Extraction of Inflation Expectations from Financial Instruments

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Abstract

In this paper, we estimate inflation expectations for several Latin American countries using an affine model that takes as factors the observed inflation and the parameters generated from zero-coupon yield curves of nominal bonds. By implementing this approach, we avoid the use of inflation-linked securities, which are scarce in many of these markets, and obtain market measures of inflation expectations free of any risk premium, eliminating potential biases included in other measures such as breakeven rates. Our method provides several advantages, as we can compute inflation expectations at any horizon and forward rates such as the expected inflation over the five-year period that begins five years from today. We find that inflation expectations in the long-run are fairly anchored in Chile and Mexico, while those in Brazil and Colombia are more volatile and less anchored. We also find that expected inflation increases at longer horizons in Brazil and Chile, while it is decreasing in Colombia and Mexico.

Keywords: inflation expectations, affine model, real interest rate, risk premium.

JEL classification: G12, E43, E44, C54.

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1. INTRODUCTION

Agents' inflation expectations are decisive when studying changes in many of the variables shaping households' and firms' decision making. One approach to obtain inflation expectations is based on the consensus view of specialist economic forecasters, such as the surveys of professional forecasters by the European Central Bank and the Federal Reserve Bank of Philadelphia, both of which are released quarterly. Other surveys also exist, such as the monthly University of Michigan Survey of Consumers in the United States, which elicits information from consumers rather than professional economic forecasters. In Latin America, several central banks also publish surveys about inflation expectations.[1] A drawback of these surveys is that they are released relatively infrequently and, thus, the information received has a time lag. Moreover, they only cover a small range of time horizons and, as identified in the literature (Ang et al., 2007; Chan et al., 2013), there is some bias and inertia in their responses.

An alternative way of obtaining agents' inflation expectations is to use prices of market-traded financial instruments employed to hedge against inflation such us inflation-linked bonds, inflation swaps, and inflation options. One may argue that, given that investors risk their funds when taking investment decisions based on expected future inflation and professional forecasters do not have any vested interest, they could provide a better forecast since they have more skin in the game. Another advantage to this approach is that it is possible to derive the whole probability function (Gimeno and Ibañez, 2017). This makes it possible to estimate, for example, the probability of the occurrence of certain extreme events or the uncertainty of future inflation. Another additional advantage in comparison with surveys is that changes in expectations can be observed almost in real time. This makes it easier to identify the effect of specific events or decisions on inflation expectations. Unfortunately, there are not many markets of inflation-linked securities available for most countries. For example, in Latin American only a few have inflation-linked bonds, and there are no markets for inflation

1 For example, the central banks of Chile, Colombia and Mexico publish a monthly survey about inflation expectations; the Bank of Brazil publishes a daily survey.

options at all. Another problem of obtaining inflation expectations using this approach is the presence of various risk premia, which are included in the prices of the underlying financial assets and which may also vary over time. The presence of these premia may distort the information content of these indicators, which may affect measures of agents' inflation expectations.

Due to the lack of inflation-linked securities in Latin American markets, we use an alternative approach developed by Gimeno and Marques (2012) to obtain inflation expectations: An affine model that takes as factors the observed inflation and the parameters generated in the zero-coupon yield curve estimation of nominal bonds. Also, by implementing this approach, we obtain a measure of inflation expectations free of any risk premia, since the model breaks down nominal interest rates as the sum of real risk-free interest rates, expected inflation, and the risk premium.

To the best of our knowledge, this is the first attempt to obtain pure inflation expectations using nominal government bonds for Latin American countries. We obtain government bond data for Brazil, Chile, Colombia, and Mexico, being able to estimate the zero-coupon yield curve and decompose that curve into the real risk-free rate, the risk premia, and inflation expectations. We can obtain inflation expectations for all of the horizons computed in the zero-coupon yield curve as well as forward rates such as the expected inflation over the five-year period that begins five years from today (the 5Y5Y forward rate). We find that inflation expectations in the long-term (5Y5Y) seem to be anchored in Chile and Mexico, although the level of expected inflation is above the central bank target rate of 3%. On the other hand, long-term inflation expectations in Brazil and Colombia are more volatile and have been fluctuating over time, experiencing a large decrease during 2017. These results may also point out that government bond markets in Brazil and Colombia do not provide as much information about future inflation as the other +markets.

We also find the expected inflation is currently increasing with the horizon in Brazil and Chile, while it is decreasing in Colombia and Mexico. For Mexico, there has been an important shock on expected inflation after the last US presidential elections, experiencing a large increase. None of the other countries analyzed have shown this pattern, limiting the spillovers effects of the results of the US presidential elections to inflation expectations in Mexico. Finally, we compare the forecasting power over one year of inflation expectations obtained using our approach with expected inflation obtained from surveys. Our approach performs better predicting inflation for Chile, while surveys do better for Brazil, Colombia, and Mexico.

Further analysis shows that inflation expectations from our model complement those from surveys and provide additional information. A simple average of the expected inflation obtained using our approach and expected inflation from surveys provides a better fit than using only expectations from surveys for all countries but Brazil. Overall there is a trade-off between the two ways of obtaining expected inflations, as surveys are less responsive to inflation shocks and our approach produces expected inflation levels that are more correlated with current inflation.

The paper proceeds as follows: Section 2 describes the financial instruments from which information about inflation expectations can be derived, analyzing their availability for Latin American markets. Section 3 summarizes the main features of the affine model we implement to obtain inflation expectations, and Section 4 shows the results. Section 5 concludes.

2. FINANCIAL INSTRUMENTS WITH INFORMATION ABOUT INFLATION EXPECTATIONS

2.1. Inflation-linked Bonds

One of the most popular metrics of inflation expectations based on financial asset prices is the one obtained from inflation-linked bonds (break-even inflation rates). This is calculated by comparing the yield of a conventional bond (whose associated coupon and principal payments are fixed in nominal terms), with that of an inflation-linked bond (indexed to a price index) of the same maturity from the same issuer.

The inflation-linked bond market is particularly active in the United States, where these assets (known as Treasury inflation-protected securities or TIPS) are issued in sufficient quantity to create a liquid market in which price formation is fluid. However, the situation in Europe is fragmentized due to the existence of multiple issuers (namely the traditional issuer of treasuries for France, Italy, and Germany, and the less frequent issuer Greece, later joined by

Spain in 2014) and the use of different consumer price indices (national and European) as a reference. These factors reduce liquidity and are an obstacle to obtaining a clear signal on the compensation demanded by investors for the expected increases in the cost of living. In Latin America, there are several markets of inflation-linked bonds in countries such as Brazil, Chile, and Mexico.

