Does the Exchange Rate Respond to Monetary Policy in Emerging Markets? Evidence from Mexico †

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Abstract

This paper addresses the exchange rate puzzle in emerging markets. Existing evidence shows that monetary policy in advanced economies exerts a strong impact on exchange rates, yet the response of emerging market currencies to domestic monetary policy is small, nonexistent or inconsistent with standard open economy models. I construct 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 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. I show that the puzzle is 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.

JEL Classification: E52, E58, E43, F31, G14.

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1 Introduction

The exchange rate response to monetary policy in emerging markets is an open question. 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, early evidence for advanced economies (Grilli and Roubini, 1995) found that contractionary monetary policy leads to a currency depreciation, which was referred to as the exchange rate puzzle. This puzzle owes to the assumptions made to identify the monetary policy surprises, giving rise to a problem of reverse causality (Zettelmeyer, 2004).[1] For advanced economies, event studies with high-frequency data identify exogenous changes in the policy rate and show that a rate hike indeed leads to an appreciation of their currencies; this effect can be seen using intraday (Andersen et al., 2003; Kearns and Manners, 2006; Faust et al., 2007) and daily (Wright, 2012; Ferrari et al., 2021) event windows, and even exhibits persistence over subsequent days (Rosa, 2011b; Ferrari et al., 2021). For emerging markets, however, event studies with *daily* data 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). Kohlscheen (2014) refers to this as the high-frequency exchange rate puzzle in emerging markets.[2]

The null or weak response of the currency to the policy rate in emerging markets reported in the literature (the puzzle) raises the question of whether their central banks can actually exert an influence on their own currencies. The question is 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 economies to monetary policy increased after the global financial crisis (Ferrari et al., 2021), even in countries who continued to use conventional tools—like Australia and Canada—and so it would be striking if emerging market currencies remain insensitive to monetary policy. Third, the currencies of emerging markets do respond to *foreign* monetary policy surprises (Hausman

[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. Kim and Lim (2016) find similar results for emerging markets.

[2]Yet, nowadays, the term 'high-frequency' is usually associated with the term 'intraday', not 'daily'.

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 intraday changes in asset prices bracketing all regular monetary policy announcements in Mexico from 2011 to 2021.[3] Mexico is a small open economy with relatively liquid financial markets, a market-based exchange rate, and a credible inflation targeting regime, criteria that make it a reasonable candidate for this type of analysis (Kearns and Manners, 2006; Pennings et al., 2015). 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).[4] Nevertheless, they have rarely been applied to study the transmission of monetary policy to asset prices in Mexico.[5] Kohlscheen (2014) does include Mexico in his study of the exchange rate response to monetary policy, but does not use intraday data nor swaps to measure surprises in the policy rate as in this paper.

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 about 55 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 economies 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 economies; namely, a 25-basis-point hike in the policy rate reduces the spread between the 10- and 2-year yields by 6 basis points. Moreover, policy rate surprises have a larger influence on the yield curve in

[3]The few extraordinary meetings that took place over the sample period are excluded because the announcements generally included additional measures, some aimed at the foreign exchange market.

[4]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.

[5]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, 2021), whereas De Pooter et al. (2014) use it to study whether inflation expectations are well-anchored.

Mexico than U.S. policy rate surprises have on the U.S. yield curve which, according to the expectations hypothesis, suggests that in Mexico there is a relatively higher degree of long-term inflation uncertainty or a larger effect of surprises on the term premium.[6]

The main contribution of the paper, however, is to solve what Kohlscheen (2014) calls the high-frequency exchange rate puzzle in emerging markets. In event studies with *daily* data, he shows that the currencies of emerging markets do not respond to monetary policy. The currencies of advanced economies, in contrast, react to monetary policy even using daily data, although the precision decreases relative to intraday data (Wright, 2012; Ferrari et al., 2021). Pennings et al. (2015) suggest that the weaker response in emerging markets relative to advanced economies could be driven by more noisy measurement of monetary policy surprises. To understand the puzzle, I compare the response of the exchange rate using two lengths for the event window, intraday and daily, in a validation study (Bound et al., 1994). To the best of my knowledge, this is the first paper highlighting the differences between intraday and daily changes in asset prices to study the effects of monetary policy in emerging markets. The analysis reveals that the exchange rate response is sensitive to data frequency as it can only be perceived using intraday data. This sensitivity is characteristic of the exchange rate since the effect of the policy rate on the yield curve can still be observed with daily data. I show that the puzzle is the result of wide event windows when measuring changes in the exchange rate, rather than noisy measurement of monetary policy surprises. Moreover, daily exchange rate returns give rise to bias due to omitted variables which, in fact, declines after controlling for potential omitted variables. 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 countries—particularly emerging markets—have a preference for smooth currency fluctuations or, equivalently, that they fear large currency swings (Calvo and Reinhart, 2002). Because of this 'fear of floating', the central bank would adjust its policies—including changes in the policy rate

[6]Prices are flexible in the long run, so long-term expected real interest rates would not be affected.

and foreign exchange interventions—to keep the currency from experiencing large swings. This phenomenon, however, is unrelated to the question of whether an unanticipated change in the policy rate affects the currency. In fact, by focusing on the effects of policy rate surprises, this paper is neutral on how monetary policy expectations are determined.

The paper proceeds as follows. Section 2 describes how policy rate surprises are measured. Section 3 discusses their effects on the currency and the yield curve. Section 4 addresses the exchange rate puzzle in emerging markets. The last section concludes.

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 the deputy governors.

The starting date for daily data is 2004 based on the following. When Banxico was granted autonomy in 1994, inflation was 7%. Less than a year later, in December 1994, the Mexican peso crisis started. As a result, inflation peaked at 52% and a floating exchange rate system was adopted (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. Inflation targeting was formally adopted in 2001 and the following year, 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.[7]

[7]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-

After the adoption of the current policy rate, two major institutional changes were made. First, in 2011, Banxico reduced the number of its regularly-scheduled monetary policy meetings to 8 and started releasing minutes of those meetings two weeks after the date of the respective policy decision. Previously, between 2003 and 2005, there were 23 regular meetings per year but, due to convergence of inflation to the target, Banxico reduced the number of meetings to 12 in 2006 and 2007, and to 11 between 2008 and 2010. Second, the timing of the announcements changed 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.[8]

The regularity and scheduled timing of the announcements allow me to study the effects of 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. Between January 2004 and November 2021, there were 189 regularly-scheduled monetary policy announcements, 86 of which happened since 2011. Over that period, Banxico made four unscheduled announcements, two of them in response to the Covid-19 crisis. Appendix B explains the reasons for excluding those extraordinary meetings from the analysis.[9]

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.[10] 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 global financial crisis started. The tightening cycle intensified in the second half of 2016 due to

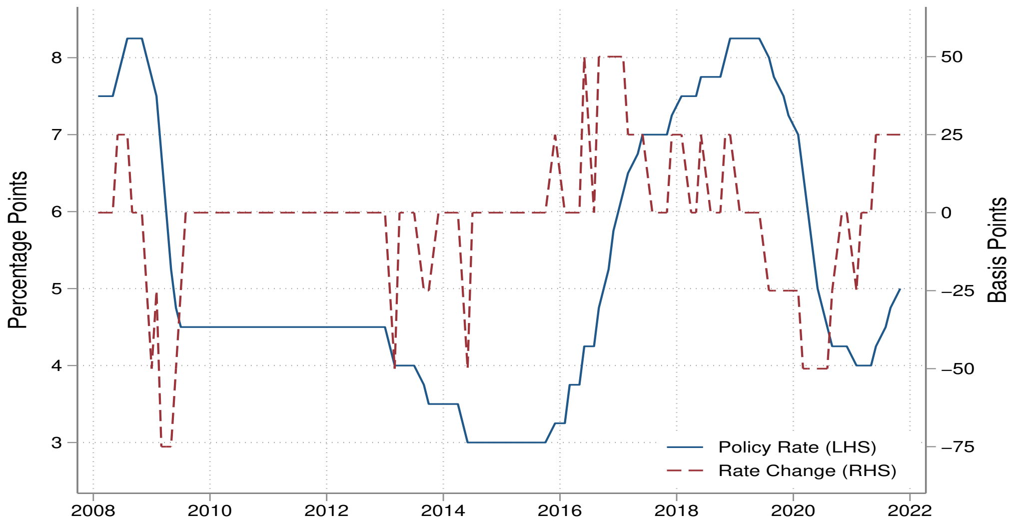
95 currency crisis until the adoption of the current policy rate.

[8]According to Banxico's governor at the time, the new timing gives market participants more time to react to policy decisions before the weekend.

[9]The emergency announcements took place on April 2004, February 2016, and March and April 2020. Tables B.1 to B.3 in the appendix replicate the main results in the paper including the two extraordinary meetings of 2020, and show that the main conclusions in the paper remain.

