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Term Premium Dynamics and its Determinants: The Mexican Case[*]

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Abstract

We estimate the term premium implicit in 10-year Mexican government bonds from 2004 to 2019, and analyze the main determinants explaining its dynamics. To do so,

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we decompose the long-term interest rate into its two components: the expected short-term interest rate and the term premium. The first component is obtained using different methodologies, two affine models and data on interest rate swaps. The second component is computed as the difference between long-term interest rates and such short-term rate. The Mexican term premium is represented by the average of the three estimations. We find that the Mexican term premium increased considerably during three episodes compared to the entire dynamics of said premium: i) the Global Financial Crisis of 2008; ii) the Taper Tantrum of 2013; and iii) the U.S. presidential election of 2016. In contrast, we find that the Mexican term premium decreased, to historically low levels, during the U.S. Quantitative Easing and Operation Twist programs. Additionally, in order to identify the main determinants that explain the behavior of this premium, we run a time varying parameters regression. In this analysis, we find that the main determinants that explain the dynamics of the premium are the compensation for FX risk (as a proxy of inflationary risk premium), the real compensation, and the U.S. term premium (as a global factor).
Keywords: Term premium, short-term interest rate expectation, affine model.
Classification JEL: G12, E43, C12, C53.

1 Introduction

The study of the dynamics of long-term interest rates is relevant for central banks and policy makers because these influence households and businesses savings and spending decisions. The expectations hypothesis of the term structure of interest rates states that the longer-term rates should be equal to the average of the current short-term interest rate and its expectations for the long-term.[1] Central banks can influence the short-term interest rate and expectations through monetary policy actions and its communication strategy.

The literature considers that long-term interest rates also include a term premium,[2] which is defined as the compensation that investors demand for maintaining long-term financial instruments instead of rolling-over short-term ones. Investors will demand higher premiums on longer terms rates because macroeconomic and financial condition are more uncertain over longer horizons.[3] Changes in the premium can be derived from various events that affect the economy, such as changes in global liquidity conditions and the relative demand for financial instruments with different maturities. Kim and Orphanides (2007) state that compensation for long-term bonds depends on both the amount of risk and its price, which can change due to fundamentals, such as perceptions of uncertainty about inflation, economic activity and monetary policy. The business cycle can also affect the term premium as investors might be more risk-averse in recessions than in booms. Thus, the term premium can be explained by other premia, for instance, the inflationary risk premium - considered the most important -, the liquidity risk premium, the sovereign risk premium, the currency risk premium, the flight to quality effect or search for yield in extreme volatil-

[1]See Fama and Bliss (1987) and Bekaert and Hodrick (2001).

[2]This is also known as bond risk premium or simply risk premium.

[3]See Kaminska and Roberts-Sklar (2015) and Maggio et al. (2016) and references there included. It is important to note that, the term premium is thought to be positive, given that it is the compensation that investors demand to maintain long-term instruments. In fact, this is not the case with term premium as it may be negative in order to avoid the risk associated with short-term instruments when there is uncertainty and the fluctuations in the short-term rate are high. This is common in pension fund investments, specially in periods of financial or macroeconomic stress when they prefer to invest in long-term instruments with low yields than to invest in short-term instruments with lot of fluctuations. Thus, sign and magnitude are empirical issues, as mentioned in Swanson (2007).

ity periods, geopolitical events, supply and demand for certain maturity of bonds. After the 2008 Great Financial Crisis (GFC), a growing literature has placed a greater emphasis on the term premium as a key factor in explaining the evolution of long-term interest rates.[4] In this sense, it is also relevant to understand the dynamics of the term premium and its determinants for the conduct of monetary policy. Thus, the goal of this paper is to estimate the term premium implicit in 10-year Mexican government bond yields, and to study the main determinants explaining its recent evolution. The term premium has been studied from different perspectives, the first perspective has focused on analysing the behaviour of the long-term interest rates. In the last 25 years, long-term interest rates in advanced economies (AEs) have shown a downward trend, so central banks have been monitoring closely this behaviour. Researchers have analysed the two components of the long-term interest rates: the average expectation of the future short-term interest rates and the term premium and found that most of the fluctuations of the rates are related to the term premium. For example, according to Bernanke (2013), the behaviour of the term premium is the reflection of investors' concerns about the level of inflation and the inflationary risk premium, uncertainty about the future course of short-term interest rates, and a global demand for safe and liquid assets. In contrast, Hamilton and Kim (2002), Ang et al. (2006) and Rosenberg and Maurer (2008), decompose the slope (defined as the difference between the long-term interest and a short-term one) of the yield curve into its two components, the future expectation of the interest rate and the term premium. This to study the predictive role that the slope has on future economic activity, since the effect varies if these components are analysed separately. In particular, the authors find that expectations of short-term interest rates appear to be more important in predicting future activity. The second perspective has focused on studying the effect of changes in monetary policy on long-term interest rates, given the conventional and unconventional monetary policies implemented after the GFC from 2008. In this context, Albagli et al. (2018) studied the impact of U.S.

[4]See Kim and Orphanides (2007), Wright (2011), Adrian et al. (2013), Bernanke (2013, 2015), Ceballos et al. (2014) and BIS (2017).

monetary policy shocks on long-term treasury bond yields of both emerging and AEs, finding that the larger effect on the former is through the term premium. The third perspective has focused on analysing how the interest rate normalization in 2013 could have been implemented by the U.S. Federal Reserve (Fed), and how this process could have affected central bank's decisions around the world. At the time, researchers and policy makers thought that this process could bring significant challenges for central banks. On the one hand, a faster than expected normalization pace, as a response to higher inflation expectations, could cause an abrupt and disordered increase of the term premia in this country. On the other hand, an overly gradual normalization could cause an overheating of the U.S. economy in addition to financial instability. For example, the Taper Tantrum showed that a rapid decompression of the term premia in the U.S. could cause high volatility in the international financial markets, mainly in emerging economies (EMEs). Even though there was a generalized perception that the decompression could be ordered and gradual, there was a chance of this not happening. The uncertainty around this, generated an increase in long-term interest rates in EMEs and in their term premia. The goal of this paper is to estimate the term premium implicit in 10-year Mexican government bond yields and to analyse the main determinants explaining its evolution from January 2004 to December 2019 in daily frequency.[5] Moreover, an analysis of the effects of the events mentioned on the term premium dynamics is provided. To do so, we use a standard methodology in the literature to estimate the term premium implicit in long-term interest rates, decomposing these rates into two components:[6] the average expected short-term interest rates in a 10-

[5]The year 2004 was chosen as the start of the sample because the ACM method uses interest rates data with continuous monthly maturities ranging from 1 month to 120 months and this data is available as of that date. It is worth mentioning that the year 2019 was chosen as the end date of the sample because it was the year before the COVID-19 pandemic and the drop in global oil prices affected the economy. We use daily frequency data because the interest rates are variables in high frequency that can show sudden movements in short periods of time, which may not be captured in lower frequency data. With daily estimates, it is possible to capture said changes in the components of interest rates, which can be very useful in the analysis of monetary policy.

[6]See Kim and Wright (2005), Kim and Orphanides (2007), Adrian et al. (2013), Benson (2014), Blake et al. (2015), Bernanke (2015 and 2013), Claro and Moreno (2015), Kaminska and Roberts-Sklar (2015), Maggio et al. (2016), among others.

years horizon and its corresponding term premium. Hence, the term premium represents the degree of uncertainty perceived in the economic outlook. We proceed as follows: First, we estimate the average expected short-term rates in a long-term horizon using different methodologies, and second, we calculate the term premium as the residual between the observed long-term rate and this expectation. Given that both components are unobservable, it is important to recognize that the estimation entails some degree of uncertainty. To obtain robust results, we consider different estimation methods and take the average of these as our Mexican indicators. We estimate the expected short-term interest rate using two affine term structure models, one based on the structure to Kim and Wright (2005) and one based on Adrian et al. (2013), both implemented with Mexican data. We also use data on TIIE (equilibrium interbank interest rate) swaps as a third methodology. We then compute the corresponding term premium for each methodology. Then, we take the average of the expected short-term interest rates and their corresponding term premium across the different estimates. The main results show different levels of expected short-term interest rates and term premia across different estimations, but similar dynamics.[7] We find that short-term interest rate expectations decreased significantly after the GFC of 2008, reaching their lowest levels around 2014 and 2015. This trend was reversed from Jan 2016 through Dec 2019. Moreover, the term premium in Mexico decreased significantly during the Quantitative Easing (QE) and the Operation Twist (OT) programs implemented by the Fed, reaching their minimum levels at the beginning of 2013. Furthermore, this premium increased considerably during three periods compared to the entire dynamics of said premium: i) the GFC in 2008; ii) the Taper Tantrum in 2013; and iii) the U.S. presidential election at the end of 2016. To analyse the main determinants associated with the evolution of the average term premium, we then perform a time varying parameters (TVP) regression estimation that includes variables commonly identified in the literature as main determinants of the

[7] Consistent with Li et al. (2017) and BIS (2017).

term premium.[8] It is important to mention that the scope of this analysis is to decompose the term premium in three major determinants as a first approximation. These determinants were relevant in explaining the Mexican term premium evolution, they are: the U.S. term premium (as a global factor), the real compensation, and the compensation for FX risk (as an approximation of the inflationary risk premium). It is worth mentioning that within the real compensation and the constant of the TVP-regression, other premia that are not considered in this analysis are contained, such as the liquidity risk premium, the sovereign risk premium, geopolitical risks, among others. The effect of these specific premia on the Mexican term premium is left for future work, especially the study of the liquidity risk premium that is known to have an important effect in periods of financial stress, such as the GFC. In relation to other studies we can say that previous estimates of the term premium for Mexico have been made in an international context, in order to compare different countries using the same methodology or to find a global factor.[9] To the best of our knowledge, this is the first paper that focuses on analysing the term premium for Mexico on a daily frequency, as well as on studying the determinants that explain its dynamics. The paper has the following structure. Section 2 describes the most relevant literature in analysing the term premium in advanced and emerging economies. Section 3 shows the three methodologies used in the estimation. Section 4 shows the main results of the estimated expected short-term interest rate and its corresponding term premium in Mexico, and some robustness exercises of our estimations. Section 5 displays the estimation and the analysis of the main determinants that describes the evolution of the term premium. Finally, Section 6 concludes.

