Introduction

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The control of inflation and its volatility are fundamental issues for any country. Economies with a high level of inflation or uncertainty on its future value can lead, for example, to high costs for economic agents, distortions on future investment plans and welfare implications for society. On the contrary, economies with low levels of inflation and volatility, for instance, can enhance their population living conditions, access to credit sources, and confidence indicators for international investors (e.g., Madeira and Zafar, 2015; and Strohsal and Winkelmann, 2015).

Accordingly, keeping inflation under control becomes a crucial task for the monetary authority. In this regard, a strand of the economic literature has established an explicit relation between inflation, its long term expectations and their anchoring to a target level. In particular, the literature has underlined the relation of this anchoring to the ability of central banks to control inflation, set up an effective monetary policy strategy, and improve the transmission mechanisms (e.g., Haubrich *et al.*, 2012; Autrup and Grothe, 2014; and Strohsal *et al.*, 2016).

In this context, the appropriate measurement of inflation expectations and their degree of anchoring are essential elements for making monetary policy decisions by central banks. Nevertheless, these variables are unobservable and, hence, their monitoring and assessment are not straightforward.

In practice, inflation expectations are measured through surveys of specific population groups (e.g., financial market agents, firms, and consumers), or inferred from financial instruments' market prices (e.g., break-even inflation rates, inflation-linked bonds, swaps, and options). However, the analyses of such expectations from these two sources of information do not necessarily lead to the same conclusions (e.g., Pierdzioch and Rülke, 2013; and Nautz and Strohsal, 2015).

These measures have different features associated with their empirical counterparts. Survey-based expectations are a direct estimate of the probability distribution of inflation rates from different economic sectors. Nonetheless, these expectations are usually only available at low-frequencies (e.g., monthly or quarterly) and for a limited number of short-term horizons (typically, one or two years) (e.g., Autrup and Grothe, 2014; and Pierdzioch and Rülke, 2013).

By contrast, financial market-based expectations can be accessible in real time, at a higher-frequency (e.g., daily), and with multiple time horizons, including the long-term ones (e.g., five or ten-year). Nonetheless, these data are indirect measures of inflation expectations, whose measurement can be contaminated by several factors. For instance, break-even inflation rate[1] is considered a measure of inflation compensation that, in addition to inflation expectations, includes the inflation risk and liquidity premiums. The latter is associated with market conditions and the availability of liquid nominal and inflation-linked bonds (e.g., Antunes, 2015; and Strohsal and Winkelmann, 2015).

For authorities, another fundamental aspect is the formation process of inflation expectations. This process is essential to understanding how monetary policy decisions are transmitted to expectations (e.g., economic channels and their speed) and, in turn, to inflation. This enables central banks to design an effective policy strategy (e.g., Evans and Honkapohja, 2001; and Maertens and Rodríguez, 2013).

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[1] These rates are derived from the spread between nominal and inflation-linked government bond yields.

The academic literature has directed its attention to two main schemes of expectations, namely, adaptive and rational. The former considers that inflation dynamics are based only on their own past values, and hence agents form their expectations using the observed price information (that is, a backward-looking rule). Under the latter scheme, each time expectations are formed, individuals consider all available information including, for example, the learning from previous prediction errors, the probable future actions of the central bank as well as the agents' beliefs (that is, a forward-looking rule) (e.g., Taylor, 1985; Kiley, 2007; and Golden and Monks, 2009). There have been other expectations formation mechanisms proposed in literature. For example, Gerberding (2001) has studied a combination of both adaptive and rational schemes, while Ekeblom (2012) has proposed some degree of learning in the formation of expectations. Other examples within this literature are Carlson and Valev (2002), Heinemann and Ullrich (2006), and Oral *et al.* (2011).

As mentioned, the anchoring of inflation expectations is fundamental for monetary policy. In fact, the literature points out that well-anchored expectations reduce the inflation risk premium, improve investment decisions, enhance the valuation of long-term assets, lower the volatility on long-term interest rates and make them less sensitive to shocks (e.g., Gürkaynak *et al.*, 2010; Mehrotra and Yetman, 2014; and Berument and Froyen, 2015).