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

Figure 1. Policy Rate in Mexico: Level and Change



Notes: This figure shows the evolution of the level (solid line) and the raw change (dashed line) of the policy rate in Mexico from January 2008 to November 2021. Banxico adopted the overnight interbank interest rate as its monetary policy instrument in January 2008 in substitution of *el corto*.

inflation concerns linked to a depreciation of the currency and the 2016 U.S. presidential election. Finally, in response to the Covid-19 crisis, Banxico accelerated an easing cycle that started in August 2019 in which the policy rate had lowered 1.25%, by cutting it an additional 2.75% between March and September 2020.

2.1.1 Timing of the Announcements

To correctly measure surprises in the policy rate with intraday data, it is crucial to have the *time* of the announcements right, which requires to consider both the change in the timing of Banxico's announcements in 2015 and the differences in the usage of Daylight Saving Time (DST) between Mexico and the U.S.

The two relevant times for Banxico's announcements are 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, but not Mexico. Therefore, there are four relevant ET times for Banxico's policy decisions. All announcements before 2007 happened at 10 a.m. ET. Between 2007 and 2014, the announcements took place 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

The analysis of the effects of monetary policy focuses 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, by the time of the announcement, the expected part is already reflected in prices. The unanticipated part is thus the relevant component of policy decisions, usually referred to as the 'surprise' or the 'shock'. Surprises in the policy rate can be thought of as the difference between the raw change and the expected one.[11] The prices of certain financial instruments provide a market-based measure of expectations about monetary policy.[12]

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.[13] Instead, the swap market in Mexico references an interbank interest rate that closely follows the policy rate, the 28-day interbank interest rate (TIIE28D).[14] The TIIE28D is denominated in local currency and is the benchmark rate for banking loans in Mexico. Banxico calculates the TIIE28D once a day based on quotes it receives from commercial banks.

The most liquid swap referencing the TIIE28D, and indeed the main local derivative, is the 3-month swap. Importantly, unlike the TIIE28D itself, the 3-month swap trades

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

[12] For the U.S., for instance, Kuttner (2001) uses futures on the federal funds rate. Surveys of professional forecasters are an alternative source of expectations about monetary policy decisions.

[13] 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 the U.S. itself, Germany, Japan and the U.K.

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

within the day, which is needed to calculate changes in the swap rate in intraday windows.[15] A 1-month swap referencing the TIIE28D also trades in the market, but it has a shorter history (it essentially did not trade between mid 2006 and early 2012) and is less liquid (it trades only a few times a day).

The policy rate surprises in this paper are equal to the change in the 3-month swap rate around windows containing monetary policy announcements. These surprises are model-free and represent a change in the information set of market participants. A positive value represents a tightening of the monetary stance, while a negative value represents an easing. In principle, changes in the 3-month swap rate may capture surprises not only about the current level of the policy rate—the variable of interest—but also about its future path, given that the contract may cover more than one policy meeting ahead. An alternative measure of policy rate surprises, used by De Pooter et al. (2014), is the difference between the actual policy rate change and the average of survey expectations reported by Bloomberg. The correlation between the market-based and the survey-based measures is slightly above 0.9. In addition, the 1-month swap arguably does not capture surprises about the future path of the policy rate. The correlation between the daily changes in the 1-month swap and the 3-month swap rates is 0.7.[16] Lastly, Solís (2021a) shows that changes in the 1-year swap rate that are uncorrelated to changes in the 3-month swap rate nicely align with surprises about the future path of the policy rate communicated by Banxico via statements. Therefore, even though the 3-month swap might capture more than one policy meeting ahead, changes in the rate adequately capture the monetary stance in the short run.

Changes in the 3-month swap rate measure the shift 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,[17] 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

[15] Appendix C discusses relevant considerations if the TIIE28D were to be used to measure the surprises.
[16] The 1-month swap is not used to compute the policy rate surprises because its low liquidity does not allow to compute intraday changes.
[17] A risk premium compensates investors in case their policy rate expectations turn out to be wrong.

(Piazzesi and Swanson, 2008; García-Verdú et al., 2019).[18] In fact, Piazzesi and Swanson (2008) document that monetary policy surprises based on the *change* in the derivative 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. The windows start 10 minutes before and end 20 minutes after each announcement. Differences over the same 30-minute windows are also calculated for the exchange rate (expressed in pesos per U.S. dollar) and for yields of bonds issued by the Mexican government with maturities of 2, 5, 10 and 30 years.[19] Changes in interest rates are calculated directly using quotes before and after the announcements, while for the exchange rate, 100 times log differences are used to approximate the percentage change (or return) over the window. All changes are expressed in basis points.

The dataset also includes daily changes for all the assets given that access to long spans of intraday data in emerging markets is not as common as for advanced economies. Daily changes are calculated as the price change around the monetary policy announcements. The comparison of the results using intraday versus daily data is key to understand the high-frequency exchange rate puzzle (Kohlscheen, 2014), which is addressed in section 4.

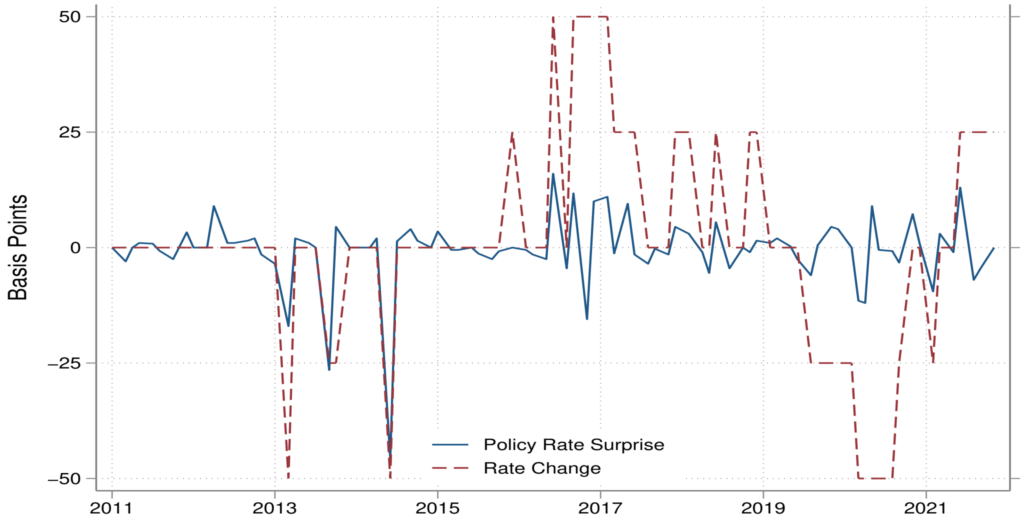
All the data for the analysis come from Bloomberg. The information to calculate intraday changes is available since 2011 for the exchange rate and the 3-month swap, and since 2013 for most bond yields; data for the 5-year yield start on December 2014. Daily changes start in 2004, except for the 30-year yield for which they start on October 2006. The dataset covers up to the meeting on November 2021.

Figure 2 compares the raw changes in the policy rate and the policy rate surprises

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

[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 change in the rates; this only happens for the swap on a few days.

Figure 2. Policy Rate in Mexico: Change vs. Surprises



Notes: This figure compares the evolution of the policy rate surprises (solid line) and the raw changes in the policy rate (dashed line). Policy rate surprises are equal to the change in the 3-month swap rate in 30-minute windows bracketing monetary policy announcements from January 2011 to November 2021.

identified using intraday data. The difference between the two is the anticipated change in the policy rate. As is common with cleanly identified surprises (Nakamura and Steinsson, 2018), the policy rate surprises are small relative to the raw changes, which indicates that most of Banxico's policy rate decisions are anticipated by market participants. Indeed, Banxico, like other central banks, works hard to communicate information to financial markets ahead of time so that, by the time of an announcement, most of it has already been anticipated.

Table 1 shows summary statistics for the intraday and daily changes in asset prices. 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 also have similar characteristics, although they vary slightly more using daily data. In contrast, the standard deviation of the exchange rate returns doubles when the frequency goes from intraday to daily.

Table 1. Summary Statistics for Asset Price Changes

	Mean	Std. Dev.	Min.	Max.	Obs
Intraday					
Policy Rate Surprises	-0.3	7.6	-45.8	16.0	86
PRS > 0	4.4	4.1	0.3	16.0	36
PRS < 0	-5.2	8.8	-45.8	-0.3	36
FX Returns	-8.7	34.5	-165.4	55.3	86
Δ 2-Year Yield	-0.5	6.6	-37.7	11.1	70
Δ 5-Year Yield	-0.1	4.8	-15.4	19.1	55
Δ 10-Year Yield	-0.7	5.0	-25.8	10.9	70
Δ 30-Year Yield	-0.8	4.2	-19.8	8.2	70
Daily					
Policy Rate Surprises	-0.4	7.9	-45.8	18.5	86
PRS > 0	4.5	5.0	0.2	18.5	35
PRS < 0	-4.8	8.4	-45.8	-0.2	40
FX Returns	-14.3	68.5	-170.4	142.2	86
Δ 2-Year Yield	-1.2	7.8	-32.6	23.3	86
Δ 5-Year Yield	-1.7	8.8	-41.1	31.8	86
Δ 10-Year Yield	-1.9	7.3	-34.8	10.5	86
Δ 30-Year Yield	-2.1	6.6	-28.1	12.6	86

Notes: This table reports summary statistics for intraday and daily changes in the 3-month swap rate (i.e., the policy rate surprises or PRS), exchange rate (FX) returns and changes in bond yields around monetary policy announcements. Daily changes are calculated around monetary policy announcements; intraday changes are calculated from 10 minutes before to 20 minutes after an announcement. All values are expressed in basis points. The sample includes all regular monetary policy announcements from January 2011 to November 2021; intraday changes for the 5-year yield start on December 2014 and for all other yields on January 2013.