[8] See for example Fountas and Karanasos (2007), Wright (2011), Bauer et al. (2014), Kim and Lin (2012), and Ceballos et al. (2014).

[9] See for example Hördahl et al. (2016).

2 Literature Review

In the last few years, central banks in AEs have been concerned with the low interest rates of long-term government bonds. In this regard, various research papers, as well as some members of the FOMC, documented the main factors that had determined, in general, the behavior of long-term interest rates at least in the U.S.[10] These factors include: i) the decline in government bond price volatility, partly explained by the zero lower bound (ZLB) and the fact that these rates were expected to remain in low levels for a long period of time; ii) the fact that the correlation between bond prices and stock prices has become more negative over time, implying that bonds are preferred by investors as hedging instruments over equities; and iii) the increase in the price of bonds, as a result of a higher global demand for safe assets, that has pushed down interest rates, specially long-term ones. For example, many governments and central banks, particularly those with a surplus in their current account, hold international reserves in the form of U.S. long-term bonds. Likewise, the financial and economic stress experienced in recent years seems to have significantly raised the demand for safe assets, such as long-term bonds; and, iv) other causes that might explain the decline in long-term interest rates in AEs are, on the one hand, low and stable inflation expectations which reflect the credibility of central banks' mandate in the AEs and, on the other hand, the slack in their labor markets. The expected short-term rates in the AEs have also been low due to their monetary policy stances helping the recovery of their economies and reducing the risk. All the aforementioned factors can explain the downward trend in the AEs expected short-term rates and their corresponding term premia.

In particular, it has been documented that some actions of the Fed in the U.S. pushed the term premium downwards through the asset purchase programs, or QE's, which in turn lowered long-term interest rates. The magnitude of this effect varies from study to study.[11]

[10] See, for example, Campbell et. al (2013) and Bernanke (2013).

[11] See Gagnon et al. (2010); Krishnamurthy and Vissing-Jorgensen (2011); Bauer and Rudebush (2011); Li and Wei (2012); Hamilton and Wu (2012); D'Amico and King (2012); Rosa (2012); Hancock and Passmore (2011); Bernanke (2013).

The term premium has also declined in other AEs including Canada, Germany, Japan, and UK. This can be attributed to the slow economic recovery and the monetary policy actions taken by the Fed after the GFC, which suggests that there is a global factor that explains the behavior of the term premium in these AEs.[12] In this context, the main factors affecting the term premium dynamics can be summarized in: (i) changes in the perceived risk of long-term assets; and (ii) changes in the demand for a specific asset in relation to its offer.[13]

When the long-term instruments' perceived risk increases, the term premium will show a greater increase when investors are more risk averse. In this sense, the most significant risk for this kind of instruments, throughout history, has been the inflationary risk.[14] For example, periods in which the term premium is very close to zero, or even negative, are tend to be related to low inflation and accommodative monetary policies, which make long-term bonds less risky for investors. In this case, long-term bonds can provide hedging against deflationary risk, and investors should accept low compensation, or even negative, to maintain these bonds rather than holding short-term instruments.[15] Another perceived risk that affects the term premium is uncertainty around the economic outlook in the short-term or monetary policy. In addition, it has been documented that term premium grows in recessions and in periods in which the forecast dispersion for the economy increases.[16]

Furthermore, changes in supply and demand of assets can also have an effect on the term premium. An illustrative example is found in the U.S. government bonds, which are the instruments that governments choose to accumulate foreign reserves, pushing down both interest rates and term premia. This is an example of what happened in the period known as *conundrum*, in which there was an excessive demand for long-term bonds in the U.S. causing a decrease in the term premium, while increases in the short-term rates

[12] See Claro and Moreno (2015); Kaminska and Roberts-Sklar (2015).

[13] See Kaminska et al. (2013); Bernanke (2013); Benson (2014).

[14] See Bernanke (2015).

[15] An example of this case is documented in Papanyan (2015), who estimates and analyses the term premium for U.S., and find this has reached negative levels.

[16] See Rudebush et al. (2007) and Rosenberg and Maurer (2008).

did not affect the long-term structure. Another example is the set of QE programs, that increased demand for U.S. long-term government bonds, reducing the term premium. In addition, changes in regulation and market practices also affect the demand for safe and liquid assets, such as government bonds, which can also be a factor that decreases the term premium.[17]

Summarizing the international evidence in AEs, the behavior of the term premium helps explain the low levels of long-term interest rates in these economies in recent years, together with the low expectations of both inflation and short-term interest rates. In addition, low term premium reflects the fact that there are no concerns, on the part of investors, with respect to inflationary risk; that there is a low uncertainty about changes in the levels that will take the short-term interest rate in the U.S., and finally, that there is a global demand for safe and liquid assets of central banks.

In the case of EMEs, the term premium has been less studied. Blake et al. (2015), using a similar model to the one from Adrian et al. (2013), show evidence of the benefits of adopting an inflation targeting regime in a group of Latin American countries, among which a decrease in the term premium stands out, as well as the anchoring of expectations of regarding the monetary policy rate. To obtain the expectations, they use synthetic prices from the yield curves of those countries, which could contrast with the results obtained with an analysis for each country using observable data. Claro and Moreno (2015) analyze the fact that interest rates of EMEs sovereign bonds are highly correlated with those of U.S. bonds. In the case of Chile, evidence shows that this correlation can be explained by a synchronization between its term premium and the one in the U.S. Their paper also argues that the aggressive monetary stimulus implemented since the GFC from 2008, along with

[17]See Bernanke (2013 and 2015).

the change in the profile of bond-holding investors were the factors behind the decline in the term premium and the increase in its volatility.[18]

3 Methodologies

As mentioned, the long-term interest rate can be decomposed into the expected short-term interest rate in the long-term horizon and the term premium, as follows:

$$i_t^n = \frac{1}{n}\sum_{i=0}^{n-1} E_t(i_{t+i}^{(1)}) + TP_t^n$$

where i_t^n is the long-term interest rate with n-maturity, $i_{t+i}^{(1)}$ is the short-term interest rate at time $t+i$, and $\frac{1}{n}\sum_{i=0}^{n-1} E_t(i_{t+i}^{(1)})$ is the expected short-term interest rate in the n-horizon, and TP_t^n is the term premium in the n-horizon.

We use different methodologies to estimate this expected average of the short-term interest rate, and then we calculate the term premium as the residual between the observed long-term interest rate and said average as:

$$TP_t^n = i_t^n - \frac{1}{n}\sum_{i=0}^{n-1} E_t(i_{t+i}^{(1)}) \tag{1}$$

In particular, the methodologies used to estimate the expected average of the short-term interest rate are the following. We use two affine models: one similar in structure to that presented in Kim and Wright (2005), henceforth KW, and another in line with Adrian et al. (2013), henceforth ACM. The main differences between these models are the way in which parameters are estimated, the estimation sample, the information included in the model, and the number of factors considered in the estimation. Additionally, we use the average

[18]Similar evidence is found by Ceballos et al. (2014). In particular, the authors find that most of the fall of long-term interest rates are related to the term premium, and this is explained by nominal uncertainty, i.e. the uncertainty for expected inflation and the U.S. term premium.

of the TIIE swaps with maturities of 1, 3, 5, 7 and 10 years. This last variable considers the expectations of economic agents on the short-term interest rate at different horizons drawn from financial instruments.

3.1 Affine Model similar in structure to Kim and Wright (KW)

Affine models are standard in the literature.[19] These models assume no-arbitrage conditions in financial markets to compute an expected average of the short-term nominal interest rate for a n-maturity bond in a k-period horizon. The model can be written in state-space form as

$$X_t = \underbrace{\mu + \phi X_{t-1} + \vartheta_{t+1},}_{\text{TRANSITION EQUATION}} \tag{2}$$

$$i_t^{(n)} = \underbrace{A_n + B_n' X_t,}_{\text{MEASUREMENT EQUATION}} \tag{3}$$

where X_t is a vector of factors or state variables, $i_t^{(n)}$ is the nominal interest rate of a bond with maturity of n months, ϑ_t are white-noise state innovations and they are distributed $N(0, \Sigma)$ with Σ variance-covariance matrix of the factors, ϕ and B_n are coefficient matrices, μ and A_n are coefficient vectors. Note that A_n and B_n are indexed for each maturity n.

The model assumes an affine or linear relation between state variables and the short-term interest rate ($i_t^{(1)}$), and risk prices (λ_t), such that:

$$i_t^{(1)} = \delta_0 + \delta_1' X_t + \epsilon_t^{(1)} \tag{4}$$

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

[19]See Ang and Piazzesi (2003), Kim and Wright (2005), Kim and Orphanides (2007), Swanson (2007), Rudebusch et al. (2007), Wright (2011), Li and Wei (2012), Adrian et al. (2013), BIS (2017), among others. For the case of Mexico see Cortés and Ramos-Francia (2008a, 2008b), Cortés, et al. (2007) and Elizondo (2017).