Besides the lack of market depth and liquidity, an additional problem with this indicator is that it includes other components as well as investors' expectations about future price developments. Firstly, given that investors are averse to inflation risk, they will demand a premium on conventional bonds that compensates them for the risk incurred, but not on inflation-linked bonds, as they are protected against this risk. For this reason, the indicator does not strictly measure the level of expectations, but rather the compensation for inflation that investors demand. Secondly, the different level of liquidity of the two instruments used to obtain the indicator (generally higher for conventional bonds than inflation-linked ones) means the yield spread between them is also influenced by their different liquidity premiums. As well as the aforementioned inflation-related factors, conventional bonds include a component reflecting the expected future course of the real interest rate, together with its associated risk premium. Finally, it should be borne in mind that the size of the premia present in the break-even rate (inflation risk and relative liquidity) may change over time, depending on changes in investors' risk appetite, the level of inflation risk, or market liquidity conditions.

The inflation compensation metric derived from inflation-linked bonds may also be temporarily affected by other factors in addition to those mentioned. Thus, for instance, changes in the supply and demand for conventional bonds relative to inflation-linked bonds, such as those associated with quantitative easing programs,[2] for

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[2] Only conventional government bonds were purchased in the Federal Reserve Board's first quantitative easing program. During the Federal Reserve Board's second quantitative easing program (QE II), a total of USD 600 billion-worth of government securities was purchased, of which 26 billion was in the form of inflation-linked bonds. The fact that more conventional bonds are being bought than inflation-linked bonds could push down their relative yield, and therefore depress the inflation expectations indicator in a way that is due to a mismatch in the supply and demand for bonds used to calculate the indicator rather than to agents' forecasts of future consumer price trends.

example, may cause distortions in these indicators. Given all these drawbacks, economists have developed extensive academic literature seeking to isolate different components of the inflation expectation indicators obtained from inflation-linked bonds.[3]

2.2. Inflation-linked Swaps

Along with inflation-linked bonds, inflation-linked swaps (ILS) are another type of financial asset containing information about agents' inflation expectations. In this derivative instrument, one of the contracting parties agrees to pay the counterparty a fixed sum on a future date in exchange for a payment linked to the future level of a price index. For example, in the case of a one-year ILS, the fixed-rate party could agree to pay 2% of €1 million in consideration for receiving a fraction of this nominal €1 million equivalent to the increase in the CPI over this 12-month period. Contrary to the case of inflation-linked bonds, the ILS market is more liquid in Europe than in United States (Gimeno and Ibáñez, 2017) and there are not ILS markets in Latin America, except in Brazil.

ILSs are bilaterally negotiated private contracts with no intermediary clearinghouse. This creates the risk that the other party will fail to meet its commitment at the end of the period, so the negotiated price incorporates the corresponding premium. Nevertheless, the absence of cash transfers before the expiry date reduces the size of this premium, as well as the liquidity premium, as there is no opportunity cost relative to alternative investments (Fleming and Sporn, 2013).

Like inflation-linked bonds, inflation swaps contain an inflation risk premium. Therefore, they measure compensation for inflation as well as inflation expectations. One of the main advantages of the ILS-based indicator relative to the one obtained from inflation-linked bonds is that, since it is not necessary to compare two different bonds, the distortions caused by ad hoc factors that affect the markets asymmetrically are eliminated. Particularly, these indicators would not have been directly affected by distortions linked to the implementation of central banks' asset purchase programs.

[3] See, for example, D'Amico et al. (2014) and Chernov and Mueller (2012).

2.3. Inflation-linked Options

Inflation options are contracts in which one of the parties agrees to pay the other an amount depending on whether a price index exceeds (cap) or falls below (floor) a given threshold (the strike rate) within a given period. If the condition is met, the payment would be the difference, in absolute terms, between the index and the threshold. Unlike both inflation-linked bonds and ILSs, which give estimates of the averages only at specific points in time, options can be used together with ILSs to obtain additional information such as the full probability distribution of the future course of inflation or implied volatility of inflation. This gives information about risk and uncertainty around the expected average value. In particular, an increase in the implied volatility suggests that agents are more concerned and there is more uncertainty over the future course of price indices.

As in the case of ILSs, options are negotiated bilaterally without the intervention of a clearinghouse, so prices may include a counterparty risk premium. Most of these derivatives are negotiated using the harmonized euro area CPI, the UK RPI (Retail Price Index), or the US CPI (Consumer Price Index), with maturities ranging from 1 to 30 years. The most liquid market is linked to the euro area index, followed by that of the UK (see Smith, 2012). It should also be noted that, as in the case above of the other financial instruments, option prices also contain premiums for inflation risk, and potentially, for liquidity risk. Currently, there are no markets for inflation options in Latin America.

The inflation risk premium is present in all three indicators, and the amount is the same. For its part, the liquidity risk premium is negative in the case of the bond-based metric, as conventional bonds are more liquid than interest-linked bonds, whereas, in the ILS, the sign of this premium is positive. The counterparty risk premium is only present in the case of ILSs and inflation options. Finally, the estimation error may be more significant for an indicator based on inflation-linked bonds.[4]

[4] Unlike ILSs, where the compensation for inflation is directly observable from the price, the bond-based indicator requires a comparison of the yields on inflation-linked bonds and conventional bonds. The differences in the features of both types of bonds, beyond the fact that in the case of inflation-linked bonds payments are linked to inflation (such as, for example, their expiry), may distort the inflation expecta-

2.4. Inflation Expectations from Financial Instruments in Latin America

Given the scarcity of financial instruments linked to price indexes in Latin American, obtaining indicators of inflation expectations from these securities is difficult and limited to a few countries. Also, the only indicator we can obtain is the break-even rate for those markets where inflation-linked bonds and conventional bonds exist and are liquid. This break-even rate is used as a proxy for expected inflation but, as we mentioned earlier, also includes several premia such as the risk and liquidity premia. We do not know the size of these premia, and thus we must keep in mind that this indicator provides only information about inflation compensation rather than pure inflation expectations.