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 using 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:

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

in which 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.[20] The error term ε_t captures variations in the dependent variable unrelated to policy rate surprises.

The parameter of interest in equation (1) is the slope coefficient β_1, it measures the response of asset prices to policy rate surprises.[21] The classical assumption to identify β_1 is that ε_t is orthogonal to Δx_t or, equivalently, 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 equal to the *intraday* change in the 3-month swap rate around monetary policy announcements—conceptually the surprise in the policy rate—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 changes in days with monetary policy announcements (Gürkaynak and Wright, 2013).

Changes in asset prices start to capture 'noise' when they are computed using wider windows. The wider the window, the larger the noise or measurement error. Wider windows open the door for other variables to play a role in the relationship between asset prices and policy rate surprises. For instance, since 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 like simultaneity and omitted

[20] As explained in section 2.2.1, changes in interest rates are calculated directly using quotes before and after the announcements; for the exchange rate, 100 times log differences are used to calculate the return over the window. All changes are expressed in basis points.

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

variables. Daily data mitigates those problems; however, noise in daily data can at times blur the relationship between the variables of interest, as is discussed in section 4.

3.2 Results

The dependent variable determines the sign of β_1. 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 interest rate increase in Mexico should lead to a contemporaneous appreciation of the peso, i.e. a fall in the exchange rate.[22] 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 bond yields.

3.2.1 Intraday Data

Table 2 reports the estimation of 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.

A contractionary monetary policy appreciates the currency. A 25-basis-point increase in the policy rate leads, on average, to an appreciation of the currency of about 55 basis points. For comparison, the currencies of advanced economies 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., 2021). Table 2 thus provides evidence against the exchange rate puzzle in emerging markets, it shows that their currencies are no different to those in advanced economies 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 on average 17, 14, 11, and 8 basis points, respectively; as such, the spread between the 10- and 2-year

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

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

	Δ FX		Δ 2Y Yield		Δ 5Y Yield		Δ 10Y Yield		Δ 30Y Yield	
PR Surprise	-2.22**	-2.22**	0.68***	0.68***	0.54***	0.54***	0.44***	0.45***	0.31***	0.32***
	(0.94)	(0.93)	(0.08)	(0.08)	(0.14)	(0.14)	(0.07)	(0.07)	(0.07)	(0.07)
PR Expected		0.0087		-0.032		-0.031		-0.033		-0.041*
		(0.24)		(0.02)		(0.02)		(0.02)		(0.02)
Observations	86	86	70	70	55	55	70	70	70	70
R-squared	0.23	0.23	0.73	0.74	0.38	0.41	0.55	0.57	0.38	0.42

Notes: The first column for each dependent variable shows the coefficient estimates in regressions of intraday yield changes or exchange rate (FX) returns 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 includes all regular monetary policy announcements starting on January 2011 for the exchange rate, on January 2013 for 2- 10- and 30-year yields, and on December 2014 for 5-year yields; the sample ends on November 2021 in all cases. 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.

yields—the term spread—narrows by 6 basis points.[23] These results are in line with the evidence for the U.S. in a comparable period; that is, when its policy rate was not constrained by the zero lower bound (Kuttner, 2001; Gürkaynak et al., 2005). However, two differences are worth pointing out. First, the magnitude of the yields' response in Mexico is larger than in the U.S. For instance, a 25-basis-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, 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, the surprises are the most important factor influencing 2- and 10-year yields in Mexico, with an R^2 of 0.73 and 0.55 versus 0.4 and 0.08 in the U.S., respectively.

According to the expectations hypothesis, the larger influence of policy rate surprises on the yield curve in Mexico compared to the U.S. suggests that in Mexico there is a relatively higher degree of long-term inflation uncertainty or a larger effect of surprises on the term premium.[24] On the one hand, even though inflation expectations in Mexico are anchored (De Pooter et al., 2014), surprises in the policy rate can sometimes influence long-term inflation compensation (see Table 9 in De Pooter et al. (2014)), which means that inflation expectations are less firmly anchored in Mexico than in the U.S. On the other hand, the larger reaction of bond yields in Mexico can also reflect a larger effect of policy rate surprises on the term premium, which could be explained by how reach-for-yield investors react (Hanson and Stein, 2015). These investors rebalance their portfolios in order to take on more or less risk in response to monetary policy decisions, which influences term premia. Quantifying the relative importance of each channel is an interesting question, but it requires to decompose the yields, a task that is beyond the scope of this paper.[25]

In robustness checks, I re-estimate equation (1) using two alternative measures of pol-

[23] A one-basis-point increase in the policy rate affects the term spread by -0.23 basis points, and the effect is statistically significant at the 1% level.

[24] Prices are flexible in the long run, so long-term expected real interest rates would not be affected.

[25] The three-part decomposition for the yields of emerging markets proposed by Solís (2021b) can be used to better understand how policy rate surprises transmit to bond yields in Mexico.

icy rate surprises: (i) changes in the 3-month swap rate computed using wider 50-minute windows (starting 20 minutes before and ending 30 minutes after each announcement), and (ii) the survey-based surprises mentioned in section 2.2. As before, the exchange rate returns and the changes in bond yields are based on the tight 30-minute windows. The results using the wider-window surprises are largely the same as those reported in table 2. The signs and the statistical significance of the effects using the survey-based surprises remain in all cases, although the magnitude of the effects decreases somewhat.

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.[26] Similar to the findings in Kuttner (2001) for the U.S., asset prices in Mexico respond to surprises but not to anticipated changes in the policy rate.[27] This result highlights the importance of focusing on policy rate surprises in emerging markets as well. Indeed, if raw changes were being used instead, one would incorrectly conclude that monetary policy has no effect on neither the currency nor the yield curve.[28]

In summary, 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 estimation of equation (1) using daily, instead of intraday, data. Remember that although intraday changes in swap rates and the exchange rate are available since 2011 (and somewhat later for bond yields), 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 with a sample starting in 2004.

The first two columns of table 3 illustrate the exchange rate puzzle identified by Kohlscheen (2014); that is, the exchange rate in emerging markets does not respond to

[26]The expected part is the difference between the raw change and the surprise in the policy rate.
[27]The statistically significant effect of the anticipated part on the 30-year yield is economically small.
[28]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).

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

	Δ FX		Δ 2Y Yield		Δ 5Y Yield		Δ 10Y Yield		Δ 30Y Yield	
PR Surprise	–0.61	0.06	0.70***	0.50***	0.77***	0.53***	0.56***	0.45***	0.35**	0.40***
	(1.35)	(0.54)	(0.09)	(0.07)	(0.24)	(0.09)	(0.12)	(0.07)	(0.15)	(0.08)
Obs. since 2011	86		70		55		70		70	
Obs. since 2004		189		189		189		189		134
R-squared	0.00	0.00	0.54	0.37	0.35	0.34	0.41	0.26	0.18	0.22

Notes: This table shows the coefficient estimates in regressions of daily yield changes or exchange rate (FX) returns on daily changes in the 3-month swap rate (PR Surprise). Daily changes are calculated around monetary policy announcements. The first column for each dependent variable uses the same sample period as Table 2; that is, the sample includes all regular monetary policy announcements starting on January 2011 for the exchange rate, on January 2013 for 2- 10- and 30-year yields, and on December 2014 for 5-year yields. The second column for each dependent variable uses a larger sample size, including all regular monetary policy announcements starting on January 2004. The sample ends on November 2021 in all cases. 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.

policy rate surprises when the changes are calculated using daily event windows. Section 4 addresses this puzzle.

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. Moreover, comparing table 3 against table 2 shows that there are gains in the precision of the coefficient estimates for bond yields and in terms of explanatory power (measured by R^2) if someone using daily data were to get access to intraday data (over the same sample period). The largest gains can be seen at the long end of the curve, where the standard error is half as large and the R^2 doubles when intraday changes are used instead of daily ones.

On the whole, the main conclusion from comparing tables 2 and 3 is that intraday data is key to identify the currency response to the policy rate.