δ_0 and λ_0 are constants, while δ_1 and λ_1 are coefficients vectors and $\epsilon_t^{(1)}$ are the errors.

The coefficients A_n and B_n of equation (3) are obtained recursively as follows:

$$\begin{aligned}\hat{A}_{n+1} &= \hat{A}_n + \hat{B}_n^{'}(\mu - \Sigma\lambda_0) + \frac{1}{2}\hat{B}_n^{'}\Sigma\Sigma^{'}\hat{B}_n - \delta_0 \\ \hat{B}_{n+1}^{'} &= \hat{B}_n^{'}(\phi - \Sigma\lambda_1) - \delta_1^{'}\end{aligned} \tag{5}$$

with $\hat{A}_0 = 0$ and $\hat{B}_0 = 0.$

Then, the expected short-term interest rate is defined as:

$$\frac{1}{n}\sum_{i=0}^{n-1} E_t(i_{t+i}^{(1)}) = -\delta_0 - \delta_1^{'}(I + \phi + \phi^2 + ... + \phi^{n-1})\mu + \delta_1^{'}X_t \tag{6}$$

In particular, our estimated affine model based on Kim and Wright (2005) has three unobservable or latent state variables. It is worth mentioning that these latent variables, or factors of the yield curve, are named according to their effect on the latter: the level factor affects the entire curve; the slope factor affects the short- and long-term maturities of the curve; and the curvature factor has a larger effect on medium term maturities, between 3 and 7 years.[20] Additionally, these factors are related to some macroeconomic variables, for example, Dewachter and Lyrio (2006) find that the level factor is correlated with long-term inflation, the slope factor is related to the predictable components of inflation and the business cycle, and the curvature factor is associated with the current monetary policy stance. In the particular case of Mexico, Cortés et al. (2008) show that the first two factors - the level and the slope- explain 95% of the variation in the Mexican yield curve. In addition, they conclude that the level factor has a positive correlation with measures of long-term inflation expectations, while the slope factor shows a negative correlation with the bank funding rate (the monetary policy instrument). In this context, they find that shocks that affect long-term inflation expectations tend to influence the level of the yield curve, while

[20] See for example Diebold and Li (2006) and Ang and Piazessi (2003).

shocks that induce the central bank to move the short-term interest rate influence the slope of the yield curve.

We estimate this model through maximum likelihood, and the Kalman filter. The model was estimated in daily frequency from January 2004 to December 2019, using yields from government zero-coupon bonds with maturities of 1,3 and 6 months, and of 1, 2, 3, 5, 7 and 10 years. Additionally, we use the 10-year nominal interest rate.[21]

3.2 Regression Model of Adrian, Crump and Moench (ACM)

For the regression model we based our estimation on Adrian et al. (2013). This model satisfies equations (2)-(3) from the affine model, the difference lies on the estimation method. The model introduces a new concept based on the excess of returns, given by four terms. The first one corresponds to the expected return, the second one is derived from a convexity adjustment, the third one is the innovation of the price return, and the fourth one is the error term. Specifically, and following Adrian et al. (2013), we have:

$$rx_{t+1}^{(n-1)} = \beta^{(n-1)\prime}(\lambda_0 + \lambda_1 X_t) - \frac{1}{2}(\beta^{(n-1)\prime}\Sigma\beta^{(n-1)} + \sigma^2) + \beta^{(n-1)\prime}\upsilon_{t+1} + e_{t+1}^{(n-1)} \quad (7)$$

where $rx_{t+1}^{(n-1)}$ is the excess of return in the maturity $n-1$, the term $\beta^{(n-1)}$ comes from the covariance between the excess of return and the innovations of the factors, multiplied by the inverse of the factor matrix, i.e., $\beta_t^{(n-1)} = Cov_t[rx_{t+1}^{(n-1)}, \upsilon_{t+1}']\Sigma^{-1}$, υ_{t+1} are the factor errors and follows a Gaussian distribution with variance-covariance matrix Σ, and $e_{t+1}^{(n-1)}$ are the return pricing errors conditionally independently and identically distributed (i.i.d.) with variance σ^2. We suppose that factors are observable and are estimated through principal components, this makes β constant by construction, $\beta_t^{(n-1)} = \beta^{(n-1)}$.[22]

[21] The zero-coupon bonds are obtained from Valmer and the nominal interest rate is obtained from PiP.
[22] All details of this derivation can be consulted in Adrian et al. (2013).

Writing equation (7) in matrix terms we have that:

$$rx = \beta^{'}(\lambda_0 1_T^{'} + \lambda_1 X_{\text{-}}) - \frac{1}{2}(B^{*}vec(\Sigma) + \sigma^2 1_N)1_T^{'} + \beta^{'}V + E \quad (8)$$

The term $\beta = [\beta^{(1)}\beta^{(2)}...\beta^{(N)}]$ is the matrix of weights of each factor, 1_N y $1_T^{'}$ are $(N \times 1)$ and $(1 \times T)$ vectors of ones, $X_{\text{-}} = [X_0 X_1 ... X_{T-1}]$ is the matrix of factors lagged, $B^{*} = [vec(\beta^{(1)}\beta^{(1)\prime})...vec(\beta^{(N)}\beta^{(N)\prime})]'$, V is an estimator of the matrix of variance covariance of factors and E is the matrix of errors.

To solve the parameters of the system given by (8) we follow the next steps according to Adrian et al. (2013):

1. In the model, we consider five observable factors and we calculate them through principal components. We estimate the factor dynamics through equation (2) by ordinary least squares (OLS). Then, we estimate the innovations $\hat{V}$ and construct the estimator $\hat{\Sigma} = \hat{V}\hat{V}'/T$, with T as the number of observations in the sample.

2. We estimate a regression between the excess of return of yields, rx, and a constant, the lagged factors and contemporary innovations.

$$rx = a1_t^{'} + \beta'\hat{V} + cX_{\text{-}} + E \quad (9)$$

It is worth mentioning that the excess of return is computed as $rx_t^{(n)} = p_t^{(n-1)} - p_t^{(n)} - r_t$. With $r_t = p_t^{(1)}$ as short run interest rate and $p_t^{(n)} = log(P_t^{(n)})$. If we let $Z = [1_T \ \hat{V}' \ X_{\text{-}}^{'}]'$, estimation by OLS implies that $[\hat{a} \ \hat{\beta}' \ \hat{c}] = rxZ^{'}(ZZ^{'})^{-1}$.

Thereupon we save the residual of this regression as $\hat{E}$ and estimate $\hat{\sigma}^2 = trace(\hat{E}\hat{E}^{'})/NT$ with N the number of maturities and T the size of sample. We construct $\hat{B}^{*}$ from $\hat{\beta}$.

3. We estimate the prices of risk λ_0 y λ_1 with the following expressions:

$$\begin{aligned} \hat{\lambda_0} &= (\hat{\beta}\hat{\beta}')^{-1}\hat{\beta}[\hat{a} + \frac{1}{2}(\hat{B}^* vec(\hat{\Sigma}) + \hat{\sigma^2} 1_N)] \\ \hat{\lambda_1} &= (\hat{\beta}\hat{\beta}')^{-1}\hat{\beta}\hat{c}. \end{aligned} \tag{10}$$

with $\hat{a} = \hat{\beta}'\lambda_0 - \frac{1}{2}(\hat{B}^* vec(\hat{\Sigma}) + \sigma^2 1_N)$ and $\hat{c} = \hat{\beta}' 1_N$.

Once all the parameters have been estimated, we built the coefficients of equation (5) and calculate yields through equation (3).

In this model, if λ_0 and λ_1 are equal to zero in recursive coefficients given by (5), they generate the risk-adjusted bond pricing coefficients A_n^{RF} and B_n^{RF}, where risk neutral yields are estimated as $-(1/n)(A_n^{RF} + B_n^{RF} X_t)$, and they equal the time t expectation of average future short-term interest rate in the next n periods. The term premium can be calculated as the difference between the risk neutral yield and the yield implied by the model given by the fitted values.

We estimate the model from January 2004 to December 2019 using zero-coupon bonds with maturities which go from 1 to 120 months. Additionally, we use the 10-year nominal interest rate.[23] In this model, there are five observable factors estimated by principal components of the all zero-coupons bonds involved in the estimation. Similar to the KW model, the first factor represents the level of the yield curve, the second one is the slope of said curve, the third one corresponds to the curvature, the fourth one is related to the return, and the fifth one is related to the risk premium.

3.3 TIIE Swaps

The contracts of cash flow exchanges, or Swaps Over-The-Counter (OTC), are bilateral contracts in which it is arranged to exchange, in future dates, cash flows based on interest rates, or the value or currency profitability, goods, stock indexes, stocks or bonds. The more

[23] The zero-coupon bonds are obtained from Valmer and the nominal interest rate is obtained from PiP.

common Swap contracts are the interest rate Swaps (IRS), calculated cash flows using two interest rates (fixed vs variable, or variable vs variable) over the same principal or reference. The fixed interest rate refers to the average of the fixed interest rates relative to interest rates signed on the agreed date and classified according to its maturity term (expressed in natural days).

