Does the Exchange Rate Respond to Monetary Policy in Emerging Markets? Evidence from Mexico [a]

M. Pavel Solís M.*

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Abstract

This paper addresses the exchange rate puzzle in emerging markets. While monetary policy in advanced countries exerts a strong impact on exchange rates, existing evidence for emerging markets shows that the response is small, nonexistent or inconsistent with standard open economy models. I use a new dataset of intraday changes in asset prices around policy events to estimate the impact of monetary policy on the exchange rate and the yield curve in Mexico. I find that an unanticipated increase in the policy rate appreciates the currency and flattens the yield curve, in line with the evidence for advanced economies. Comparing the results obtained with intraday and daily changes in asset prices reveals that, unlike the yield curve, the response of the exchange rate is sensitive to data frequency as it is only perceived using intraday data. The puzzle is thus the result of wide event windows when measuring changes in the exchange rate with daily data, giving rise to a standard omitted variable bias.

Keywords: Monetary policy, exchange rate, yield curve, emerging markets, high-frequency data, event study.

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*Department of Economics, Johns Hopkins University, 3400 N. Charles Street, 544E Wyman Bldg., Baltimore, MD 21218, United States. E-mail address: msolism1@jhu.edu. The author states that there is no conflict of interest.

1 Introduction

The exchange rate response to monetary policy in emerging markets has so far been an unsolved puzzle. Standard open economy models suggest that an increase in the policy rate leads to an immediate appreciation of the currency (Dornbusch, 1976). Contrary to this prediction, earlier evidence for advanced countries (Grilli and Roubini, 1995), and recently for emerging markets (Kim and Lim, 2016), found that contractionary monetary policy leads to a currency depreciation, commonly referred to as the exchange rate puzzle. These results, however, can be attributed to the assumptions made to identify the monetary policy surprises (Zettelmeyer, 2004); for instance, monetary policy actions could in fact be reacting to changes in the exchange rate. Using more robust identification methods, subsequent studies for advanced countries report that a policy rate hike indeed leads to an appreciation of the currency (Kearns and Manners, 2006; Faust et al., 2007). Nevertheless, the same methods applied to emerging markets show that the currency response to monetary policy is low or nonexistent (Aktaş et al., 2009; Duran et al., 2012; Kohlscheen, 2014; Pennings et al., 2015), leading to a stronger version of the puzzle (Kohlscheen, 2014).

The exchange rate puzzle in emerging markets raises the question of whether their central banks can actually exert an influence on their own currencies. This question is particularly relevant for three reasons. First, the transmission of monetary policy via the exchange rate is vital for open economies. Second, the sensitivity of the currencies in advanced countries to monetary policy increased since the global financial crisis (Ferrari et al., 2017), even in countries who continued to use conventional tools—like Australia and Canada—and so it would be striking if emerging market currencies remained insensitive to monetary policy. Third, the currencies of emerging markets do respond to *foreign* monetary policy surprises (Hausman and Wongswan, 2011; Kearns et al., 2018).

This paper studies whether and how the exchange rate responds to monetary policy in a representative emerging economy, and compares the results with the response of the yield curve. I use an event study methodology and a new dataset of daily *and* intraday changes in asset prices bracketing monetary policy announcements in Mexico from 2011 to 2019. In particular, changes in swap rates are used to systematically measure surprises in the policy rate, independent of any model.[1] By now, event studies with high-frequency data are a well-established strategy in macro-finance to overcome endogeneity concerns because they isolate the surprise component of policy decisions (Gürkaynak and Wright, 2013; Nakamura and Steinsson, 2018).[2] Nevertheless, they have rarely been applied to study the monetary policy transmission to asset prices in Mexico.[3]

This paper documents significant responses of the exchange rate and the yield curve to policy rate surprises in Mexico. First, an unanticipated increase in the policy rate appreciates the currency; specifically, a 25 basis point increase in the rate leads to an appreciation of close to 50 basis points. This provides evidence against the exchange rate puzzle in emerging markets and thus shows that their currencies are no different to those in advanced countries in terms of their responsiveness to the domestic policy rate. Second, a contractionary monetary policy raises bond yields in a way that flattens the yield curve, also in line with the evidence for advanced countries. Moreover, policy rate surprises have a larger influence on the yield curve in Mexico than U.S. policy rate surprises have on the U.S. yield curve, potentially reflecting a relatively higher degree of long-run inflation uncertainty in Mexico.

The main contribution of the paper is to solve the exchange rate puzzle in emerging markets. According to the high-frequency exchange rate puzzle (Kohlscheen, 2014), the currencies of emerging markets do not respond to monetary policy using event studies with *daily* data. In contrast, the evidence shows that the currencies of advanced countries react to monetary policy even using daily data, although the precision decreases relative to intraday data (Wright, 2012; Ferrari et al., 2017). I exploit the availability of two lengths

[1]The traditional approach to identify monetary policy surprises is to estimate a vector autoregression model using a recursive assumption, see Christiano et al. (1999). The exchange rate puzzle is a well-known feature of this approach, which Zettelmeyer (2004) attributes to a problem of reverse causality.

[2]It is reasonable to assume that surprises in monetary policy decisions on announcement days are exogenous and so one can give a causal interpretation from policy decisions to asset price responses.

[3]For the Mexican case, the event study methodology has been applied to analyze the effects of *foreign* monetary policy on asset prices (Borensztein et al., 2001; Rosa, 2011a; Hausman and Wongswan, 2011; Kearns et al., 2018) and portfolio flows (Hernandez Vega, 2018), whereas De Pooter et al. (2014) use it to study whether inflation expectations are well-anchored. The only exception is Kohlscheen (2014) who uses the methodology to study the exchange rate response to monetary policy as in this paper; however, he does not use intraday data nor swaps to measure surprises in the policy rate.

for the event window (intraday and daily) in the dataset to understand the puzzle.[4] The analysis reveals that the exchange rate response is indeed sensitive to data frequency; it can only be perceived using intraday data. This sensitivity, however, is characteristic of the exchange rate since the effect of the policy rate on the yield curve can still be observed with daily data. The puzzle is thus the result of wide event windows when measuring the changes in the exchange rate, giving rise to a standard omitted variable bias. Intuitively, a lot of factors other than monetary policy decisions affect the exchange rate that even a daily frequency is not enough to prevent their influence. Using intraday data, at least for the exchange rate, avoids this problem.

An early interpretation of the exchange rate puzzle is that some countries—particularly emerging markets—have a preference for stable exchange rate fluctuations or, equivalently, they fear large currency swings (Calvo and Reinhart, 2002). This fear of floating would make the central bank adjust its policies—including changes in the policy rate and exchange market interventions—so as to keep the exchange rate from experiencing large swings. This, however, is unrelated to the question of whether an unanticipated change in the policy rate affects the currency in emerging markets. In fact, by focusing on the effects of policy rate surprises, this paper is neutral on how monetary policy expectations are determined. Finally, to answer the question of interest, it is important to consider small open economies with relatively liquid financial markets, a market-based exchange rate, and a credible inflation targeting regime (Kearns and Manners, 2006; Pennings et al., 2015). Mexico meets all these criteria.

The paper proceeds as follows. Section 2 describes how policy rate surprises are measured, and section 3 discusses their effects on the exchange rate and the yield curve. Section 4 addresses the high-frequency exchange rate puzzle. The last section concludes.

[4] To the best of my knowledge, this is the first paper studying the effects of monetary policy in emerging markets that highlights the differences between intraday and daily changes in asset prices.

2 Identification of Policy Rate Surprises

This section briefly reviews the institutional developments in Mexico that are relevant for the identification of policy rate surprises. It then describes how to measure them.

2.1 Monetary Policy in Mexico

The Bank of Mexico, also known as Banxico, is an independent central bank that implements monetary policy through a five-member Governing Board. The chair of the Board is the governor of Banxico; the other four members are deputy governors.

Analyses of the policy rate with daily data can arguably start in 2004 based on the following. When Banxico was granted autonomy in 1994, inflation was 7%. Less than a year later, the Mexican peso crisis started (in December 1994), a floating exchange rate system was adopted and inflation peaked at 52% (Carstens and Werner, 1999). During 1999, inflation decreased from 19 to 12%, and Banxico announced that inflation should decrease to 3% by the end of 2003. In line with this goal, inflation targeting was formally adopted in 2001 and one year later, the official target for inflation was set at 3% with respective upper and lower bounds of 4 and 2%. Since 2003, Banxico follows a calendar of monetary policy meetings which is publicly announced ahead of time. The transition period for the adoption of Banxico's current monetary policy instrument, the overnight interbank interest rate, started in 2004 and concluded in 2008.[5]

After the adoption of the overnight policy rate, two major institutional changes were made. First, although monetary policy statements have accompanied every policy decision since 2000, Banxico started releasing minutes of its monetary policy meetings two weeks after the date of the respective policy decision in 2011. Second, the timing of the announcements was modified in 2015. Up until 2014, the announcements were made at 9 a.m. local time on the scheduled day, usually Fridays. Since 2015, announcements are now made at 1 p.m. local time on the scheduled day, usually Thursdays.[6]

[5]Before 2008, Banxico used a quantitative target, 'el corto', which indirectly influenced interest rates. Sidaoui and Ramos-Francia (2008) review the transmission of monetary policy in Mexico since the 1994-95 currency crisis until the adoption of the current policy rate.

[6]According to Banxico's governor at the time, the new timing would give market participants more time to react to policy decisions before a weekend.

The regularity and scheduled timing of these announcements allow me to study the effects of the policy decisions on asset prices using an event study methodology. Appendix A contains a list of the dates and times of Banxico's monetary policy announcements since 2004, along with relevant macroeconomic data from Mexico and the U.S. released on the same days. From 2004 to 2019, there were 155 regularly scheduled monetary policy announcements, and 72 between 2011 and 2019.[7] On average, Banxico's Governing Board met monthly between 2004 and 2010, and every six weeks since 2011.