Inflation expectations are *well-anchored* (that is, central bank's credibility is strong) if shocks affecting current inflation and its short-term expectation do not lead to long-run deviations from the target level. If they are well-anchored, then long-term expectations should be insensitive to macroeconomic shocks or other surprises, so that once shocks have dissipated, inflation should return to its long-run target. On the contrary, if central bank's credibility is weak, economic shocks could deviate long-term inflation expectations away from its inflation target (e.g., Demertzis *et al.*, 2009; Galati *et al.*, 2011; and Pagenhardt *et al.*, 2015).

Recent literature has carried out the measurement of the degree of anchoring through several methodologies, which capture theoretical aspects from two main lines of research. The first one evaluates if long-term inflation expectations are moving close to a target level, so the degree of anchoring depends on the deviation of these expectations regarding a specific inflation target (e.g., Mehrotra and Yetman, 2014; and Strohsal and Winkelmann, 2015).

The second line studies the dependence relation between short- and long-term inflation expectations. This literature assesses if shocks that affect short-term inflation expectations have effects on those of the long-term, so that the degree of anchoring depends on how statistically significant is the joint movement between short- and long-term inflation expectations in response to shocks (e.g., Gürkaynak *et al.*, 2010; and Antunes, 2015).

Figure 1 illustrates recent research works on the anchoring of inflation expectations. Each of these studies is characterized according to both the methodology considered and the source of data used in its empirical exercises.

A broad segment of this literature has investigated mainly two issues. The first one is the assessment and characterization of differences in the degree of anchoring between countries with and without an inflation-targeting regime. For instance, Gürkaynak *et al.* (2005), Gürkaynak *et al.* (2007), Demertzis *et al.* (2009), Gürkaynak *et al.* (2010), and Beechey *et al.* (2011) examined this matter for the United States (US) and the euro area, for sample periods between the 1990s and the end of 2000s. These studies find that a credible inflation-targeting strategy improves the anchoring of long-term inflation expectations, reduces their volatility and makes them less sensitive to inflation shocks.

The second issue is the evolution of the degree of anchoring over time. For example, the dynamics of anchoring in the pre- and post-Global Financial Crisis periods in the US between 2004 and 2014 is studied by Galati *et al.* (2011), Autrup and Grothe (2014), Nautz and Strohsal (2015), and Strohsal *et al.* (2016). The first three works state that inflation expectations have been deanchored since the Global Financial Crisis, while the latter work points out that the deanchoring lasted a short period in 2008, after which expectations were anchored again .

The works by Lemke and Strohsal (2013), Antunes (2015), Pagenhardt *et al.* (2015), and Scharnagl and Stapf (2015) carry out similar research for the euro area for sample periods between 2000 and 2015. Lemke and Strohsal (2013) and Scharnagl and Stapf (2015) stated that although the European Sovereign Debt Crisis increased the volatility of inflation expectations in 2011, these were not deanchored. On the other hand, Antunes (2015) and Pagenhardt *et al.* (2015) found that the same crisis' events increased the joint movement

of short- and long-term inflation expectations, and since then the latter have been responding to economic shocks.

The variation in the degree of anchoring has also been studied in other countries for diverse samples between 1996 and 2013. De Pooter *et al.* (2014) find that inflation expectations in Brazil, Chile, and Mexico are anchored, and that these react to US news' surprises. Kabundi and Schaling (2013), and Çiçek and Akar (2014) provide evidence on the unsuccessful anchoring of inflation expectations in South Africa and Turkey. These are due to low credibility in each country. Mehrotra and Yetman (2014), and Berument and Froyen (2015) show that inflation expectations are more firmly anchored after the adoption of credible inflation-targeting regimes. Other recent examples are the studies about the degree of anchoring in Singapore by Ee and Supaat (2008); the US, European Monetary Union, United Kingdom and Sweden by Strohsal and Winkelmann (2015), and Colombia by Gamba *et al.* (2016).

Another topic associated directly with inflation expectations is the continuous monitoring and forecasting of inflation. This is highly relevant for central banks and their monetary policy strategies, particularly in economies with inflation-targeting regimes. Inflation forecasts are computed using various types of macroeconometric and time series methodologies. Recently, forecasting models based on large data sets, high numbers of predictors and direct combination of different forecast models have attracted the attention of modelers and practitioners. These techniques are useful considering that central banks have inflation forecasts coming from different models.