The time series related to the indicators of Swaps OTC which are fixed interest rate vs 28-days TIIE or fixed rate vs 90-days LIBOR rate signed by banks (multiple banks and development banks), brokerage houses and regulated SOFOMES, exclusively consider: a) standardized Swaps, which exchange cash flows in 28-days periods, which result from applying a fix interest rate and 28-days TIIE rate, over principal in Mexican pesos not amortizable and which original term is between 56-days and 30-years;[24] b) IRS which exchange cash flows that result from applying a fixed interest rate and 90-days LIBOR rate in U.S. dollars over a principal not amortizable denominated in dollars.

The term in the agreed date, refers to the term in natural days between the negotiation day of the Exchange Operation (or Swap) or OTC and the liquidation date of the last cash flow (to give or receive).

We now give an example with the 3-month swap, in order to illustrate how it allows us to see the TIIE in the future.

The 3-month TIIE swap is a contract that generates the obligation to exchange cash flows calculated with a constant rate (also called fixed interest rate/fixed-rate leg) to 28, 56 (28x2) and 84 days (28x3), 3 times in total, in exchange of receiving the TIIE (floating interest rate/floating-rate leg) that Banco de Mexico published the date of every transaction over the value of 100,000 Mexican pesos (notional principal) by contract.

The starting value of the contract is zero in present value, this is, the present value of the paid flows with the fixed interest rate is equal to the present value of the flows received with the floating interest rate. What changes when starting the contract is the exposure to

[24] This standardization is referred to the Banco de Mexico's memorandum 4/2012.

risk (exchanging the risk of a floating interest rate by the one of the fixed interest rate or viceversa).

For example, this contract can be used to avoid the risk of a change in TIIE during the 3 month period, so it could allow us to have constant and known payments. In general, this happens when the 28-days TIIE is expected to rise. Given this definition, the Swap's fixed interest rate, represents the average of the TIIE that would be paid in those 84-days (3-months), so it is the fixed interest rate that is equivalent to the pay of 28-days TIIE, in 28-days, 56-and 84-days.

The rest of the swaps are defined in a similar way, given that 1-year swap is 364-days (13x28) and allows the exchange of 13-fixed payments (notional principal x fixed interest rate) for 13 variable payments (notional principal by floating interest rate). The 2-years Swap implies, 26 exchanges, the 3-years swap 39 payments and so on. For this reason, the number of exchanges is used, (13x1, 26x1, 39x1) to refer us to the terms.

In our analysis, we use TIIE-28 swaps with maturities from 1, 3, 5 and 10 year.[25] We compute the average and subtract around 30 or 40 basis points, which is the difference between the overnight interbank nominal interest rate and the 28-day TIIE. We consider this average our expected short-term interest rate in a long-term horizon.

4 Results of the Expected Short-Term Interest Rates and the Term Premium

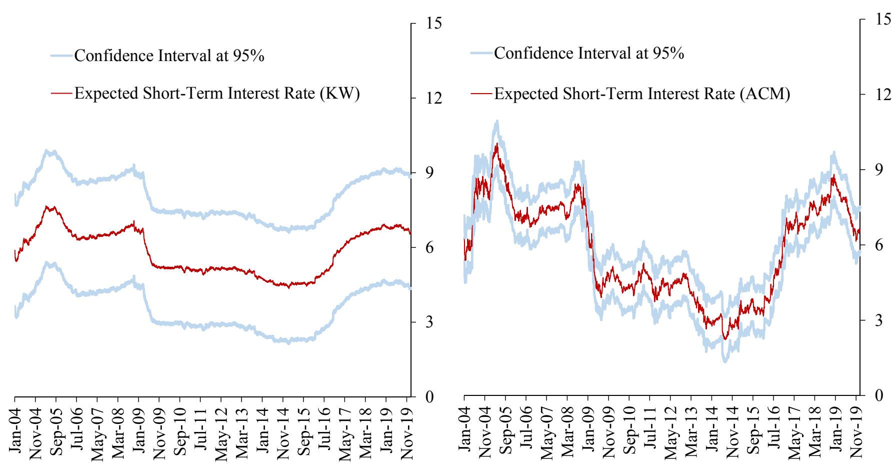
In this section we show the results of our estimations for the three methodologies we described. We exhibit the trajectories of the expected short-term interest rates and the term premia dynamics. Finally, we show the average of our estimations.

[25] The TIIE swaps are obtained from Bloomberg.

4.1 Estimation of the Expected Short-Term Interest Rates

Figure 1 shows the expected short-term interest rate and the term premium with their 95% confidence intervals for the KW and ACM methods, respectively. It is observed that the confidence intervals of the KW method are wider than those of the ACM, this due to the fact that in the estimation by the KW method there are 2 sources of error: the estimation of the factors that are latent and the estimation of the expected short-term interest rate. It is worth mentioning that in the estimation using the TIIE Swaps, it is not possible to estimate confidence intervals because the expected short-term interest rate comes from an average of hard data. From now on, we will use the central trajectories of our estimations for both methods.

Figure 1: Expected Short-Term Interest Rates with Confidence Intervals



Note: Confidence intervals are estimated using the Monte Carlo method with 10000 trajectories. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

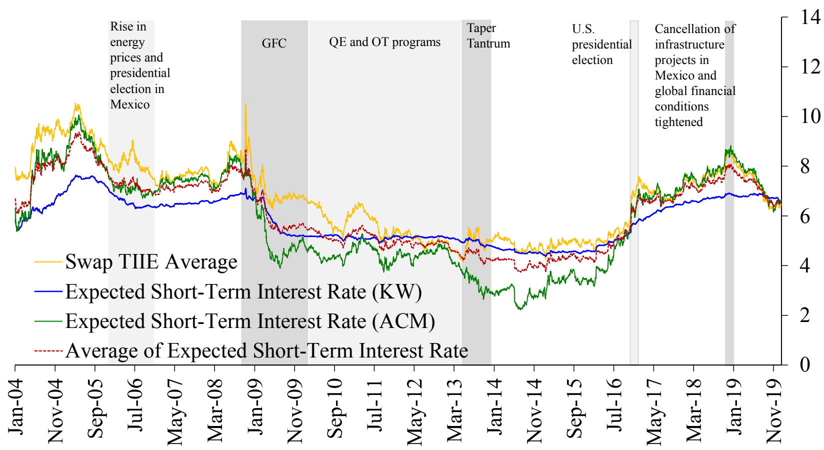
Figure 2 shows the expected short-term interest rates using three methodologies. We observe that the estimated interest rates have different levels but very similar dynamics. In fact, the correlation between these estimations is above 90%.[26]

[26] It is worth mentioning that the mean square error of the model's fit with respect to the observed 10-year interest rate is 0.48 and 0.01 for the KW model and the ACM model, respectively.

It is worth mentioning that the expected short-term interest rate estimated with the KW model is smoother than the ACM and the TIIE swaps models, which are more volatile, since these methodologies capture higher frequency movements in short-term interest rates.

In particular, the expected short-term interest rates decreased sharply since the GFC from September 2008 to December 2009, from around 8% to 5%, remaining low and stable and reaching their historical minimum between 2014 and 2015. Then, they increased to reach pre-crisis levels during the U.S. presidential election at the end of 2016. Then, these continued to increase reaching average levels of 8% at the end of 2018, similar levels to the ones observed during the GFC. In 2019, the expected short-term interest rates reversed their trend, reaching average levels around 6.5%.

Figure 2: Expectations of Short-Term Interest Rates

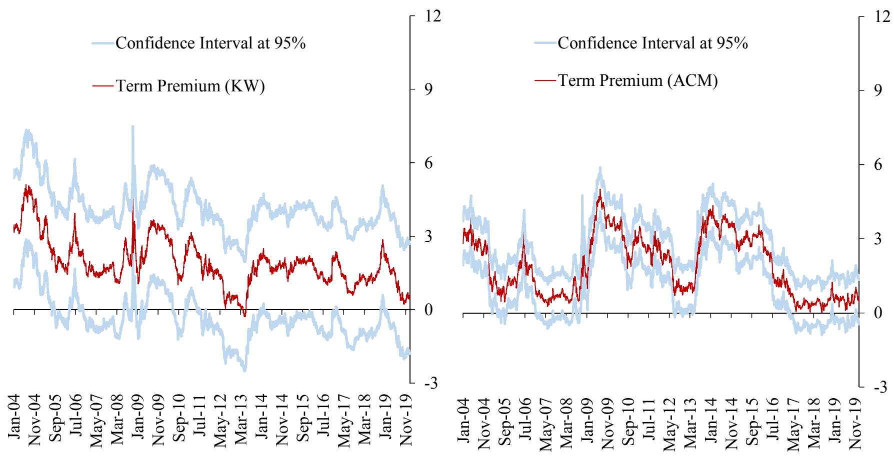


Note: We use three methodologies to estimate these expectations: two affine models and TIIE Swaps. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

4.2 Estimation of the Term Premium

Figure 3 shows the term premium with its confidence intervals at 95% for the KW and ACM methods. Analogously, the confidence intervals are higher with the KW method, due to sources of uncertainty. We will use the central trajectories of our estimations for both methods.

