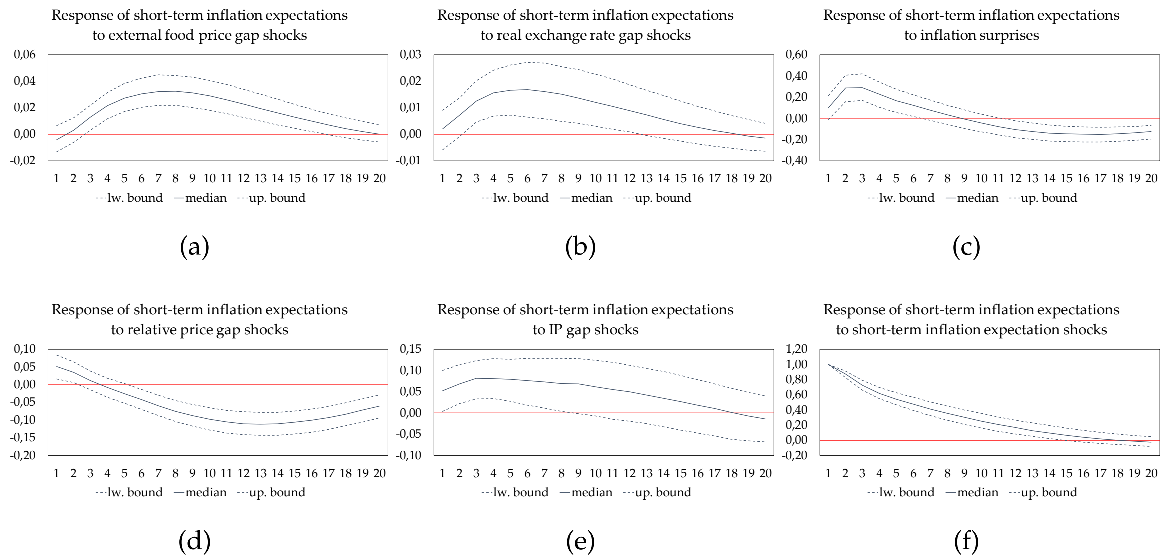

Figure 8: BVARx impulse responses (endogenous variables) Short-run inflation expectations

Source:Author's calculations

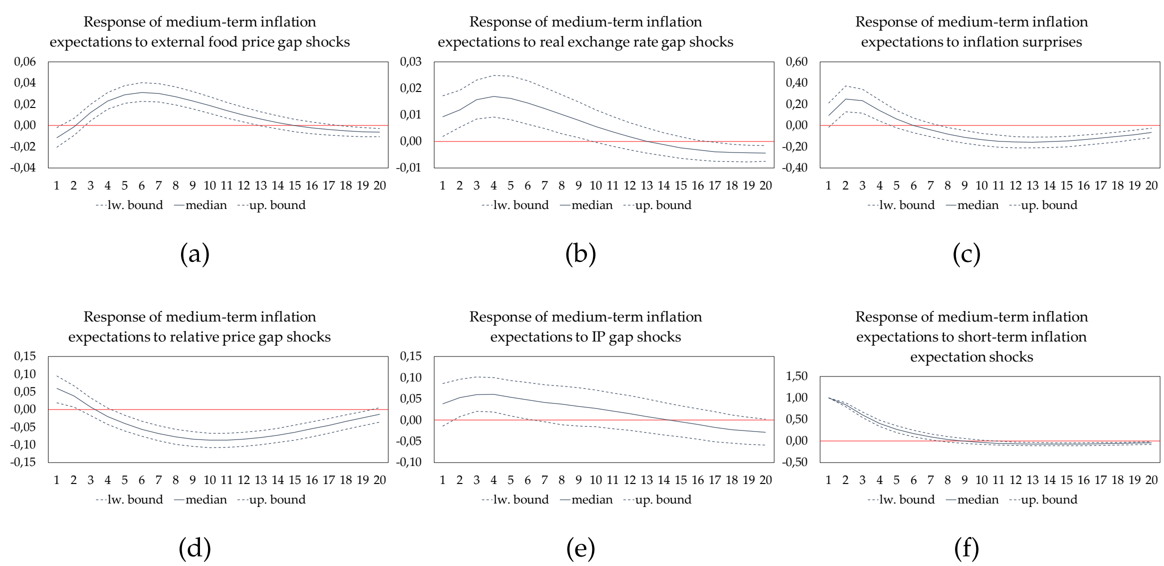

Figure 9: BVARx impulse responses (endogenous variables) Medium-term inflation expectations