Recent examples of these forecasting tools are the Bayesian model averaging (BMA) (e.g., Wright, 2009), factor-augmented vector autoregressive (FAVAR) models (e.g., Bernanke *et al.*, 2005) and schemes for combining forecasts, proposed by Reid (1968), and Bates and Granger (1969). Hall and Mitchell (2007), and Geweke and Amisano (2011) consider combinations of forecasting densities instead of punctual predictions. Tian and Anderson (2014) proposed new schemes for combining forecasts with possible structural changes, and Kapetanios *et al.* (2015) extended the previous literature with weighting schemes.

A fundamental topic in forecasting is the performance evaluation of prediction models and their comparison with respect to a benchmark or other forecasts. The works by Giacomini and White (2006), and Giacomini and Rossi (2010) are recent examples of static

Figure 1

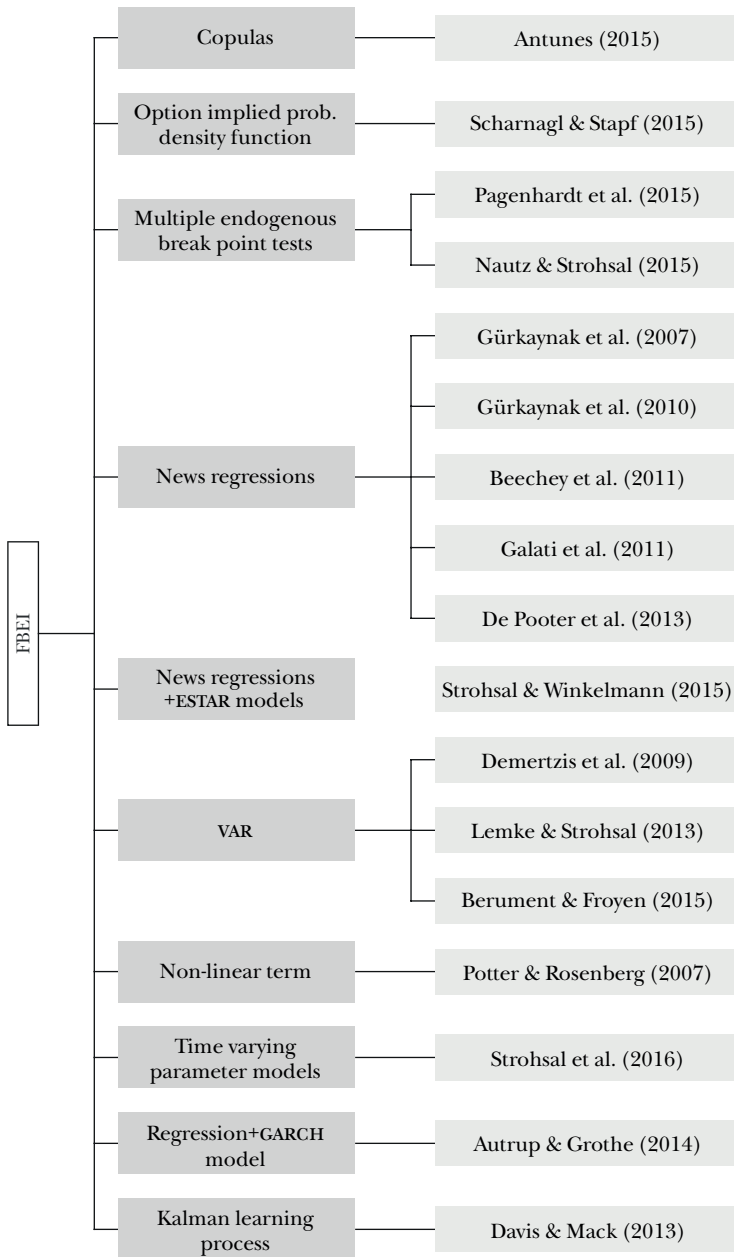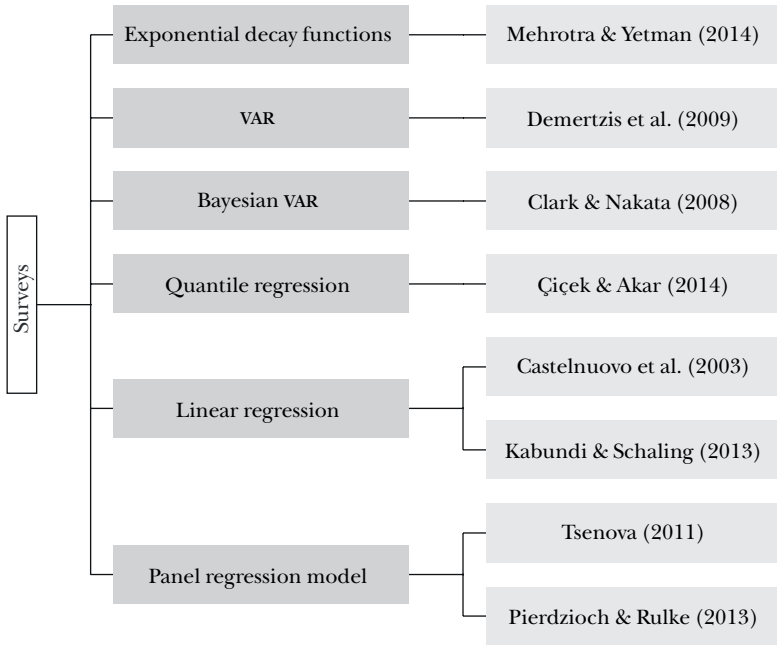## RECENT LITERATURE ON THE ANCHORING OF INFLATION EXPECTATIONS