3.2.3 Persistence

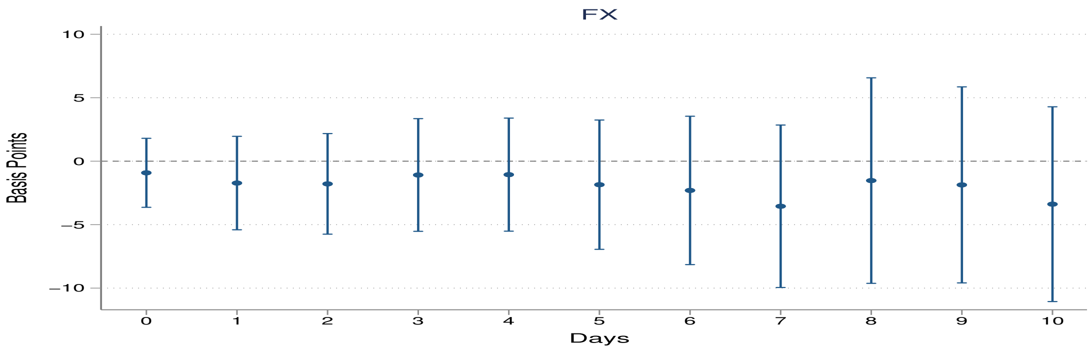
In addition to the initial reaction of asset prices to policy rate surprises, policymakers are interested in the persistence of the response. One way to address this issue, and to assess the robustness of the results, is to re-estimate equation (1) but with the change in the dependent variable calculated over subsequent days after a monetary policy announcement. Specifically, I run the following local projections:

$$y_{t+h} - y_{t-1} = \alpha_h + \gamma_h \Delta x_t + u_{t+h}, \tag{2}$$

in which h indicates the horizon (in days) with $h = 0, 1, \ldots, 10$ and Δx_t represents the policy rate surprises (i.e., changes in the 3-month swap rate in 30-minute windows around the announcements). The parameters of interest, γ_h, measure the average response of the asset price change to policy rate surprises at horizon h. All responses are assessed relative to a one-basis-point increase (a tightening) in the policy rate. Figures 3 and 4 show the persistence of the exchange rate and the yield curve, respectively.

There is no on-impact nor delayed response of the exchange rate to policy rate surprises. Since this exercise involves daily changes in asset prices, figure 3 illustrates the exchange rate puzzle in Kohlscheen (2014) from a different angle since the currencies of

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



Notes: This figure plots the coefficient estimates and 95% confidence intervals for the response of the exchange rate (FX) returns to policy rate surprises. Returns are calculated from close of day $t-1$ to day $t+h$, where t is a day with a monetary policy announcement and $h = 0, 1, \ldots, 10$. The announcements are always more than ten days apart from each other, see appendix A. The sample includes all regular monetary policy announcements from January 2011 to November 2021.

advanced economies do exhibit persistence over subsequent days (Rosa, 2011b; Ferrari et al., 2021).

Figure 4 shows that Banxico's decisions have persistent effects on the yields of bonds with maturities up to 10 years. In particular, the flattening of the yield curve highlighted before continues in the days following a policy rate tightening. The response of the 2-year yield increases over time,[29] while that of the 10-year yield is relatively more stable.

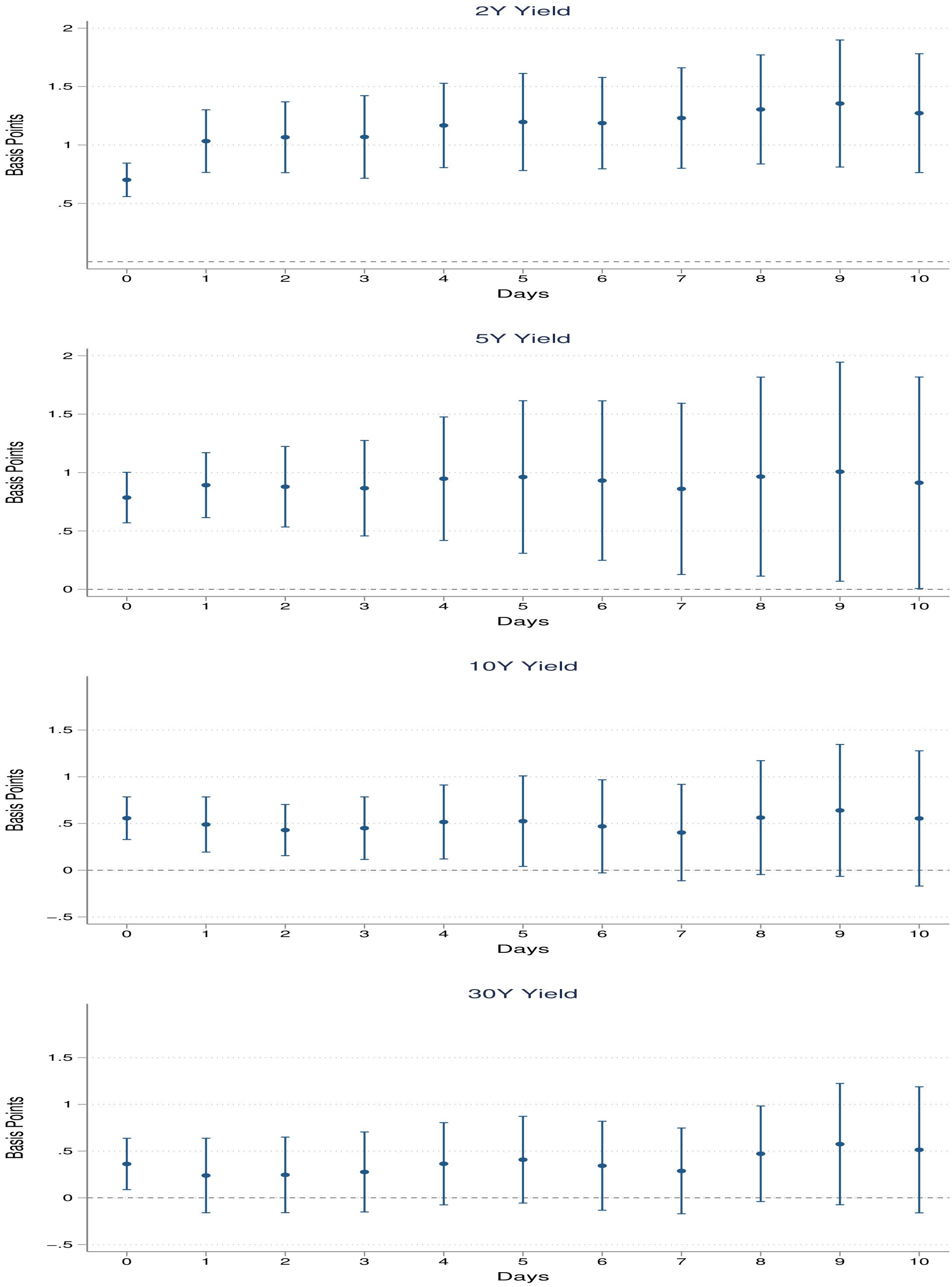
4 Solving the High-Frequency Exchange Rate Puzzle

This section argues that the apparent lack of response of the exchange rate to monetary policy in emerging markets illustrated in table 3 is the result of wide event windows when measuring the exchange rate returns, giving rise to a standard omitted variable bias.

The key insight from comparing tables 2 and 3 is that one reaches different conclusions about 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 evidence for advanced

[29] Some investors might take time to respond to monetary policy decisions, in which case the sluggish response of the 2-year yield could be attributed to slow-moving capital.

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



Notes: This figure plots the coefficient estimates and 95% confidence intervals for the response of the 2-, 5-, 10- and 30-year yield changes to policy rate surprises. Yield changes are calculated from close of day $t-1$ to day $t+h$, where t is a day with a monetary policy announcement and $h = 0, 1, \ldots, 10$. The announcements are always more than ten days apart from each other, see appendix A. The sample includes all regular monetary policy announcements from January 2011 to November 2021.

economies. 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) refers to as the high-frequency exchange rate puzzle in emerging markets.[30] This phenomenon indeed seems characteristic of emerging markets since the response of the currencies of advanced economies to the policy rate can still be seen with daily data and even exhibits persistence over subsequent days (Rosa, 2011b; Wright, 2012; Ferrari et al., 2021).

To understand the puzzle, I compare the response of the exchange rate using the two lengths for the event window, intraday and daily, in a validation study (Bound et al., 1994). Hereinafter, the exchange rate returns are the only dependent variable.

4.1 Validation Study

It is helpful to think about the puzzle from an errors-in-variables perspective. Intraday changes in asset prices are treated as if they were the true surprises, whereas daily changes are seen as if they were the true surprises plus measurement error because they capture all news happening during a day, not just the response to Banxico's decisions. From this perspective, the analysis using daily data involves measurement error in *both* the dependent and independent variables.[31]

The classical measurement error model suggests that the reason behind the puzzle is 'noise' in the policy rate surprises. Table 3, when compared against table 2, indicates that when there is measurement error in the dependent and independent variables, $\hat{\beta}_1$ is biased.[32] In the classical 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 but with a larger standard error. Accordingly , the culprit for the bias in $\hat{\beta}_1$ would be measurement error in the independent variable.

[30] Yet, nowadays, the term 'high-frequency' is usually associated with the term 'intraday', not 'daily'.

[31] To clarify, the reference to measurement error in the validation study does not mean that asset price changes are actually measured with error, it is rather used because it helps to think in those terms.