Figure 1 shows the evolution of the policy rate along with the *changes* in the rate since it was adopted. After the global financial crisis intensified, Banxico cut its policy rate by 3.75% in 7 months. More stimulus started in March 2013 via an unanticipated 50 basis point reduction in the rate.[8] Since then, the first increase in the rate occurred in December 2015, a day after the first hike in the U.S. policy rate since the Great Recession. The tightening cycle intensified in the second half of 2016 due to inflation concerns.

[Insert Figure 1 here.]

2.1.1 Timing of the Announcements

To correctly measure intraday policy rate surprises, it is crucial to have the *time* of the announcements right. In particular, one needs to consider the change in the timing of Banxico's announcements and the usage of Daylight Saving Time (DST).

Given that Banxico changed the timing of its policy announcements in 2015, there are two relevant times: 9 a.m. up until 2014 and 1 p.m. afterwards, both expressed in the Central Time zone used in Mexico's capital. The data, however, is recorded in the Eastern Time (ET) zone used in the U.S. capital. The time zone matters because the usual one-hour time difference between the two cities widens to two hours during non-overlapping DST days since 2007, when the U.S. extended its usage of DST time.

The relevant ET times for Banxico's policy decisions are as follows. All announcements before 2007 happened at 10 a.m. ET. Between 2007 and 2014, the announcements

[7] Appendix B explains the reasons for excluding an extraordinary meeting on February 17, 2016.

[8] A basis point is equal to one hundredth of one percent.

occurred at 10 a.m. ET most of the time, except on non-overlapping DST days in which they occurred at 11 a.m. ET. Finally, since 2015 the announcements take place at 2 p.m. ET most of the time, except on non-overlapping DST days in which they occurred at 3 p.m. ET. Further details are in appendix A.

2.2 Measuring Policy Rate Surprises

It is important to focus on 'surprises' in policy decisions. The raw change in the policy rate can be decomposed into an expected and an unexpected part. Kuttner (2001) shows that asset prices only respond to unexpected changes, since the expected part is already reflected in prices by the time of the announcement. The unanticipated part is thus the relevant component of policy decisions, usually referred to as the 'surprise' or the 'shock'.[9]

One can think of policy rate surprises as the difference between the raw change in the policy rate and the expected one. Surveys of professional forecasters are a source of expectations about monetary policy decisions. Alternatively, financial market prices can be used to obtain a market-based measure of those expectations.[10]

This paper uses swap rates to measure surprises in the policy rate. An overnight indexed swap (OIS) referencing the policy rate would be an ideal candidate.[11] Instead, the swap market in Mexico references an interbank interest rate denominated in local currency that closely follows the policy rate, the 28-day interbank interest rate (TIIE28D).[12] Banxico calculates the TIIE28D once a day based on quotes it receives from commercial banks, it is the benchmark rate for banking loans in Mexico. The most liquid swap with the shortest maturity and the longest history is the 3-month swap, it is indeed the main local derivative.[13] Importantly, unlike the TIIE28D itself, the 3-month swap trades within the day, which allows me to calculate differences in the swap rate in intraday windows.[14]

[9] Leaving the policy rate unchanged can still be a surprise if market participants expected a move. A zero raw change can be a loosening surprise if, for instance, the market expected a 25 basis point increase.

[10] For instance, Kuttner (2001) uses futures on the federal funds rate for the U.S.

[11] As an alternative to the U.S.-specific futures contracts of the policy rate, Lloyd (2018) shows that OIS can be used to measure monetary policy surprises in Germany, Japan, the U.S. and the U.K.

[12] The average difference between the TIIE28D and the overnight policy rate is around 30 basis points.

[13] Currently, a 1-month swap is also traded in the market but is not as liquid and has a shorter history.

[14] Appendix C discusses relevant considerations if TIIE28D were to be used to measure the surprises.

Even though the 3-month swap might capture more than one meeting ahead, it is still a good measure of the monetary stance in the short-term.

Policy rate surprises are measured as the difference in swap rates around windows containing monetary policy announcements. These differences represent a change in the information set of market participants, the surprise. A positive surprise refers to a tightening of the monetary stance, while a negative value represents an easing.

The difference in swap rates captures the change in expectations for the policy rate around the announcements. Even though swap rates can be decomposed into an expectation for the policy rate and a risk premium,[15] the premium is not a problem to how the surprises are measured as long as it does not change over the length of the window, a reasonable assumption given that risk premia vary at business-cycle frequencies (Piazzesi and Swanson, 2008; García-Verdú et al., 2019).[16] In fact, Piazzesi and Swanson (2008) document that monetary policy surprises based on the *change* in the derivatives rate over small windows around the announcements are robust to the presence of risk premia. Moreover, García-Verdú et al. (2019) show that the risk premium in TIIE28D swap rates is relevant at medium but not at short horizons—the 3-month swap in particular.

2.2.1 A Dataset of Asset Price Changes

The preferred measure of policy rate surprises in this paper is the difference in the 3-month swap rate in 30-minute windows bracketing monetary policy announcements.[17] The windows start 10 minutes before and end 20 minutes after each monetary policy announcement.[18] Similarly, differences over the same intraday windows are also calculated for the exchange rate (expressed in pesos per dollar) and for yields of bonds issued by the Mexican government with maturities of 2, 5, 10 and 30 years.[19]

[15] A risk premium compensates investors in case their policy rate expectations turned out to be wrong.

[16] Also notice that the change in the swap rate differences out any constant risk premium.

[17] An alternative measure, used by De Pooter et al. (2014), is the difference between the actual policy rate change and the average of survey expectations. The correlation between the two measures is 0.92.

[18] Wider 50-minute windows, starting 20 minutes before and ending 30 minutes after each announcement, were used in robustness checks. All the results with tight windows remain using wider windows.

[19] When no data is available at any of those times, the next available quote is used to compute the changes. In extreme cases, in which there are no quotes in wider windows for a day, the open and close quotes are used to compute the differences. This only happens on a few days for the swaps.

Given that access to intraday data in emerging markets is not as common as for advanced countries, daily differences for all the assets are also used, calculated as the one-day change in the price around monetary policy announcements. The comparison of the results using intraday versus daily data receives special attention in the rest of the paper, playing a key role in section 4 on the high-frequency exchange rate puzzle.

All the data for the analysis is obtained from Bloomberg. The information to calculate the intraday differences for the swap rates and the exchange rate is available since 2011, since December 2014 for the 5-year yield and since 2013 for the other yields. Daily changes start in 2004, except for the 30-year yield for which they start in October 2006.

Figure 2 plots the raw changes in the policy rate along with the (intraday) policy rate surprises. The difference between the two is the anticipated change in the policy rate. Policy rate surprises are generally smaller than the raw changes, indicating that most of the policy rate changes are anticipated by market participants.

Table 1 shows summary statistics for the intraday and daily changes in asset prices. According to the policy rate surprises identified using intraday data, there was no surprise in 12 out of the 72 regularly scheduled meetings between 2011 and 2019. Moreover, several of the insights documented formally in the next two sections can already be seen in table 1. There is no much difference between the policy rate surprises calculated using intraday and daily data. Changes in bond yields using the two frequencies also have similar characteristics, although they vary slightly more using daily data. In contrast, the standard deviation of the exchange rate returns almost doubles (from 33 to 65 basis points) when the frequency goes from intraday to daily.

3 The Effects of Policy Rate Surprises on Asset Prices

This section documents that the response of asset prices to policy rate surprises is statistically and economically significant. It also shows that the comparison of the results from intraday and daily data turns out to be relevant for the exchange rate.

3.1 Methodology

The analysis of the response of the exchange rate and bond yields to policy rate surprises uses the following event-study regression:

$$\Delta y_t = \beta_0 + \beta_1 \Delta x_t + \varepsilon_t, \tag{1}$$

where Δy_t is the change in the variable of interest (exchange rate or bond yields) and Δx_t is the policy rate surprise (i.e. the change in the 3-month swap rate), both computed over the same window around monetary policy announcements. Whenever interest rates are used, the differences are calculated directly using quotes before and after the announcements; for the exchange rate, 100 times log differences are used to approximate the percentage change (or return) over the window. All variables are expressed in basis points. Finally, the error term ε_t captures variations in the dependent variable unrelated to shocks in the policy rate.

The parameter of interest in equation (1) is the slope coefficient β_1, it measures the response of asset prices to policy rate surprises.[20] The classical assumption to identify β_1 is that ε_t is orthogonal to Δx_t, which is equivalent to say that Δx_t is exogenous.

The frequency at which asset price changes are calculated is crucial to satisfy the exogeneity assumption. When Δx_t is measured as the intraday change in the 3-month swap rate around monetary policy announcements—conceptually the policy rate surprise—the exogeneity assumption is plausible. It is unlikely that, during such small windows, other variables influence asset prices in a systematic fashion or that monetary policy reacts to events happening minutes before the announcements are released. One can then give a causal interpretation from policy decisions to asset price responses on the days of monetary policy announcements (Gürkaynak and Wright, 2013).

The variable of interest starts to be measured with "noise" when wider windows are used to calculate the changes in asset prices. The wider the window, the larger the noise. Such noise, or measurement error, opens the door for other variables to play a role in the relationship between asset prices and policy rate surprises. For example, since

[20] The intercept β_0 is generally dropped because the asset price is not expected to change when there is no surprise in the policy rate in small windows.

asset prices and the policy rate are both forward-looking variables, the estimation of equation (1) using quarterly or monthly data is plagued with endogeneity problems (e.g. simultaneity, omitted variables). Daily data mitigates those problems. Nevertheless, even with daily data, in certain situations the noise can blur the relationship between the variables of interest, as is discussed in section 4.

3.2 Results

The sign of β_1 depends on the dependent variable. Regarding the exchange rate, uncovered interest rate parity implies that the interest rate differential between Mexico and the U.S. should equal the expected change in the exchange rate. Other things equal, an increase in the interest rate in Mexico should lead to a contemporaneous appreciation of the peso, i.e. a fall in the exchange rate.[21] Thus, β_1 is expected to be negative for the exchange rate. Regarding bond yields, Kuttner (2001) shows that a monetary tightening leads to higher yields at all maturities due to upward expectations for the policy rate. As such, β_1 is expected to be positive for the yield curve.