Figure 3: Expected Short-Term Interest Rates with Confidence Intervals



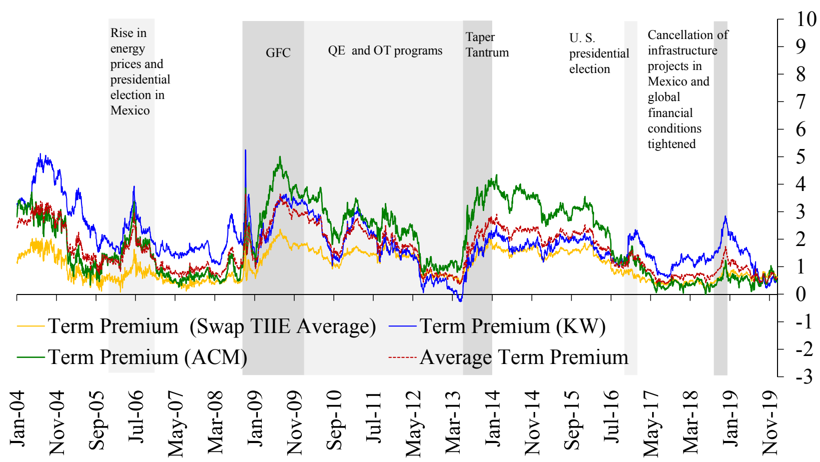
Note: Confidence intervals are estimated using the Monte Carlo method with 10000 trajectories. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

Comparing the term premium of the three methodologies, we observe that the dynamics are similar across all methodologies, although levels are different. In particular, the correlation between different estimations is above 70%.

It is relevant to study how the Mexican term premium reacted to stress events, both domestic and global. Figure 4 shows in shaded areas the most important global events: i) the GFC from September 2008 to December 2009; ii) the QE and OT programs from January 2010 through April 2013; iii) the Taper Tantrum since mid-2013 through early 2014; and iv) the U.S. presidential election from November 2016 through January 2017. Some domestic events include the Mexican presidential election in June 2006, the liberalization of gasoline prices in January 2017 and the cancellation of some infrastructure projects in October-November 2018. It is worth mentioning that these stress events generated high volatility in global and domestic financial markets, which translated into a higher term premium demanded by investors, except for the QE and OT programs where the term premium decreased.

Figure 4 shows that the average term premium increased significantly during the Mexican elections from June 2006 and the GFC from September 2008 to December 2009, reaching levels around 3 and 3.7%, respectively. Later on, during the QE and OT programs, from September 2010 to December 2012, it reached its historical minimum around levels of 0.5%, and reverted its trend reaching levels of 2.5% during the Taper Tantrum from May 2013 until the end of 2016, when it started to decrease again to levels of 1% before the presidential election in the U.S. From November 2016 to January 2017, the term premium increased to 1.6%, amid the election results in the U.S and the liberalization of gasoline prices in Mexico, and dropped again to 0.6% in September 2018. Between October 2018 and January 2019, during the cancellation of some infrastructure projects by the Mexican government together with the tightening of global financial conditions, the term premium increased to 1.7% and fell to 0.6% at the end of 2019.

Figure 4: Term Premia

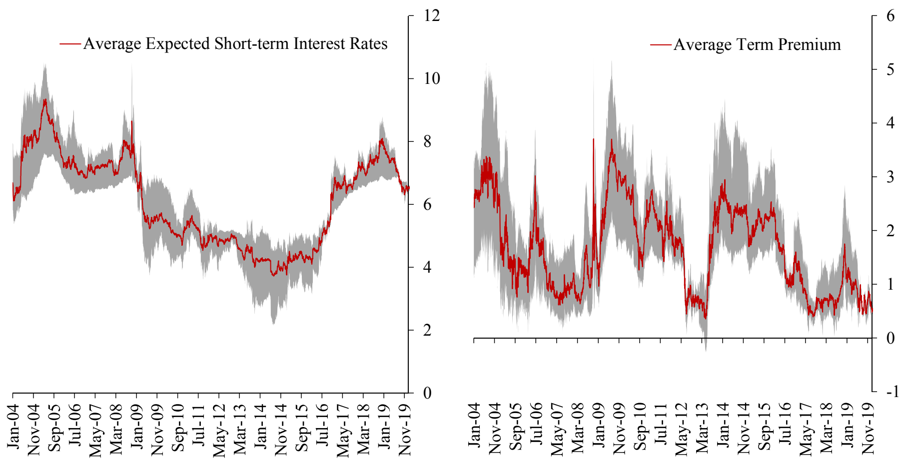


Note: The term premium is the residual between the 10-year government bond interest rate and the expected short-term interest rate in the long-term. The latter is estimated using three different methodologies including two affine models and TIIE swaps. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

4.3 Average Estimates

As we mentioned before, the Mexican indicators of the expected short-term interest rate and its corresponding term premium are the average of all the estimated trajectories, and its range is built as the maximum and minimum of all the methodologies as shown in Figure 5.

Figure 5: Averages of the Expected short-term Interest Rate and the Term Premium



Note: The expected short-term interest rate and the term premium are the average of all the estimates. We use two affine models and TIIE swaps. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

Results suggest that during stress periods when the term premium increases, the estimates show higher dispersion, thus the range increases too. According to Table 1, the average level of the expected short-term interest in the long-term, during the analyzed period, is around 6.13%, while the average of the term premium is 1.64%. Thus, the expected short-term rate in the long term corresponds to 79% of the 10-year interest rate, while rest can be explained by the term premium.

In Table 1, we can also see, in annual terms, results consistent with the ones found when using daily data in Section 4.2. From 2007 to 2009 the term premium increased 184 basis points (bp) and the expected short-term rate in the long term decreased around 139bp, leading to an increase of 46pb of the 10-year interest rate. During the implementation of QE and OT programs in 2010-2012, the 10-year interest rate decreased 136bp, of which 105pb may be explained by the decline in the term premium. In 2013, during the Taper Tantrum, while the expected short-term interest rate continued to decline 45bp, the term premium increased 30bp, causing the 10-year interest rate to drop by 15bp. Between 2016 and 2017, the expected short-term rate increased 164pb, as a result of the restrictive monetary policy stance adopted by Banco de México amid the uncertainty on the inflation outlook resulting from the liberalization of gasoline prices in Mexico and the U.S. presidential election of 2016. In contrast, the term premium decreased 76pb during this period, implying an 88pb increase on the 10-year interest rate. This result contrasts with the increase observed in the term premium during this period when using daily data as presented in Subsection 4.2. The difference arises from the fact that uncertainty is only present for short periods of time.

4.4 Robustness Exercises of the Estimated Short-Term Interest Rate and the Term Premium

As a robustness exercise for the estimates of expected short-term interest rate and the term premium in Mexico, we consider a different methodology used by James et al. (2017). In contrast with the other methodologies, they estimate the term premium empirically by using the forward errors, namely, by using the predicted and actual moves of forward rates. The expected short-term interest rate is calculated as the difference between the long-term interest rate and said premium. As we show in Figure 6, the expected short-term interest rate and its corresponding term premium (green dotted lines on the left graph and right graph, respectively) are very similar to our average estimates, and are within the range of our estimates.

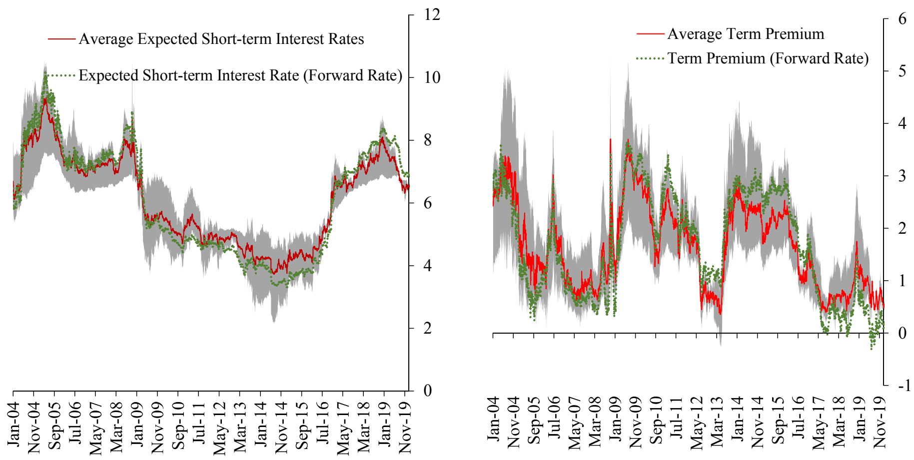
An additional robustness exercise consists on the comparison of the average of the expected short-term interest rate in the long term with estimates of the neutral rate, as a mea-

Table 1: Summary of Annual Results: Components of 10-Year Interest Rate

Years	*10-year* Int. Rate	*Exp. Short-Term Rate* Low Range	Point Est.	High Range	*Term Premia* Low Range	Point Est.	High Range
2004	10.35	6.21	7.46	8.76	1.56	2.87	4.12
2005	9.98	7.38	8.46	9.32	0.65	1.51	2.60
2006	8.77	6.51	7.17	8.00	0.75	1.59	2.25
2007	8.09	6.49	7.20	7.65	0.43	0.89	1.60
2008	8.74	6.73	7.49	8.11	0.62	1.23	2.00
2009	8.55	4.84	5.81	6.86	1.69	2.74	3.71
2010	7.44	4.41	5.21	6.03	1.42	2.24	3.04
2011	7.29	4.50	5.12	5.76	1.54	2.18	2.80
2012	6.08	4.47	4.90	5.19	0.89	1.19	1.61
2013	5.95	3.52	4.45	5.06	0.87	1.49	2.42
2014	6.45	2.75	4.06	4.84	1.62	2.40	3.70
2015	6.40	3.43	4.28	4.87	1.52	2.12	2.97
2016	6.57	4.53	5.05	5.47	1.11	1.52	2.06
2017	7.45	6.21	6.69	7.01	0.43	0.76	1.24
2018	8.24	6.71	7.41	7.79	0.45	0.84	1.54
2019	7.89	6.68	7.08	7.36	0.54	0.82	1.23
Average	**7.77**	**5.35**	**6.13**	**6.76**	**1.00**	**1.64**	**2.41**

Note: Column 2 is the annual average of observed 10-year interest rate. From Column 3 to Column 8 the annual averages of each component with their respective ranges that are estimated in daily frequency, are displayed.