	Copulas	Antunes (2015)
	Option implied prob. density function	Scharnagl & Stapf (2015)
	Multiple endogenous break point tests	Pagenhardt et al. (2015)
		Nautz & Strohsal (2015)
	News regressions	Gürkaynak et al. (2007)
		Gürkaynak et al. (2010)
		Beechey et al. (2011)
		Galati et al. (2011)
		De Pooter et al. (2013)
FBEI	News regressions +ESTAR models	Strohsal & Winkelmann (2015)
	VAR	Demertzis et al. (2009)
		Lemke & Strohsal (2013)
		Berument & Froyen (2015)
	Non-linear term	Potter & Rosenberg (2007)
	Time varying parameter models	Strohsal et al. (2016)
	Regression+GARCH model	Autrup & Grothe (2014)
	Kalman learning process	Davis & Mack (2013)

Figure 1 (cont.)

**RECENT LITERATURE ON THE ANCHORING
OF INFLATION EXPECTATIONS**

Surveys		
	Exponential decay functions	Mehrotra & Yetman (2014)
	VAR	Demertzis et al. (2009)
	Bayesian VAR	Clark & Nakata (2008)
	Quantile regression	Çiçek & Akar (2014)
	Linear regression	Castelnuovo et al. (2003)
		Kabundi & Schaling (2013)
	Panel regression model	Tsenova (2011)
		Pierdzioch & Rulke (2013)

and dynamic predictive ability tests, while Rossi and Sekhposyan (2010) is an application of these tests in inflation forecasting.

Currently, the literature on inflation expectations has gotten the attention of academics and policy makers. Their renewed interest in these issues is the result of recent shocks that have affected inflation. In particular, between the end of 2014 and the beginning of 2017, the global economy suffered a sudden and abrupt fall in oil prices with diverse effects on other prices and macroeconomic variables. Likewise, between 2015 and the first-half of 2016, some economies

were affected by a climate phenomenon known as *El Niño*[2] with direct effects on the food supply and its prices, as well as indirect effects on core inflation through indexation mechanisms. The impact of these shocks on current inflation has underlined the relevance of bringing up old and new questions about the formation and measurement of inflation expectations, the estimation of their degree of anchoring, as well as the development of more accurate forecasts of future inflation and their relation with expectations.

This is inconsistent. Sometimes they use, for example, the empirical identification of inflation expectation formation processes (e.g., adaptive, rational, hybrid, or adaptive learning), their changes over time, the statistical validation of these schemes and the characterization of their main determinants. Likewise, these queries relate to the measurement of an informative signal of expectations, the choice of a suitable source of data and time horizons as well as the theoretical and empirical implications of such an election for monetary policy decision making.