3.2.1 Intraday Data

Table 2 presents the results of estimating equation (1) using intraday data. The first column for each of the dependent variables reports the estimate of β_1. In all cases, the estimates have the expected sign and are highly significant.

[Insert Table 2 here.]

A 25 basis point increase in the policy rate leads to an appreciation of the currency of close to 50 basis points. For comparison, the currencies of advanced countries responded around two times the magnitude of the policy rate surprise before the global financial crisis (Rosa, 2011b) and up to five times afterwards (Wright, 2012; Ferrari et al., 2017). Table 2 thus provides evidence against the exchange rate puzzle in emerging markets, it

[21] Uncovered interest rate parity also implies that a contemporaneous appreciation of the peso generates an expected depreciation over time, which offsets the initial increase in the interest rate in Mexico.

shows that their currencies are no different to those in advanced countries in terms of their responsiveness to the policy rate.

A contractionary monetary policy also flattens the yield curve. Following a 25 basis point hike in the policy rate, 2- 5- 10- and 30-year bond yields increase by approximately 17, 9, 11, and 8 basis points, respectively; as such, the spread between the 10- and 2-year yields—the term spread—narrows by 6 basis points. Although these results are in line with the evidence for the U.S. in a comparable period, i.e. when its policy rate was not constrained by the effective lower bound (Kuttner, 2001; Gürkaynak et al., 2005), it is worth pointing out three differences. First, the magnitude of the yields' response in Mexico is larger than in the U.S. For instance, a 1/4 percentage point increase in the policy rate raises 2- 5- and 10-year yields by approximately 11, 7 and 3 basis points in the U.S. according to the estimates in Gürkaynak et al. (2005). Second, the effect on bond yields is not monotonic since the response of the 5-year yield is lower than for the 2- and 10-year yields.[22] Third, policy rate surprises in Mexico explain a larger fraction of the variability in bond yields (measured by the R^2 statistic) than in the U.S.; specifically, they are the most important factor influencing the 2- and 10-year yields with an R^2 of 0.79 and 0.53 compared to 0.4 and 0.08 in the U.S., respectively.

These results imply that policy rate surprises have a larger influence on the yield curve in Mexico than in the U.S. Since bond yields can be decomposed into an expectation for the policy rate and a risk premium, for which inflation and inflation uncertainty are respectively important drivers (Abrahams et al., 2016), this finding is potentially reflecting that inflation is higher and more volatile in Mexico than in the U.S.

The second column for each dependent variable in table 2 reports the responses of asset prices to the two components of the raw changes in the policy rate, the anticipated and unanticipated parts.[23] As in the U.S. (Kuttner, 2001), asset prices in Mexico only respond to the surprise component.[24] This highlights the importance of focusing on policy rate surprises in emerging markets as well. Indeed, if raw changes were being used

[22]This non-monotonicity, however, is less pronounced with daily data (see table 3).
[23]The expected part equals the difference between the raw change and the surprise in the policy rate.
[24]Statistically significant effects to the anticipated part are economically small.

instead, one would incorrectly conclude that monetary policy has no effect on neither the currency nor the yield curve.[25]

Summing up, there is a statistically and economically significant response of the exchange rate and the yield curve to policy rate *surprises*.

3.2.2 Daily Data

Table 3 reports the results of estimating equation (1) using daily, instead of intraday, data. Remember that intraday changes in swap rates and the exchange rate are available since 2011 and later for bond yields; however, daily data is available much earlier for all assets. Thus, the first column for each dependent variable in table 3 reports the results over the same sample period as in table 2, while the second column shows the results since 2004.

[Insert Table 3 here.]

The first column of table 3 illustrates the exchange rate puzzle identified by Kohlscheen (2014), the exchange rate does not respond to policy rate surprises when the changes are calculated using daily windows. This is discussed in detail in section 4.

Unlike the exchange rate, the significance of the effects on the yield curve remains high. The results are broadly similar even with a larger sample size.[26] In addition, there are gains in the precision of the coefficient estimates and in terms of explanatory power (measured by R^2) when going from daily to intraday data. The largest gains, however, can be seen in the long end of the curve, where the standard error is half as large and the R^2 almost doubles when intraday data is used.

The main conclusion from comparing tables 2 and 3 is that intraday data is key to identify the currency response to the policy rate but not so much for the yield curve.

[25] In unreported regressions of intraday asset price changes on raw changes in the policy rate, the slope coefficient is not significant. These regressions suffer from an error-in-variables problem because the raw change is a noisy measure of the surprise component, which leads to attenuation bias (Kuttner, 2001).

[26] The differences amount to 3 or 4 basis points under a 25 basis point change in the policy rate.

3.2.3 Persistence

In addition to the initial reaction of asset prices to policy rate surprises, monetary policymakers are interested in the persistence of the response. One way to address this issue, and assess the robustness of the results, is to re-estimate equation (1) but with the change in the dependent variable calculated over subsequent days after a monetary policy announcement.[27] Figures 3 and 4 show the persistence of the exchange rate and the yield curve, respectively.

Since this exercise involves daily frequencies, figure 3 illustrates the exchange rate puzzle from a different angle since the currencies of advanced countries do exhibit persistence over subsequent days (Rosa, 2011b; Ferrari et al., 2017). Meanwhile, figure 4 shows that the flattening of the yield curve highlighted before continues in the days following a policy tightening. The response of 2- and 5-year yields increases over time, while for 10- and 30-year yields the response is relatively more stable.

4 Solving the High-Frequency Exchange Rate Puzzle

This section argues that the apparent lack of response of the exchange rate to monetary policy in emerging markets illustrated in table 3 is due to measurement error in the daily returns of the exchange rate.

The key insight from comparing tables 2 and 3 is that one reaches different conclusions for the response of the exchange rate depending on the data frequency used. With intraday data, the currency appreciates following a tightening, a response that is consistent with standard open economy models and with the literature for advanced countries. This finding is relevant given the importance of the exchange rate in the transmission of monetary policy in small open economies. In contrast, the currency does not respond to the policy rate when daily data is used, what Kohlscheen (2014) calls the high-frequency exchange rate puzzle in emerging economies. This phenomenon indeed seems characteristic of emerging markets since the reaction of the currencies of advanced countries can

[27] Note that there is no overlap between observations because the announcements are always more than ten days—the maximum days used in the figure—apart from each other, see appendix A.

still be seen with daily data (Wright, 2012; Ferrari et al., 2017).

To explain the puzzle, it is helpful to think about it from an errors-in-variables perspective. The availability of intraday and daily data allows me to conduct what is known as a validation study (Bound et al., 1994). I treat intraday changes as the true values and daily ones as if the values were measured with error since they capture other shocks happening during the rest of the day. From this perspective, the analysis using daily data involves measurement errors in *both* the dependent and independent variables. In the rest of the analysis, the dependent variable is the exchange rate returns, unless otherwise stated.

In the classical measurement error model, when only the independent variable is measured with error, the least squares estimator $\hat{\beta}_1$ is biased towards zero, commonly referred to as attenuation bias; but when there is measurement error only in the dependent variable, the estimator $\hat{\beta}_1$ is consistent albeit with a larger standard error. Since the 'noisy' (daily) and 'true' (intraday) values for the dependent and independent variables are observed, the measurement errors can also be treated as observed and thus used to test traditional assumptions. The errors are calculated as the difference between daily and intraday changes in the variables.

Appendix D shows that, in the data, the measurement error in the dependent variable is larger than that in the independent variable. Intuitively, monetary policy decisions are the main event for swap rates during announcement days, and so the measurement error in policy rate surprises is small. Meanwhile, a lot of factors other than monetary policy decisions affect the exchange rate that even a daily frequency is not enough to avoid their influence.[28] Appendix D also shows that the assumptions behind the classical measurement error model are not satisfied in the data, and confirms that attenuation bias is indeed small—since the measurement error in policy rate surprises is small.[29]

Table 4 exploits the availability of daily and intraday data to shed light on the puzzle.

[28] In line with this, regressing daily on intraday values gives an R^2 of 0.96 for policy rate surprises and of 0.14 for the exchange rate. In addition, the standard deviation of the exchange rate returns almost doubles when the frequency goes from intraday to daily (see table 1).

[29] In addition, appendix D extends the classical model to explain the inconsistency in the estimator as a result of measurement error in the dependent variable.

Since the changes in the exchange rate and the 3-month swap rate are measured with (daily) and without (intraday) error, there are four possible combinations of the variables to estimate equation (1). The ideal case is when there is no measurement error in neither of the variables, the opposite instance happens when there is measurement error in both. These two cases are reported in the first columns of tables 2 and 3, respectively, and are reproduced in table 4 for ease of comparison.

[Insert Table 4 here.]

Table 4 shows that the main reason behind the puzzle is noise in the daily returns of the exchange rate. In the first two columns, the dependent variable is measured without error; the independent variable is also measured without error in the first column and with error in the second. The first column shows that a tightening leads to an appreciation of the currency, as discussed above. The second column meanwhile confirms a relatively small attenuation bias, and thus the effect of policy rate surprises on the currency is still significant and relevant. In the next two columns, the dependent variable is now measured with error. In these cases, the slope coefficient is upward biased and its standard error increases by more than 55%, leading one to incorrectly conclude that there is no significant effect of the policy rate on the exchange rate.

Pennings et al. (2015) suggest that the weaker response of the exchange rate in emerging markets relative to advanced countries could be driven by less liquid financial markets or more noisy measurement of monetary policy surprises. The evidence in table 4 indicates that, instead of measurement error in the policy rate surprises, the reason behind the puzzle is measurement error in the returns of the exchange rate.