Figure 6: Expected short-term Interest Rate and Term Premium in Forward Rates

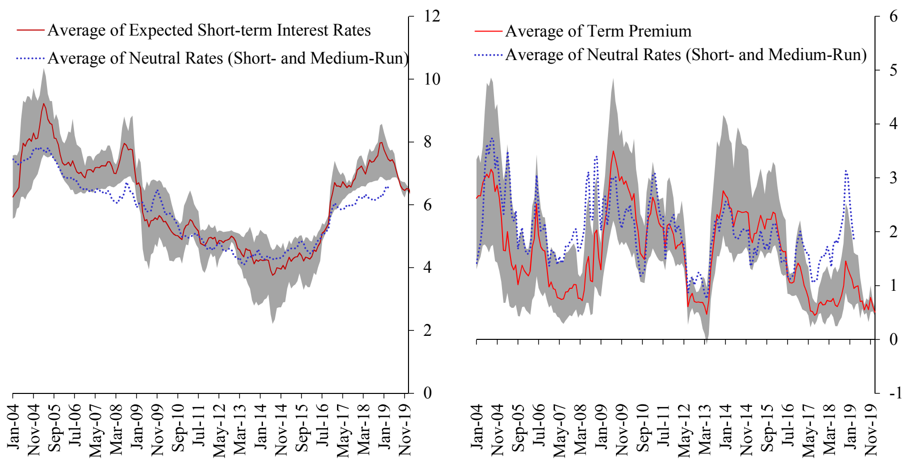


Note: The red lines are the average of all the estimates of the expected short-term interest rates and the term premium. The gray area is the range of our estimates. The green lines are the new estimate. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

sure of the short-term interest rate in the short and medium run. To do so, we average the estimations of the short and medium run of the nominal neutral rates estimated by Carrillo et al. (2018), updated to March 2019, except those related to affine models. Additionally, we compare the neutral term premium, obtained as the difference between long-term interest rate and said nominal neutral rate, with our average term premium. Figure 7 shows that the estimated expected short-term interest rate (red line on the left graph) follows closely the trajectory of the nominal neutral rate (blue dotted line on the left graph). Analogously, our average term premium (red line on the right graph) is very similar in trajectory and level to the neutral term premium (blue dotted line in the right graph).

In what follows we will study the determinants explaining the dynamics of the average term premium and how these determinants have changed over time.

Figure 7: The Nominal Neutral Rate and its Corresponding Term Premium



Note: The blue dotted line in the left graph corresponds to the average of the nominal neutral rates estimated by Carrillo et al. (2018), the blue dotted line on the right graph is the neutral term premium calculated as the difference between long-term interest rate and said neutral rate. The red lines are the estimates of the expected short-term interest rate and its term premium proposal in this paper. The gray area is the range of our estimates. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

5 Determinants of the Average Term Premium

It has been documented in the literature that the dynamics of the term premium can be mainly explained by two determinants: a real term premium and an inflationary risk premium.[27] However more recently, Hördahl et al. (2016) found that the U.S. term premium is more important than the expected short-term interest rate to explain the dynamics of the long-term interest rate of the EMEs, and their correlation is positive. Additionally, Albagli et al. (2018) show that changes in the U.S. term premium dominate changes in the yields of the EMEs. Thus, as a first approximation, for our analysis we consider three main determinants that explain the term premium: a real term premium, an inflationary risk premium, and the U.S. term premium as a global factor. Thus, we evaluate the extent to which these three determinants allow us to explain Mexican term premium dynamics.[28]

The real term premium can be related to the degree of uncertainty around monetary policy and the economic outlook. The inflationary risk premium is related to the investors' perception of risk about the future interest rate path. Furthermore, the U.S. term premium reflects changes in the supply and demand for safe assets.

To study in what proportion each of the determinants described above explain the Mexican term premium over time, we estimate a time varying parameter regression, or TVP regression. For this estimation, we use the average of the previously presented term premium estimations as our dependent variable, for which we aim to identify its determinants' dynamics over time. In particular, we estimate a TVP regression using Bayesian methods

[27] More details can be found in Abrahams et al. (2015), Bauer (2017), and Bernanke (2015).

[28] It is worth mentioning that other premia can also explain the term premium, such as liquidity risk premium, sovereign risk premium, geopolitical risk, effects of flight to quality or search for yield, between others. All these premia in our analysis are contained in our real term premium or in the constant of our estimated regression.

as follows:[29]

$$
\begin{aligned}
Y_t &= \gamma_{0,t} + \gamma_{1,t} Z_{1t} + ... + \gamma_{k,t} Z_{kt} + \eta_t; \quad \eta_t \sim N(0, \sigma_\eta^2) \\
\gamma_{i,t+1} &= \gamma_{i,t} + \varepsilon_{it}; \quad \varepsilon_{it} \sim N(0, \sigma_i^2); \;\; i = 0, ..., k; cov(\eta_t, \varepsilon_t) = 0
\end{aligned}
$$

where Y_t is the average term premia, $\gamma_{i,t}$ are the estimated coefficients and Z_t is a matrix of explanatory variables. Given the availability of the data, the sample used for the estimation covers the period from January 2007 to December 2019.[30] Furthermore, this type of estimation has the advantage of allowing a relatively large number of parameters with a relatively small sample, hence, letting us capture structural changes in these coefficients.[31]

The explanatory variables included in the estimation are: i) the U.S. term premium estimated by Kim and Wright (2005), which according to the literature can be interpreted as a global risk factor for EMEs;[32] ii) the real compensation as a proxy of the real term premium, estimated as the difference between the 10-year and 3-years real interest rates.[33] This is one of the most important determinant of the term premium, since it explains changes in the demand and supply of bonds that are not related to changes in inflationary expectations, but with demand for safe assets, market sentiment, or possible price errors, among others;[34] and finally, iii) the inflationary risk premium, which is not available for daily frequency so we use the compensation for FX risk as a proxy and compute it as the dif-

[29]In the Bayesian estimation we use Gibbs sampling and Carter-Kohn algorithms. To estimate the priors we use the estimated values of the regression considering a 2-year subsample, it is our training sample. $30,000$ iterations were considered, of which only $2,000$ of them were taken to estimate the posterior parameters.

[30]The data from 2007 to 2008 are used to estimate the priors. While the data from 2009 to December 2019 is the period of our estimation.

[31]It is worth mentioning that when m tends to zero, prior dominates likelihood.

[32]See for example Hördahl et al. (2016) and Albagli et al. (2018). This premium can be obtained from Economic Data of Federal Reserve Bank of ST. Louis in the following link: https://fred.stlouisfed.org/series/THREEFYTP10.

[33]We consider 3-years, because it is the smallest maturity that is quoted in the Mexican market for real rates. The real interest rates are obtained from Bloomberg.

[34]See Abrahams et al. (2015), Bauer (2017) and Bernanke (2015). The first two break down the term premium into two determinants: the real term premium and the inflationary risk premium, while the last studies the possible determinants of both the real term premium and of the inflationary risk.

ference between the 10-year Mexican Government bonds denominated in Mexican pesos and in dollars (UMS),[35] the latter is the return of the Mexican bond, Mbono, issued in U.S. dollars.[36]

Table 2 shows the average coefficients, considering the entire sample, of each component of the Mexican term premium, which are statistically different from zero. The three determinants impact the Mexican term premium positively, namely, if any of these determinants increases (decreases) then the premium increases (decreases). The positive or negative contribution to the term premium depends on the behavior of each variable over time.

Additionally, Figure 8 shows the dynamics of the estimated coefficients by the TVP regression.[37] We can see that the U.S. term premium coefficient gained relevance over time, with a positive trend, from 0.2 in 2009 to 0.6 in 2019. Conversely, the real compensation coefficient lost importance through time, in this case its trend is negative, going from a level from 0.8 to one of 0.1. While the coefficient of the compensation for FX risk remained relatively close to an average level of 0.24. It is worth mentioning that the first two coefficients are more volatile than the last. Finally, the constant coefficient also lost relevance over time, and has a negative trend. This coefficient can be interpreted as the

[35]The bond denominated in pesos is obtained from PiP and the bond denominated in dollars is obtained from Valmer.

[36]We believe that the compensation for FX risk could be a good approximation for the inflationary risk premium. On the one hand, in the face of a significant exchange rate depreciation- which implies a higher compensation for FX risk- it generates an increase in the output gap and, in turn, inflationary pressures, which will increase the inflationary risk premium. On the other hand, if inflation increases, which could imply a higher inflationary risk premium, the domestic currency depreciates, since an increase in local prices must lead to an increase in the exchange rate to keep real prices relatively aligned with global ones, which could then generate a higher compensation for FX risk. However, there may be other ways to approximate the inflationary risk premium, one of them may be to measure it directly through a model. Other possibility is to use the break-even-inflation, which contains the inflationary risk premium but also contains inflation expectations. Finally, this inflationary risk premium can also be approximated by the difference between forward real interest rates and the 10-years expected real rate. In the future work, we will seek to have a better estimate of said variable.

[37]The confidence intervals (dotted blue lines) of the coefficients are tight because we are not considering the uncertainty of the Mexican term premium and the U.S. term premium, whose variables are unobservable and come from estimates, which represents a limitation for our estimate.