Unfortunately, obtaining data on break-even rates for other countries is difficult because of the lack of inflation-linked securities. Table 1 shows the availability of each type of securities for Latin American countries. Even though there are several markets for inflation-linked bonds, it may be the case that, for some countries, it is difficult to obtain accurate prices, as there is either a small variety of bond maturities or bond markets are relatively illiquid. In the next section, we describe a different approach to obtain indicators about inflation expectations without the need for data on inflation-linked securities. This approach will provide two main advantages: First, it uses data only on conventional nominal bonds and realized inflation; second, it makes it possible to identify the risk premia component, obtaining a more accurate portrait of pure inflation expectations.

Table 1

INFLATION LINKED SECURITIES

Inflation linked bonds	Brazil, Chile, Mexico, Peru, Argentina, Colombia, Bolivia, Costa Rica, Uruguay
Inflation swaps	Brazil
Inflation options	–

tions indicator. The indicator is also seasonal, in a way that is linked to the behavior of inflation. To correct for these distortions, models or adjustments are often used that are subject to potential estimation errors.

3. MODELING INTEREST RATES FROM PUBLIC DEBT MARKETS

The methodology we implement decomposes nominal interest rates into three components from an affine model of the nominal term structure. This methodology is related to the macro-finance literature in which authors such as Diebold et al. (2006), Diebold et al. (2005), Carriero et al. (2006), and Ang et al. (2008) (ABW) incorporate macro-determinants into a multi-factor yield curve model with non-arbitrage opportunities. Our decomposition departs from previous approaches by extracting the risk premia from the difference between the nominal term structure and a notional term structure where the price of risk is set equal to zero.

We also propose an affine model where interest rates are affine relative to a vector of factors that includes inflation rates and exogenously determined factors based on the Nelson-Siegel exponential components of the yield curve (Nelson and Siegel, 1987), in a similar vein to Carriero et al. (2006) and Diebold and Li (2006). Moreover, in our case, we include the condition of non-arbitrage opportunities along the yield curve and take into account risk-aversion. Taking these two conditions together allows us to decompose nominal interest rates as the sum of real risk-free interest rates, expected inflation, and risk premium.

3.1. The Model

Affine term structure models allow the risk premium to be separated from expectations about future interest rates. An affine model assumes that interest rates can be explained as a linear function of certain factors,

$$y_{t,t+k} = \frac{-1}{k}\left(A_k + B_k' X_t\right) + u_{t,t+k} \quad u_t \quad N(0,\sigma^2 1),$$

where $y_{t,t+k}$ is the nominal interest rate in period t with term k, X_t is a vector of factors, A_k and B_k' are coefficients, and $u_{t,t+k}$ represents the measurement error. We also assume that X_t factors follow a VAR structure (in the same vein as Diebold et al., 2006):

$$X_t = \mu + \Phi X_{t-1} + \Sigma\varepsilon_t \quad \varepsilon_t \quad N(0, I),$$

where μ is a vector of the constant drifts in the affine variables X_t, Σ is the variance-covariance matrix of the noise term and Φ is a matrix of the autoregressive coefficients. To avoid arbitrage opportunities, the values of parameters A_k and $B_k^{'}$ should be restricted according to the following equation:

$$e^{A_{k+1} + B'_{k+1} X_t} = E_t[e^{A_1 + B'_1 X_t} e^{A_k + B'_k X_{t+1}}]$$

The consideration of risk-aversion in this framework implies some compensation for the uncertainty of longer maturities, in which the random shocks ε_t accumulate. Coefficients that translate matrix Σ into the risk premium are called prices of risk (λ_t) and, following the literature, these coefficients are affine to the same factors X_t ,

$$\lambda_t = \lambda_0 + \lambda_1 X_t,$$

where λ_0 is a vector, and λ_1 a matrix of coefficients. If λ_1 is set to be equal to zero, then the risk premium will be constant, whereas if it is left unrestricted, we will obtain a time-varying risk premium.

We must consider the variables that could determine the term structure of interest rates in order to select the factors in the model. There is ample evidence in the literature that the information content of the whole term structure could be shortened to a small number of factors. The proposal of Diebold and Li (2006) is used, with the level (L_t), slope (S_t) and curvature (C_t) parameters from the Nelson and Siegel (1987) term structure specification as factors of an affine model. These factors can be found in most central bank estimations of the zero-coupon yield curve. This estimation implies that nominal interest rates can be modeled in the following equation,

$$y_{t,t+k} = L_t + S_t \frac{1 - e^{-k/t}}{k/\tau} + C_t \left(\frac{1 - e^{-k/\tau}}{k/\tau} - e^{-k/\tau} \right) + u_{t,t+k},$$

where τ , L_t , S_t , and C_t are the parameters that give us the interest rate at time t with maturity in k periods.

Although including a fourth factor in the model may not be necessary to obtain a good fitting of the interest rate term structure, if Nelson and Siegel's model is considered, adding the inflation rates allows us to take into account the yield curve information that could be useful in forecasting inflation.

$$X_t = \begin{bmatrix} L_t \\ S_t \\ C_t \\ \pi_t \end{bmatrix}$$

Once the affine model, represented by the previous equations, has been estimated, it is possible to decompose k-period nominal interest rates $(y_{t,t+k})$ into real risk-free rates $(Er_{t,t+k})$, inflation expectations $(E_t\left[\pi_{t,t+k}\right])$ and risk premia (denoted by $\gamma_{t,t+k}$), according to the following equation:

$$y_{t,t+k} = Er_{t,t+k} + E_t[\pi_{t,t+k}] + \gamma_{t,t+k}.$$

Therefore, real risk-free rates $(Er_{t,t+k})$ could be obtained by subtracting inflation expectations and risk premia from estimated nominal interest rates.

