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RESEARCH ARTICLE

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. We decompose the long-term interest rate into its two components: the expected short-term interest rate and the term premium. The first is obtained using two affine models and data on interest rate swaps. The second is computed as the difference between long-term rates and such expectation. The results show that the term premium increased significantly during three episodes: the global financial crisis; the "Taper Tantrum"; and the U.S. presidential election of 2016. In contrast, the term premium decreased, to historically low levels, during the U.S. "Quantitative Easing" and the "Operation Twist" programs. Additionally, 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.
JEL codes: G12, E43, C12, C53.

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1. Introduction

Analyzing the dynamics of long-term interest rates is relevant to central banks, among other factors, because households and businesses spending decisions can be influenced by such rates. According to the expectations hypothesis of the term structure of interest rates,[1] the longer-term rates should be equal to the average of the current short-term interest rate and the expectations of the latter in the long-term. In principle, a central bank can influence the short-term interest rate expectations in the long term through its monetary policy actions and its communication strategy.

However, the literature on the subject considers that long-term interest rates also include a term premium,[2] which is defined as the compensation that investors demand for maintaining longer-term financial instruments instead of rolling-over those of short term under uncertain macroeconomic and financial conditions.[3] In general, the greater the uncertainty, the larger will be the premium demanded by investors.[4] Changes in the premium can be derived from various events that affect the economy, such as changes in liquidity conditions in international financial markets and the relative demand for financial instruments with different maturities. Likewise, the term premium may reflect the degree of uncertainty in the economic environment, since with increasing uncertainty the premium demanded by investors would be higher. In particular, Kim and Orphanides (2007) mention that the compensation demanded for holding long-term bonds can depend on both the amount of risk and the price of that risk, either of which can change over time due to variable fundamentals, such as perceptions of uncertainty about inflation, real activity and monetary policy, as well as, the business cycle, 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, which is 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 volatility periods, geopolitical risk events, supply and demand for certain maturity of bonds, relevant new events, etc. After the 2008 Global Financial Crisis (GFC), a growing literature has placed a greater emphasis on the term premium as an important factor that explains the evolution of long-term interest rates.[5] In this sense, for the conduct of monetary policy it is also relevant to understand the dynamics of the term premium and its determinants. 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 evolution.

As mentioned, the term premium has been studied for its role in explaining the behavior of long-term interest rates. In the last 25 years, long-term interest rates in advanced economies (AEs) have shown a downward trend. In this context, central banks have been closely monitoring this behavior. In order to explain it, researchers have analyzed the two components of the long-term interest rates: the average expectation of the future short-term interest rates and the term premium. In this sense, it has been documented that many of the fluctuations of the long-term rates are related to the dynamics of the term premium. For example, according to Bernanke (2013), the behavior of the term premium is the reflection of investors' concern 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

[1] SeeFama 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.

[4] 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).

[5] See Kim and Orphanides (2007), Wright (2011), Adrian et al. (2013), Bernanke (2013,2015), Ceballos et al. (2014) and Bank for International Settlements (2017).

the slope (defined as the difference between the long-term interest rate 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 in order to study the predictive role that the slope has on future economic activity, since the effect varies if these components are analyzed separately. In particular, the authors find that expectations of short-term interest rates appear to be more important in predicting future activity.

The term premium is a relevant component that explains the behavior of long-term interest rates. In this context, as we already mentioned, the goal of this paper is to estimate the term premium implicit in 10-year Mexican government bond yields and to analyze the main determinants explaining its evolution from January 2004 to December 2019 in daily frequency.[6] Moreover, an analysis of the effects of the aforementioned events 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:[7] the average expected short-term interest rates in a 10-years horizon and its corresponding term premium. Hence, the term premium represents the degree of uncertainty perceived in the economic outlook. In particular, 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 their estimation entails some degree of uncertainty.

In order to obtain robust results, we consider different estimation methods and take the average of these estimations as our Mexican indicators. In particular, 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 the term premia across different estimations, but similar dynamics.[8] In particular, in line with monetary policy actions, we find that short-term interest rate expectations decreased significantly immediately after outburst of the GFC of 2008, reaching their lowest levels around 2014 and 2015, period in which the reference rate in the country reached its historically low level. This was shaped by the sharp deceleration in economic activity in Mexico given the deep trade and financial links with the U.S., the epicentre of the crisis (contrary to other Latin American economies, the Mexican economy did not benefit from large exports to China). This trend was reversed from January 2016 through December 2019, at the same time as authorities began to withdraw monetary

[6]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.

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

[8]Consistent with Li et al. (2017) and Bank for International Settlements (2017).

policy accommodation which led to a period of significant monetary policy tightening. 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.

In order to analyze 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 term premium.[9] 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, as well as other variables not considered in the regression. In particular, in order to explain the constant of the TVP-regression, as an exploratory exercise, we run a linear regression using perception factors that could affect the growth of economic activity in Mexico in the next 6 months, as dependent variables, these are obtained of Banco de México's survey. We find that factors such as fiscal policy that is being implemented, absence of structural change, the level of indebtedness of firms and households explain around 69% of this constant. Thus, the effect of these perception factors and/or these specific premia on the Mexican term premium require further study, which we will address in future work. Specially, the study of the liquidity risk premium, which 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.[10] To the best of our knowledge, this is the first paper that focuses on analyzing the term premium for Mexico on a daily frequency, and to study the determinants that explain its dynamics. In this context, the estimates of the two components of the long-term interest rate: the average expectation of the short-term interest rates and the average of the term premium, as well as the determinants of this premium for Mexico, provide a useful tool to study its evolution, and the relative importance at each moment of time. This, to be able to consider different risk scenarios in the face of changes in any of these components and/or determinants. Additionally, the average expectation of the short-term interest rate can be considered as an indicator of short- or medium-term of the neutral rate.

The paper has the following structure. Section 2 describes the most relevant literature in analyzing 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

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

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

5 displays the estimation and the analysis of the main determinants that describes the evolution of the term premium. Finally, Section 6 concludes.

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.[11] 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.[12] 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.[13] 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.[14]

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.[15] 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

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

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

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

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

[15] See Bernanke (2015).

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.[16] 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.[17]

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 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.[18]

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. Bernanke (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. Albagli et al. (2018) 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 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.[19]

In the particular case of Mexico, as other Latin American economies, continued strengthening its macroeconomic framework prior to the GFC. In 1994, the Central Bank of Mexico became autonomous and its ability to finance the public sector was prohibited. As most central banks in the emerging market

[16] 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.

[17] See Rudebusch et al. (2007) and Rosenberg and Maurer (2008).

[18] See Bernanke (2013,2015).

[19] 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.

spectrum, it abandoned a fixed exchange rate regime and chose a flexible one and inflation targeting as its nominal anchor. After a disinflationary process triggered by the Tequila crisis in the mid-nineties, inflation and its volatility were reduced. Simultaneously, to support this strategy, Mexico took decisive steps to consolidate public finances and strengthen fiscal institutions with the implementation of the fiscal responsibility law in 2006. One aspect that shaped the global influence in the long-term rates was the expansion of local currency sovereign debt markets. This expansion was supported by the pension system institutional reforms that allowed the issuance of longer-term government securities. The Mexican case was not the exception, as it rapidly extended its local denominated yield curve. By 2010, the entrance of government bonds to international indexes that serve as benchmarks for the composition of risky portfolios primed its presence as an international asset.

These fundamentals helped Mexico to sort out the challenges abroad and to intermediate the large inflows coming from the unconventional monetary policies in advanced economies, and moderate their effect in the long-term rates. In this context, it is very important to analyze which component moved the long-term interest rate in Mexico on face of these changes.

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 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.

Finally, in order to obtain robust results, we average our estimations of expected short-term interests rates and term premia, using the three mentioned methodologies.[20]

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

Affine models are standard in the literature.[21] 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, they are obtained recursively and their expressions can be seen in the Appendix 1.

Specifically, the short-term interest is given by:

$$i_t^{(1)} = A_1 + B_1^{'} X_t + \epsilon_t^{(1)} \tag{4}$$

with $A_1 = -\delta_0$ is a constant, $B_1 = -\delta_1$ is a vector, and $\epsilon_t^{(1)}$ are the errors.