Source:Author's calculations

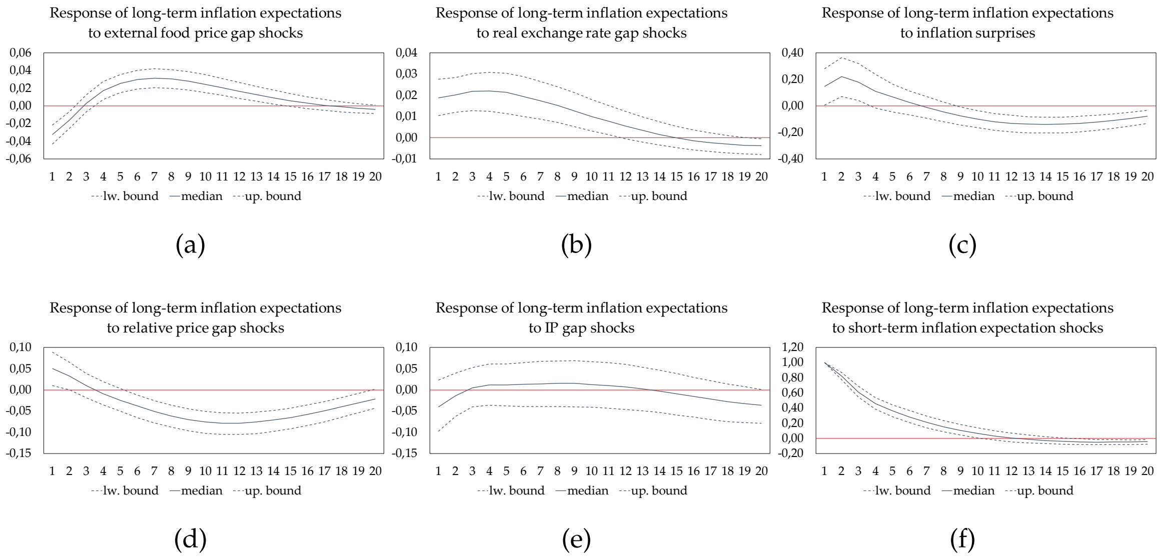

Figure 10: BVARx impulse responses (endogenous variables) Long-run inflation expectations