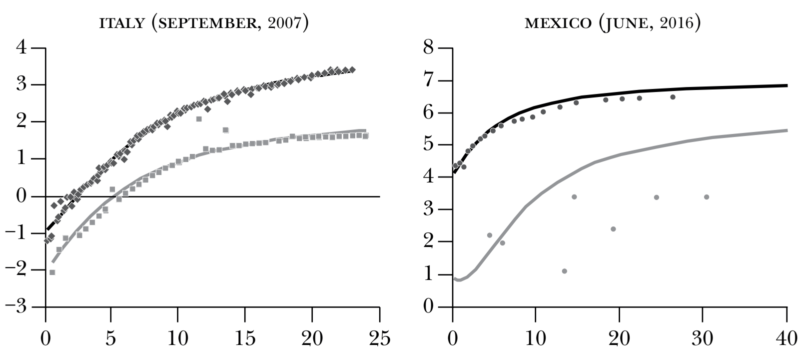
4. RESULTS OF INFLATION EXPECTATIONS FROM PUBLIC DEBT MARKETS

4.1 Yield Curve Estimation

To estimate the affine model proposed, we use monthly spot nominal interest rates for the Brazilian, Colombian, Chilean and Mexican government yield curve. These data have been obtained from a yield curve estimation that follows Diebold and Li (2006). We first analyze the yield curve estimates using both nominal interest rates, and inflation-indexed rates when available, to check the goodness of fit. For the sake of comparison, Figure 1 shows the yield curve estimates both for Mexican and Italian government bonds. The black (gray) line represents yield curve estimates for nominal government bonds (inflation-indexed government bonds). The dots represent the yield and maturity of traded bonds. Nominal yield curve estimates provide accurate estimates for both countries while inflation-indexed yield curve estimates only provide a good fit for Italy. Lack of inflation-indexed bonds for different maturities, low liquidity and low market depth make these yield curve estimates for Mexico unreliable. We find similar problems using inflation-linked bonds for Brazil, Chile, and Colombia. On the contrary, nominal yield curve estimates provide a reasonable fit for all these markets, and they will be the input to solve the affine model and obtain inflation expectations for the countries we analyze. We do also estimate the yield curve for the inflation-linked bonds in Chile. The Chilean market is one of the most active in Latin America, and we can compute the break-even rate as the difference between the estimated yield curves from nominal bonds and inflation-linked bonds. Figure 2 shows the one-year break-even rate for Chile obtained from the estimated yield curves. The break-even rate seems to be affected by the liquidity premia in the inflation-linked bond market as the rate decreases during the period when inflation rises.[5]

Figure 1

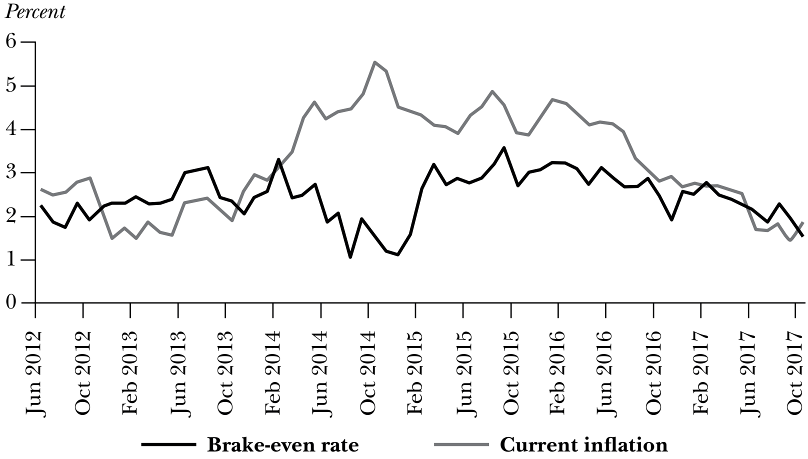
YIELD CURVE ESTIMATES
NOMINAL (BLACK) VS. INFLATION LINKED BONDS (GRAY)



[5] The break-even rate includes the spread between the liquidity premium of the nominal and the inflation-linked bond markets. Because of that, it decreases if the liquidity premium in the inflation-linked bond market rises more than the premium of the nominal bond market.

Figure 2

ONE YEAR BREAK EVEN RATE FROM YIELD CURVE ESTIMATES VS. CURRENT INFLACION FOR CHILE



The availability of nominal government bonds for the estimation of the zero-coupon yield curve is different for each country, both regarding the number of nominal bonds used and the length of the sample. Table 2 summarizes this information for each market.

Table 2

NOMINAL BONDS AVAILABILITY

	Number of bonds	*Period*	*Original bond maturity*
Brazil	104	Since Feb 2007	3 months – 11 years
Chile	15	Since July 2012	4 years – 30 years
Colombia	70	Since Feb 2005	1 year – 20 years
Mexico	47	Since May 2001	3 years – 30 years

4.2. Empirical Results

We mainly focus on the results related to inflation expectations, leaving aside a deeper interpretation of the term premia and the real yield curve. We obtain inflation expectations from the VAR equation. Since vector X_t includes current inflation (π_t), expectations on this variable can be computed from projections of the dynamics of the affine factors in the VAR equation.

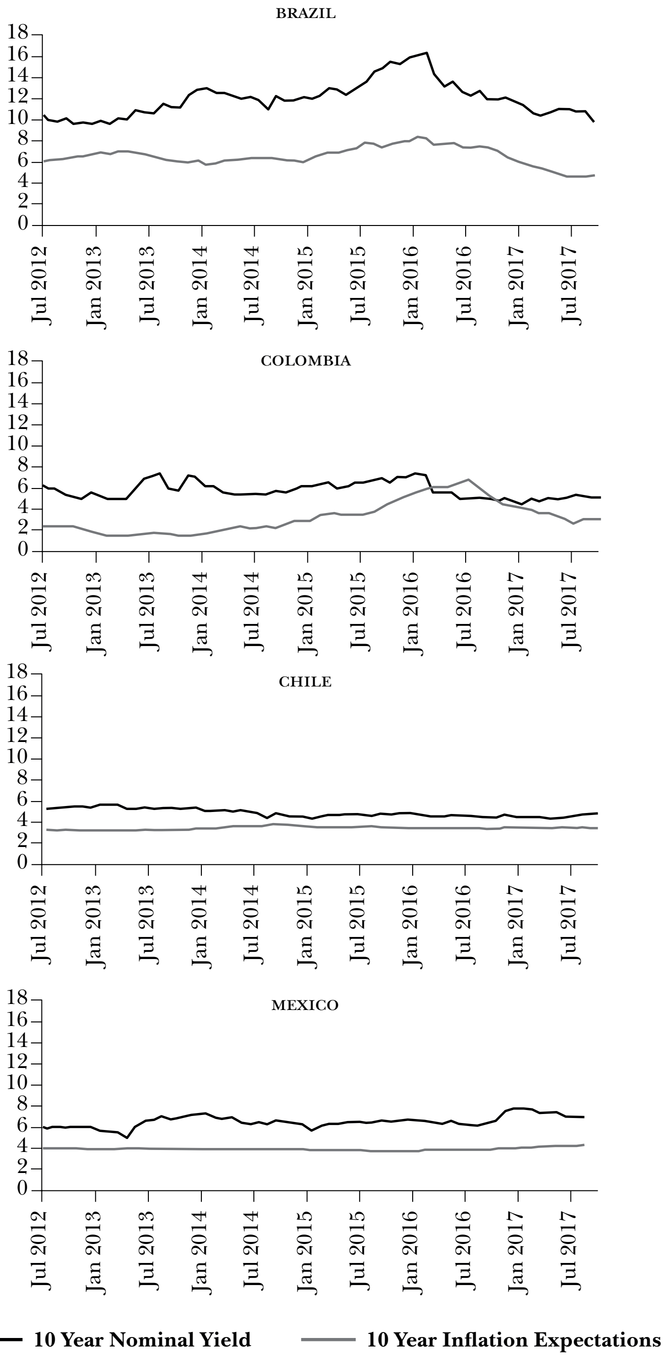
$$E_t[X_{t+h}] = (1 + \Phi + \Phi^2 + \ldots + \Phi^{h-1})\mu + \Phi^h X_t.$$