[20] As stated in Moral-Benito (2011), choosing only one model for an estimation tends to overestimate real uncertainty. In this context, the author mentions two types of uncertainty: one related to the estimation and is conditional to the model, and another one that is associated to the particular specification of the model. Hence, in order to avoid these uncertainties, he suggests to take the weighted average of the estimations from different models. It is important to point out that, a condition to apply any of the methodologies that help us find those weights such as Frequentist Model Averaging (FMA) and Bayesian Model Averaging (BMA), is to know the information criterion and the number of estimated parameters, as well as the observed value of the term premium, in order to minimize the variance of our estimate. However, this is not possible to do with our models because the observed value of the term premium is not known. In addition, one of the estimations is an average of Swaps of TIIE, so we do not know its information criterion nor the estimated parameters. Additionally, in Aiolfi et al. (2011) find that calculating a simple average of surveys forecasts has a better performance that the best model-based forecast combination, for the majority of the analyzed macro variables and horizons. In this context, Clemen (1989) and Stock and Watson (2001) find that the combination of elaborated models in which multiple parameters are estimated may have lower performance than the combination with equal weights. While the equal-weighted pool might be thought to be biased, it could also have a smaller estimation errors than the pool with estimated data weights, which could offset the bias. So given the reasons above, we decided to give the same weight to each model of our estimation.

[21] 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), Bank for International Settlements (2017), among others. For the case of Mexico see Cortés and Ramos-Francia (2008a,b), Cortés et al. (2008) and Elizondo (2017)

Finally, the expected short-term interest rate in horizon n is defined as:

$$\frac{1}{n}\sum_{i=0}^{n-1} E_t(i_{t+i}^{(1)}) = -\delta_0 - \delta_1^{'}(I + \phi + \phi^2 + ... + \phi^{n-1})\mu + \delta_1^{'} X_t \quad (5)$$

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.[22] 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 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.[23]

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, defined as $rx_{t+1}^{(n-1)}$ in the maturity $n-1$, which is given by four terms. The first one corresponds to the expected return, given by $\beta^{(n-1)'}(\lambda_0 + \lambda_1 X_t)$, where 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., $\beta_t^{(n-1)} = Cov_t[rx_{t+1}^{(n-1)}, \upsilon_{t+1}^{'}]\Sigma^{-1}$, with υ_{t+1} the factor errors and follows a Gaussian distribution with variance-covariance matrix Σ. The second one is derived from a convexity adjustment and is given by $\frac{1}{2}(\beta^{(n-1)'}\Sigma\beta^{(n-1)} + \sigma^2)$. While the third one is the innovation of the price return and is given by $\beta^{(n-1)'}\upsilon_{t+1}$. Finally, the fourth is the error term, $e_{t+1}^{(n-1)}$, with $e_{t+1}^{(n-1)}$ 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,

[22] See for example Dewachter and Lyrio (2006) and Ang and Piazzesi (2003).
[23] The zero-coupon bonds are obtained from Valmer and the nominal interest rate is obtained from PiP.

this makes β constant by construction, thus $\beta_t^{(n-1)} = \beta^{(n-1)}$.[24]

Thus, writing all these terms together we have the excess return equation:

$$rx_{t+1}^{(n-1)} = \beta^{(n-1)'}(\lambda_0 + \lambda_1 X_t) - \frac{1}{2}(\beta^{(n-1)'}\Sigma\beta^{(n-1)} + \sigma^2) + \beta^{(n-1)'}v_{t+1} + e_{t+1}^{(n-1)} \tag{6}$$

Writing equation (6) in matrix terms we have that:

$$rx = \beta^{'}(\lambda_0 1_T^{'} + \lambda_1 X_{\_}) - \frac{1}{2}(B^* vec(\Sigma) + \sigma^2 1_N)1_T^{'} + \beta^{'}V + E \tag{7}$$

The term $\boldsymbol{\beta} = [\beta^{(1)}\beta^{(2)}\dots\beta^{(N)}]$ is the matrix of weights of each factor, $\mathbf{1}_N$ and $\mathbf{1}_T^{'}$ are $(N \times 1)$ and $(1 \times T)$ vectors of ones, respectively. $\mathbf{X}_{-} = [X_0 X_1 \dots X_{T-1}]$ is the matrix of factors lagged. $B^* = [vec(\beta^{(1)}\beta^{(1)'})\dots vec(\beta^{(N)}\beta^{(N)'})]'$, where 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 (7) 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.

$$rx = a1_t^{'} + \beta'\hat{V} + cX_{\_} + E \tag{8}$$

   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 $Z = [1_T\ \hat{V}'\ X_{\_}^{'}]'$, 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:

$$\begin{aligned}\hat{\lambda_0} &= (\hat{\beta}\hat{\beta}')^{-1}\hat{\beta}[\hat{a} + \frac{1}{2}(\hat{B}^* vec(\hat{\Sigma}) + \hat{\sigma^2}1_N)] \\ \hat{\lambda_1} &= (\hat{\beta}\hat{\beta}')^{-1}\hat{\beta}\hat{c}.\end{aligned} \tag{9}$$

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

[24] All details of this derivation can be consulted in Adrian et al. (2013).

Once all the parameters have been estimated, we built the coefficients of equation 17 and calculate yields through equation 17.

In this model, if λ_0 and λ_1 are equal to zero in recursive coefficients given by 17, 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.[25] 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 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;[26] 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

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

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

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 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.[27] 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.

3.4. Comparison Between Methodologies

In this section we describe the differences between the models used for the estimation of the expected short-term interest rate.

Even though the affine models KW and ACM, use the temporal structure of interest rates in order to get the expected short-term interest rate in a long-term horizon, their econometric techniques are different, as well as their specifications. KW only uses some of the maturities of zero coupon bonds and includes three latent factors that use the Kalman filter for its estimation. Furthermore, the model parameters and these factors are jointly estimated using maximum likelihood, which makes the model more difficult to estimate computationally. On the other hand, ACM uses more maturities of zero-coupon bonds, includes five observable factors estimated through principal components and estimates the parameters using multiple linear regressions, which makes the estimation less demanding computationally.

Another important difference between these two models is the fact that, the estimations of the expected interest rates that come from ACM are likely to overreact to changes in the general level of interest rate, given that these estimations only use information coming from interest rates. In particular, these tend to interpret a change in interest rates as evidence that the stationary state of the expected short-term interest rates (in the long term) has changed, which causes overreaction on the projections

[27] The TIIE swaps are obtained from Bloomberg.

Table 1: *Differences Between Models*

KW	ACM	Swaps of TIIE
Estimation period		
From January 2004 to December 2019		
Factors		
3 latent	5 observed	NA
Estimated using Kalman filter	Estimated using principal components	NA
Interest rate's maturities (in months)		
1, 3, 6 ,12 ,24, 36, 60, 84, 120	1, 2, 3, 4, 5, ..., 120	12, 36, 60, 84, 120
Estimation method		
Maximum likelihood	Multiple linear regressions	Arithmetic average

of long-term interest rates. Nevertheless, expected short-term interest rates coming from KW capture the high persistency observed in interest rates, given that the factors are estimated using the Kalman filter, which means that its trend is highly correlated with these rates. As in ACM, in KW the factors explaining interest rates are derived only from these rates.

Additionally, some advantages of using Swaps of TIIE to estimate the expected short-term rate it uses observed data, few maturities and it is a measure that considers economic agents expectations of the short-term interest rate in different horizons coming from financial instruments, reflecting agents portfolio positions. In this context, it is important to mention that given the degree of development of Mexican financial markets, the information included in these instruments is reliable and useful for the analysis of the expected short-term rate. On the other hand, disadvantages of these instruments are that they could include some risk premiums that we are not accounting for as well as consider arbitrage opportunities.

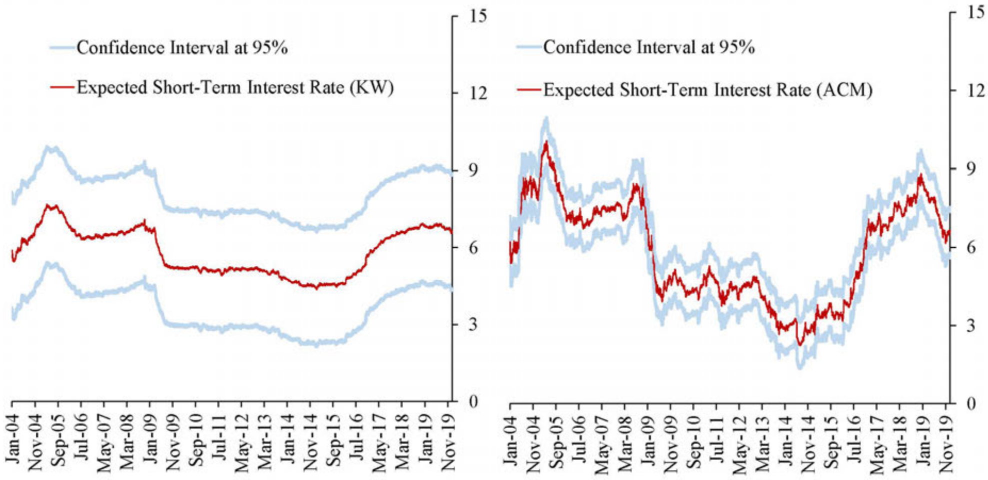
Table 1 presents the differences between the models.

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.

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.