Source:Author's calculations

A.4 Unit root tests

	UNIT ROOT TEST TABLE (PP)									UNIT ROOT TEST TABLE (ADF)									
	With Constant			With Constant & Trend			Without Constant & Trend			With Constant			With Constant & Trend			Without Constant & Trend			
At Level	t-Statistic	Prob.		t-Statistic	Prob.		t-Statistic	Prob.		t-Statistic	Prob.		t-Statistic	Prob.		t-Statistic	Prob.		Decision
BVARx Variables																			
ENSO	-3.26	0.02	**	-3.25	0.08	*	-3.26	0.00	***	-3.37	0.01	**	-3.52	0.04	**	-3.36	0.00	***	I(0)
Relative price gap	-3.17	0.02	**	-3.16	0.09	*	-3.17	0.00	***	-6.10	0.00	***	-6.09	0.00	***	-6.12	0.00	***	I(0)
Monthly inflation surprises	-11.21	0.00	***	-11.21	0.00	***	-11.24	0.00	***	-5.80	0.00	***	-5.81	0.00	***	-5.82	0.00	***	I(0)
IP Gap	-2.82	0.06	*	-2.78	0.21		-2.82	0.00	***	-3.95	0.00	***	-3.93	0.01	**	-3.96	0.00	***	I(0)
International food prices gap	-3.47	0.01	***	-3.45	0.05	**	-3.47	0.00	***	-4.07	0.00	***	-4.05	0.01	***	-4.08	0.00	***	I(0)
Real exchange rate gap	-4.45	0.00	***	-4.44	0.00	***	-4.46	0.00	***	-5.40	0.00	***	-5.38	0.00	***	-5.41	0.00	***	I(0)
Synthetic inflation expectation index (deviation from the inflation target)																			
Short -term inflation expectations	-3.37	0.01	**	-3.36	0.06	*	-3.14	0.00	***	-3.75	0.00	***	-3.73	0.02	**	-3.05	0.00	***	I(0)
Medium- term inflation expectations	-4.68	0.00	***	-4.68	0.00	***	-3.73	0.00	***	-4.24	0.00	***	-4.23	0.00	***	-3.54	0.00	***	I(0)
Long- term inflation expectations	-4.33	0.00	***	-4.33	0.00	***	-2.81	0.01	***	-4.10	0.00	***	-4.13	0.01	***	-2.44	0.01	**	I(0)
Break-even inflation																			
BEI_1	-3.53	0.01	***	-3.55	0.04	**	-3.52	0.00	***	-3.24	0.02	**	-3.24	0.08	*	-3.27	0.00	***	I(0)
BEI_2	-3.83	0.00	***	-3.85	0.02	**	-3.68	0.00	***	-3.78	0.00	***	-3.79	0.02	**	-3.66	0.00	***	I(0)
BEI_3	-4.15	0.00	***	-4.17	0.01	***	-3.82	0.00	***	-4.10	0.00	***	-4.11	0.01	***	-3.75	0.00	***	I(0)
BEI_4	-4.37	0.00	***	-4.40	0.00	***	-3.79	0.00	***	-4.31	0.00	***	-4.33	0.00	***	-3.69	0.00	***	I(0)
BEI_5	-4.50	0.00	***	-4.54	0.00	***	-3.69	0.00	***	-4.66	0.00	***	-4.72	0.00	***	-3.53	0.00	***	I(0)
BEI_6	-4.62	0.00	***	-4.66	0.00	***	-3.53	0.00	***	-4.64	0.00	***	-4.20	0.01	***	-3.33	0.00	***	I(0)
BEI_7	-4.60	0.00	***	-4.64	0.00	***	-3.39	0.00	***	-4.19	0.00	***	-4.22	0.01	***	-3.13	0.00	***	I(0)
BEI_8	-4.21	0.00	***	-4.21	0.01	***	-3.30	0.00	***	-4.22	0.00	***	-4.23	0.00	***	-2.93	0.00	***	I(0)
BEI_9	-4.52	0.00	***	-4.54	0.00	***	-3.14	0.00	***	-4.36	0.00	***	-4.41	0.00	***	-2.76	0.01	***	I(0)
BEI_10	-4.42	0.00	***	-4.42	0.00	***	-3.06	0.00	***	-4.25	0.00	***	-4.28	0.00	***	-2.60	0.01	***	I(0)
Forward Break-even inflation																			
FBEI_1_1	-4.38	0.00	***	-4.38	0.00	***	-4.00	0.00	***	-4.43	0.00	***	-4.42	0.00	***	-4.00	0.00	***	I(0)
FBEI_2_1	-4.80	0.00	***	-4.82	0.00	***	-3.91	0.00	***	-4.88	0.00	***	-4.93	0.00	***	-3.83	0.00	***	I(0)
FBEI_3_1	-4.78	0.00	***	-4.93	0.00	***	-3.58	0.00	***	-4.14	0.00	***	-4.24	0.00	***	-2.47	0.01	**	I(0)
FBEI_4_1	-4.71	0.00	***	-4.42	0.00	***	-3.25	0.00	***	-4.00	0.00	***	-4.08	0.01	***	-2.32	0.02	**	I(0)
FBEI_5_1	-4.54	0.00	***	-4.58	0.00	***	-3.00	0.00	***	-4.04	0.00	***	-4.12	0.01	***	-2.57	0.01	**	I(0)
FBEI_6_1	-4.37	0.00	***	-4.42	0.00	***	-2.75	0.01	***	-3.78	0.00	***	-3.78	0.02	**	-2.29	0.02	**	I(0)
FBEI_7_1	-4.39	0.00	***	-4.38	0.00	***	-2.72	0.01	***	-3.61	0.01	***	-3.60	0.03	**	-2.10	0.03	**	I(0)
FBEI_8_1	-4.41	0.00	***	-4.39	0.00	***	-2.67	0.01	***	-3.56	0.01	***	-3.54	0.04	**	-2.02	0.04	**	I(0)
FBEI_9_1	-4.44	0.00	***	-4.44	0.00	***	-2.76	0.01	***	-3.57	0.01	***	-3.57	0.04	**	-1.81	0.07	*	I(0)
E-BEI (correcting for liquidity)																			
1Y - EBEI	-3.27	0.02	**	-3.25	0.08	*	-3.28	0.00	***	-3.26	0.02	**	-3.27	0.07	*	-3.27	0.00	***	I(0)
2Y - EBEI	-3.07	0.03	**	-3.05	0.12		-3.07	0.00	***	-3.49	0.01	***	-3.60	0.03	**	-3.49	0.00	***	I(0)
3Y -EBEI	-2.97	0.04	**	-2.97	0.14	n0	-2.94	0.00	***	-3.43	0.01	**	-3.58	0.03	**	-3.38	0.00	***	I(0)
5Y - EBEI	-2.85	0.05	*	-2.91	0.16	n0	-2.66	0.01	***	-2.83	0.06	*	-3.50	0.04	**	-2.64	0.01	***	I(0)
8Y -EBEI	-2.70	0.08	*	-2.81	0.19	n0	-2.24	0.02	**	-2.74	0.07	*	-2.87	0.17	n0	-2.28	0.02	**	I(0)
Focus Economics Survey																			
FOCUS_1	-3.04	0.03	**	-3.02	0.13		-2.82	0.00	***	-2.86	0.05	*	-2.84	0.18		-2.71	0.01	***	I(0)
FOCUS_2	-4.36	0.00	***	-4.47	0.00	***	-3.82	0.00	***	-4.33	0.00	***	-4.42	0.00	***	-3.88	0.00	***	I(0)
FOCUS_3	-4.11	0.00	***	-4.28	0.00	***	-3.91	0.00	***	-3.98	0.00	***	-3.02	0.13		-3.80	0.00	***	I(0)
FOCUS_4	-3.59	0.01	***	-4.05	0.01	***	-3.60	0.00	***	-2.17	0.22		-2.69	0.24		-2.19	0.03	**	I(0)
FOCUS_5	-3.66	0.01	***	-4.04	0.01	***	-3.58	0.00	***	-2.01	0.28		-2.50	0.33		-1.99	0.05	**	I(0)
Central Bank Survey																			
End of the current year	-2.85	0.05	*	-2.81	0.19		-2.72	0.01	***	-2.66	0.08	*	-2.63	0.27		-2.59	0.01	***	I(0)
1-year ahead	-3.22	0.02	**	-3.29	0.07	*	-2.76	0.01	***	-3.01	0.04	**	-3.06	0.12		-2.69	0.01	***	I(0)