There are several advantages in using this method to obtain inflation expectations. First, there is a large degree of flexibility, as we can estimate expectations at different horizons. Moreover, we can also compute forward rates, allowing us to estimate, for example, the expected inflation over the five-year period that begins five years from today. This is a measure commonly used by central banks to analyze the anchoring of inflation expectations in the long-run. It is difficult to obtain these estimates in markets without inflation-linked securities and, to the best of our knowledge, this is the first time that these kinds of estimates are computed for Brazilian, Colombian, Chilean and Mexican markets. Also, as we pointed out in the introduction, using existing surveys on inflation expectations provides a limited picture, as the horizons are usually short and the frequency of publication is only monthly at best. Later we describe the characteristics of the surveys published by the central banks of the countries we analyze and compare the expectations obtained from these surveys with those we obtain.

Figure 3 shows the estimates of the nominal yield and inflation expectations over the ten-year horizon obtained from our proposed model. The difference between the two curves represents the real risk-free rate and the risk premium. For the sake of comparison, we restrict the sample period to be the same for the four countries. The results show two main features. First, inflation expectations seem to be more anchored both in Chile and Mexico, showing less volatility. Second, the level of inflation expectations is higher in Brazil, with the other three countries showing expected rates close to or below 4 percent.

Figure 3

10 YEAR NOMINAL BOND YIELD AND INFLATION EXPECTATIONS



As we previously mentioned, the model we propose allows us to compute inflation expectations at different horizons. Figure 4 shows inflation expectations for the one-year, five-year and ten-year horizons, as well as the inflation targeting level established by the central bank in each country. We can see again the different degree of anchoring by comparing the evolution of expectations for the one-year horizon with those for the five-years and ten-year horizons. Inflation expectations in Brazil and Colombia show a similar pattern for all horizons while expectations in Chile and Mexico are more volatile over the one year horizon, showing little changes over longer horizons.

Regarding the inflation targeting levels established by the central banks, most countries currently show inflation expectations at long horizons within the window limits,[6] although Brazil and Colombia have experienced recent periods where inflation expectations were well above these limits. Both countries showed inflation expectations above 6% before the large decreased experienced since the beginning of 2016. On the other hand, Mexico shows long-term inflation expectations slightly above the upper band of 4%, mainly due to the recent increase in expectations after the last US presidential elections. This effect is more apparent for the evolution of the one-year horizon, fading out at longer terms. Interestingly, it seems that the results of these elections have barely affected inflation expectations in other countries. For Brazil, the deep recession of 2015-2016 has affected expectations, with a large decrease experienced since the beginning of 2016. The path of inflation expectations changed again for Brazil at the end of 2016, with expectations turning higher at longer horizons, which signals a possible recovery. In the case of Colombia, the monetary policy implemented by the central bank during 2016, with increases in the policy rate from 4.5% in September 2015 to 7.75% in August 2016, have contained inflation expectations, being now closer to the inflation target. Longer-term inflation expectations continue to show lower levels than short-term ones for this country. Finally, Chile has experienced a decreasing trend in short-term expectations since mid-2014 which has been associated, first to the fall in oil prices, and since 2016 to the appreciation of the Chilean peso. Although short-term inflation expectations remain below the inflation target, expected inflation at long-term horizons is higher and have experienced little change.

[6] The Bank of Brazil sets the inflation target at 4.5% with a window limit of ±1.5%. The central banks of Chile, Colombia and Mexico set the inflation target at 3% with a window limit of ±1 percent.