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

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

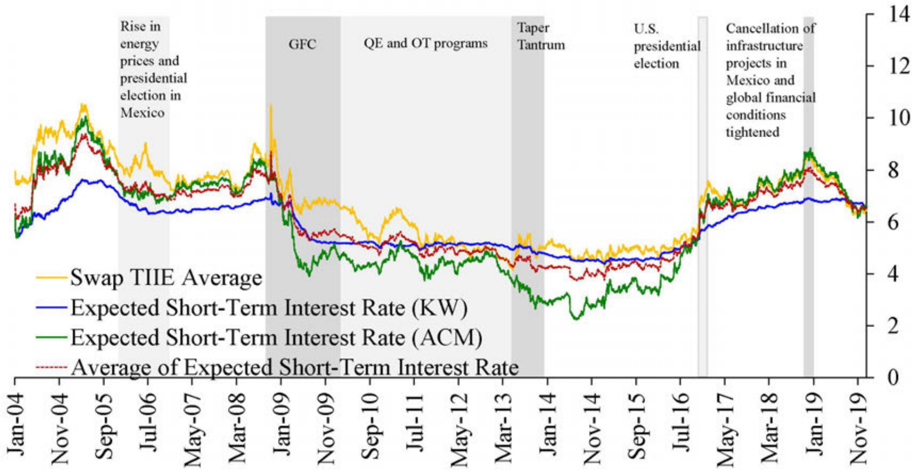
Figure 2 shows the expected short-term interest rates using three methodologies. We observe that the estimated interest rates have different levels but very similar dynamics. In fact, the correlation between these estimations is above 90%.[28]

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

[28] 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.

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%.



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.

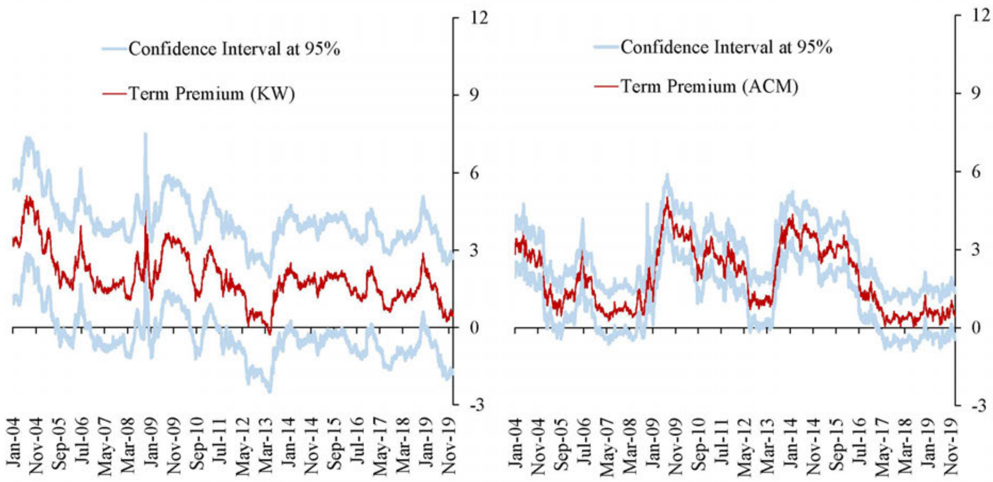
Figure 2: *Expectations of Short-Term Interest Rates*

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.

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

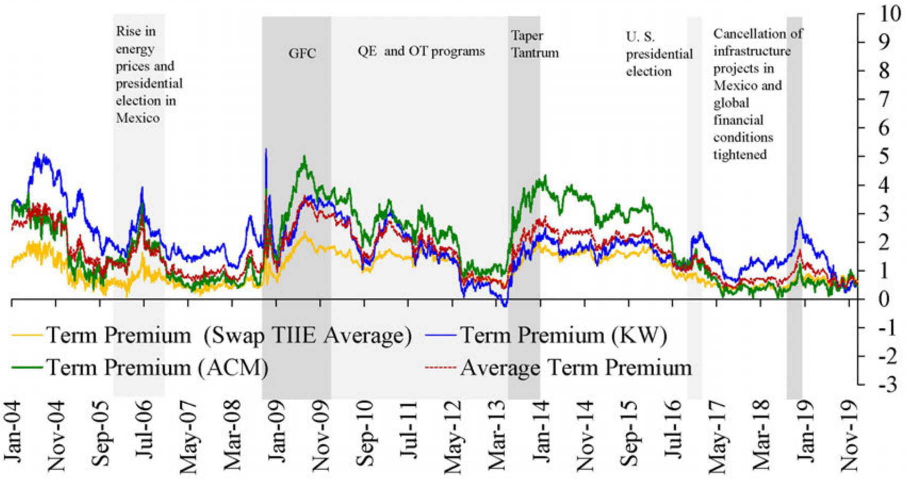


Note: Confidence intervals are estimated using the Monte Carlo method with 10000 trajectories. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

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

2006, the liberalization of gasoline prices in January 2017, which led to an increase in inflation and its expectations, and was accompanied by an increase in the reference interest rate, and the cancellation of some infrastructure projects in October-November 2018, which open the door to policy uncertainty. 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.

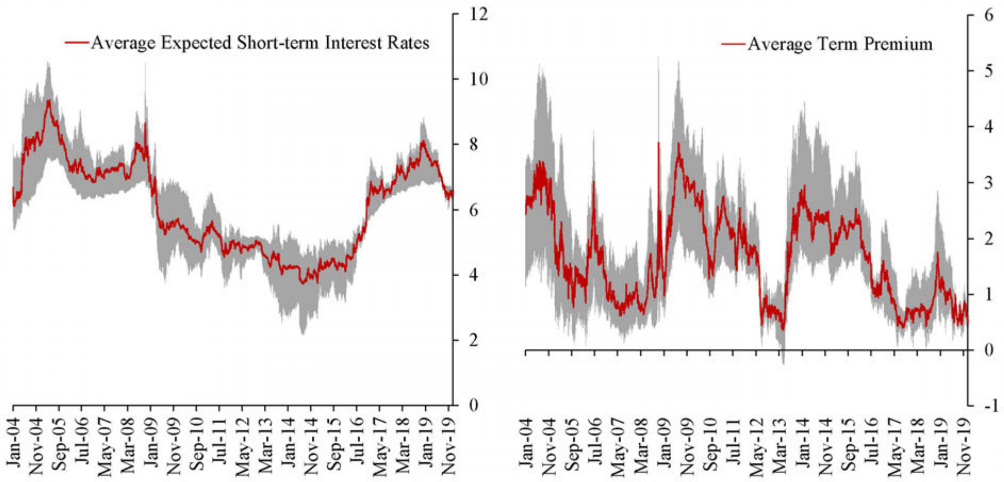


Note: The term premium is the residual between the 10-year government bond interest rate and the expected short-term interest rate in the long-term. The latter is estimated using three different methodologies including two affine models and TIIE swaps. *Source:* Own estimates with data from Bloomberg,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

Figure 4: *Term Premia*

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.



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.

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

Results suggest that during stress periods when the term premium increases, the estimates show higher dispersion, thus the range increases too. According to Table 2, 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 2, 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.

Table 2: *Summary of Annual Results: Components of 10-Year Interest Rate*

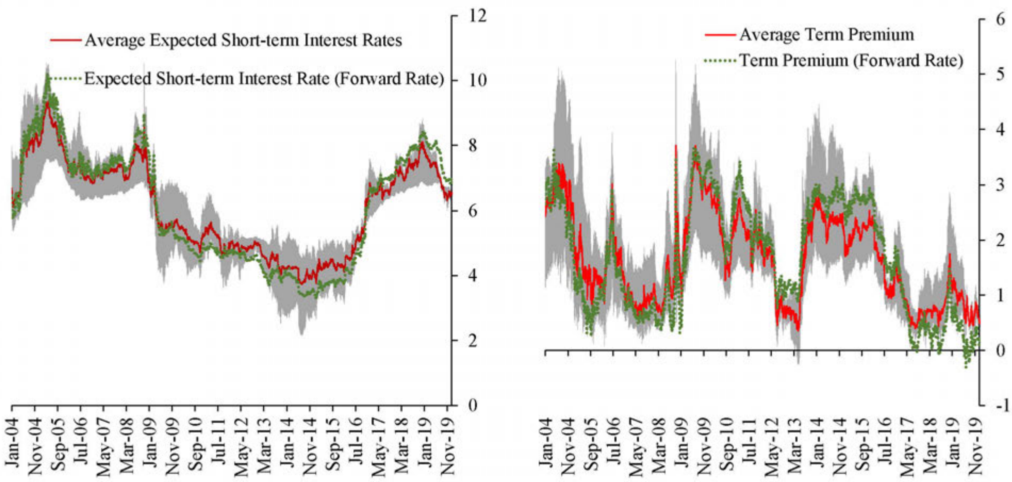
Years	*10-year* Int. Rate	*Exp. Short-Term Rate* Low Range	Point Est.	High Range	*Term Premia* Low Range	Point Est.	High Range
2004	10.35	6.21	7.46	8.76	1.56	2.87	4.12
2005	9.98	7.38	8.46	9.32	0.65	1.51	2.60
2006	8.77	6.51	7.17	8.00	0.75	1.59	2.25
2007	8.09	6.49	7.20	7.65	0.43	0.89	1.60
2008	8.74	6.73	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.