*MacKinnon (1996) one-sided p-values.
Notes: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1%. and (no) Not Significant

A.5 BVAR Estimation procedure

This section is based on Dieppe et al. (2016). In our estimation we use and independent normal-Wishart prior with unknown $\sum$ and arbitrary ω_0. We start by defining the likelihood of the data in the following form:

$$f(y \mid \beta, \sum) \propto \mid \sum \mid^{-\frac{T}{2}} exp\lceil -\frac{1}{2}(\beta - \hat{\beta})'(\sum \otimes (X'X)^{-1})^{-1}(\beta - \hat{\beta})\rceil \\ \times exp\lceil -\frac{1}{2}tr\{\sum^{-1}(Y - X\hat{\beta})'(Y - X\hat{\beta})\}\rceil \tag{19}$$

Concerning the prior for β, we assume that it follows a multivariate normal distribution with mean β_0 ($aq1$ vector) and a covariance matrix ω_0 which is an arbitrary q×q matrix. Hence:

$$\beta \sim \aleph(\beta_0, \Omega_0) \tag{20}$$

In typical applications, Ω_0 will take the form of the Minnesota covariance matrix but any choice is possible. Similarly, β_0 will typically be defined as the Minnesota β_0 vector but any structure could be adopted. Given β_0 and Ω_0, the prior density for β is given by:

$$\pi(\beta) \propto exp\lceil -\frac{1}{2}(\beta - \beta_0)'\Omega_0^{-1}(\beta - \beta_0)\rceil \tag{21}$$