Figure 4

INFLATION EXPECTATIONS AT DIFFERENT HORIZONS

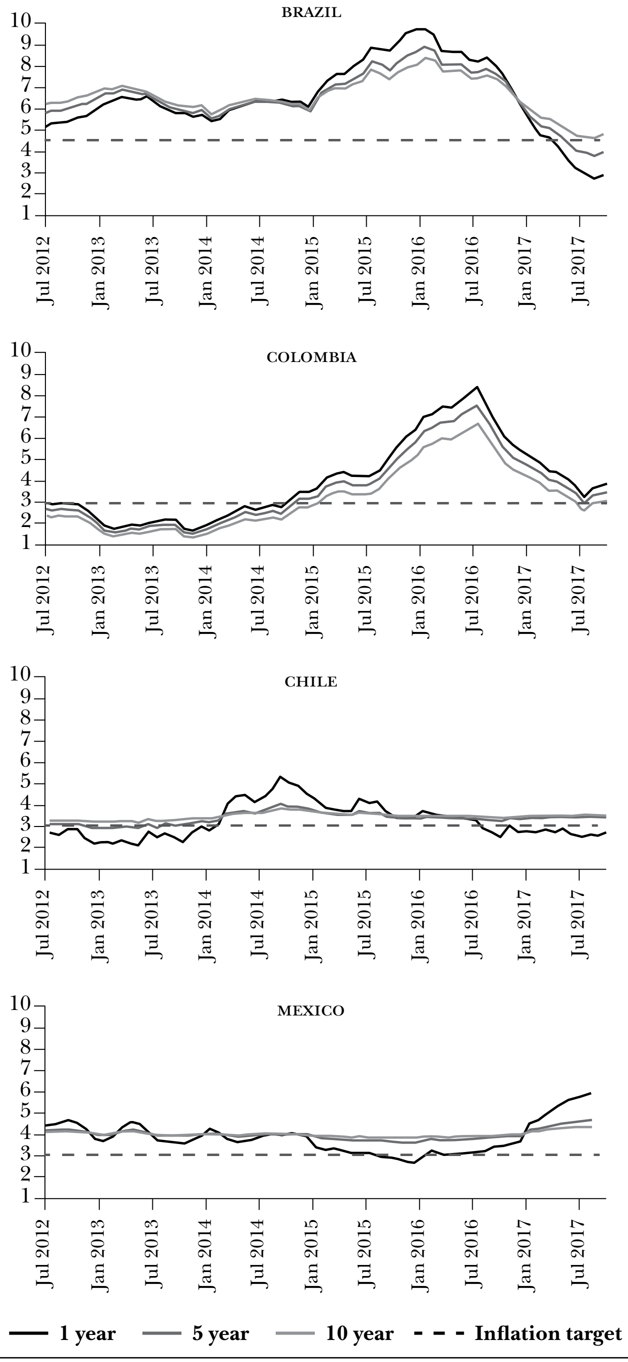


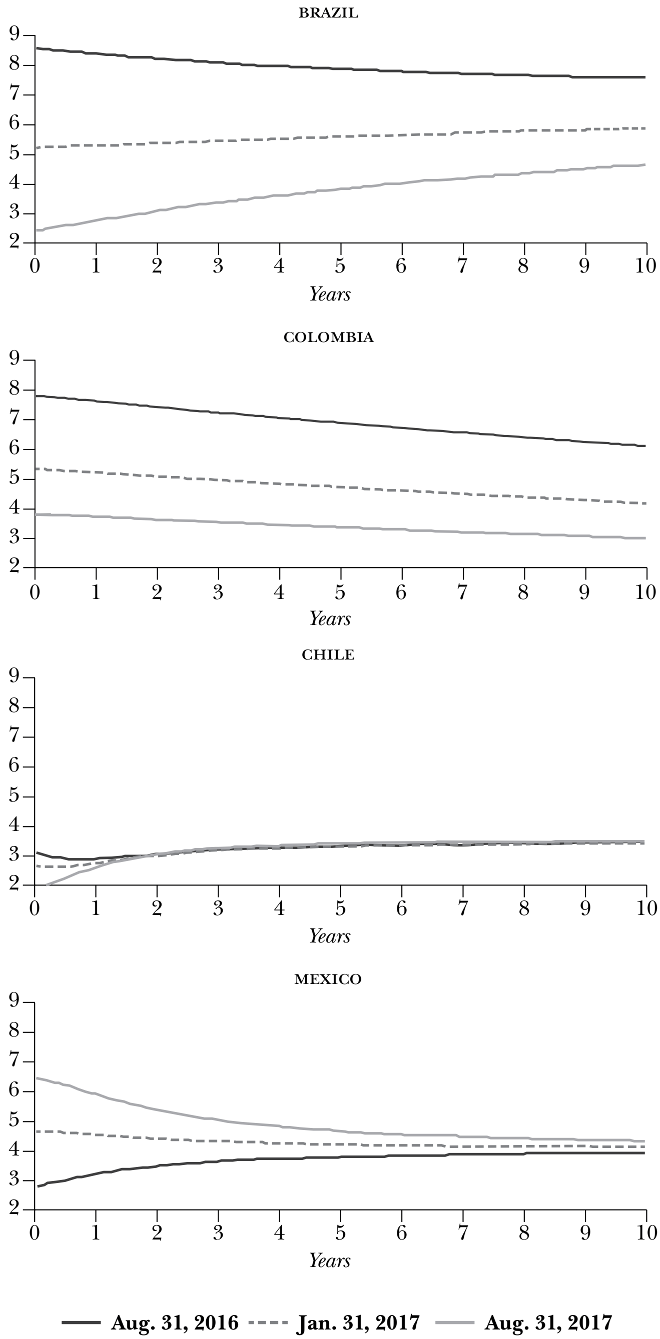
Figure 4 also provides information about the term structure of inflation expectations. Expected inflation in Colombia and Mexico is decreasing with the horizon, while in Brazil and Chile inflation is expected to increase in the future. Figure 5 shows the term structure of inflation expectations at three different dates for all the horizons we compute, giving an idea about how inflation expectations should evolve and how the term structure has changed since August 2016. The evolution of the term structure differs among the four countries. For Chile, expectations from the two-year horizon have barely changed at the three dates, experiencing a decrease over time for short-term expectations. For Brazil, there is an overall decrease at all horizons since August 2016, although the shape of the term structure has changed. At the end of August 2016, the term structure showed a decreasing trend that has currently change into an increasing one. For Mexico, the situation is the opposite, with inflation expectations increasing at all horizons since August 2016, and turning from an increasing trend to a decreasing one. The developments in the US have influenced these changes in Mexican inflation expectations after the last presidential elections. Finally, Colombia shows a decrease in the level of inflation expectations at all horizons, with a decreasing trend over time at the three dates.

Being able to decompose the yield curve and extracting inflation expectations at different horizons let us compute forward rates as well. This is especially useful in order to analyze the anchoring of inflation expectations over the medium and long-term. Forward rates such as the 5Y5Y (expected inflation over the five-year period that begins five years from today) are used by central banks to assess the level of long-term inflation anchoring. Figure 6 shows the 2Y2Y and 5Y5Y forward rates of inflation expectations together with the inflation target established by each central bank. Similarly, to the behavior of the ten-year horizon inflation expectations, the forward rates for Chile and Mexico are more stable and hardly move over time. The levels are above the inflation target but within the window of ±1% for Chile and almost within that window for Mexico. These results show that investors have almost kept unchanged the level of long-term expected inflation for these two countries.