Other questions are addressed, for instance, the measurement of the degree of inflation expectations anchoring over time and under different policy regimes, the implementation of existing methodologies, the design of new methods and the comparison of their results. A recent challenge is the prediction of variations in the degree of anchoring in response to diverse shocks (e.g., climate related shocks and commodity price's shocks). Other discussions arise on the evaluation of the measures of expectations as forecasts of future inflation, structural changes in these predictions and how to model them.

With the aim of providing empirical and theoretical support to the economic research and the policy decisions of central banks, the Center for Latin American Monetary Studies (CEMLA) in coordination with the Banco de la República (that is, the Central Bank of Colombia) organized the 2017 Joint Research Annual Program to study inflation expectations and other relevant topics associated with them. In the development of this program, the Financial Stability Group of the Inter-American Development Bank and the CEMLA provided academic support to the research groups through

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[2] This is a season of high temperatures, shortage of rains and droughts.

academic feedback given by professors Olivier Coibion,[3] Massimil-iano Marcellino,[4] and Andrea Tambalotti.[5]

This joint program was an opportunity to deal with some of the previous questions, learn about the current research on inflation expectations in central banks and contribute to the burgeoning economic literature on these issues. The results of this research agenda are compiled in this book, which includes 13 chapters. The first one is this Introduction. The remaining 12 chapters correspond to works from 10 central banks (Argentina, Bolivia, Brazil, Colombia, Costa Rica, Guatemala, Mexico, Paraguay, Peru, and Spain) and two international institutions (Bank for International Settlements – BIS, and CEMLA). These works address topics on the formation of inflation expectations, their measurement through surveys and financial market data, the estimation of the degree of anchoring adopting several methodological approaches, and the forecasts of inflation using novel techniques. The works were divided into four main sections, as follows.

1. THE FORMATION AND MEASUREMENT OF INFLATION EXPECTATIONS

In chapter 2, Alberto Fuertes, Ricardo Gimeno and José Manuel Marqués of the Banco de España use the affine model proposed by Gimeno and Marqués (2009) to decompose the nominal interest rates from Chile, Mexico, Colombia, and Brazil into real risk-free rates, inflation expectations and risk premium. For each country, the empirical exercises consider different sample periods between 2001 and 2016, depending on the availability of data on nominal government bonds. Results suggest that expectations in Mexico and Chile were anchored during the periods of study. On the contrary, in Colombia and Brazil, during the sample period analyzed, the inflation expectations deanchored and fluctuated over time.

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[3] Associate Professor at University of Texas at Austin.
[4] Full Professor of Econometrics at Bocconi University.
[5] Assistant Vice President and Function Head, Macroeconomic and Monetary Studies Function, Research and Statistics Group, Federal Reserve Bank of New York.

Chapter 3 presents the work by Alonso Alfaro and Aarón Mora from the Banco Central de Costa Rica. The authors use the model by Mankiw and Reis (2002) to examine information rigidities in inflation expectations of agents from several economic sectors between 2006 and 2017. Although previous studies suggest the existence of these rigidities in the expectations formation process in Costa Rica, the results of this research do not support these claims. Estimates show that the magnitude of the rigidities captured from data is not large enough to validate that statement.

The work by Pablo Alonso of the Banco Central del Paraguay is presented in chapter 4. Alonso estimates a model of determinants of the formation of inflation expectations in Paraguay since the adoption of the inflation-targeting scheme in 2011. His results show that expectations are a function of past inflation and the credibility in the central bank. Other variables such as the foreign exchange rate depreciation and the changes in oil prices do not seem to play a key role in their determination.

2. THE DEGREE OF ANCHORING OF INFLATION EXPECTATIONS

In chapter 5, Rocío Gondo and James Yetman of the Banco Central de Reserva del Perú and the BIS, respectively, use the work by Mehrotra and Yetman (2014) to infer from inflation expectations, for several Latin American countries between 1993 and 2016, an implicit anchor in the data. They also assess how it has evolved over time and compare it with the central bank's target level. Results show that most countries have an anchor whose importance has increased over time as a result of improvements in the credibility after the adoption of an inflation-targeting regime.