[32] An alternative explanation is that the true effect of policy rate surprises on the exchange rate returns is zero, but it would imply that there is a large market inefficiency, in which someone can bet against the exchange rate and systematically be gaining.

Validation studies provide evidence about the magnitude of the measurement errors. In these studies, the measurement errors are observed since the 'noisy' (daily) and 'true' (intraday) values for the dependent and independent variables are observed. The errors are calculated as the difference between daily and intraday changes in the variables.

In the data, the measurement error in the dependent variable is much larger than in the independent variable (see table D.1 in the appendix).[33] 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.

The validation study also sheds light on the puzzle by exploiting the two lengths for the event window when estimating equation (1). 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. Table 4 reports the results. The independent variable is measured without error in the first row, and with error in the second. The dependent variable is measured without error the first two columns, and with error in the last two. 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 of them. These two cases are reported in the first columns of tables 2 and 3, respectively, and are reproduced (columns at the far ends) in table 4 for ease of comparison. The remaining two cases, reported in the middle columns, are those in which only one of the variables is measured with error.

Table 4 shows that measurement error in the policy rate surprises does not explain the puzzle. If measurement error in the independent variable were the reason behind the bias in $\hat{\beta}_1$, as suggested by the classical model, table 4 would show an attenuation bias and larger standard errors when there is measurement error in the policy rate surprises (bottom row) than when they are measured without error (top row). Conversely, larger

[33] In line with this, regressing daily on intraday changes gives an R^2 of 0.94 for policy rate surprises and of 0.18 for exchange rate returns. Also, remember that the standard deviation of the exchange rate returns doubles when the frequency goes from intraday to daily, whereas that of the policy rate surprises remains essentially the same (see table 1).

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

	Intraday FX Returns		Daily FX Returns	
PRS Intraday	-2.22**		-0.92	
	(0.94)		(1.37)	
PRS Daily		-2.01**		-0.61
		(0.84)		(1.35)
Observations	86	86	86	86
R-squared	0.23	0.20	0.01	0.00

Notes: This table shows the coefficient estimates in regressions of exchange rate (FX) returns on intraday (PRS Intraday) and daily (PRS Daily) changes in the 3-month swap rate. The returns are calculated with *intraday* data in the first two columns and with *daily* data in the last two. Daily changes are calculated around monetary policy announcements; intraday changes are calculated from 10 minutes before to 20 minutes after an announcement. The sample includes all regular monetary policy announcements from January 2011 to November 2021. Figures 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.

bias and standard errors are seen when the exchange rate returns are measured with error (last two columns) than when there is no such error (first two columns).[34]

The reason behind the puzzle is therefore noise in the daily returns of the exchange rate. For the purposes of the validation study, the coefficient in the first column is treated as *the* parameter, since it is obtained from the 'true' variables. It shows that a tightening leads to an appreciation of the currency, as already discussed. The second column shows how much measurement error in the independent variable biases the coefficient towards zero, an upward bias. In particular, the comparison of the estimated coefficients in the first two columns shows that attenuation bias is relatively small (see also appendix D). This means that the effect of policy rate surprises on the currency is significant and relevant even when the surprises are measured with error. In contrast, relative to the first column, the upward bias in $\hat{\beta}_1$ in the last two columns of table 4 is larger than the one in the second column (1.3 and 1.59 versus 0.21 basis points) and the standard errors increase by more than 40%. Measurement error in the returns of the exchange rate

[34] In a similar exercise in which changes in bond yields are the dependent variable instead of exchange rate returns, there is also a relatively small attenuation bias when there is measurement error in the policy rate surprises and an upward bias when there is measurement error in yield changes. The upward bias dominates the attenuation bias, which explains why the coefficients for bond yields in table 3 for the sample starting in 2011 are slightly larger than in table 2.

therefore leads one to incorrectly conclude that there is no significant effect of the policy rate on the exchange rate.

4.2 Why Noise in Exchange Rate Returns Explains the Puzzle?

Measurement error in exchange rate returns is key to understand the puzzle. Pennings et al. (2015) suggest that the weaker response of the exchange rate in emerging markets relative to advanced economies could be driven by more noisy measurement of monetary policy surprises—or less liquid financial markets. The evidence in table 4 indicates instead that the reason behind the puzzle is measurement error in exchange rate returns. Comparing the last two columns relative to the first two shows that the error causes not only imprecision—as the classical model would suggest—but also bias in the estimation.

The explanation of the puzzle lies in omitted variables. In the classical model, the estimator is consistent but with a larger standard error when the dependent variable is measured with error. However, measurement error in the dependent variable can cause bias in $\hat{\beta}_1$ if it is systematically related to the independent variable—creating an endogeneity bias—or, more generally, if it captures the effects of other variables influencing the exchange rate—generating an omitted variable bias. In the data, the measurement error in the daily exchange rate returns is not systematically related to surprises in the policy rate; the null hypothesis of zero correlation is not rejected (see table D.1 in the appendix), and the slope coefficient of regressing the error on the policy rate surprises is not significant. 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.

Appendix D extends the classical model to derive the inconsistency in the estimator when the measurement error in the dependent variable captures an omitted variable. In that case, there will be bias and imprecision in the estimator, even without measurement error in the independent variable, which is consistent with the evidence in table 4.

4.3 Potential Omitted Variables

An omitted variable for the daily exchange rate returns can be anything that affects the exchange rate. The task is therefore to focus on variables with a high likelihood of influencing it. Successful candidates should be exogenous to Banxico's monetary policy, and correlated with the daily exchange rate returns and with the policy rate surprises (see appendix D). To support the argument that noise in daily exchange rate returns gives rise to bias due to omitted variables, controlling for potential candidates when regressing the daily exchange rate returns on the policy rate surprises should at least reduce the bias and the larger standard errors identified in the last two columns of table 4.

Variables with influence across global financial markets are natural candidates. Two key factors driving the global financial cycle are the Cboe's volatility index (VIX) and the monetary stance of the Federal Reserve. The VIX captures the implied volatility in stock option prices, and is considered a measure of risk aversion and economic uncertainty. The 2-year U.S. Treasury yield is a benchmark commonly used by market participants to capture the monetary stance in the U.S. The West Texas Intermediate (WTI) crude oil price is another potential candidate because the budget of the Mexican government is closely tied to it given that Mexico is an oil exporter country.

In the case of emerging markets, it is also important to look at external events when considering omitted variable candidates. For instance, the U.S. dollar responds significantly to different U.S. macroeconomic news (Andersen et al., 2003; Faust et al., 2007). If those news happen to be released on days in which Banxico announces monetary policy decisions, daily returns of the peso-dollar exchange rate will reflect at least those two events. The calendar in appendix A shows that it is indeed common for Banxico's monetary policy announcements to coincide with releases of relevant U.S. macroeconomic news.

U.S. labor market data seem to be a good example of omitted variables for the daily returns of the exchange rate. The U.S. Department of Labor releases at 8:30 a.m. ET the change in nonfarm payrolls monthly generally on a Friday, and initial jobless claims weekly generally on a Thursday. Banxico's monetary policy announcements coincided with releases of nonfarm payrolls on 11 occasions between 2011 and 2014, and 30 times with releases of initial jobless claims between 2015 and 2018.[35] Consider, for instance, the announcement on September 6, 2013, in which Banxico unexpectedly cut its policy rate by 25 basis points at 10 a.m. ET. According to the estimation results with intraday data, this would have *depreciated* the currency by around 55 basis points, but the peso actually *appreciated* 168 basis points during the day.[36] Earlier that day, at 8:30 a.m. ET, nonfarm payrolls data for the previous month were released. Job gains were less than expected according to survey forecasts (169,000 versus 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—what is known as the taper tantrum. 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).

The following regression helps testing whether these variables indeed reduce the bias and standard error detected when the dependent variable is measured with error:

$$\Delta y_t = \beta_0 + \beta_1 PRS_t + \beta_2 \Delta VIX_t + \beta_3 \Delta USY_t + \beta_4 WTI_t + \beta_5 Job_t + \varepsilon_t, \qquad (3)$$

in which the dependent variable is the daily exchange rate returns, PRS denotes the policy rate surprises (measured with and without error), ΔVIX indicates the daily change in the VIX, ΔUSY refers to the daily change in the 2-year U.S. Treasury yield from the Federal Reserve's H.15 dataset,[37] WTI is the closing price of the oil benchmark, and Job is the surprise part in releases of U.S. labor market data. Surprises in initial jobless claims, nonfarm payrolls and in the unemployment rate are calculated as the difference between the released number and survey expectations from Money Market Services.[38] Any of the three U.S. labor market surprises can be used, but only the effect of surprises in initial jobless claims ($IJC\,Surprise$) is statistically significant. Table 5 reports the results. The first two columns reproduce the last two columns of table 4 for ease of

[35] In fact, the timing change of Banxico's announcements in 2015—from 10 a.m. ET Fridays to 2 p.m. ET Thursdays—made their coincidence with U.S. macro news almost a certainty (see appendix A).

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

[37] Results using the 10- instead of the 2-year U.S. Treasury yield are similar.