Furthermore, table 4 also indicates that the explanation of the puzzle lies on omitted variables. The dependent variable in the last two columns of table 4 is the measurement error in the daily exchange rate returns—the difference between daily and intraday data—in order to see if it is systematically related to policy rate surprises. Although the magnitudes of the slope coefficients in these regressions match the upward bias found with daily returns, their standard errors are large. Therefore, rather than being correlated with the independent variable, the measurement error in the daily exchange rate returns is capturing the effects of other variables influencing the currency, giving rise to a standard omitted variable bias.

4.1 Potential Omitted Variables

To understand the other factors influencing the daily returns of the exchange rate, it is particularly important in the case of emerging markets to look at external—in addition to local—events when considering omitted variable candidates. The U.S. dollar responds significantly to different U.S. macroeconomic news (Faust et al., 2007). If those news happen to be released on the same day that a monetary policy decision by Banxico, the daily return of the exchange rate will reflect at least those two events. As appendix A shows, it is indeed common for Banxico's monetary policy announcements to coincide with the release of relevant U.S. macroeconomic news.

U.S. labor market data is a good example of an omitted variable for the daily returns of the exchange rate. The change in nonfarm payrolls is released monthly by the U.S. Department of Labor on a Friday at 8:30 a.m. ET. Between 2004 and 2014, Banxico's announcements coincided with releases of nonfarm payrolls on 13 occasions, in four of them the average difference between the daily and intraday returns of the exchange rate exceeded 115 basis points, compared to 48 basis points for the whole sample.[30]

Consider, for instance, the announcement on September 6, 2013, in which Banxico unexpectedly cut its policy rate by 25 basis points. According to the estimation results with intraday data, this would have *depreciated* the currency by close to 50 basis points, but the peso actually *appreciated* 168 basis points during the day.[31] On this regard, it is worth noting that earlier that day, at 8:30 a.m. ET, nonfarm payrolls data for the previous month was released. Job gains were less than expected according to survey forecasts—169,000 vs 180,000—which analysts interpreted as evidence that it would take the Fed longer than previously anticipated to remove the monetary stimulus it suggested earlier in the year. Asset prices in turn reacted as if there was a loosening surprise in the U.S. policy rate, depreciating the U.S. dollar (and appreciating the Mexican peso).

[30] Those dates are: 08 March 2013, 06 September 2013, 06 December 2013, 05 December 2014.

[31] In the 30-minute window around Banxico's announcement, the peso appreciated only 15 basis points.

It is worth pointing out that the timing change of Banxico's announcements in 2015—from 10 a.m. ET Fridays to 2 p.m. ET Thursdays—did not reduce their coincidence with U.S. macroeconomic releases. On the contrary, it is now a certainty. Initial jobless claims in the U.S. are released every Thursday at 8:30 a.m. ET. Using intraday exchange rate data avoids this problem.

Summing up, the presence of measurement error in the daily returns of the exchange rate causes not only imprecision in the estimation—as in the classical model—but also bias due to omitted variables. Even if policy rate surprises are measured without error, the noise in the daily exchange rate returns blurs the response of the currency to the policy rate. Moreover, this phenomenon seems to be characteristic of the currencies of emerging markets since the reaction of the exchange rate of advanced countries can still be captured with daily data (Wright, 2012; Ferrari et al., 2017), as well as the response of the yield curve (see table 3).

5 Concluding Remarks

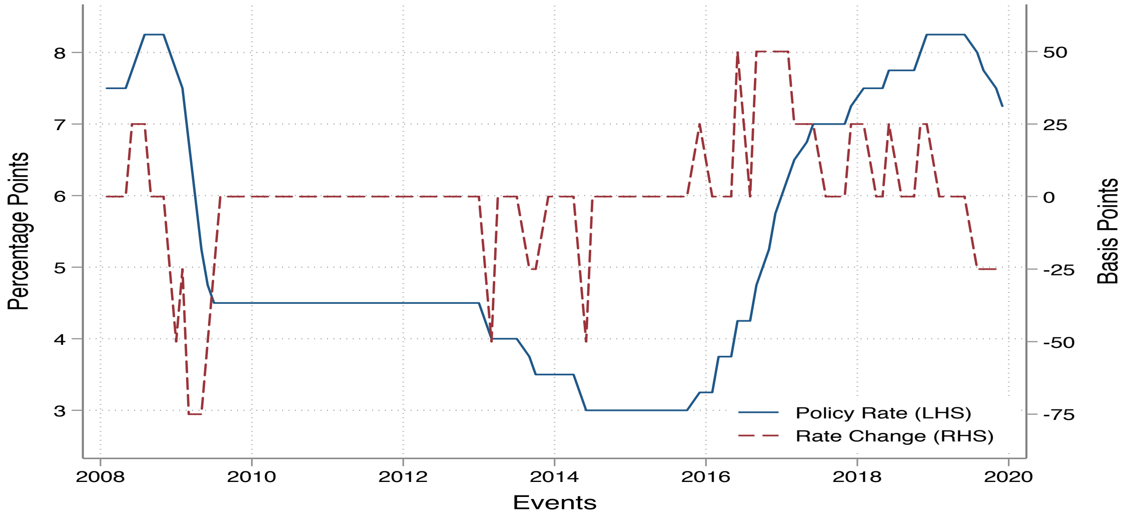
This paper uses a new dataset to provide evidence of the effects of monetary policy on the exchange rate and bond yields in an emerging economy. Surprises in the policy rate have significant effects on asset prices. An unanticipated increase in the policy rate appreciates the currency and flattens the yield curve. The currencies of emerging markets are thus no different to those in advanced countries in terms of their responsiveness to the domestic policy rate. Meanwhile, policy rate surprises have a larger influence on the yield curve in Mexico than in the U.S., potentially reflecting a relatively higher degree of long-run inflation uncertainty in Mexico.

This paper finds that the lack of response of the exchange rate in emerging markets found so far in the literature is the result of wide event windows; the response can only be perceived using intraday data. This sensitivity to data frequency, however, is characteristic of the exchange rate since the response of the yield curve is still observed with daily data. This evidence suggests that, at least for emerging markets, intraday data on financial variables subject to significant cross-border trading (like exchange rates) is needed to detect their response to the domestic monetary policy.

The results in this paper can be extended in different directions. One of them relates to the evidence for advanced countries indicating that monetary policy has more than one dimension (Gürkaynak et al., 2005; Swanson, 2018); for instance, asset prices react not only to surprises in the policy rate but also to changes in policy statements. A relevant question on that regard is whether the multidimensionality of the monetary policy in advanced countries is a feature shared by emerging economies.

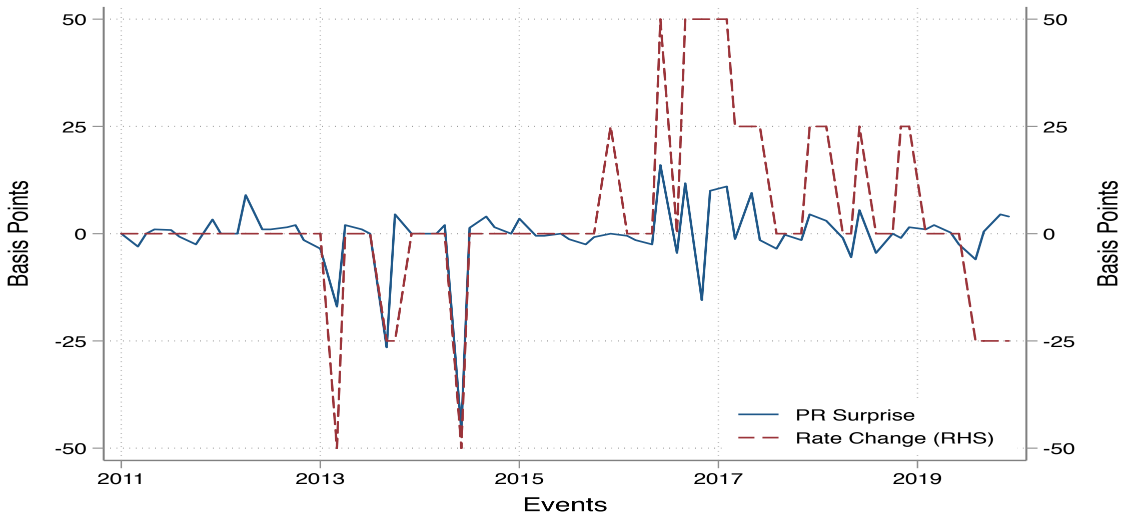
Understanding the transmission of monetary policy to financial markets is the starting point. The ultimate goal is to understand the real effects of monetary policy. However, it is hard to measure the persistence of policy surprises identified with intraday data since noise filters when the event window is widened; Wright (2012) proposes a solution by imposing parametric restrictions in a vector autoregression. Relatedly, the policy rate surprises in this paper can be used as external instruments in a structural vector autoregression (known as proxy-SVAR or SVAR-IV) to identify the effects of monetary policy on macroeconomic variables, as in Li and Zanetti (2016) and Stock and Watson (2018).

Figure 1. Policy Rate in Mexico: Level and Change



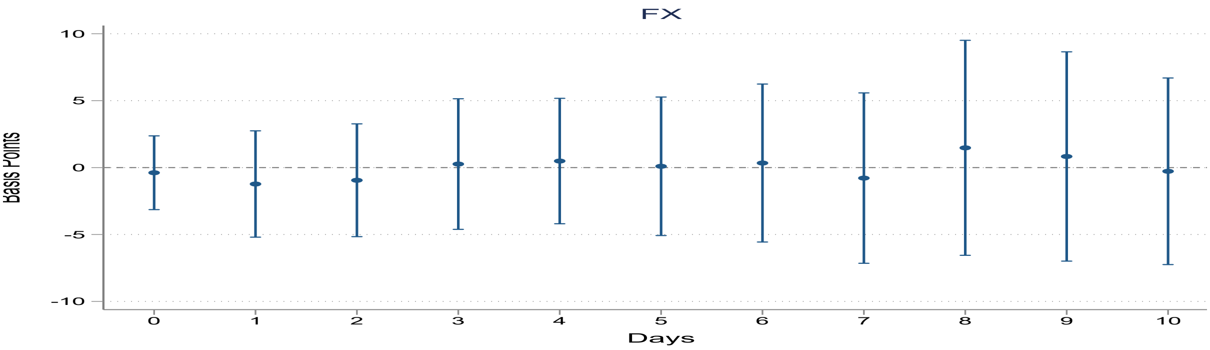
Notes: The solid line shows the evolution of the policy rate in Mexico. The dashed line shows the raw changes in the policy rate. The events are all regular monetary policy announcements from January 2008 to December 2019. The policy rate is the overnight interbank interest rate, Banxico adopted it as its monetary policy instrument in January 2008 in substitution of *el corto*.