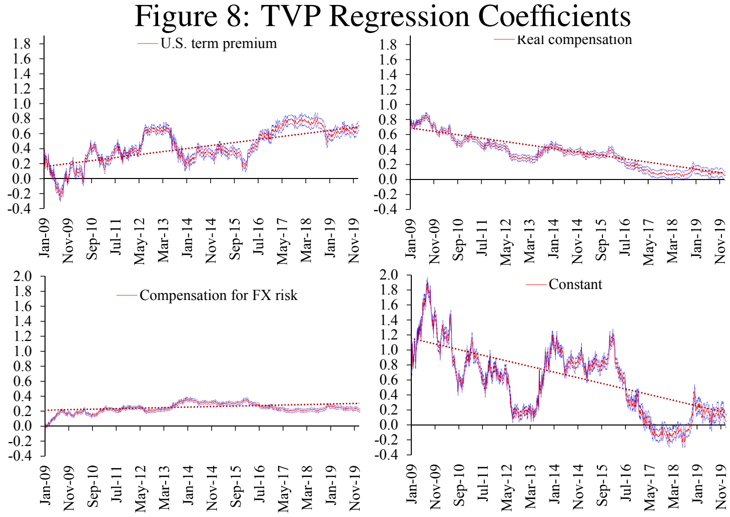
Table 2: Average Coefficients of the Determinants of the Mexican Term Premium (January 2009-December 2019)

Variable	*Coefficient*
U.S. term premium	0.44
	[0.39 0.49]
Real compensation	0.34
	[0.31 0.38]
Compensation of FX risk	0.24
	[0.22 0.26]
Constant	0.58
	[0.52 0.64]

Note: The numbers in square brackets correspond to the 16% and 84% quantiles.

level of the Mexican term premium or as omitted variables, which has not been constant over time. Indeed, this coefficient reached levels near zero from 2017 to 2019.

Figure 8: TVP Regression Coefficients

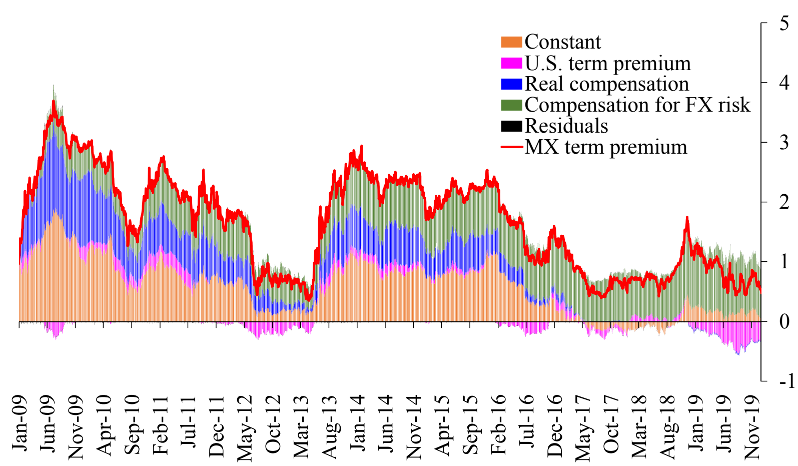


Note: The coefficients are estimated using TVP regression. The dotted blue line are the confidence intervals to 16% and 84%.*Source:* Own estimates with data from Bloomberg, PiP and Valmer.

Figure 9 shows the contribution of each component to the Mexican term premium. In particular, we can see that the U.S. term premium has largely contributed to reduce or to increase the Mexican term premium, although the contribution to decrease it has been greater. In periods where the Mexican term premium has been higher, the real term premium and the compensation for FX risk have contributed positively to increase this premium, except from 2017 when the real term premium is no longer important to explain the behavior of the Mexican term premium. Additionally, we observe that the compensation for FX risk has been important over time to explain the behavior of Mexican term premium. Indeed, in recent years this compensation has been the unique determinant that has explained positively the dynamics of this premium.

As we already mentioned, within the real compensation and the constant of TVP-regression, other premia are included, such as the liquidity risk premium, the sovereign risk premium, geopolitical risks, etc. The analysis of the effect of these specific premia on the Mexican term premium is left for future work, especially the study of the liquidity risk premium that is known to have an important effect in periods of financial stress, such as the GFC.

Figure 9: Term Premium and its Determinants



Note: The contribution of each determinant is obtained multiplying each variable by its corresponding coefficient. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

In the following Subsection, we study in more detail the behaviour of the Mexican term premium and its determinants in three relevant periods, the Operation Twist as a part of the QEs programs, the Taper Tantrum, and finally, the U.S presidential election of 2016.

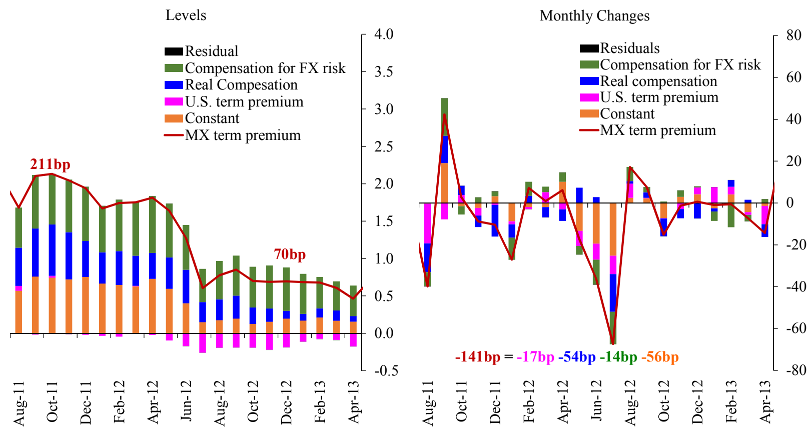
5.1 Mexican Term Premium: Three Relevant Episodes

Now that we have estimated the dynamics of the determinants of the term premium over time, we analyze the contribution of each determinant during three relevant episodes where the Mexican premium showed sharp changes: the Operation Twist programs that were implemented from September 2011 to December 2012. The Taper Tantrum from April 2013 to January 2014, and finally, the U.S. election process from October 2016 to January 2017.

5.1.1 First Episode - Operation Twist (OT)

The Fed in the U.S. implemented two Operation Twist programs from September 2011 to December 2012. The first OT was implemented by the Fed from September 2011 to June 2012, and the second one was an extension, from July 2012 to December 2012. Through these programs, the Fed sought to stimulate its economy by buying long-term instruments and selling short-term ones to lower long-term yields. This period was characterized by a strong capital inflow to EMEs, which significantly reduced interest rates, particularly long-term rates, in these economies. Figure 10 shows that during this time, the Mexican term premium decreased 141bp, from which 17bp corresponds to the decline in the U.S. term premium, this premium reached its historical minima, 54bp due to the fall in real compensation, only 14bp due to a compensation for FX risk, and 56bp to the constant. This is consistent with an improved outlook in EMEs, increasing demand for long-term instruments in these economies, with respect to those in AEs. In the period of QE programs Mexican term premium reached its historical minima too.

Figure 10: Operation Twist Programs (September 2011 - December 2012)

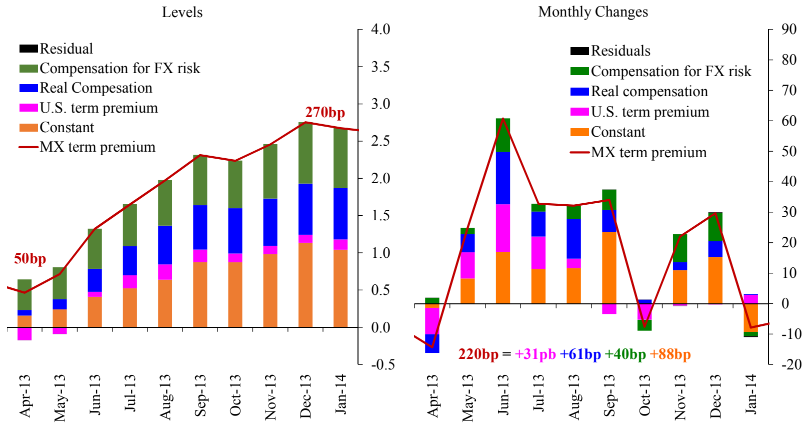


Note: The contribution of each determinant is obtained multiplying each variable by its corresponding coefficient. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

5.1.2 Second Episode - Taper Tantrum

The Taper Tantrum, from April 2013 to January 2014, started when the Fed Chairman, announced the possibility of reducing, in the future, the volume of its bond purchases, i.e, the Fed would reduce the speed at which it was feeding money into the economy. Since the Fed would not buy any more bonds in the near future, investors sold their bonds, causing prices to drop significantly. This, in turn, caused both the yields and the term premium to increase. As a consequence, the international financial markets presented high volatility. This had an important effect reflected in capital outflows from EMEs. In particular, Figure 11 shows that this outlook was reflected in the Mexican term premium increasing 220bp, of which the greatest effects, 61bp, may be explained by the real compensation, 40pb by the compensation for FX risk, 31bp comes from the U.S. term premium, and 88bp by the constant.