On the contrary, inflation anchoring for Brazil and Colombia seems to be lower, with forward rates showing more volatility. In Brazil, long-term inflation expectations are above the target level but below the upper limit of ±1.5%, due to the large decrease experienced

Figure 5

TERM STRUCTURE OF INFLATION EXPECTATIONS



since the beginning of 2016. For Colombia, there is a similar pattern, with long-term inflation expectations currently below the target level of 3% after the decrease in the 5Y5Y forward rate experienced since mid-2016. The behavior of forward rates for Brazil and Colombia show that investors seem to face more uncertainty about the expected inflation in the long-term for these two countries. It could be also the case the government bond markets provide less information about future inflation for these two countries.

These results may question the effectiveness of monetary policy to anchor expected inflation. The results shown in Figure 5 indicate that the central banks of Chile and Mexico have been able to anchor long-term inflation expectations, although at levels above target, while central bank in Brazil and Colombia face more challenges to do so. Dincer and Eichengreen (2014) compute measures of central bank transparency and independence for a large set of countries. Regarding central bank transparency, among the four countries we analyze, the central banks of Brazil and Chile were the most transparent in 2010, the central bank of Colombia was less transparent and the central bank of Mexico was the least transparent.

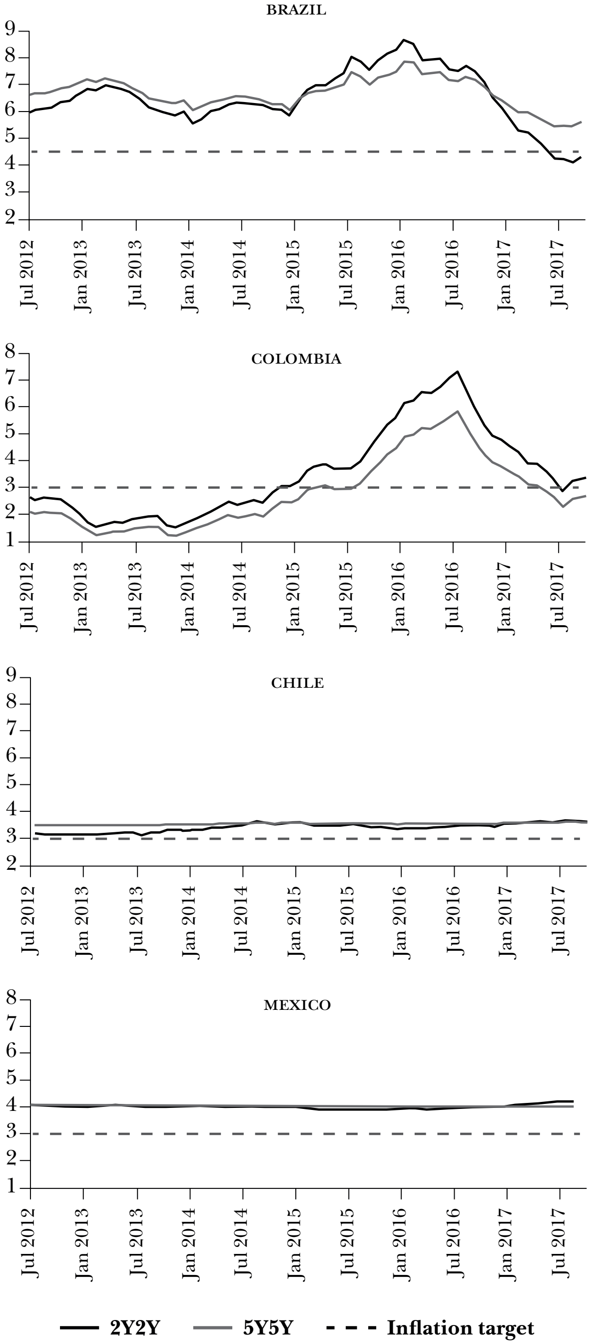
Their measure of central bank transparency does not seem to be related to the level of expected inflation anchoring we observe from our results. On the contrary, central bank independence may play a role. According to their measure of central bank independence, Chile and Mexico's central banks are more independent than the central bank of Colombia (unfortunately, they do not provide a measure of central bank independence for Brazil). In line with this result, Gutiérrez (2003) and Jácome and Vázquez (2008) find a relationship between central bank independence and inflation performance for Latin American countries.[7]

The purpose of our analysis is to identify the inflation expectations implicit on financial markets, something that would not necessarily be the best forecast for future inflation. However, we analyze the forecast capacity of this methodology in order to compare it with other alternatives frequently used by professional forecaster of inflation trends. In this vein, we compare the information about expected

[7] Gutiérrez (2003) provides the values of the central bank independence indexes for the four countries in our study. Although we should be careful as the indexes were calculated long time ago, Mexico and Chile show the largest values of central bank independence.

Figure 6

INFLATION EXPECTATIONS OF FORWARD RATES



inflation obtained from our model with that provided by surveys. First, as we obtain expectations from nominal government bonds, expected inflation is derived from investor's perceptions, complementing the information from surveys which is usually obtained from the views of economists and forecasters. Second, we can obtain inflation expectations at different horizons and forward rates. Surveys usually provide few horizons, with limited information about long-term inflation expectations. Table 3 summarizes the information provided by the surveys published by the central banks in the four countries analyzed. Even though there is information about expected inflation at different horizons in the surveys, we cannot get all the different horizons we can compute using our proposed methodology. The surveys do not provide forward rates either. We next compare the forecasting accuracy of the inflation expectations obtained from our model with those provided by surveys and a simple autoregressive process AR(1). Figure 7 shows expected inflation obtained from surveys and our methodology as well as ex-post realized inflation for the 12-months horizon.[8] Inflation expectations obtained from surveys tend to be broadly stable over time and show little changes and reaction.

On the other hand, inflation expectations obtained from our model seem to be too reactive and more dependent on current inflation. Expected inflation from surveys fail to react to inflation shocks while our measures produce expectations that respond too late to inflation shocks. The AR(1) process provides similar inflation expectations to those obtained from our model although these expected values seem smoother. The difference between the inflation expectations obtained from the model and the AR(1) represents the additional information about future inflation once that we consider the inflation expectations embedded on bond prices. In order to analyze the forecast accuracy of the measures, we compute the mean square error (MSE) concerning ex-post realized inflation.

[8] In the case of Chile, it is 11-months horizon inflation expectations (annual change).