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.[29]

[29]Using the methodology of James et al. (2017) the term premium is estimated directly, using the current and predicted movements of the forward rates. In the case of Mexico, there are no forward rates for the short-term interest rate, so these are



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.

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

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 measure of the short-term interest rate in the short and medium run.

In particular, the neutral interest rate is the one that keeps the output gap closed in a stable inflation environment, and is conditioned by structural or transitory factors. In this context, the long-term neutral interest rate depends on structural factors, which are expected to vary slowly over time, such as population growth. Whereas, the short- or medium-term neutral interest rate depends on transitory factors, or shocks, and fluctuates around its long-term level. These shocks, although temporary, can be very persistent. It is worth mentioning that the neutral interest rate helps to identify the monetary policy stance in a Central Bank, hence its importance in knowing it. In this context, the estimation of the average expectations of the short-term interest rate in the long term can provide an approximation of the neutral interest rate in the short and medium term.

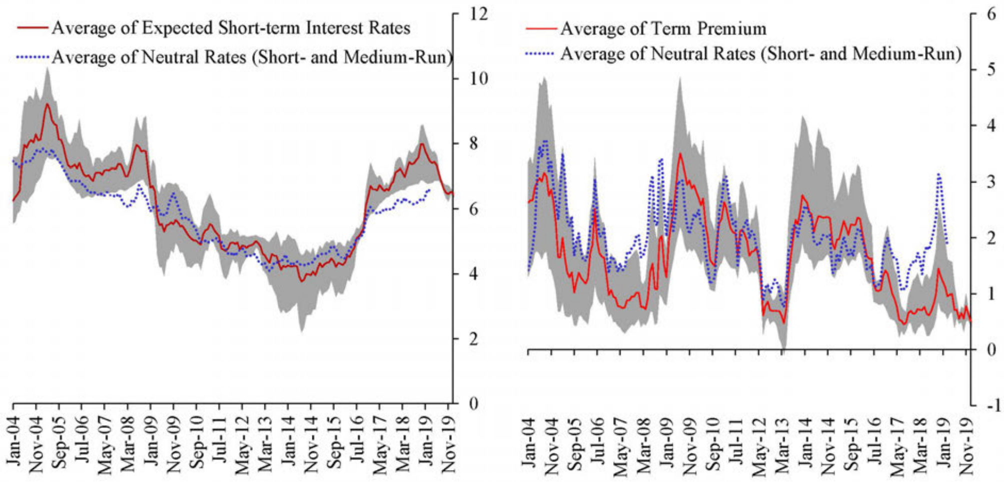
In order to obtain the neutral rate, we average the estimations of the short and medium run of the nominal neutral rates estimated by Carrillo et al. (2018), updated to March 2019, except those related to affine models. Additionally, we compare the neutral term premium, obtained as the difference between 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).

Now, to show robustness check of the term premium we illustrate the countercyclical properties of this with respect to economic activity. To do this, we estimate a SVAR with signs restrictions impose at impact of shocks, for the period 2004-2019, estimated with Bayesian methods, in order to identify a monetary policy, an aggregated demand and a financial risk shocks.[30] It is assumed that United States is an exogenous block to Mexico. The model considers macroeconomic and financial variables from the United States and Mexico. For the former, we include the economic policy uncertainty index (EPU), total factor productivity growth, the output gap, core inflation, the shadow federal funds rate, the term premium, and a measure of the financial cost premium of companies.[31] The Mexican variables considered are the output gap, underlying inflation, overnight interest rate, the exchange rate, the EMBI and

estimated directly from the interest rates on government bonds with standard formulas. Therefore, the estimates of the term premium using this methodology could be a good proxy to compare our estimate with the one that comes from hard data of the corresponding interest rates, without neglecting that any estimate of the term premium is an unobservable variable, so we do not know its level for sure. In this sense, the levels and dynamics of both estimates are very similar, which gives us more confidence in the dynamics of said premium.

[30] These restrictions follow to Carrillo et al. (2020)

[31] In particular, the monthly average EPU from Baker et al. (2012) is used; Fernald (2012) measure of productivity; a monthly interpolation of the quarterly series of the GDP and the potential GDP of the CBO; the PCE index that excludes food and energy; the average of three shadow rates of the federal funds rate proposed in the literature (Krippner (2015); Wu and Xia (2016); and Lombardi and Zhu (2018)), the average shadow rate takes negative values during the period of time in which the rate of federal funds equaled its lower limit of zero); the term premium is measured as the difference between the 10-year and 2-year Treasury bond rates; Finally, the financial cost premium for companies is measured as the difference between the average of Baa-rated Moody's corporate bonds and the 10-year Treasury bond rate.



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.

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

the term premium.[32]

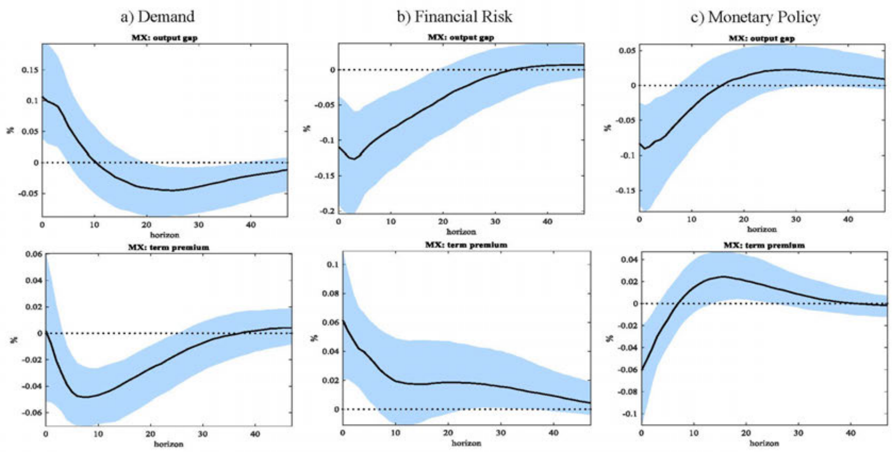
In order to analyses these shocks, we show the impulse-response functions. In Figure A1 we illustrate an aggregate demand shock. In the face of this shock, the economic activity, the prices and the interest rate increase. This boom in the economy makes investors see better economic prospects in the future, which generates lower term premia, also lowering the sovereign risk and generating an exchange rate appreciation. In this context, the economic activity and the term premium moves in opposite senses, see panel a) of the Figure 8.

Analogously, Figure A2 shows a financial risk shock. In the face of this shock, the term premium and sovereign risk increase, this generates an exchange rate depreciation. This makes that investors perceive bad economic perspectives in the future causing a drop in economic activity. While the inflation and the short-term interest rate do not have changes. Similarly, to demand shock, the economic activity and the term premium moves in opposite senses, see panel b) of the Figure 8.

In the case of a monetary policy shock of the Figure A3, the economic activity and the prices fall, there is an exchange rate appreciation, and because this shock is by stabilising the economy investors do not perceive risk, therefore, the sovereign risk and the term premium decrease to this shock. In this case, the economic activity and the term premium move in the same sense, see panel c) of the Figure 8.

It is worth mentioning that, Crump and Gospodinov (2022) comment that care must be taken in estimating the term structure of interest rates with few factors, because up to now it is not clear what is the precise characterization of the true factorial structure of the data by the correlation that exists in the cross-section of the maturities of said structure. Therefore, there may be a certain weakness in the methods based on selecting a minimum number of factors, since these methods may not be reliable because these chosen factors may not be informative. This could affect the estimation of the affine models KW and ACM, that are based on the estimation of factors, the first with 3 factors and the second with 5 factors. On the one hand, although the number of factors differs in both models and the way to estimate them is with different methodologies, Kalman filter and principal component analysis respectively, the estimates of the short-term rate expectations and term premia are similar and highly correlated. It is worth mentioning that, the estimated parameters of the ACM model by Adrian et al. (2013) is based on yield returns and testing with a different number of factors which is the best estimate of this model, as Crump and Gospodinov (2022) make in their paper. In the case of ACM model for Mexico, we make the same obtaining better results with 5 factors. On the other hand, we get similar results from affine models in comparison with the average of the TIIE swaps, the neutral rate and the James et al. (2017), whose models do not involve the estimation of factors, which gives us confidence that the estimate of the expectation of the short-term interest rate in the long term and the term premium is robust with the tools that have been developed to date. Without forgetting that, all models are perfectible and none of them represents exact reality, so there is a lot of work to be done to develop better theoretical and empirical models that can estimate in a better way the term structure of interest rates, as well as the two components of the long-term interest rate.