The prior distribution for $\sum$ is an inverse Wishart distribution, with scale matrix $\S_0$ and degrees of freedom α_0:

$$\sum \sim JW(S_0, \alpha_0) \tag{22}$$

Thus, the prior density of $\sum$ is given by:

$$\pi(\sum) \propto \mid \sum \mid^{-\frac{(\alpha_0+n+1)}{2}} exp\lceil -\frac{1}{2}tr\{\sum^{1} S_0\}\rceil \tag{23}$$

The following equation lead to a posterior of the following form:

$$\pi(\beta, \sum \mid y) \propto \mid \sum \mid^{-\frac{T+\alpha_0+n+1}{2}} exp\lceil -\frac{1}{2}(\beta - \overline{\beta})'\overline{\Omega}^{-1}(\beta - \overline{\beta})\rceil \\ \times exp\lceil -\frac{1}{2}\hat{\beta}'(\sum^{-1} \otimes X'X)\hat{\beta} + \beta_0'\Omega_0^{-1}\beta_0 - \overline{\beta'\Omega}^{-1}\overline{\beta}\rceil \\ \times exp\lceil -\frac{1}{2}tr\{\sum^{-1}\lceil(Y - X\hat{\beta}) + S_0\rceil\}\rceil \tag{24}$$

Where:

$$\hat{\beta} = (X'X)^{-1}X'Y$$
$$\epsilon \sim \aleph(0, \overline{\sum}) \quad Where \overline{\sum} = \sum \otimes I_t$$
$$\overline{\Omega} = [\Omega_0^{-1} + \sum^{-1} \otimes X'X]^{-1}$$
$$\overline{\beta} = \overline{\Omega}[\Omega_0^{-1}\beta_0 + (\sum^{-1} \otimes X')y]$$

Importantly, it is not possible to derive an analytical marginal distribution for β and $\sum$ from expression (A6). However, it is possible to derive their conditional distributions. To do so, one considers the joint posterior distribution for all parameters and retain only the terms involving parameters whose conditional distribution must be determined. All terms do not involve these parameters and do not contain information about their distribution and thus, are relegated to the proportionality constant. With these conditional distributions it is possible to use Gibbs sampling to obtain random draws from the unconditional posterior distributions of the parameters of interest.

A.6 Complete model structure

IS Curve and potential GDP growth

$$\overline{y}_t = \overline{y}_{t-1} + \frac{\Delta\overline{y}_t}{4}$$
$$\Delta\overline{y}_t = \rho_{\Delta\overline{y}}\Delta\overline{y}_{t-1} + (1-\rho_{\Delta\overline{y}})(\Delta\overline{y}_{ss} + \kappa_{\Delta\overline{y}}(\Delta\overline{rp}_t^{oil} - \Delta\overline{rp}_{ss}^{oil})) + \epsilon_t^{\Delta\overline{y}}$$
$$\hat{y}_t = \beta_1\hat{y}_{t-1} + \beta_2 E_t\hat{y}_{t+1} - \beta_\phi\phi_t + \beta_{\hat{y}^*}\hat{y}_t^* + \beta_{r\hat{p}_t{}^{oil}} r\hat{p}_t^{oil} + \eta_t^{\hat{y}_t}$$
$$\phi_t = \beta_{\hat{r}}\hat{r}_t - (1-\beta_{\hat{r}})\hat{z}_t$$
$$\eta_t^{\hat{y}} = \beta_{\eta^{\hat{y}}}\eta_{t-1}^{\hat{y}} + \epsilon_t^{\hat{y}}$$

Phillips Curves, Relative Prices and CPI aggregation

$$\pi_t^j = \alpha_{\pi^j}\pi_{t-1}^j - (1-\alpha_{\pi^j})\pi_t^{e,j} + \alpha_{rmc^j}^{\pi^j} rmc_t^j + \epsilon_t^{\pi^j}$$