[38] Data from Money Market Services is available from 2000 to 2018. When there is no U.S. labor market news on a day in which Banxico announces a monetary policy decision, Job_t is set to zero.

Table 5. Exchange Rate Response to Policy Rate Surprises and Omitted Variables

	Daily FX Returns			
PRS Intraday	-0.92		-1.45	
	(1.37)		(1.24)	
PRS Daily		-0.61		-1.36
		(1.35)		(1.25)
ΔVIX			14.8***	15.1***
			(4.40)	(4.38)
Δ 2Y Yield			0.95	1.04
			(3.22)	(3.22)
WTI Price			-0.20*	-0.20*
			(0.11)	(0.11)
IJC Surprise			-1.73**	-1.79**
			(0.86)	(0.90)
Observations	86	86	86	86
R-squared	0.01	0.00	0.20	0.19

Notes: This table shows the coefficient estimates in regressions of daily exchange rate (FX) returns on intraday (PRS Intraday) and daily (PRS Daily) changes in the 3-month swap rate, controlling for potential omitted variables. The control variables are the daily change in the VIX, the daily change in the 2-year U.S. Treasury yield, the WTI crude oil price and the surprise in releases of U.S. initial jobless claims (*IJC Surprise*). Daily changes are calculated around monetary policy announcements; intraday changes are calculated from 10 minutes before to 20 minutes after an announcement. The sample includes all regular monetary policy announcements from January 2011 to November 2021. Figures 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.

comparison, and the last two columns control for the potential omitted variables.[39]

The evidence in table 5 supports that noise in daily exchange rate returns gives rise to bias due to omitted variables. After controlling for the potential omitted variables when the dependent variable is measured with error, both the bias and the standard error decline.[40] Also notice that the R^2 statistic increases substantially.[41] Even though the magnitudes of the coefficients for the potential omitted variables are not directly of

[39]Since the intercept is not included in the regressions reported in table 4, it is also excluded in the regressions reported in table 5 so that the results are comparable. The outcome is similar when the intercept is included.

[40]Table E.1 in the appendix also shows that the upward bias when changes in the 10-year yield are the dependent variable instead of exchange rate returns (see footnote 34) declines after controlling for the same variables.

[41]The R^2 from regressing the measurement error in the dependent variable on all the potential omitted variables is 0.12. The variables are jointly statistically significant at the 1% level.

interest, their signs are. The signs of the coefficients are not only intuitive but also help to characterize the bias. In particular, appendix D shows that all the potential omitted variables considered contribute for the estimator $\hat{\beta}_1$ to be upward bias when the dependent variable is measured with error. Notwithstanding, these improvements are not enough to detect a significant effect of policy rate surprises on the the exchange rate. 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.

Summing up, 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 daily exchange rate returns blurs the response of the currency to the policy rate.

5 Concluding Remarks

This paper constructs a new dataset to quantify 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 economies in terms of their responsiveness to the domestic policy rate. Meanwhile, the yield curve in Mexico responds stronger to policy rate surprises than that in the U.S., suggesting that in Mexico there is a relatively higher degree of long-term inflation uncertainty or a larger effect of surprises on the term premium.

The evidence in the paper indicates that the lack of response of the exchange rate in emerging markets to monetary policy found so far in the literature is the result of wide event windows. The response can only be perceived using intraday data for the exchange rate. Omitted variables explain the lack of response of daily exchange rate returns.

The sensitivity of the response of the currency to data frequency does not mean that monetary policy is not important. It means that surprises in the policy rate are small enough that their effect on the exchange rate can only be seen in intraday windows. Banxico, like other central banks, works hard to communicate information to market participants ahead of time so that, by the time of an announcement, most of it is already expected.

The results in this paper can be extended in different directions. Monetary policy in advanced economies has more than one dimension since asset prices react not only to surprises in the policy rate but also to changes in policy statements and asset purchase programs (Gürkaynak et al., 2005; Swanson, 2021; Altavilla et al., 2019). A relevant question is whether the multidimensionality of monetary policy in advanced economies is a feature shared by emerging markets. Solís (2021a) shows that monetary policy in Mexico is indeed multidimensional, but more work is needed to see whether this result is observed more broadly among emerging markets.

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; 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 (see Stock and Watson, 2018; Gortz et al., 2021).

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Appendix

A Calendar of Monetary Policy Announcements

This appendix contains the dates and times of Banxico's monetary policy announcements along with relevant macroeconomic data from Mexico and the U.S. released on the same dates. Data releases are obtained from Bloomberg.[42]

Regarding 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 because both countries followed the same DST arrangements. DST in both countries began on the first Sunday in April and ended on the last Sunday of October.[43] 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. (up until 2014) and 3 p.m. (starting in 2015). Seven announcements happened in those weeks prior to 2015 (at 11 a.m. ET) and seven afterwards (at 3 p.m. ET) for a total of 14 cases. It is also more likely to observe those meetings in 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 14 cases fell in October.

In recent years, Banxico's calendar aligned with that of the Fed. 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 of Banxico's monetary policy meetings were scheduled one or two weeks after those of the Fed.

[42] The abbreviations and acronyms used in table A.1 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.

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

Table A.1. Calendar of Monetary Policy Announcements

Date	ET	Macroeconomic Data from Mexico and the U.S. Released on the Same Day
09-Jan-2004	10:00	MX: Consumer Confidence, IGAE. US: Change in Nonfarm Payrolls, Unemp. Rate.
23-Jan-2004	10:00	MX: Trade Balance.
06-Feb-2004	10:00	US: Change in Nonfarm Payrolls, Unemp. Rate.
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.
07-Apr-2004	10:00	MX: Gross Fixed Investment. US: Mortgage Applications.
23-Apr-2004	10:00	MX: Trade Balance. US: Durable Goods Orders.
27-Apr-2004	13:15	US: Consumer Confidence.
14-May-2004	10:00	US: CPI, UoM Sentiment, IP.
28-May-2004	10:00	US: UoM Sentiment, Personal Income, Personal Spending.
11-Jun-2004	10:00	MX: IP.
25-Jun-2004	10:00	MX: IGAE. US: GDP, UoM Sentiment.
09-Jul-2004	10:00	MX: Trade Balance.
23-Jul-2004	10:00	MX: Trade Balance.
13-Aug-2004	10:00	US: UoM Sentiment.
27-Aug-2004	10:00	US: GDP, UoM Sentiment.
10-Sep-2004	10:00	
24-Sep-2004	10:00	MX: IGAE. US: Durable Goods Orders.
08-Oct-2004	10:00	US: Change in Nonfarm Payrolls, Unemp. Rate.
22-Oct-2004	10:00	MX: Bi-Weekly CPI, Retail Sales.
12-Nov-2004	10:00	US: UoM Sentiment, Retail Sales.
26-Nov-2004	10:00	
10-Dec-2004	10:00	US: UoM Sentiment.
14-Jan-2005	10:00	MX: Gross Fixed Investment. US: IP.
28-Jan-2005	10:00	US: GDP.
11-Feb-2005	10:00	MX: IP.
25-Feb-2005	10:00	US: GDP, Existing Home Sales.
11-Mar-2005	10:00	
23-Mar-2005	10:00	MX: Trade Balance. US: CPI, Mortgage Applications, Existing Home Sales.
08-Apr-2005	10:00	MX: Gross Fixed Investment.
22-Apr-2005	10:00	MX: Bi-Weekly CPI, Trade Balance.
13-May-2005	10:00	US: UoM Sentiment.
27-May-2005	10:00	MX: Unemployment. US: UoM Sentiment, Personal Income, Personal Spending.
10-Jun-2005	10:00	
24-Jun-2005	10:00	MX: Unemployment. US: Durable Goods Orders, New Home Sales.
08-Jul-2005	10:00	US: Change in Nonfarm Payrolls, Unemp. Rate.
22-Jul-2005	10:00	MX: Bi-Weekly CPI, Trade Balance.
12-Aug-2005	10:00	US: UoM Sentiment.
26-Aug-2005	10:00	US: UoM Sentiment.
09-Sep-2005	10:00	MX: Trade Balance.
23-Sep-2005	10:00	MX: Trade Balance.
14-Oct-2005	10:00	US: CPI, UoM Sentiment, Retail Sales, IP.
28-Oct-2005	10:00	US: GDP, UoM Sentiment.
11-Nov-2005	10:00	MX: IP.
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.

Date	ET	Macroeconomic Data from Mexico and the U.S. Released on the Same Day
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.
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.

Date	ET	Macroeconomic Data from Mexico and the U.S. Released on the Same Day
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.
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.