[32] To calculate the output gap, monthly GDP was estimated following the Elizondo (2012) methodology; The term premium is measured as the difference between the 10-year and 2-year bond rates. For the daily variables, the monthly averages were taken. The variables for the United States were obtained from the FRED of St. Louis, the San Francisco Fed, the Atlanta Fed, and the New York Fed. The data for Mexico were obtained from INEGI, Banco de México, Valmer, PiP and Bloomberg.



Note: The x-axis denotes months after the shock, while the y-axis are percent points away from the long-run equilibrium value of a variable. The uncertainty band covers 68% of the distribution, and the continuous line is the median of the distribution. The IRF correspond to a 1 standard deviation innovation. *Source:* Own estimates with data from Bloomberg,FRED of St. Louis, San Francisco Fed, Atlanta Fed, New York Fed, INEGI, Banco de México, Valmer, and PiP.

Figure 8: *Economic Activity and Term Premium for Different Shocks*

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

5. Determinants of the Average Term Premium

The literature has documented that term premium dynamics can be mainly explained by two determinants: a real term premium and an inflationary risk premium.[33] 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 long-term interest rates in EMEs, and that their correlation is positive. Additionally, Albagli et al. (2018) showed that changes in the U.S. term premium dominate changes in EMEs yields. 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.[34]

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

To study the extent to which each of these determinants explain the Mexican term premium over time, we estimate a time-varying parameter regression, or TVP regression. In particular, we use the average of the previously presented term premium estimations as our dependent variable and estimate the model using Bayesian methods as follows:[35]

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

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.[36] 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 the coefficients.[37]

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

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

[35] 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, as our training sample. $30,000$ iterations were considered, of which only $2,000$ of them were taken into account to estimate the posterior parameters.

[36] 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.

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

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;[38] ii) the real compensation as a proxy of the real term premium, calculated as the difference between the 10-year and 3-years real interest rates.[39] 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;[40] and finally, iii) the inflationary risk premium, which is not available on a daily frequency so we use the compensation for FX risk computed as the difference between the 10-year Mexican Government bonds denominated in Mexican pesos and in dollars (UMS) as a proxy.[41][42]

Prior to the estimation, we did Granger Causality tests to assess whether these variables could be considered determinants of the Mexican term premium. The results in Table A1 in the Appendix show that the null hypothesis for the U.S. term premium, the real compensation and the compensation of FX risk are rejected, i.e., these three variables Granger cause the Mexican term premium. Conversely, the Mexican term premium does not Granger cause any of them.

According to the estimate of our TVP regression, Table 3 shows the average coefficients, estimated considering the entire sample, all of which are statistically different from zero. The three determinants impact the Mexican term premium positively, namely, if any of these increases (decreases) then the premium increases (decreases). The positive or negative contribution to the term premium depends on the performance (i.e. magnitude) of each variable over time.

Additionally, Figure 9 shows the dynamics of the estimated coefficients.[43] 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

[38]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/ .

[39]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.

[40]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.

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

[42]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. Additionally, 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 A4 in the Appendix A 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%. 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.

[43]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 3: *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.

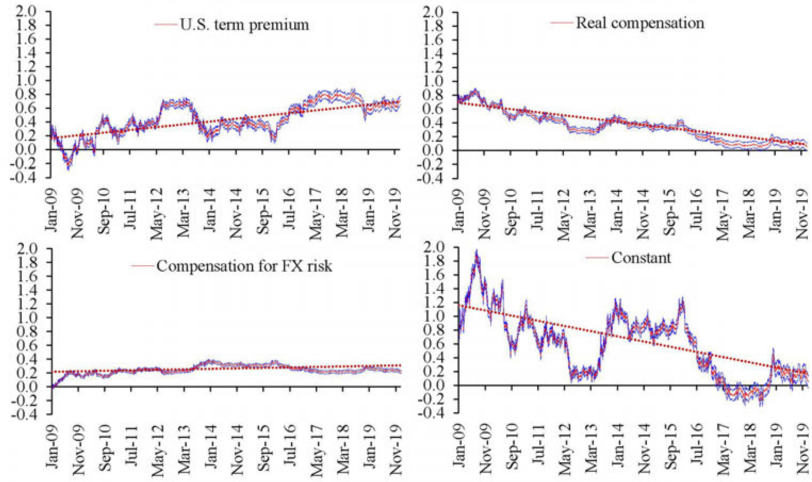
2019.[44] Conversely, the real compensation coefficient lost importance throughout time, going from a level from 0.8 to one of 0.1.[45] Mean while, the coefficient of the compensation for FX risk remained relatively close to an average level of 0.24. It is worth mentioning that the first two coefficients are more volatile than the last one. Finally, the constant coefficient also lost relevance over time. The latter can be interpreted as the level of the Mexican term premium or as omitted variables, which have not been constant over time. Indeed, this coefficient reached levels near zero from 2017 to 2019.[46]

Figure 10 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 the swings registered in 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 in 2017, when the real term premium is no longer relevant to explain the behavior of the Mexican term premium. Additionally, we observe that the compensation

[44]The positive trend in the coefficient of the U.S. term premium gained relevance over time, although long-term interest rates in the U.S., as well as its term premium, are a benchmark for the global factor that affects interest rates in Mexico and in the World during periods of stress, such as for example, the global financial crisis, the taper tantrum and the presidential elections in 2016, periods in which international financial markets were affected by high volatility, this supports the correlation that exists both in the long-term interest rates between Mexico and the U.S., and in their respective term premia, as well as the effect that U.S. rates have on those of Mexico.

[45]The negative trend observed in the real compensation coefficient is supported by the improvement of the fundamentals that occurred in Mexico in the analysis period, such as the adoption of a flexible exchange rate scheme at the end of the 90's, the inflation targeting regime adopted at the beginning of the 2000s, the consolidation of public finances by the fiscal responsibility law in 2006, the expansion of the sovereign debt markets in local currency that was reflected in the reform of the pension system around of 2006. Additionally, in 2010 Mexico entered the international index of government bonds, which serve as the basis for the composition of risk portfolios. The latter helped capital inflows in the period when unconventional policies were adopted in advanced economies after the global financial crisis.

[46]If the global factor is not considered in the estimate, that is the U.S. term premium, from Figure A5 we see that the compensation for FX risk has no changes with respect to the estimate where said premium is included. Additionally, the downward trends are maintained for the real compensation and for the constant with less volatility for the former. Nevertheless, the average coefficient for real compensation is lower when the U.S. term premium is not included.

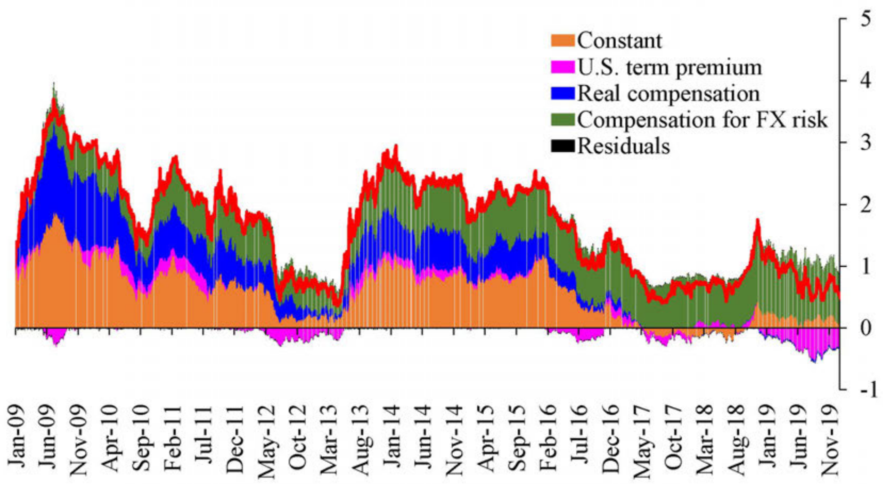


Note: The coefficients are estimated using TVP regression. The dotted blue line are the confidence intervals to 16% and 84%.*Source:* Own estimates with data from Bloomberg, PiP and Valmer.

Figure 9: *TVP Regression Coefficients*

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.[47]

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.



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.

Figure 10: *Term Premium and its Determinants*

In the following Subsection, we study in more detail the behavior 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 the 2016 U.S presidential election.

[47]Figure A6 shows the contributions of the determinants of the Mexican term premium without considering the U.S. term premium. We observe that, on average, the contributions do not change for the compensation for FX risk and the real compensation. However, the part that was explained by the U.S. term premium in Figure 10 is captured by the constant in Figure A6.