For j = Goods (g), Services (s), Regulated (r), and Food (f).

$$rmc_t^j = \begin{pmatrix} \alpha_{\hat{y}}^{rmc^j}\hat{y} + (1-\alpha_{\hat{y}}^{rmc^j})(\hat{z}_t - r\hat{p}_t^j) for j = g, s \\ \alpha_{\hat{y}}^{rmc^j}\hat{y} + (1-\alpha_{\hat{y}}^{rmc^j})(-r\hat{p}_t^{F*} + \hat{z}_t + \lambda^f ENSO_t - r\hat{p}_t^j) for j = f \\ \alpha_{\hat{y}}^{rmc^j}\hat{y} + (1-\alpha_{\hat{y}}^{rmc^j})(-r\hat{p}_t^{oil} + \hat{z}_t + \lambda^f ENSO_t - r\hat{p}_t^j) for j = r \end{pmatrix}$$

$$\hat{rp}_t^j = rp_t^j - \overline{rp}_t^j$$
$$rp_t^j = p_t^j - p_t$$
$$\overline{rp}_t^j = \overline{rp}_{t-1}^j + \frac{\Delta\overline{rp}_t^j}{4}$$
$$\Delta\overline{rp}_t^j = \rho_{\Delta\overline{rp}^j}\Delta\overline{rp}_{t-1}^j + (1-\rho_{\Delta\overline{rp}^j})\Delta\overline{rp}_{ss}^j + \epsilon^{\Delta\overline{rp}^j}$$
$$p_t = \omega^G p^G + \omega^S p^S + \omega^R p^R + \omega^F p^F + \eta_t^{p_t}$$
$$\eta_t^{p_t} = \eta_{t-1}^{p_t} + \epsilon_t^{p_t}$$
$$0 = \omega^G \hat{rp}_t^G + \omega^S \hat{rp}_t^S + \omega^R \hat{rp}_t^R + \omega^F \hat{rp}_t^F$$

Inflation Expectations and credibility

$$\pi_t^{e,j} = c_t\pi_t^j + (1-c_t)(\pi_{t+1}^j + \psi Enso_t) + \epsilon_t^{\pi^{e,j}} for j = f, r$$
$$\pi_t^{e,j} = c_t\pi_t^j + (1-c_t)(\pi_{t+1}^j) + \epsilon_t^{\pi^{e,j}} for j = g, s$$
$$c_t = \rho^c c_{t-1} + (1-\rho^c)\xi_t$$

$$\xi_t = \frac{(\epsilon_t^{bad})^2}{(\epsilon_t^{bad})^2 + (\epsilon_t^{good})^2}$$
$$\epsilon_t^{bad} = \pi_t - [\rho^\epsilon \pi_{t-1} + (1-\rho^\epsilon)\pi^{bad}]$$
$$\epsilon_t^{good} = \pi_t - [\rho^\epsilon \pi_{t-1} + (1-\rho^\epsilon)\pi^{good}]$$

To control for boundary conditions, we set $\xi_t = 0$ if $\epsilon_t^{bad} > 0$ and $\xi_t = 0$ if $\epsilon_t^{good} < 0$.

Monetary Policy Rule and Interest Rates

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left[\bar{i}_t + \psi_\pi(E_t\pi_{t+3}^A - E\overline{\pi}_{t+3}^A) + \psi_{\hat{y}}\ \hat{y}_t\right] + \epsilon_t^i$$
$$\overline{\pi}_t^A = \rho_{\overline{\pi}^y}\overline{\pi}_{t-1}^A + (1-\rho_{\overline{\pi}^y})\overline{\pi}_{ss}^A + \epsilon_t^{\overline{\pi}^A}$$
$$\bar{i}_t = \bar{r}_t + E_t\pi_{t+1}$$
$$\bar{r}_t = \bar{r}_t^* + \overline{CDS}_t + \Delta\bar{z}_{ss}$$
$$\hat{r}_t = r_t - \bar{r}_t$$
$$r_t = i_t - E_t\pi_{t+1}$$