Figure 2. Policy Rate in Mexico: Surprises and Change



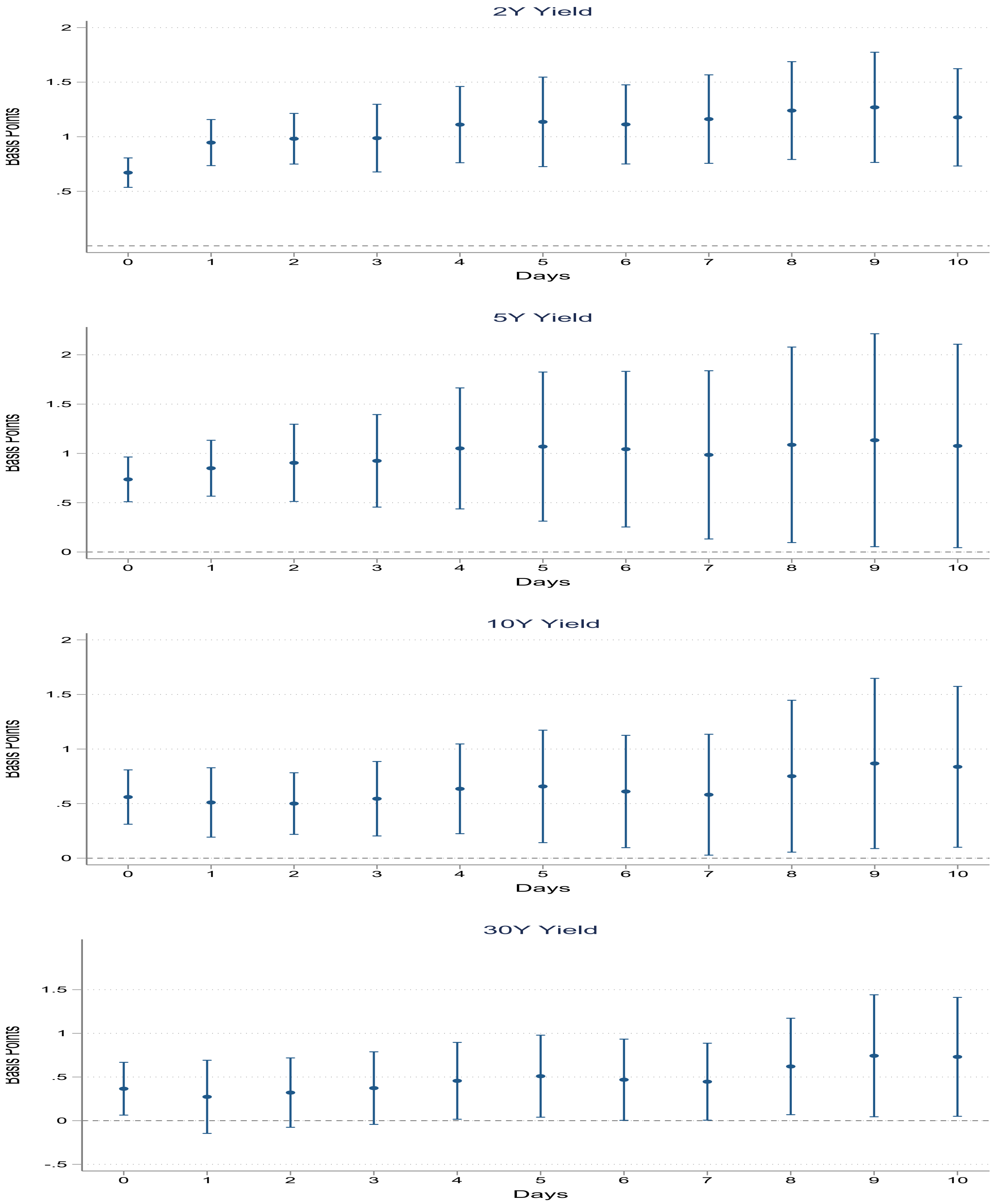
Notes: The solid line shows the policy rate surprises, the change in the 3-month swap rate in 30-minute windows bracketing monetary policy announcements. The dashed line shows the raw changes in the policy rate. The events are all regular monetary policy announcements from January 2011 to December 2019.

Figure 3. Persistence of the Exchange Rate Response to Policy Rate Surprises over Subsequent Days



Notes: This figure plots the coefficient estimates and 95% confidence intervals for the return in the exchange rate to policy rate surprises from close of day $t-1$ to day $t+k$, where t is a day with a monetary policy announcement and $k = 0, 1, \ldots, 10$. The announcements are always more than ten days apart from each other, see appendix A. The sample is all regular monetary policy announcements from January 2011 to December 2019.

Figure 4. Persistence of the Yield Curve Response to Policy Rate Surprises over Subsequent Days



Notes: This figure plots the coefficient estimates and 95% confidence intervals for yield changes to policy rate surprises from close of day $t-1$ to day $t+k$, where t is a day with a monetary policy announcement and $k = 0, 1, \ldots, 10$. The announcements are always more than ten days apart from each other, see appendix A. The sample is all regular monetary policy announcements from January 2011 to December 2019.

Table 1. Summary Statistics for Asset Price Changes

	Mean	Std. Dev.	Min.	Max.	Obs.
Intraday					
PRS	-0.5	7.9	-45.8	16.0	72
PRS > 0	4.0	4.0	0.3	16.0	31
PRS < 0	-5.5	9.7	-45.8	-0.3	29
FX	-9.4	33.4	-165.4	55.3	72
2Y Yield	-0.4	6.7	-37.7	10.7	56
5Y Yield	-0.0	3.9	-15.4	9.4	41
10Y Yield	-0.6	5.0	-25.8	10.9	56
30Y Yield	-0.8	4.4	-19.8	8.2	56
Daily					
PRS	-0.5	8.1	-45.8	16.0	72
PRS > 0	4.3	4.6	0.2	16.0	30
PRS < 0	-5.3	9.5	-45.8	-0.2	31
FX	-7.0	65.4	-167.6	142.2	72
2Y Yield	-1.2	7.6	-32.6	13.3	72
5Y Yield	-1.8	8.5	-41.1	12.9	72
10Y Yield	-1.8	7.7	-34.8	10.4	72
30Y Yield	-2.0	7.0	-28.1	12.6	72

Notes: This table reports summary statistics for intraday and daily changes in the 3-month swap rate (the policy rate surprises or PRS), exchange rate returns (FX) and changes in bond yields. Intraday changes are calculated starting 10 minutes before to 20 minutes after a monetary policy announcement. All units are expressed in basis points. The sample period is from January 2011 to December 2019.

Table 2. The Response of Asset Prices to Policy Rate Surprises: Intraday Data

	FX		2Y-Yield		5Y-Yield		10Y-Yield		30Y-Yield	
PR Surprise	-1.85**	-1.79**	0.67***	0.68***	0.34***	0.37***	0.42***	0.43***	0.30***	0.32***
	(0.89)	(0.85)	(0.09)	(0.08)	(0.11)	(0.09)	(0.09)	(0.09)	(0.08)	(0.07)
PR Expected		-0.20		-0.04		-0.04*		-0.05		-0.06**
		(0.34)		(0.03)		(0.02)		(0.04)		(0.03)
Observations	72	72	56	56	41	41	56	56	56	56
R-squared	0.18	0.19	0.79	0.81	0.23	0.27	0.53	0.56	0.35	0.42

Notes: The first column for each dependent variable shows the coefficient estimates in regressions of intraday yield changes or exchange rate returns (FX) on intraday changes in the 3-month swap rate (PR Surprise). The second column adds the expected component of the raw change in the policy rate (PR Expected) as a regressor, calculated as the difference between the raw change and the policy rate surprise. Intraday changes are calculated starting 10 minutes before to 20 minutes after a monetary policy announcement. The sample for the exchange rate is all regular monetary policy announcements from January 2011 to December 2019; for 2- 10- and 30-year yields, from January 2013 to December 2019; and for 5-year yields, from December 2014 to December 2019. All variables are expressed in basis points. No constant is included in the regressions. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

Table 3. The Response of Asset Prices to Policy Rate Surprises: Daily Data

	FX		2Y-Yield		5Y-Yield		10Y-Yield		30Y-Yield	
PR Surprise	-0.08	0.08	0.65***	0.48***	0.47***	0.50***	0.55***	0.44***	0.35**	0.39***
	(1.34)	(0.52)	(0.09)	(0.07)	(0.15)	(0.09)	(0.14)	(0.08)	(0.17)	(0.09)
Obs. since 2011	72		56		41		56		56	
Obs. since 2004		155		155		155		155		120
R-squared	0.00	0.00	0.55	0.41	0.19	0.35	0.42	0.25	0.18	0.22

Notes: This table shows the coefficient estimates in regressions of daily yield changes or exchange rate returns (FX) on daily changes in the 3-month swap rate (PR Surprise). Daily changes calculated around monetary policy announcements. The first column for each dependent variable uses the same sample period as Table 2: for the exchange rate from January 2011 to December 2019, for 2- 10- and 30-year yields from January 2013 to December 2019, and for 5-year yields from December 2014 to December 2019. The second column uses a larger sample period, it includes all regular monetary policy announcements from January 2004 to December 2019. All variables are expressed in basis points. No constant is included in the regressions. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

Table 4. The Response of the Exchange Rate to Policy Rate Surprises

	FX				Measurement Error in Daily FX	
	Intraday		Daily			
PRS Intraday	-1.85**		-0.38		1.47	
	(0.89)		(1.38)		(1.23)	
PRS Daily		-1.66**		-0.08		1.59
		(0.81)		(1.34)		(1.21)
Observations	72	72	72	72	72	72
R-squared	0.18	0.15	0.00	0.00	0.04	0.05

Notes: This table shows the coefficient estimates in regressions on intraday (PRS Intraday) and daily (PRS Daily) changes in the 3-month swap rate. The dependent variable in the first four columns is the percentage exchange rate returns (FX); in the first two columns they are *intraday* returns and in the next two they are *daily* returns. In the last two columns, the dependent variable is the measurement error in the daily exchange rate returns—the difference between daily and intraday returns. Daily changes are calculated around monetary policy announcements; intraday changes are calculated starting 10 minutes before to 20 minutes after an announcement. The sample is all regular monetary policy announcements from January 2011 to December 2019. All variables are expressed in basis points. No constant is included in the regressions. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

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Appendix

A Calendar of Monetary Policy Announcements

This appendix contains the calendar of Banxico's monetary policy announcements along with relevant macroeconomic data from Mexico[32] and the U.S. released on the same day.[33] Below there is additional information about the timing of the announcements.