5.1. Mexican Term Premium: Three Relevant Episodes

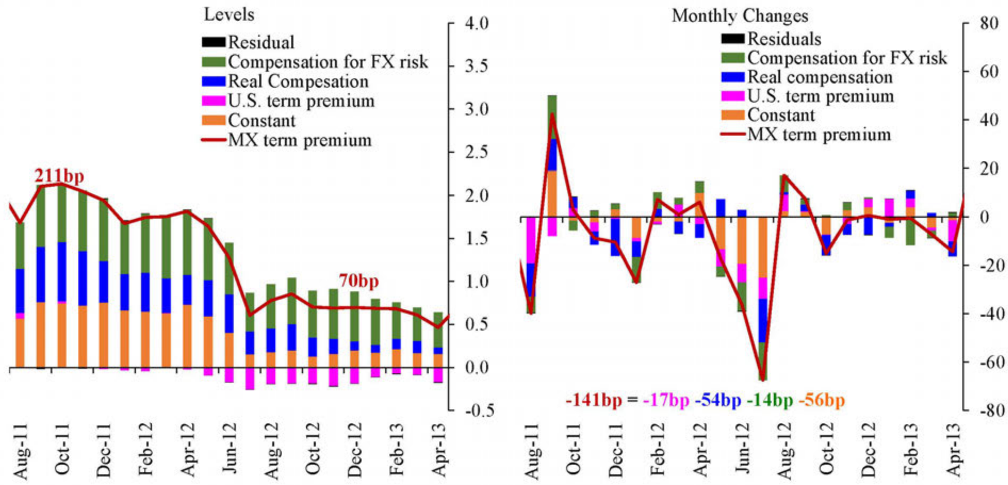
Now that we have estimated the dynamics of the determinants of the term premium over time, we analyze the contribution of each determinant during three relevant episodes where the Mexican premium showed sharp changes: the Operation Twist programs that were implemented from September 2011 to December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

5.1.1 First Episode - Operation Twist (OT)

From September 2011 to December 2012, the Federal Reserve implemented two Operation Twist programs in the U.S. The first from September 2011 to June 2012, and the second one, 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 strong capital inflows into EMEs, which significantly reduced interest rates in these economies, particularly long-term ones.The slowdown of global economic activity that started in the second half of 2011 and lingered throughout 2012 also translated into a deceleration of GDP growth in Mexico while the absence of inflationary pressures in the country led to well behaved inflation dynamics amid relatively low monetary policy rates. Figure 11 shows that during this time, the Mexican term premium decreased 141bp, from which 17bp corresponds to the decline in the U.S. term premium (the former reached its historical minima), 54bp due to the fall in real compensation, only 14bp due to a compensation for FX risk, and 56bp due 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.

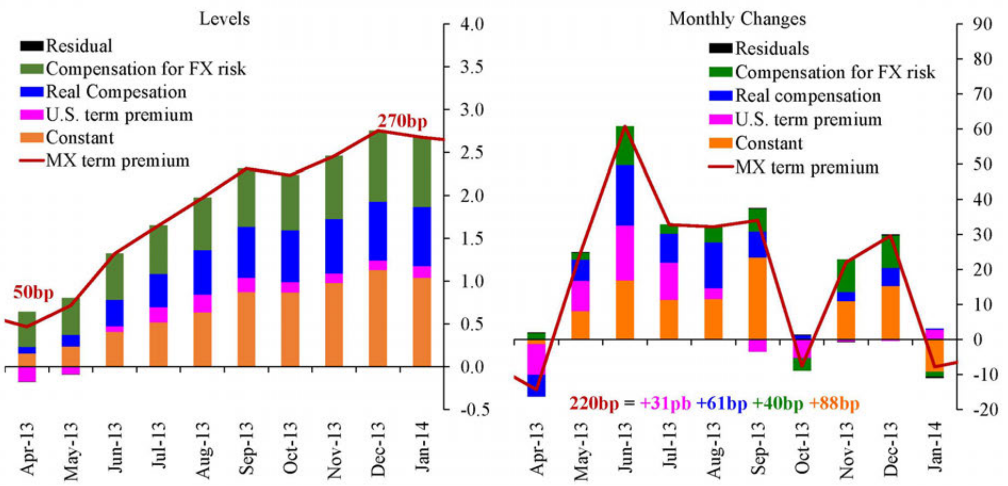
5.1.2 Second Episode - Taper Tantrum

The Taper Tantrum, from April 2013 to January 2014, started when the Fed's Chairman Ben Bernanke announced the possibility of reducing the volume of its bond purchases in the future, 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 soon, investors sold their holding causing prices to drop significantly. This, in turn, triggered increases in both yields and the term premium. As a consequence, international financial markets presented high volatility. This had an important effect reflected in capital outflows from EMEs. Amid a difficult external context, economic activity in Mexico decelerated and domestic financial assets deteriorated albeit maintaining orderly market conditions, as inflation levels increased due to the increase in volatile items and a tax increase at the beginning of 2014. Despite this, the country's relative perception $vis-\grave{a}-vis$ its peers did not deteriorated given the positive prospects that the entry into force of various structural reforms entailed. Figure 12 shows that this outlook was reflected in a 220bp increase in the Mexican term premium, of which the greatest effects, 61bp, can be explained by the real compensation, 40pb by the compensation for FX risk, 31bp comes from the U.S. term premium, and 88bp from the constant.



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.

Figure 11: *Operation Twist Programs (September 2011 - December 2012)*

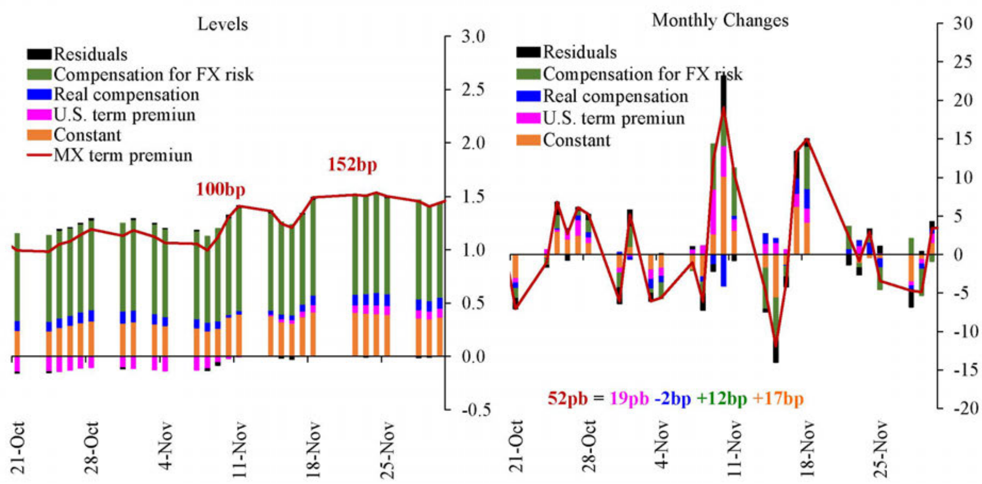


Note: The contribution of each determinant is obtained multiplying each variable by its corresponding coefficient. *Source:* Own estimates with data from Bloomberg, PiP and Valmer.

Figure 12: *Taper Tantrum (April 2013 - January 2014)*

5.1.3 Third Episode - U.S. Presidential Election

The third analyzed episode ranges from November 8 to November 18, 2016 and corresponds to the presidential elections in U.S. 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, to the electoral process carried out in the U.S.toward the end of the year. The macroeconomic challenges that the rhetoric of the newly elected president and its implications for the trade relationship between Mexico and the U.S., triggered a significant depreciation of the Mexican peso and 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. Figure 13 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.



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.

Figure 13: *U.S. Electoral Process (November 8, 2016 - November 18, 2016)*

5.1.4 Constant vs Perception Factors from Banco de Mexico's 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 to the prevailing juncture and to internal factors that could have an affect in short periods of time. As an exploratory exercise, we run a linear regression in an attempt to find variables that could explain the behavior of this constant.[48]

We use as a dependent variable the constant parameter in the TVP regression and as explanatory variables perception factors that could affect growth perspectives 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 monthly collected by Banco de Mexico. They are measured as a percentage distribution of responses and include: the prevailing fiscal policy (PFI), absence of structural change (ACEM), level of fimrs' and household's indebtedness (NEE and NEF, respectively).[49] The linear regression coefficients are represented in Table 4. All coefficients are significant at the 1% or 5% confidence level and these perception factors explain around 69% of the TVP regression constant.

Table 4: *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.