Determination of the foreign exchange rate

$$\Delta s_{t+1} = i^*_t - i_t + prem + \varepsilon^{ls}_t$$
$$\Delta E_t s_{t+1} = 4(E_t s_{t+1} - s_t)$$
$$z_t = \overline{z}_t + \hat{z}_t$$
$$z_t = s_t + p^*_t - p_t$$
$$\hat{z}_t = \hat{z}_{t-1} + \frac{\Delta \overline{z}_t}{4}$$
$$\Delta \overline{z}_t = \rho_{\Delta z} \Delta \overline{z}_{t-1} + (1 - \rho_{\Delta z})(\Delta \overline{z}_{ss} - \varepsilon_{\Delta \overline{z}}(\Delta \overline{rp}^{oil}_t - \Delta \overline{rp}^{oil}_{ss})) + \epsilon^{\Delta \overline{z}}_t$$

Exogenous variables

$$\hat{rp}^{oil}_t = rp^{oil}_t - \overline{rp}^{oil}_t$$
$$rp^{oil}_t = p^{oil}_t - p^*_t$$
$$\overline{rp}^{oil}_t = \overline{rp}^{oil}_{t-1} + \frac{\Delta \overline{rp}^{oil}_t}{4}$$
$$\Delta \overline{rp}^{oil}_t = \rho_{\overline{rp}^{oil}} \overline{rp}^{oil}_{t-1} + (1 - \rho_{\overline{rp}^{oil}}) \Delta \overline{rp}^{oil}_{ss} + \epsilon^{\Delta \overline{rp}^{oil}}_t$$
$$\hat{rp}^{oil}_t = \rho_{\hat{rp}^{oil}} \hat{rp}^{oil}_{t-1} + \epsilon^{\hat{rp}^{oil}}$$
$$y^*_t = \rho_{y^*} y^*_{t-1} + \epsilon^{y^*}$$
$$p^*_t = p^*_{t-1} + \frac{\pi^*_t}{4}$$
$$\pi^*_t = \rho_{\pi^*} \pi^*_{t-1} + (1 - \rho_{\pi^*}) \pi^*_{ss} + \epsilon^{\pi^*}$$
$$i^*_t = \rho_{i^*} i^*_{t-1} + (1 - \rho_{i^*}) i^*_{ss} + \epsilon^{i^*}$$
$$\overline{i}^*_t = \overline{r}^*_t + E_t \pi^*_{t+1}$$
$$\overline{r}^*_t = \rho_{\overline{r}^*} \overline{r}^*_{t-1} + (1 - \rho_{\overline{r}^*}) \overline{r}^*_{ss} + \epsilon^{\overline{r}^*}$$
$$CDS_t = \rho_{CDS} CDS_{t-1} + (1 - \rho_{CDS}) \overline{CDS}_t + \epsilon^{CDS}_t$$
$$\overline{CDS}_t = \rho_{\overline{CDS}} \overline{CDS}_{t-1} + (1 - \rho_{\overline{CDS}}) \overline{CDS}_{ss} + \epsilon^{\overline{CDS}}_t$$
$$\hat{rp}^{F*}_t = \rho_{\hat{rp}^{F*}} \hat{rp}^{F*}_{t-1} + \epsilon^{\hat{rp}^*}$$

A.7 Credibility mechanism in the semi-structural model

In this annex we show the dynamics of the model to 1 unit (100 basis points) increase in the ENSO shock in two different scenarios, both of them start from the steady state in all variables with the exception of credibility in the *Low credibility* simulation. In this scenario, the initial point is at 50pb lower than the steady state.

The ENSO shock has a direct effect on food and regulated inflation. This increase in these baskets is a consequence of the direct effect that adverse weather has on the marginal costs for these baskets and for the effect on inflation expectations which also increase as a result of this shock. Higher food and regulated inflation and its expectations, headline inflation and total inflation expectations increase accordingly. In these setting the monetary policy authority has to react to this shock to anchor inflation expectations by increasing the interest rates. Output gap decreases because of the increase of monetary policy.

When the credibility starts from a lower point, we can see that the effect of the ENSO shock has a higher and more persistence impact on inflation and inflation expectations. Therefore, monetary policy efforts must be higher.