Date	ET	Macroeconomic Data from Mexico and the U.S. Released on the Same Day
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.
13-Feb-2020	14:00	US: CPI, Initial Jobless Claims, Net Export Sales Corn-Old Crop, Net Export Sales Soybeans-Old, Net Export Sales Wheat-Old, Net Export Sales Cotton-Old.
20-Mar-2020	15:00	MX: Aggregate Supply and Demand. US: Existing Home Sales.
21-Apr-2020	14:00	MX: International Reserves Weekly. US: Existing Home Sales.
14-May-2020	14:00	US: Initial Jobless Claims, Net Export Sales Corn-Old Crop, Net Export Sales Soybeans-Old, Net Export Sales Wheat-Old, Net Export Sales Cotton-Old.
25-Jun-2020	14:00	MX: Retail Sales. US: Initial Jobless Claims, Net Export Sales Corn-Old Crop, GDP, Net Export Sales Soybeans-Old, Net Export Sales Wheat-Old, Net Export Sales Cotton-Old, Durable Goods Orders.
13-Aug-2020	14:00	US: Initial Jobless Claims, Net Export Sales Corn-Old Crop, Net Export Sales Soybeans-Old, Net Export Sales Wheat-Old, Net Export Sales Cotton-Old.
24-Sep-2020	14:00	MX: Bi-Weekly CPI. US: Initial Jobless Claims, Net Export Sales Corn-Old Crop, Net Export Sales Soybeans-Old, Net Export Sales Wheat-Old, Net Export Sales Cotton-Old, New Home Sales.
12-Nov-2020	14:00	US: CPI, Initial Jobless Claims, DOE U.S. Crude Oil Inventories, DOE U.S. Gasoline Inventories.
17-Dec-2020	14:00	US: Initial Jobless Claims, Net Export Sales Corn-Old Crop, Net Export Sales Soybeans-Old, Net Export Sales Wheat-Old, Net Export Sales Cotton-Old, Housing Starts.
11-Feb-2021	14:00	MX: IP. US: Initial Jobless Claims, Net Export Sales Corn-Old Crop, Net Export Sales Soybeans-Old, Net Export Sales Wheat-Old, Net Export Sales Cotton-Old.
25-Mar-2021	15:00	MX: Retail Sales, IGAE. US: Initial Jobless Claims, Net Export Sales Corn-Old Crop, GDP, Net Export Sales Soybeans-Old, Net Export Sales Wheat-Old, Net Export Sales Cotton-Old.
13-May-2021	14:00	US: Initial Jobless Claims, Net Export Sales Corn-Old Crop, Net Export Sales Soybeans-Old, Net Export Sales Wheat-Old, Net Export Sales Cotton-Old, PPI.
24-Jun-2021	14:00	MX: Bi-Weekly CPI, Unemp. Rate. US: Initial Jobless Claims, Net Export Sales Corn-Old Crop, GDP, Net Export Sales Soybeans-Old, Net Export Sales Wheat-Old, Net Export Sales Cotton-Old, Durable Goods Orders.
12-Aug-2021	14:00	US: Initial Jobless Claims, Net Export Sales Corn-Old Crop, Net Export Sales Soybeans-Old, Net Export Sales Wheat-Old, Net Export Sales Cotton-Old, WASDE Corn End Stocks, WASDE Soybean Production, PPI, WASDE Corn Yield Per Acre, WASDE Total Wheat End Stocks.
30-Sep-2021	14:00	MX: Mexico Copper Production. US: Initial Jobless Claims, Net Export Sales Corn-Old Crop, GDP, Net Export Sales Soybeans-Old, Net Export Sales Wheat-Old, Net Export Sales Cotton-Old, USDA Quarterly Corn Stocks, USDA Quarterly Soybean Stocks.
11-Nov-2021	14:00	MX: IP.

B Exclusion of Extraordinary Meetings

During the sample period, there were four unscheduled, emergency meetings. This section explains the reasons for excluding them from the analysis. As a result, the sample only includes regularly scheduled meetings.

April 2004. On Friday April 23, 2004, when monetary policy was still conducted using a quantitative target ('el corto'), Banxico's announcement noted recent spikes in inflation but left *el corto* unchanged given that medium-term inflation expectations did not deteriorate significantly. In the days after the announcement, however, short-term interest rates declined markedly. In response, Banxico increased *el corto* in an unscheduled announcement on Tuesday April 27.

Since the analysis with intraday data goes back to 2011, this extraordinary meeting only matters for the few results that use daily data since 2004. Moreover, by excluding it from the sample, the analysis focuses on regularly scheduled meetings given that there are strong reasons to exclude the other three emergency meetings.

February 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 scheduled 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—which raised concerns in the central bank about the exchange rate pass-through to inflation.

Shortly after 12 p.m. on February 17, the Finance Secretary and the Governor of Banxico held a joint press conference to announce a series of measures intended to provide confidence to market participants. 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 fiscal adjustments. As a consequence, the response of asset prices around this particular monetary policy announcement 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 foreign exchange market in the previous days and, therefore, may not be completely exogenous. Finally, the monetary policy statement clearly indicates that the decision to raise the policy rate 'does not start a tightening cycle'. The announcement can therefore be considered as a one-off policy rate surprise. For all these reasons the announcement of February 17, 2016, is excluded from the analysis.

March and April 2020. In response to the Covid crisis, Banxico unexpectedly cut its policy rate by 50 basis points on March 20, 2020, six days before a scheduled meeting, and announced four measures to provide liquidity in the foreign exchange and fixed income markets. In another unscheduled announcement, on April 21, 2020, Banxico reduced its policy rate by another 50 basis points; the announcement was accompanied by ten measures designed to promote orderly conditions in financial markets, ensure the flow of credit to the economy and provide market liquidity.

As part of the additional measures, Banxico announced the availability of new dollar auctions.[44] The measures also included reductions in reserve requirements for banks and in the cost of the ordinary additional liquidity facility, expansion of eligible securities and intermediaries for liquidity facilities, and the implementation of new repo facilities. And some measures were implemented along with the Finance Ministry to ensure that market makers in the sovereign bond market were able to provide liquidity.

Too many measures were implemented in addition to the policy rate cuts. Moreover, since some of these measures were aimed at the foreign exchange market and/or in association with the Finance Ministry, changes in the exchange rate following these two extraordinary meetings are unlikely to only reflect the reductions in the policy rate, even using intraday windows. Notwithstanding, tables B.1 to B.3 replicate the main results in the paper including the two extraordinary meetings of 2020. Of course, estimates vary but the main conclusions in the paper remain.

[44] On March 19, 2020, the Fed announced a 60 billion dollar swap line with Banxico.

Table B.1. The Response of Asset Prices to Policy Rate Surprises: Intraday Data including March and April 2020

	Δ FX		Δ 2Y Yield		Δ 5Y Yield		Δ 10Y Yield		Δ 30Y Yield	
PR Surprise	-2.07**	-2.10**	0.65***	0.66***	0.43**	0.46**	0.55***	0.54***	0.33***	0.34***
	(0.85)	(0.85)	(0.08)	(0.08)	(0.20)	(0.18)	(0.10)	(0.09)	(0.07)	(0.06)
PR Expected		0.072		-0.042*		-0.048		0.016		-0.030
		(0.23)		(0.02)		(0.03)		(0.04)		(0.02)
Observations	88	88	72	72	57	57	72	72	72	72
R-squared	0.21	0.21	0.70	0.72	0.19	0.23	0.42	0.42	0.40	0.42

Notes: The first column for each dependent variable shows the coefficient estimates in regressions of intraday yield changes or exchange rate (FX) returns 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 includes monetary policy announcements starting on January 2011 for the exchange rate, on January 2013 for 2- 10- and 30-year yields, and on December 2014 for 5-year yields; the sample ends on November 2021 in all cases. 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 B.2. The Response of Asset Prices to Policy Rate Surprises: Daily Data including March and April 2020

	Δ FX		Δ 2Y Yield		Δ 5Y Yield		Δ 10Y Yield		Δ 30Y Yield	
PR Surprise	–1.51	–0.29	0.76***	0.53***	1.36**	0.63***	0.76***	0.52***	0.43**	0.43***
	(1.36)	(0.59)	(0.10)	(0.08)	(0.53)	(0.13)	(0.24)	(0.10)	(0.19)	(0.10)
Obs. since 2011	88		72		57		72		72	
Obs. since 2004		191		191		191		191		136
R-squared	0.03	0.00	0.58	0.39	0.41	0.31	0.33	0.25	0.19	0.21

Notes: This table shows the coefficient estimates in regressions of daily yield changes or exchange rate (FX) returns on daily changes in the 3-month swap rate (PR Surprise). Daily changes are calculated around monetary policy announcements. The first column for each dependent variable uses the same sample period as Table 2; that is, the sample includes monetary policy announcements starting on January 2011 for the exchange rate, on January 2013 for 2- 10- and 30-year yields, and on December 2014 for 5-year yields. The second column for each dependent variable uses a larger sample size, including monetary policy announcements starting on January 2004. The sample ends on November 2021 in all cases. 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 B.3. The Response of the Exchange Rate to Policy Rate Surprises (including March and April 2020)

	Intraday FX Returns		Daily FX Returns	
PRS Intraday	-2.07**		-1.55	
	(0.85)		(1.43)	
PRS Daily		-1.72**		-1.51
		(0.70)		(1.36)
Observations	88	88	88	88
R-squared	0.21	0.16	0.03	0.03

Notes: This table shows the coefficient estimates in regressions of exchange rate (FX) returns on intraday (PRS Intraday) and daily (PRS Daily) changes in the 3-month swap rate. The returns are calculated with *intraday* data in the first two columns and with *daily* data in the last two. Daily changes are calculated around monetary policy announcements; intraday changes are calculated from 10 minutes before to 20 minutes after an announcement. The sample includes monetary policy announcements from January 2011 to November 2021. Figures 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.