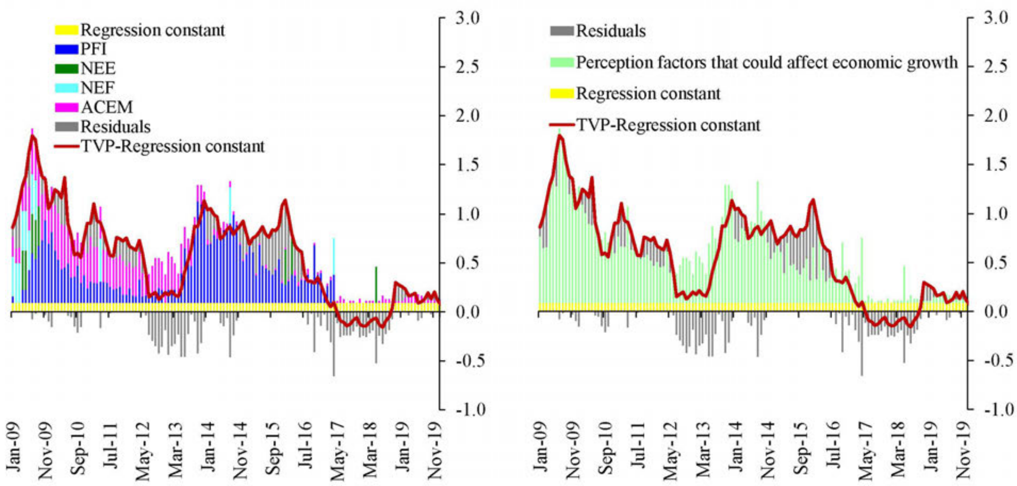
The left-hand side graph of Figure 14 shows the contribution of each perception factor, while the right graph of the same Figure displays the sum of all their contributions. Effectively, these perceptions factors seem to explain an important part of our TVP regression constant, and they gained relevance at different periods of time.

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.

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

[49]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?.



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.

Figure 14: *Constant vs Perception Factors*

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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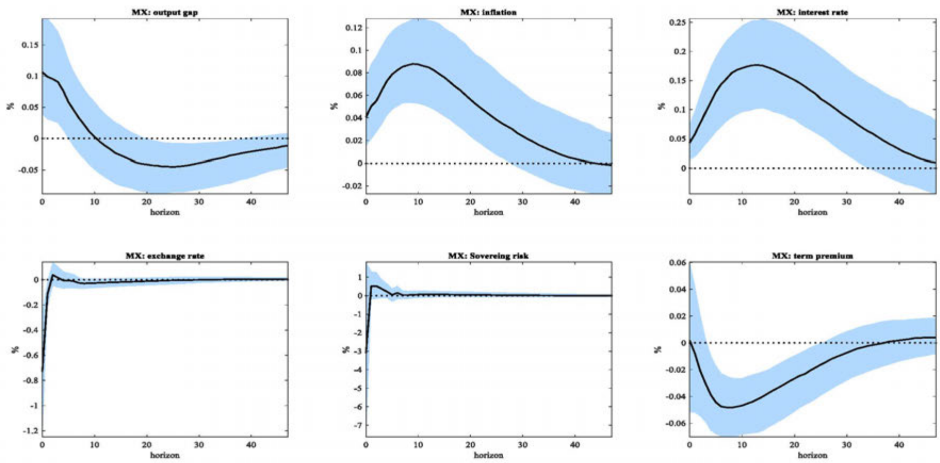
A. Additional Tables and Figures

Table A1: *Granger Causality*

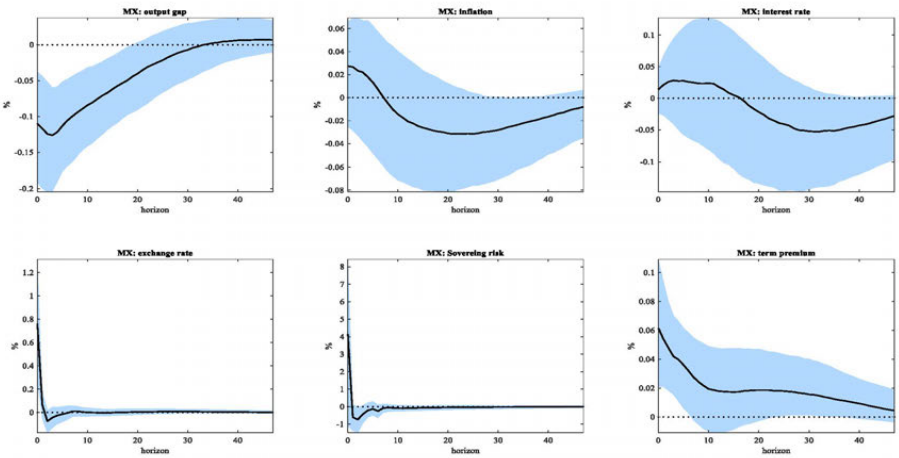
Null Hypothesis	Lags	Obs.	F-Statistic	Prob.
U.S. TP does not Granger Cause MX TP	1	2869	6.334	0.012
MX TP does not Granger Cause U.S. TP	1	2869	0.685	0.410
Real Comp. does not Granger Cause MX TP	1	2869	2.978	0.022
MX TP does not Granger Cause Real Comp.	1	2869	1.225	0.304
Comp. FX Risk does not Granger Cause MX TP	1	2869	13.229	0.000
MX tP does not Granger Cause Comp. FX Risk	1	2869	0.330	0.566

Note: TP is term premium and Comp. is Compensation. The lags are in months and Obs. are defined in days. The sample covers from January 2009 to December 2019. A probability less than 0.05 means that the null hypothesis is rejected.



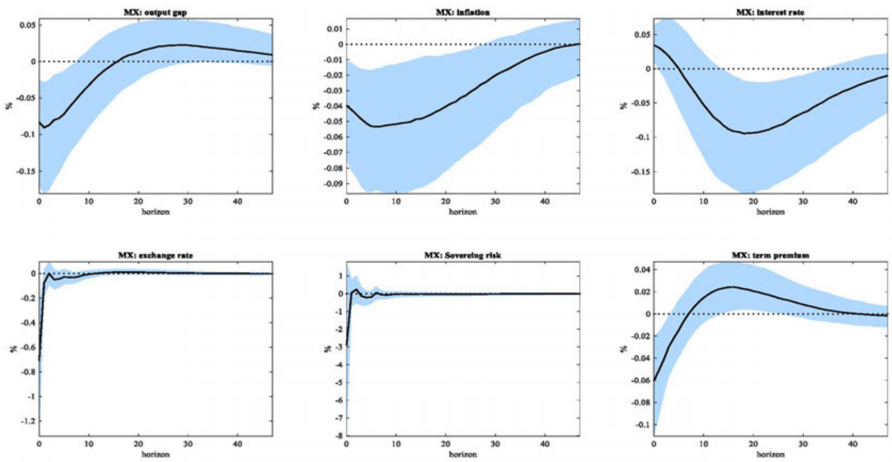
Note: The x-axis denotes months after the shock, while the y-axis are percent points away from the long-run equilibrium value of a variable. The uncertainty band covers 68% of the distribution, and the continuous line is the median of the distribution. The IRF correspond to a 1 standard deviation innovation. *Source:* Own estimates with data from Bloomberg,FRED of St. Louis, San Francisco Fed, Atlanta Fed, New York Fed, INEGI, Banco de México, Valmer, and PiP.

Figure A1: *Aggregate Demand Shocks*



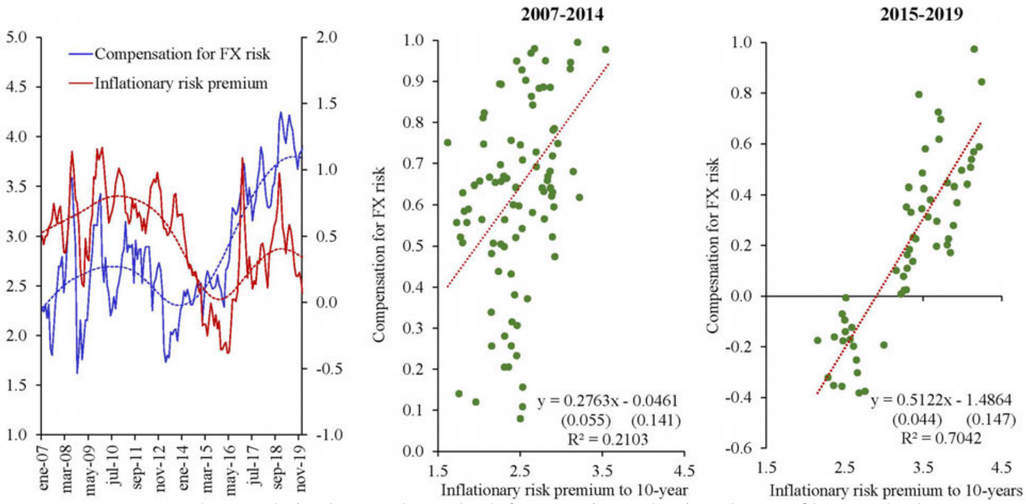
Note: The x-axis denotes months after the shock, while the y-axis are percent points away from the long-run equilibrium value of a variable. The uncertainty band covers 68% of the distribution, and the continuous line is the median of the distribution. The IRF correspond to a 1 standard deviation innovation. *Source:* Own estimates with data from Bloomberg,FRED of St. Louis, San Francisco Fed, Atlanta Fed, New York Fed, INEGI, Banco de México, Valmer, and PiP.