Since 2007 the usual one-hour time difference between the capitals of Mexico and the U.S. widens to two hours during some Daylight Saving Time (DST) days. Before 2007, the one-hour difference was constant throughout the year, even during DST days because both countries followed the same arrangements. During that period, DST in both countries began on the first Sunday in April and ended on the last Sunday of October.[34] Starting in 2007, the U.S.—but not Mexico—extended its usage of the DST time, going from the second Sunday of March to the first Sunday of November.

When Banxico's announcements are made between the second Sunday of March and the first Sunday of April, and between the last Sunday of October and the first Sunday of November, the relevant Eastern Time (ET) zone times are 11 a.m. (until 2014) and 3 p.m. (since 2015). Seven announcements happened in those weeks before 2015 (at 11 a.m. ET), and 5 afterwards (at 3 p.m. ET). It is also more likely to observe those meetings during the Spring than in the Fall since there is a two- to three-week gap in the former relative to a one-week gap in the latter. In fact, only 2 of the 12 cases fell in October.

On July 1, 2015, Banxico rescheduled the last four monetary policy announcements of that year to one or two business days after the Fed's announcements in anticipation to the first increase in the U.S. policy rate since the start of the Great Recession. In 2020, all Banxico's policy meetings were scheduled one or two weeks after those of the Fed.

[32]Between 2007 and 2012, there was a shift in the time of macroeconomic releases in Mexico, most of them were initially released during the afternoon, now they are released in the morning.

[33]The abbreviations and acronyms used in the calendar are as follows: ET is Eastern Time, GDP is gross domestic product, UoM refers to University of Michigan, IGAE is the global economic activity index, IP is industrial production, CPI is the consumer price index, PPI is the producer price index.

[34]The only exception is 2001, when lawmakers in Mexico shortened the duration of the DST period.

Table 5. Calendar of Monetary Policy Announcements

Date	ET	Macroeconomic Data from Mexico and the U.S. Released on the Same Day
23-Jan-2004	10:00	MX: Trade Balance.
20-Feb-2004	10:00	MX: IGAE. US: CPI.
12-Mar-2004	10:00	US: UoM Sentiment.
26-Mar-2004	10:00	US: UoM Sentiment, Personal Income, Personal Spending.
23-Apr-2004	10:00	MX: Trade Balance. US: Durable Goods Orders.
27-Apr-2004	10:00	US: Consumer Confidence.
28-May-2004	10:00	US: UoM Sentiment, Personal Income, Personal Spending.
25-Jun-2004	10:00	MX: IGAE. US: GDP, UoM Sentiment.
23-Jul-2004	10:00	MX: Trade Balance.
27-Aug-2004	10:00	US: GDP, UoM Sentiment.
24-Sep-2004	10:00	MX: IGAE. US: Durable Goods Orders.
22-Oct-2004	10:00	MX: Bi-Weekly CPI, Retail Sales.
26-Nov-2004	10:00	
10-Dec-2004	10:00	US: UoM Sentiment.
28-Jan-2005	10:00	US: GDP.
25-Feb-2005	10:00	US: GDP, Existing Home Sales.
23-Mar-2005	10:00	MX: Trade Balance. US: CPI, Mortgage Applications, Existing Home Sales.
22-Apr-2005	10:00	MX: Bi-Weekly CPI, Trade Balance.
27-May-2005	10:00	MX: Unemployment. US: UoM Sentiment, Personal Income, Personal Spending.
24-Jun-2005	10:00	MX: Unemployment. US: Durable Goods Orders, New Home Sales.
22-Jul-2005	10:00	MX: Bi-Weekly CPI, Trade Balance.
26-Aug-2005	10:00	US: UoM Sentiment.
23-Sep-2005	10:00	MX: Trade Balance.
28-Oct-2005	10:00	US: GDP, UoM Sentiment.
25-Nov-2005	10:00	
09-Dec-2005	10:00	MX: Trade Balance. US: UoM Sentiment.
27-Jan-2006	10:00	US: GDP, New Home Sales.
24-Feb-2006	10:00	MX: IGAE, Current Account. US: Durable Goods Orders.
24-Mar-2006	10:00	MX: IGAE. US: Durable Goods Orders, New Home Sales.
21-Apr-2006	10:00	MX: Retail Sales.
26-May-2006	10:00	MX: Retail Sales, Current Account. US: UoM Sentiment, Personal Income, Personal Spending.
23-Jun-2006	10:00	MX: Trade Balance. US: Durable Goods Orders.
28-Jul-2006	10:00	US: GDP, UoM Sentiment.
25-Aug-2006	10:00	MX: IGAE, Current Account.
22-Sep-2006	10:00	MX: Bi-Weekly CPI, Retail Sales.
27-Oct-2006	10:00	US: GDP, UoM Sentiment.
24-Nov-2006	10:00	MX: Retail Sales, Current Account.
08-Dec-2006	10:00	MX: Trade Balance. US: Change in Nonfarm Payrolls, UoM Sentiment, Unemp. Rate.
26-Jan-2007	10:00	US: Durable Goods Orders, New Home Sales.
23-Feb-2007	10:00	MX: Trade Balance, Current Account.
23-Mar-2007	11:00	MX: Trade Balance. US: Existing Home Sales.
27-Apr-2007	10:00	US: GDP, UoM Sentiment.
25-May-2007	10:00	MX: Unemp. Rate, Current Account. US: Existing Home Sales.
22-Jun-2007	10:00	MX: Bi-Weekly CPI, Retail Sales.
27-Jul-2007	10:00	US: GDP, UoM Sentiment.
24-Aug-2007	10:00	MX: Unemp. Rate, Current Account. US: Durable Goods Orders, New Home Sales.
21-Sep-2007	10:00	MX: Unemp. Rate.
26-Oct-2007	10:00	MX: IGAE. US: UoM Sentiment.
23-Nov-2007	10:00	MX: Trade Balance, Current Account.
07-Dec-2007	10:00	MX: CPI, Gross Fixed Investment. US: Change in Nonfarm Payrolls, UoM Sentiment, Unemp. Rate.
18-Jan-2008	10:00	US: UoM Sentiment.
15-Feb-2008	10:00	US: UoM Sentiment, IP.
14-Mar-2008	11:00	US: CPI, UoM Sentiment.
18-Apr-2008	10:00	MX: Unemp. Rate.
16-May-2008	10:00	US: UoM Sentiment, Housing Starts.
20-Jun-2008	10:00	MX: Unemp. Rate.