Figure 11: Taper Tantrum (April 2013 - January 2014)

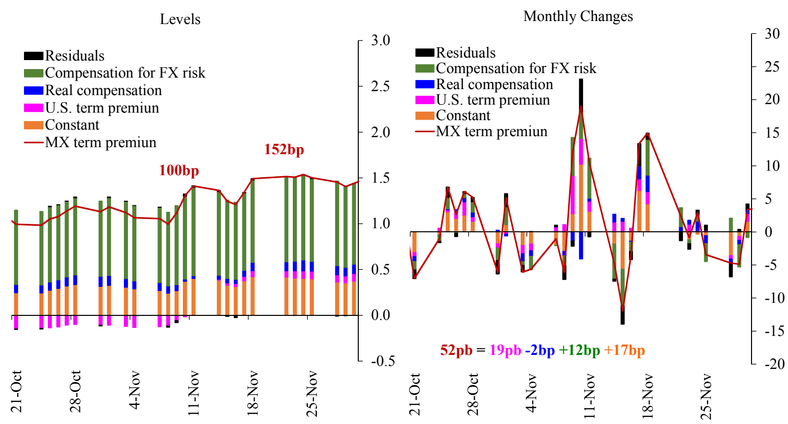


Note: The contribution of each determinant is obtained multiplying each variable by its corresponding coefficient. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

5.1.3 Third Episode - U.S. Presidential Election

The third analyzed episode corresponds to the presidential elections in U.S from November 8 to November 18, 2016. In particular, a highly volatile environment prevailed as a consequence, among other factors, of the uncertainty related to the process of normalization of the monetary policy stance in the U.S., as well as, towards the end of the year, due to the electoral process carried out in the U.S., and its outcome. This was followed by a significant depreciation of the Mexican peso, as well as increases in interest rates across all maturities. Additionally, days after the election of November 8, 2016, there was a substantial increase in the term premium in the U.S. In this context, Figure 12 shows that the Mexican term premium increased by 50 bp, of which 19bp can be attributed to the U.S. term premium, 12bpb to the compensation for FX risk, -2bp to the real compensation, and 17bp to the constant. It is important to mention that this increase responded to external factors and dissipated relatively quickly.

Figure 12: U.S. Electoral Process (November 8, 2016 - November 18, 2016)



Note: The contribution of each determinant is obtained multiplying each variable by its corresponding coefficient. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

5.1.4 Constant vs Perception Factors from Banco de Mexico Survey

As we see in each episode, the constant parameter in the TVP regression is relevant in explaining the Mexican term premium. It can be defined as the level of the term premium, but also this constant could include omitted variables, which could be more related with juncture and internal factors that could affect in short periods of time. As an exploratory exercise, we run a linear regression in order to find variables that could explain the behavior of this constant.[38]

To do so, our dependent variable is the constant parameter in the TVP regression and as explanatory variables we use perception factors that could affect the growth of economic activity in Mexico in the next 6 months. These factors are obtained from the Surveys on the Expectations of Specialists in the Economy of the Private Sector collected by Banco de Mexico. They are measured as percentage distribution of responses and include: fiscal policy that is being implemented (PFI), absence of structural change (ACEM), level

[38]The regression is estimated using the OLS method.

of indebtedness of the companies (NEE) and the families (NEF).[39] The linear regression coefficients are given by Table 3. All coefficients are significant at 1% or 5% confidence level, and these perception factors explain around 69% of the TVP regression constant.

Table 3: Coefficients of the Linear Regression term premium (January 2009-December 2019)

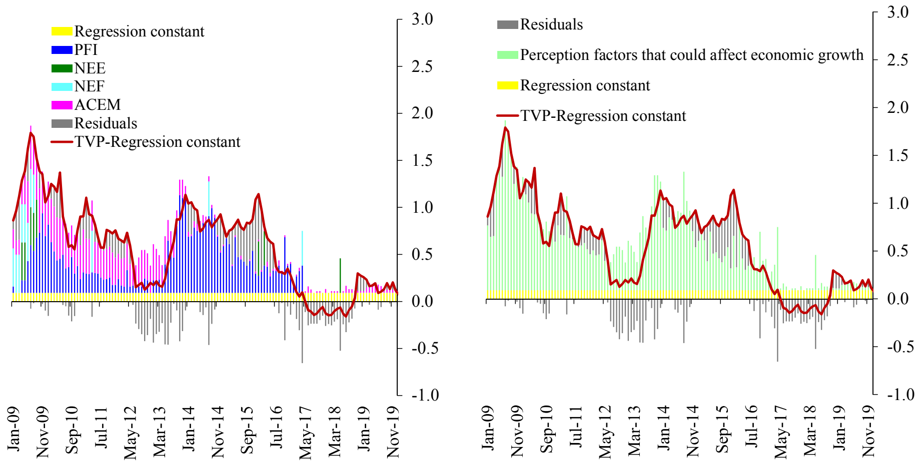
Variable	*Coefficient*
C	0.092**
	[0.039]
PFI	0.060***
	[0.005]
ACEM	0.019***
	[0.003]
NEE	0.367***
	[0.099]
NEF	0.369***
	[0.084]

The numbers in square brackets correspond to standard deviation, *** and ** represents significance at 1% and 5%, respectively.

The left hand side graph of Figure 13 shows the contribution of each perception factor, while the right graph of the same Figure displays the sum of all contributions of the perception factors. Effectively, these perceptions factors seem to explain an important part of our TVP regression constant, and they gained relevance in different periods of time.

[39] Each factor corresponds to the distribution with respect to the total responses from analysts, who can mention up to three factors that could hinder Mexico's economic growth. In particular, survey question is: in your opinion, during the next six months, what would be the three main factors limiting the growth of economic activity?.

Figure 13: Constant vs Perception Factors



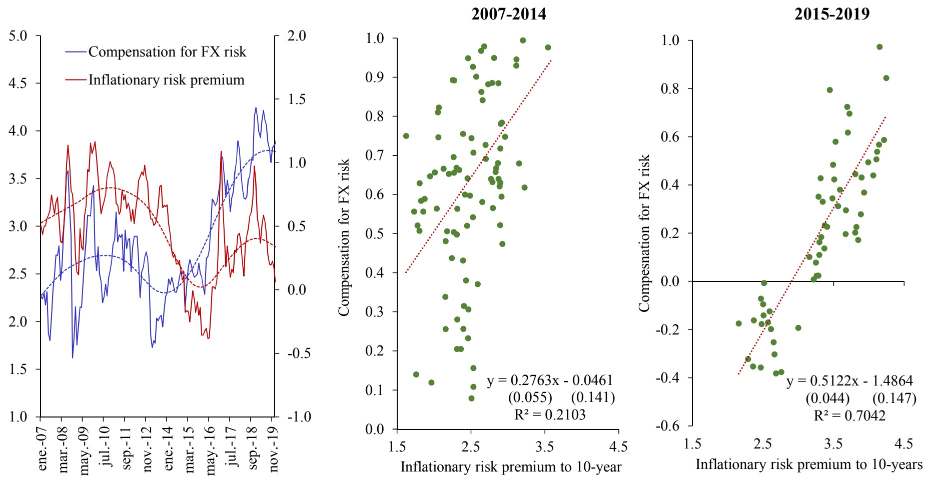
Note: The contribution of each determinant is obtained multiplying each perception factor by its corresponding coefficient. *Source:* Own estimates with data from Banco de Mexico, Bloomberg, PiP and Valmer.

5.2 Correlations: Compensation for FX Risk vs Inflationary Risk Premium

In our TVP regression we use the compensation for FX risk as an approximation to inflationary risk premium,[40] because the latter is not available at daily frequency. In order to show that this compensation is a good proxy for the inflationary risk premium, we graph both variables and its correlation in monthly frequency. The left hand side graph of Figure 14 displays both series with their trends estimate using HP filter method. Both series have similar trends and are positively correlated throughout the sample, but their correlation is stronger from 2015 to 2019 at around 50%, while the correlation from 2009 to 2014 is around 21%.

[40]This premium is estimated by Aguilar et al. (2016).

Figure 14: Compensation for FX risk and Inflationary Risk Premium



Note: The trends in the graph on the left are estimated using the HP filter method. In the regressions the numbers in parenthesis are the standard errors.
Source: Own estimates with data from Bloomberg, PiP and Valmer.

6 Conclusions

This paper estimates the two components of long-term interest rates: the expected short-term interest rate and the term premium. Since these components are unobservable variables, it is important to underline the inherent uncertainty in their estimation, so results should be taken with caution.

In order to obtain relatively more robust results for both variables and, in particular, for the term premium, different methods were considered for their estimation and an average trajectory of both components derived from the different methodologies used was computed. These average estimations are our proposed estimate for the Mexican term premium. The evolution of this premium suggests that it has been affected by various relevant global and domestic episodes. It has increased significantly during three episodes, the Taper Tantrum in 2013, at the end of the U.S. presidential election in 2016, as well as that associated with idiosyncratic events such as the cancellation of some infrastructure projects in Mexico during October and November 2018. In contrast, the term premium decreased considerably during the Quantitative Easing and Operation Twist programs implemented by the Fed from 2010 to 2012, reaching its historical minimum during 2012 and early 2013.

In order to shed light on the main determinants associated with the evolution of the Mexican term premium, using a time varying parameters regression, our analysis suggests that these determinants are the U.S term premium as a global factor, the real compensation and the compensation for FX risk as a proxy of the inflationary risk premium.

As an exploratory analysis we find that perception factors that could affect economic growth in Mexico could explain also the behaviour of Mexican term premium. A deeper analysis of these factors is left for future work.

Additionally, the effect of specific premia, such as liquidity risk premia, the sovereign risk premia, geopolitical risk, among others, on the Mexican term premium is left for future work. Specially, the study of the liquidity risk premium that is known to have an important effect in periods of financial stress, such as the GFC.

The estimation of the Mexican term premium and its determinants provide us a useful tool to study its evolution, as well as their relative importance in each moment of time, in order to be able to consider different risk scenarios for changes in any of its determinants.

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