Figure A2: *Financial Risk Shocks*



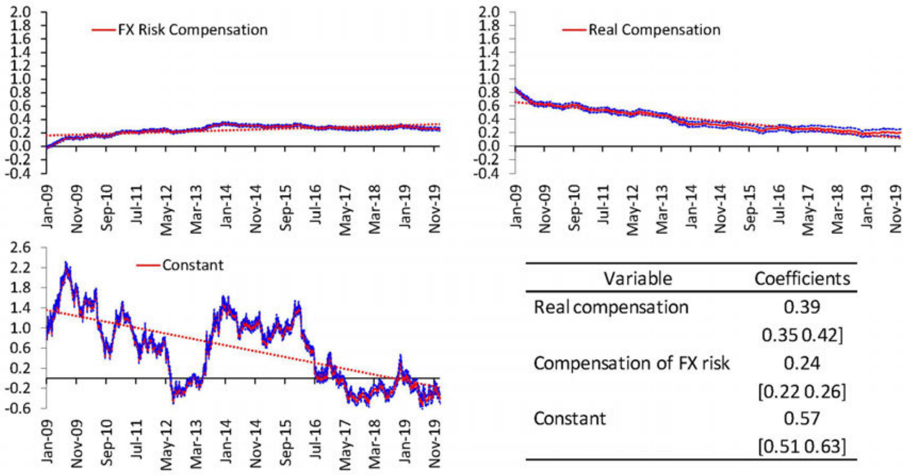
*Note:*The x-axis denotes months after the shock, while the y-axis are percent points away from the long-run equilibrium value of a variable. The uncertainty band covers 68% of the distribution, and the continuous line is the median of the distribution. The IRF correspond to a 1 standard deviation innovation. *Source:* Own estimates with data from Bloomberg,FRED of St. Louis, San Francisco Fed, Atlanta Fed, New York Fed, INEGI, Banco de México, Valmer, and PiP.

Figure A3: *Monetary Policy Shocks*



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.

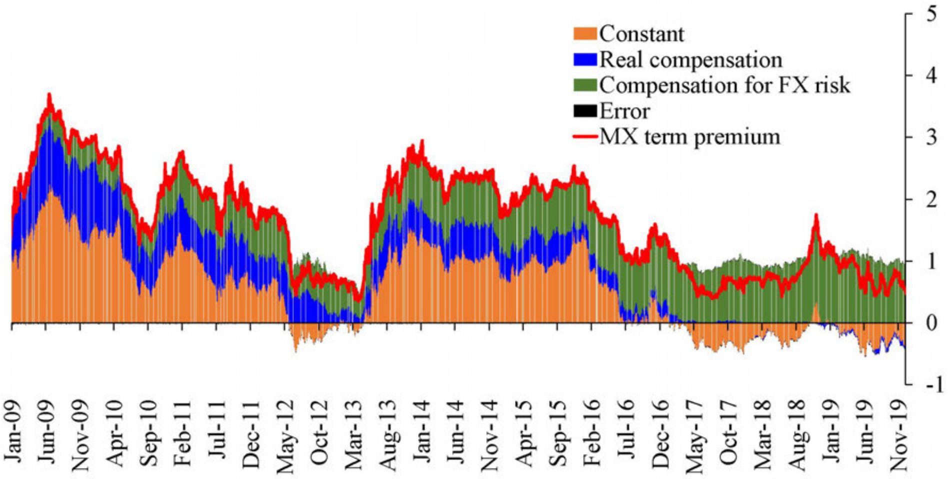
Figure A4: *Compensation for FX risk and Inflationary Risk Premium*



Variable	Coefficients
Real compensation	0.39
	0.35 0.42]
Compensation of FX risk	0.24
	[0.22 0.26]
Constant	0.57
	[0.51 0.63]

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 A5: *TVP Regression Coefficients without U.S. Term Premium*



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.

Figure A6: *Term Premium and its Determinants without U.S. Term Premium*

B. Affine Model Specifications

As mentioned in the document, interest rates in the affine models are defined as:

$$i_{t,t+n} = A_n + B_n^{'} X_t \tag{10}$$

where: $i_{t,t+n}$ is a vector of the yield in time t of every zero-coupon bond with maturity $t + n$. X_t represents the group of variables to which yields $i_{t,t+n}$ respond in time t. A_n and B_n are coefficient matrices (or weights) associated with each variable in X_t, for every maturity n.

Additionally, affine models are built by other basic equations: The first equation sets the factors or state variables dynamics X_t, as a $VAR(1)$:

$$X_t = c + \Omega X_{t-1} + \Gamma \xi_t \tag{11}$$

where $\xi_t \sim N(0, \Sigma\Sigma^{'})$ represents a vector of shocks i.i.d. and c, Σ and Γ are coefficient matrices.

The second equation describes the short term interest rate dynamics, $i_{t,t}$, as a linear function of the state variables:

$$i_{t,t} = \delta_0 + \delta_1^{'} X_t \tag{12}$$

The third equation defines the dynamics of the market risk premia, λ_t, also as a linear function of the state variables:

$$\lambda_t = \lambda_0 + \lambda_1 X_t \tag{13}$$

Regarding this last equation it is important to mention that, given that the market risk premia are variables, affine models allows the dynamics of the interest rates term structure (IRTS) to be consistent with deviations from the Expectations Hypothesis. According to this hypothesis, long term yields are the average of the future short-term yields plus a constant term premium.[50] In this context, the premia dynamics is associated with the source of uncertainty of the model, given by shocks of the state variables λ_t. Hence, the dynamics of the IRTS are function of the factors' error characteristics, λ_t. It is mentionable that the information regarding these premia is implied in the coefficients of A_n and B_n. An additional important characteristic of affine models is that its theoretical derivation can be associated with an optimization problem in which agents take decisions with respect to their asset holdings by rational expectations. In this setting, bond prices used to calculate yields in this type of models, derived from optimal conditions regarding asset valuations, consider that arbitrage opportunities in debt markets are exhausted in equilibrium.

In particular, the marginal cost (the price) of acquiring a bond has to be equal to its expected benefit (expected flows). Given that it is a zero-coupon bond, the expected flow in $t + 1$ is the price of selling it:

$$P_{t,t+n} = E_t[M_{t+1} P_{t+1,t+n-1}] \tag{14}$$

[50] Cortés et al. (2008), and García-Verdú (2011) document the existence of term premium that vary over time while analyzing the evolution of the IRTS in Mexico, which does not comply with the expectation's hypothesis.

where: $P_{t,t+n}$ is the price in t of a zero-coupon bond with maturity in period $t+n$. E_t are the expectations. M_{t+1} represents the statistical discount factor at which agents value one unit in $t+1$. $P_{t+1,t+n-1}$ is the number of units that can be obtained from the bond in $t+1$. Based on equation 14, it is possible to express the price of the asset recursively. Hence, M_{t+1}, can be defined as:

$$M_{t+1} = exp(-i_{t,t} - 0.5\lambda_t^{'}\lambda_t\xi_{t+1}) \tag{15}$$

where $i_{t,t}$ and λ_t are given by (12) and (13). Intuitively, this implies that the value of the unit of count in $t+1$ depends on the short-term interest rate and on the present and future uncertainty related to the evolution of the state variables through λ_t and ξ_t. If M_{t+1} is defined as in (15), then from (14) and (15) we can obtain that the bond prices greater than $n=1$ are a function of the state variables X_t.

Specifically, after some algebra, bond prices can be defined by:

$$P_{t,t+n} = exp(\bar{A}_n + \bar{B}_n^{'}X_t) \tag{16}$$

And its yield:

$$i_{t,t+n} = \bar{A}_n + \bar{B}_n^{'}X_t \tag{17}$$

where the last expression can be derived from $i_{t,t+n} = -log(P_{t,t+n})/n$ and:

$$\begin{aligned}
A_1 &= -\delta_0;\ \ B_1 = -\delta_1 \\
\bar{B}_{n+1}^{'} &= B_1^{'} + \bar{B}_n^{'}(\Omega - \Gamma\Sigma\lambda_1) \\
\bar{A}_{n+1} &= A_1 + \bar{A}_n + \bar{B}_n^{'}(c - \Gamma\Sigma\lambda_0) + 0.5\bar{B}_n\Gamma\Sigma\Sigma^{'}\Gamma^{'}\bar{B}_n^{'} \\
A_n &= -\bar{A}_n/n;\ \ B_n = -\bar{B}_n/n.
\end{aligned}$$