Date	ET	Macroeconomic Data from Mexico and the U.S. Released on the Same Day
18-Jul-2008	10:00	MX: Unemp. Rate.
15-Aug-2008	10:00	US: UoM Sentiment, IP.
19-Sep-2008	10:00	MX: Unemp. Rate.
17-Oct-2008	10:00	MX: IP. US: UoM Sentiment, Housing Starts.
28-Nov-2008	10:00	
16-Jan-2009	10:00	MX: IP. US: CPI, UoM Sentiment, IP.
20-Feb-2009	10:00	MX: GDP. US: CPI.
20-Mar-2009	11:00	MX: Aggregate Supply and Demand.
17-Apr-2009	10:00	MX: IP. US: UoM Sentiment.
15-May-2009	10:00	US: CPI, UoM Sentiment, IP.
19-Jun-2009	10:00	MX: Aggregate Supply and Demand.
17-Jul-2009	10:00	MX: IP. US: Housing Starts.
21-Aug-2009	10:00	MX: Retail Sales. US: Existing Home Sales.
18-Sep-2009	10:00	
16-Oct-2009	10:00	US: UoM Sentiment, IP.
27-Nov-2009	10:00	
15-Jan-2010	10:00	US: CPI, UoM Sentiment, IP.
19-Feb-2010	10:00	US: CPI.
19-Mar-2010	11:00	MX: Aggregate Supply and Demand.
16-Apr-2010	10:00	US: UoM Sentiment, Housing Starts.
21-May-2010	10:00	MX: Retail Sales.
18-Jun-2010	10:00	MX: Retail Sales.
16-Jul-2010	10:00	US: CPI, UoM Sentiment.
20-Aug-2010	10:00	MX: GDP, IGAE.
24-Sep-2010	10:00	US: Durable Goods Orders, New Home Sales.
15-Oct-2010	10:00	US: CPI, UoM Sentiment, Retail Sales.
26-Nov-2010	10:00	
21-Jan-2011	10:00	MX: Unemp. Rate.
04-Mar-2011	10:00	MX: Consumer Confidence. US: Change in Nonfarm Payrolls, Unemp. Rate, Factory Orders.
15-Apr-2011	10:00	US: CPI, UoM Sentiment, IP.
27-May-2011	10:00	US: UoM Sentiment, Personal Income, Personal Spending.
08-Jul-2011	10:00	US: Change in Nonfarm Payrolls, Unemp. Rate.
26-Aug-2011	10:00	US: GDP, UoM Sentiment.
14-Oct-2011	10:00	US: UoM Sentiment, Retail Sales.
02-Dec-2011	10:00	US: Change in Nonfarm Payrolls, Unemp. Rate.
20-Jan-2012	10:00	US: Existing Home Sales.
16-Mar-2012	11:00	US: CPI, UoM Sentiment, IP.
27-Apr-2012	10:00	MX: Trade Balance. US: GDP, UoM Sentiment.
08-Jun-2012	10:00	MX: Gross Fixed Investment.
20-Jul-2012	10:00	MX: Unemp. Rate.
07-Sep-2012	10:00	MX: CPI, Bi-Weekly CPI. US: Change in Nonfarm Payrolls, Unemp. Rate.
26-Oct-2012	10:00	US: GDP, UoM Sentiment.
30-Nov-2012	10:00	US: Personal Income, Personal Spending.
18-Jan-2013	10:00	US: UoM Sentiment.
08-Mar-2013	10:00	MX: Gross Fixed Investment. US: Change in Nonfarm Payrolls, Unemp. Rate.
26-Apr-2013	10:00	MX: Trade Balance. US: GDP, UoM Sentiment.
07-Jun-2013	10:00	MX: CPI, Bi-Weekly CPI. US: Change in Nonfarm Payrolls, Unemp. Rate.
12-Jul-2013	10:00	MX: IP. US: UoM Sentiment.
06-Sep-2013	10:00	MX: Gross Fixed Investment. US: Change in Nonfarm Payrolls, Unemp. Rate.
25-Oct-2013	10:00	MX: Trade Balance. US: UoM Sentiment, Durable Goods Orders.
06-Dec-2013	10:00	MX: Gross Fixed Investment. US: Change in Nonfarm Payrolls, UoM Sentiment, Unemp. Rate, Personal Income, Personal Spending.
31-Jan-2014	10:00	US: UoM Sentiment, Personal Income, Personal Spending.
21-Mar-2014	11:00	MX: Retail Sales.
25-Apr-2014	10:00	MX: IGAE. US: UoM Sentiment.
06-Jun-2014	10:00	US: Change in Nonfarm Payrolls, Unemp. Rate.
11-Jul-2014	10:00	MX: IP.
05-Sep-2014	10:00	MX: Consumer Confidence. US: Change in Nonfarm Payrolls, Unemp. Rate.

Date	ET	Macroeconomic Data from Mexico and the U.S. Released on the Same Day
31-Oct-2014	11:00	US: UoM Sentiment, Personal Income, Personal Spending.
05-Dec-2014	10:00	MX: Consumer Confidence. US: Change in Nonfarm Payrolls, Unemp. Rate, Factory Orders.
29-Jan-2015	14:00	US: Initial Jobless Claims.
26-Mar-2015	15:00	US: Initial Jobless Claims.
30-Apr-2015	14:00	US: Initial Jobless Claims, Personal Income, Personal Spending.
04-Jun-2015	14:00	US: Initial Jobless Claims.
30-Jul-2015	14:00	US: Initial Jobless Claims, GDP.
21-Sep-2015	14:00	US: Existing Home Sales.
29-Oct-2015	15:00	US: Initial Jobless Claims, GDP.
17-Dec-2015	14:00	US: Initial Jobless Claims.
04-Feb-2016	14:00	MX: Gross Fixed Investment. US: Initial Jobless Claims, Durable Goods Orders, Factory Orders.
17-Feb-2016	12:17	(Omitted)
18-Mar-2016	15:00	MX: Aggregate Supply and Demand. US: UoM Sentiment.
05-May-2016	14:00	US: Initial Jobless Claims.
30-Jun-2016	14:00	US: Initial Jobless Claims.
11-Aug-2016	14:00	MX: IP. US: Initial Jobless Claims.
29-Sep-2016	14:00	US: Initial Jobless Claims, GDP.
17-Nov-2016	14:00	US: CPI, Initial Jobless Claims, Housing Starts.
15-Dec-2016	14:00	US: CPI, Initial Jobless Claims, Manufacturing PMI.
09-Feb-2017	14:00	MX: CPI, Bi-Weekly CPI. US: Initial Jobless Claims.
30-Mar-2017	15:00	US: Initial Jobless Claims, GDP.
18-May-2017	14:00	US: Initial Jobless Claims.
22-Jun-2017	14:00	MX: Bi-Weekly CPI. US: Initial Jobless Claims.
10-Aug-2017	14:00	US: Initial Jobless Claims, PPI.
28-Sep-2017	14:00	US: Initial Jobless Claims, GDP.
09-Nov-2017	14:00	MX: CPI, Bi-Weekly CPI. US: Initial Jobless Claims.
14-Dec-2017	14:00	US: Initial Jobless Claims, Retail Sales, Manufacturing PMI.
08-Feb-2018	14:00	MX: CPI, Bi-Weekly CPI. US: Initial Jobless Claims.
12-Apr-2018	14:00	US: Initial Jobless Claims.
17-May-2018	14:00	US: Initial Jobless Claims.
21-Jun-2018	14:00	US: Initial Jobless Claims.
02-Aug-2018	14:00	US: Initial Jobless Claims, Durable Goods Orders, Factory Orders.
04-Oct-2018	14:00	MX: Consumer Confidence. US: Initial Jobless Claims, Durable Goods Orders, Factory Orders.
15-Nov-2018	14:00	US: Initial Jobless Claims, Retail Sales.
20-Dec-2018	14:00	MX: Retail Sales. US: Initial Jobless Claims.
07-Feb-2019	14:00	MX: CPI, Bi-Weekly CPI. US: Initial Jobless Claims.
28-Mar-2019	15:00	US: Initial Jobless Claims, GDP.
16-May-2019	14:00	US: Initial Jobless Claims, Housing Starts.
27-Jun-2019	14:00	MX: Trade Balance. US: Initial Jobless Claims, GDP.
15-Aug-2019	14:00	US: Initial Jobless Claims, Retail Sales, IP.
26-Sep-2019	14:00	MX: IGAE. US: Initial Jobless Claims, GDP.
14-Nov-2019	14:00	US: Initial Jobless Claims, PPI.
19-Dec-2019	14:00	US: Initial Jobless Claims, Existing Home Sales.

B Exclusion of the Announcement on Feb. 17, 2016

On January 20, 2016, the price of oil declined to 26 dollars per barrel (dpb), a level not seen since 2003. By February 4, the day of the first regular monetary policy meeting of Banxico that year, the price recovered to 32 dpb. One week later, however, the price declined again, now to 28 dpb, raising concerns about the current account in Mexico and the fiscal position of the government, who relies considerably on oil exports. During that week, the peso depreciated to 19.2 pesos per dollar, a level not seen before. For Banxico, this raised concerns about the exchange rate pass-through to inflation.

Shortly after 12 p.m. on February 17, the Secretary of Finance and the Governor of Banxico held a joint press conference to announce a series of measures intended to provide confidence to participants in financial markets. The measures included a 50 basis point increase in the policy rate. Although the decision was completely unexpected by market participants, it was preceded and followed by other measures during the press conference, including a fiscal adjustment. As a consequence, the response of asset prices around this particular monetary policy decision is likely to be contaminated by the other announcements; that is, identification of the actual effects of the emergency meeting is not easy, even using intraday data. Additionally, Banxico's decision to tighten was mainly influenced by the developments in the exchange rate market in the previous days and, therefore, not completely exogenous.

Finally, the statement of the emergency meeting clearly indicates that the decision to raise the policy rate 'does not start a tightening cycle'. Given that it was completely unexpected by market participants, it can be considered as a one-time policy rate surprise.

C Policy Rate Surprises Based on the TIIE28D

There are several considerations that need to be taken into account if the TIIE28D were to be used to measure monetary policy surprises. First, it is calculated once a day and thus daily changes are the highest frequency for which TIIE28D can be used, which is relevant given the 'high-frequency' exchange rate puzzle (see section 4).

Second, there is a difference between the date of the calculation and that of the publication, which needs to be taken into account to compute the daily changes. The relevant date is the former since it reflects the available information in the market at the time when banks submit their quotes to Banxico for it to calculate the TIIE28D.[35] Given

[35] Daily changes obtained using the date of the publication do not capture the event of interest (i.e. surprises in monetary policy decisions) since they reflect information one day before the event.

this timing difference, the data source for the TIIE28D matters. Bloomberg reports the series for the TIIE28D using the calculation date, while Banxico reports the series using the publication date.

One last consideration involves the timing change of Banxico's monetary policy announcements from 10 a.m. to 2 p.m. ET that started in 2015. The TIIE28D is calculated at 1 p.m. ET with quotes from at least six commercial banks.[36] This time falls in between the times of the monetary policy announcements preceding and following the timing change. Therefore, the daily changes using the TIIE28D series need to take this into account to ensure that they are correctly capturing the information before and after each monetary policy announcement. Namely, before 2015, the daily changes need to be calculated as the difference in the series the day of the announcement relative to the previous day, but starting in 2015, they need to be obtained as the difference in the series the following day of the announcement relative to the day of the announcement.

The correlation between the policy rate surprises obtained from the daily change in the TIIE28D and that obtained from the intraday change in the 3-month swap rate is 0.7. Consistent with the explanation for the 'high-frequency' exchange rate puzzle in section 4, when policy rate surprises based on the TIIE28D are used, there is no effect on the exchange rate, and not even in the yield curve.

D Derivation of Inconsistency in Slope Estimator

This appendix derives the degree of inconsistency in the slope estimator when there is measurement error in the dependent and independent variables, and an omitted variable.