Table 3

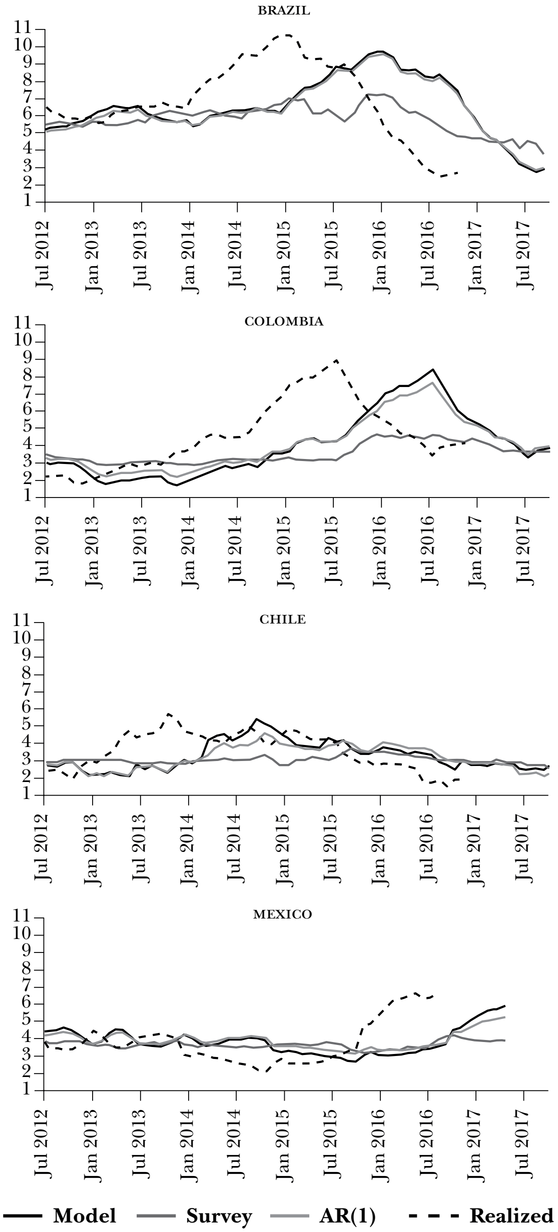
SURVEYS ON INFLATION EXPECTATIONS–CENTRAL BANKS		
	Frequency	*Horizons*
Brazil	Daily	Next 12 months; current year (t) and t+1, t+2, t+3, t+4.
Chile	Monthly	Next 11 months; next 23 months; current year (t) and t+1, t+2.
Colombia	Monthly	Next 12 months; next 24 months; current year (t) and t+1.
Mexico	Monthly	Next 12 months; next 1-4 years; next 5-8 years.

Table 4 shows the ratio of the MSE obtained using expectations from surveys, as well as from our model and the AR(1) process, to the MSE computed using current inflation as the predicted future value (like in a unit root process). If the ratio is lower than one, it means that the expected values provide a better prediction of future inflation than assuming inflation will remain the same as today. The three measures, inflation expectations from surveys, from the AR(1) and our model show lower MSE than the unit root prediction. Comparing the three measures, expected inflation from surveys shows lower MSE for Brazil and Colombia. The model is the best predictor for Chile and the AR(1) process provides the lowest MSE for Mexico.

Inflation expectations from our model provide lower MSE for Chile and Mexico than for Brazil and Colombia. It seems that our measures of expected inflation are more accurate for countries where expectations are fairly anchored in the long-run. Our measures do complement those from surveys in terms of predictability, providing additional forecasting power and a much richer set of expected inflation horizons, and frequency.

Figure 7

12-MONTHS INFLATION EXPECTATIONS FROM SURVEY AND PROPOSED MODEL VS. REALIZED INFLATION



Source: DataStream, Banco Central de Chile, Banco de la República - Colombia, Banco Central do Brasil, Banco de México. Inflation expectations in 12 months for Brazil, Colombia and Mexico. Inflation expectations in 11 months for Chile.

Table 4

EXPECTED INFLATION FORECAST ERRORS

	Sample	*Survey*[1]	*Model*[1]	*AR(1)*[1]
Brazil	Feb 2007-Oct 2016	**0.5833**	0.8812	0.8415
Chile	Jul 2012-Dec 2016	0.7813	**0.6946**	0.7148
Colombia	Feb 2005-Nov 2016	**0.7956**	0.9354	0.8015
Mexico	May 2001-Nov 2016	0.6350	0.7078	**0.6324**

[1] Ratio of mean square error of expected inflation from surveys, an AR(1) process and our model with respect to a naïve prediction of expected inflation equal to current inflation. Expected inflation in 12 months for Brazil, Colombia and Mexico; 11 months for Chile.

5. CONCLUSIONS

Agents' inflation expectations are decisive when studying changes in many of the variables shaping households' and firms' decision making. We use a methodology to obtain inflation expectations from nominal government bonds and realized inflation, overcoming the problems of obtaining expected inflation using inflation-linked securities. This is especially useful for markets where inflation-linked securities are scarce and illiquid as it is the case of Latin America. In this article, we estimate inflation expectations for Brazil, Chile, Colombia, and Mexico. We find that inflation expectations seem to be anchored in Chile and Mexico in the long-term (5Y5Y forward rate), although the level of expected inflation is above the central bank target rate of 3 percent.

On the other hand, long-term inflation expectations in Brazil and Colombia are more volatile and have been fluctuating over time, experiencing a large decrease during 2017. These results advise further efforts from the Brazilian and Colombia central banks to anchor inflation expectations to make credible their inflation targets. Mexican and Chilean central banks should be more concerned in reducing the level of expected inflation as long-term expectations seem to be fairly anchored and show low levels of volatility.

We also find the expected inflation is currently increasing with the horizon in Brazil and Chile, while it is decreasing in Colombia and Mexico. For Mexico, there has been an important shock on expected inflation after the last US presidential elections, experiencing a large increase. None of the other countries analyzed have shown this pattern, limiting the spillovers effects of the results of the US presidential elections to inflation expectations in Mexico.

Finally, we compare the forecasting power over one year inflation expectations obtained using our approach with expected inflation obtained from surveys. Our approach performs better predicting inflation for Chile, while surveys do better for Brazil, Chile, and Colombia. There is a trade-off in terms of predictability as expected inflations from surveys is less responsive to inflation shocks, and our approach produces inflation expectations that are more correlated with current inflation.

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