The research work by Mauricio Mora, Juan Carlos Heredia and David Zeballos of the Banco Central de Bolivia (BCB) is presented in chapter 6. Authors assess whether inflation expectations in Bolivia between 2005 and 2017 were anchored, in the sense that they were coherent with the inflation future path and the target level announced by the central bank.[6] Results indicate that long-term

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[6] Bolivia is under a monetary-targeting scheme, such that the main reference for future inflation are the central bank's projections.

expectations were strongly anchored since 2014 due to a greater credibility of the BCB linked with a larger intervention in the money market, a more active communication strategy and a stable macroeconomic environment.

Chapter 7 presents the research by Fernando Nascimento de Oliveira and Wagner Gaglianone of Banco Central do Brasil (BCBr). They build several time-varying expectation anchoring indexes of the BCBr from 2002 to 2017, which are based on the monetary authority's capability to anchor long-term inflation expectations. Those indexes consider variables of fiscal and monetary policy in their estimation. Authors state that estimated indexes are consistent with the central bank's credibility perceived by economic agents in Brazil over the sample period.

3. INFLATION FORECASTING AND ITS PERFORMANCE EVALUATION

Chapters 8 and 9 present the research works developed by Lorena Garegnani and Maximiliano Gómez, and Luis Libonatti of the Banco Central de la República Argentina, respectively. Garegnani and Gómez estimate Bayesian VAR models with Argentinian data from 2004 to 2017, and forecast the headline inflation for several time horizons under a rolling window scheme. In the same line of research, Libonatti uses a mixed data sampling regression model to forecast the monthly core inflation of Argentina between 2015 and 2017 using a daily online price index captured by web scraping. In both works, authors compare their results to forecasts from traditional benchmark models and show, in general, a good performance of their predictions.

In chapter 10, the Economic Research Department of the Banco de Guatemala (Banguat) presents its work. This research assesses the performance of both unconditional and conditional inflation forecasts for several time horizons between 2011 and 2017. These predictions are built using time series tools and structural macroeconomic models used by the Banguat. In line with the traditional literature, their results show that forecasts computed with time series tools provide more accuracy in the shortest terms while structural macroeconometric models provide better predictions for medium- and long-term horizons.

In chapter 11, Héctor Zárate and Daniel Zapata from Banco de la República (Colombia) use artificial neural networks to forecast inflation expectations in a set of 16 countries with inflation-targeting regimes and a sample period between 1991 and 2016. Their predictions consider different expectations patterns depending on perceptions about the oil shock in 2014. Authors show that their exercises provide more accurate forecasts than the benchmark model and, anticipate turning points of inflation in most of the cases.

4. INFLATION EXPECTATIONS AND ITS RELATION WITH ECONOMIC POLICY

In chapter 12, Sebastián Cadavid and Alberto Ortiz from CEMLA examine empirically if the economic reforms implemented in Brazil, Chile, Colombia, Mexico, and Peru between 1999 and 2002 –particularly the adoption of an inflation-targeting regime and a flexible exchange rate– led to the observed reduction of inflation in these countries. Their empirical exercises consider counterfactual scenarios in an open economy with monetary factors. The authors show that if these reforms had not been adopted in these Latin American countries, they would have experienced higher inflation rates, variations in gross domestic product with small gains in economic growth and a large volatility in nominal variables.

Finally, chapter 13 presents the work by Bernabé López-Martin, Alberto Ramírez de Aguilar and Daniel Sámano from Banco de Mexico. They analyze the interaction between inflation, its expectations and fiscal deficits in Mexico between 1969 and 2016. The authors extend the model developed by Sargent et al. (2009) to study how fiscal policy can affect inflation expectations in a context of central bank independence. Their results suggest that the fiscal deficits financed through money creation are central to explain the behavior of Mexican inflation and its expectations during the sample period.

The editors trust that this brief introduction will motivate readers to carry on with each of the research works in this book. This publication is an opportunity to learn about relevant issues on inflation expectations for central banks in the region, as well as the current state of their research. We also think that this book will encourage relevant policy discussions on inflation, its expectations and other related issues, contributing to literature on monetary policy.

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