Let μ_i and σ_i^2 denote respectively the expected value and variance of variable i, and σ_{ij} the covariance between variables i and j. For ease of exposition, I assume that the dependent and independent variables in the following model have mean zero:

$$y^* = \beta x^* + \varepsilon,$$

[36] If less than six banks submit their quotes, the time for the calculation is delayed at most twice in 15-minute intervals. All these times increase by one hour during non-overlapping DST days between Mexico and the U.S.

where the error ε is independent and identically distributed with zero mean, variance σ_ε^2 and uncorrelated with x^*, so $\mu_\varepsilon = \sigma_{\varepsilon x^*} = 0$. Both y^* and x^* are unobserved variables, while the observed variables, y and x, are measured with an additive error:

$$x = x^* + u,$$

$$y = y^* + \nu,$$

where the measurement errors have zero means and variances given by σ_u^2 and σ_ν^2, plus they are uncorrelated among themselves and with the error term ε; that is, $\mu_u = \mu_\nu = \sigma_{u\nu} = \sigma_{u\varepsilon} = \sigma_{\nu\varepsilon} = 0$. The estimated equation is thus:

$$y = \beta x + \tau = \beta x + \varepsilon - \beta u + \nu,$$

where the error τ mixes together the 'true' error ε, and the measurement errors u and ν.

The classical measurement error model assumes that there is only measurement error in the independent variable, which is uncorrelated with the true dependent and independent variables; that is, $\sigma_u^2 > 0$ and $\sigma_\nu^2 = \sigma_{ux^*} = \sigma_{uy^*} = 0$. Under these assumptions, the classic result is that the least squares estimators for β and σ_ε^2, $\hat{\beta}$ and $\hat{\sigma_\varepsilon^2}$, are inconsistent. In particular, the estimator $\hat{\beta}$ is biased towards zero, commonly referred to as attenuation bias. The degree of inconsistency in $\hat{\beta}$ can be seen by taking its probability limit:

$$\text{plim}\left(\hat{\beta}\right) = \frac{cov(x, y^*)}{var(x)} = \frac{cov(x^* + u, \beta x^* + \varepsilon)}{var(x^* + u)} = \beta \frac{\sigma_{x^*}^2}{\sigma_{x^*}^2 + \sigma_u^2} = \beta\lambda,$$

where λ is the attenuation factor, also known as the signal-to-total variance ratio.[37] Since $0 < \lambda < 1$, $|\text{plim}(\hat{\beta})| < |\beta|$. Hence, the extent of the bias depends asymptotically on λ, the farther away it is from one, the larger the attenuation bias.[38] Lastly, the estimator for the asymptotic variance s of $\hat{\beta}$ is also inconsistent.[39]

When there is measurement error in the dependent variable only, it is usually assumed to be uncorrelated with the true dependent and independent variables; that is, $\sigma_\nu^2 > 0$ and $\sigma_u^2 = \sigma_{\nu x^*} = \sigma_{\nu y^*} = 0$. These assumptions imply that the estimator $\hat{\beta}$ is consistent but with a larger standard error.

[37]Notice that λ can also be defined as $\lambda = \sigma_{x^*}^2 / \sigma_x^2$.

[38]When there is no measurement error in the independent variable, $\sigma_u^2 = 0$, $\lambda = 1$ and $\hat{\beta}$ is consistent.

[39]See Pischke (2007) for a derivation of plim $(\hat{s}) = \lambda s + \lambda(1-\lambda)\beta^2$. Thus, when $\lambda = 1$, $\hat{s}$ is consistent.

Validation studies provide evidence about the magnitude of the measurement errors and permit one to asses the validity of the classic assumptions for the case at hand. Table 6 compares the classic assumptions in measurement error models against the data for the exchange rate and the policy rate surprises.[40]

[Insert Table 6 here.]

The measurement error in the independent variable is relatively small (σ_u is less than 2 basis points). Indeed, the attenuation factor is close to 1 and so the attenuation bias is relatively small asymptotically.[41] Most importantly, table 6 shows that the classical assumptions are not satisfied in the data. In particular, the measurement error in the dependent variable is quite high (σ_ν is close to 60 basis points) and is slightly correlated with the independent variable ($\rho_{\nu x^*} = 0.2$ at the 10% level of significance).

The main reason behind the puzzle is then noise in the daily exchange rate returns. The estimator $\hat{\beta}$ can be biased because the error ν is systematically related to the independent variable creating an endogeneity bias or, more generally, because it captures the effects of other variables influencing the exchange rate generating a standard omitted variable bias. To address both cases, the measurement error model is extended as follows:

$$y^* = \beta x^* + \gamma\omega + \varepsilon,$$

where the new variable ω is the omitted one ($\gamma \neq 0$) and it is assumed to be uncorrelated with ε and with the measurement errors u and ν. The measurement error in the dependent variable is now allowed to be correlated with the independent variable; that is, $\sigma_\nu^2 > 0$ and $\sigma_{\nu x^*} \neq 0$. With these assumptions, the degree of inconsistency in $\hat{\beta}$ is:

$$\text{plim}\left(\hat{\beta}\right) = \frac{cov(x,y)}{var(x)} = \frac{cov(x^* + u, \beta x^* + \gamma\omega + \nu + \varepsilon)}{var(x^* + u)} = \frac{\beta\sigma_{x^*}^2 + \gamma\sigma_{\omega x} + \sigma_{\nu x}}{\sigma_{x^*}^2 + \sigma_u^2}$$

$$\text{plim}\left(\hat{\beta}\right) = \beta\frac{\sigma_{x^*}^2}{\sigma_x^2} + \gamma\frac{\sigma_{\omega x}}{\sigma_x^2} + \frac{\sigma_{\nu x}}{\sigma_x^2} = \beta\lambda + \gamma\delta_{\omega x} + \delta_{\nu x}. \quad (2)$$

[40]The null hypotheses $\mu_u = 0$ and $\mu_\nu = 0$ are not rejected. Also, the null hypothesis $\rho_{u\nu} = 0$ is not rejected, the sample correlation between the two measurement errors is 0.13 with a p-value of 0.28. The correlations of the measurement errors with the true error are not considered because a validation study allows one to observe u and ν but never ε, as pointed out by Bound et al. (1994).

[41]Since the attenuation factor is shared among the dependent variables (exchange rate and bond yields), there is also a relatively small attenuation bias in the estimated coefficients of the yield curve when intraday changes in yields are regressed on daily changes in the 3-month swap rate.

This result provides several insights. Now terms related to ω and ν also affect the inconsistency in $\hat{\beta}$.[42] Notice that $\delta_{\omega x}$ and $\delta_{\nu x}$ are the slope coefficients from regressing the omitted variable ω and the measurement error ν on the mismeasured covariate x, respectively. Even without measurement error in the independent variable ($\lambda = 1$), the estimator $\hat{\beta}$ will still be biased whenever there is an omitted variable and/or the measurement error in the daily exchange rate returns is correlated with the policy rate surprises;[43] this can actually be seen in the third column of table 4. The second term is a standard omitted variable bias whose magnitude and sign depend on the influence of that variable on the exchange rate (γ) and the correlation it has with the policy rate surprises ($\delta_{\omega x}$). The third term is the endogeneity bias created because $\sigma_{\nu x^*} \neq 0$.

From the two additional terms in the probability limit of $\hat{\beta}$, the second one cannot be assessed directly—because ω is unobserved—but the third one can indeed be estimated, plus it is expected to be positive (since $\hat{\rho}_{\nu x^*} > 0$ in table 6). Precisely, the last two columns in table 4 test whether the error ν is systematically related to the policy rate surprises. Both $\hat{\delta}_{\nu x^*}$ and $\hat{\delta}_{\nu x}$ are positive and their magnitudes match the upward bias, but their standard errors are large, consistent with the high p-value for $\rho_{\nu x^*}$ in table 6. Therefore, rather than being correlated with the independent variable, the measurement error in the daily exchange rate returns is giving rise to an omitted variable bias.

Finally, the bias due to an omitted variable can be characterized by noticing that its sign depends on the signs of γ and $\delta_{\omega x}$. Assume $\beta < 0$ and $\sigma_{\nu x} = 0$ in equation (2). An upward bias implies either $\gamma > 0$ and $\delta_{\omega x} > 0$, or $\gamma < 0$ and $\delta_{\omega x} < 0$. In the first case, the omitted variable correlates positively with the policy rate surprises but has an offsetting effect on the exchange rate; for instance, when there is a surprise easing ($x < 0$) that depreciates the currency ($\beta < 0$), the omitted variable falls ($\omega < 0$ since $\delta_{\omega x} > 0$) appreciating the currency ($\gamma > 0$). This example actually aligns with the response of the exchange rate on September 6, 2013, described in section 4.

[42]Similarly, additional terms related to ω and ν appear in the probability limit of $\hat{s}$.

[43]If there is no measurement error in x ($\sigma_u^2 = 0$), ω and ν are regressed on x^* instead of x.

Table 6. Assessment of Classic Measurement Error Assumptions

Measurement Error in	Classic Assumptions	Data	p-value
Independent Variable Only	$\sigma_\nu = 0$	59.96	
	$\rho_{ux^*} = 0$	0.02	0.856
	$\rho_{uy^*} = 0$	0.10	0.407
Dependent Variable Only	$\sigma_u = 0$	1.70	
	$\rho_{\nu x^*} = 0$	0.20	0.097
	$\rho_{\nu y^*} = 0$	-0.11	0.368
	$0 < \lambda < 1$	0.956	

Notes: This table compares the classic assumptions in measurement error models against the data. Measurement errors are calculated as the difference between daily and intraday changes in the variables. σ_i, σ_i^2 and ρ_{ij} denote the standard deviation and variance of variable i, and the correlation between variables i and j, respectively. Although the assumptions in the models are expressed in terms of covariances, this table reports correlations. The last column tests the null hypothesis of zero correlation. The attenuation factor is calculated according to $\lambda = \sigma_{x^*}^2 / \left(\sigma_{x^*}^2 + \sigma_u^2\right)$, where $\sigma_{x^*} = 7.93$. The sample is all regular monetary policy meetings from January 2011 to December 2019.