C TIIE28D-Based Policy Rate Surprises

Several considerations 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 discussed in see section 4.

Second, there is a difference between the date of the calculation and that of the publication, which matters when computing daily changes. The relevant one is the calculation date 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.[45] Given 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.

Third, the timing change of Banxico's monetary policy announcements from 10 a.m. to 2 p.m. ET that started in 2015 matter. The TIIE28D is calculated at 1 p.m. ET with quotes from at least six commercial banks.[46] This time falls in between the times of the

[45] 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.

[46] If less than six banks submit quotes, the calculation time is delayed at most twice in 15-minute

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 correctly capture the information before and after each monetary policy announcement. Specifically, prior to 2015, 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 one day after the announcement relative to the day of the announcement.

TIIE28D-based policy rate surprises, however, do not capture the unanticipated part of monetary policy decisions cleanly. First, their correlation with the survey-based (0.67) and swap-based (0.55 with 3-month intraday, 0.63 with 3-month daily, 0.57 with 1-month daily) surprises is not particularly strong. Second, TIIE28D-based surprises, when used to estimate equation (1), do not affect the exchange rate nor the 10- and 30-year yields, and weakly affect the 2- and 5-year yields.

D Derivation of Inconsistency in Slope Estimator

This appendix derives the degree of inconsistency in the slope estimator when the measurement error in the dependent variable captures an omitted variable, regardless of whether the independent variable is measured with error.

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

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

in which the error ε is independent and identically distributed with mean zero, variance σ_ε^2 and uncorrelated with x^*, so $\mu_\varepsilon = \sigma_{\varepsilon x^*} = 0$. Both y^* and x^* are unobserved variables,

intervals. These times increase by one hour in non-overlapping DST days, see section 2.1.1.

whereas y and x are observed but measured with an additive error:

$$\begin{aligned} x &= x^* + u, \\ y &= y^* + \nu, \end{aligned} \tag{D.1}$$

in which 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:

$$y = \beta x + \tau = \beta x + \varepsilon - \beta u + \nu, \tag{D.2}$$

in which τ mixes together the 'true' error ε with the measurement errors u and ν.

The classical measurement error model assumes that there is measurement error only 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 classical 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:

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

in which λ is the ratio $\sigma_{x^*}^2/\sigma_x^2$, and is known as the attenuation factor or the signal-to-total variance ratio. Since $0 < \lambda < 1$, $|\text{plim}(\hat{\beta})| < |\beta|$. The extent of the inconsistency depends on λ; the farther away it is from one, the larger the attenuation bias.[47] Lastly, the estimator for the asymptotic variance s of $\hat{\beta}$ is also inconsistent.[48]

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.

Validation studies allow testing the validity of the classical assumptions for a particular case and assessing the magnitude of the measurement errors. Here, the 'noisy' (daily) and

[47] When there is no measurement error in the independent variable, $\sigma_u^2 = 0$, $\lambda = 1$ and $\hat{\beta}$ is consistent.
[48] See Pischke (2007) for a derivation of plim $(\hat{s}) = \lambda s + \lambda(1-\lambda)\beta^2$, so when $\lambda = 1$, $\hat{s}$ is consistent.

Table D.1. Assessment of Assumptions in Classical Measurement Error Models

Measurement Error in	Assumptions	Data	p-value
Dependent Variable Only	$\sigma_u = 0$	1.86	
	$\rho_{\nu x^*} = 0$	0.16	0.149
	$\rho_{\nu y^*} = 0$	-0.08	0.444
Independent Variable Only	$\sigma_\nu = 0$	62.18	
	$\rho_{u x^*} = 0$	-0.01	0.958
	$\rho_{u y^*} = 0$	0.08	0.474
	$0 < \lambda < 1$	0.944	

Notes: This table compares the assumptions in classical 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} respectively denote the standard deviation and variance of variable i, and the correlation between variables i and j. 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 $\sigma_{x^*} = 7.64$. The sample includes all regular monetary policy announcements from January 2011 to November 2021.

'true' (intraday) values for the dependent and independent variables—exchange rate returns and policy rate surprises—are observed, so the measurement errors are also treated as observed. The errors are calculated as the difference between daily and intraday changes in the variables.

Table D.1 compares the classical assumptions in measurement error models against the data.[49] The hypothesis $\rho_{ux^*} = 0$ is not rejected in the data, so equation (D.1) implies that the 'observed' independent variable x and the measurement error u are correlated ($\rho_{ux} \neq 0$);[50] therefore, the estimator $\hat{\beta}$ for equation (D.2) is going to be biased and inconsistent as long as there is measurement error in the independent variable ($\sigma_u \neq 0$). Nevertheless, σ_u is relatively small (less than 2 basis points), which explains why the attenuation factor λ is close to 1. Comparing the estimated coefficients in the first two columns of table 4 confirms that attenuation bias is indeed relatively small.[51]

The reason behind the puzzle is then noise in the daily exchange rate returns. In

[49] 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 0.09 with a p-value of 0.43. 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).

[50] In the data, $\rho_{ux} = 0.23$ and is statistically different from zero at the 5% level.

[51] 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 for the yield curve when intraday changes in yields are regressed on daily changes in the 3-month swap rate.

fact, table D.1 shows that the measurement error in the dependent variable is quite large (σ_ν is more than 60 basis points).[52] This error can cause bias in $\hat{\beta}$ if it is systematically related to the independent variable—creating an endogeneity bias—or, more generally, if it captures the effects of other variables influencing the exchange rate—generating an omitted variable bias. Table D.1 itself shows that the measurement error in the daily exchange rate returns is not systematically related to surprises in the policy rate ($\rho_{\nu x^*} = 0$ is not rejected).[53] 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.

To address this case, the measurement error model is extended as follows:

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

in which ω is the omitted variable (i.e. $\gamma \neq 0$) and it is assumed to be uncorrelated with ε and with the measurement errors u and ν. The estimated model, however, is again that in equation (D.2), but in which $\nu = \gamma\omega$. With these assumptions, the degree of inconsistency in $\hat{\beta}$ is:

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

$$\text{plim}\left(\hat{\beta}\right) = \beta\frac{\sigma^2_{x^*}}{\sigma^2_x} + \gamma\frac{\sigma_{\omega x}}{\sigma^2_x} = \beta\lambda + \gamma\delta_{\omega x}. \tag{D.3}$$

This result indicates that the inconsistency in $\hat{\beta}$ now also depends on a term related to the omitted variable ω; notice that $\delta_{\omega x}$ is the slope coefficient from regressing the omitted variable ω on the mismeasured covariate x.[54] An additional term related to ω also appears in the probability limit of $\hat{s}$. This means that there will be bias and imprecision in the estimator $\hat{\beta}$ whenever measurement error in the dependent variable captures the effects of an omitted variable ($\gamma \neq 0$), even without measurement error in the independent variable ($\lambda = 1$). For the exchange rate returns, the last two columns of table 4 are consistent

[52] For reference, the standard deviation of the measurement error in the 10-year yield is 4.48 basis points.

[53] Similarly, the hypothesis $\rho_{\nu x} = 0$ is also not rejected in the data.

[54] If there is no measurement error in x ($\sigma^2_u = 0$), ω is regressed on x^* instead of x.

with this result.

The second term in equation (D.3) cannot be assessed directly—because ω is unobserved—but it is helpful to characterize the bias and to identify potential omitted variables. It indicates that the magnitude and sign of the bias depend on both the influence of the omitted variable on the exchange rate returns (γ) and the correlation of that variable with the policy rate surprises ($\delta_{\omega x}$). In particular, the sign of the bias depends on the signs of γ and $\delta_{\omega x}$. For instance, an upward bias in equation (D.3) implies either $\gamma > 0$ and $\delta_{\omega x} > 0$, or $\gamma < 0$ and $\delta_{\omega x} < 0$. The first alternative ($\gamma > 0$, $\delta_{\omega x} > 0$) actually aligns with the response of the exchange rate on September 6, 2013, described in section 4.3. In that case, job gains (the omitted variable) correlate positively with the policy rate surprise but have an offsetting effect on the exchange rate. A surprise easing ($x < 0$) depreciates the currency ($\beta < 0$), but a decline in job gains ($\omega < 0$ since $\delta_{\omega x} > 0$) appreciates it ($\gamma > 0$).

Table D.2 reports the outcome of regressing the potential omitted variables suggested in section 4.3 on the policy rate surprises (measured with and without error). To characterize the bias, what matters is the signs of the slope coefficients. Notice that, for each of the potential omitted variables i, table D.2 essentially reports $\delta^i_{\omega x^*}$ and $\delta^i_{\omega x}$, whereas table 5 reports γ^i. Notice further that the signs of the coefficients for the corresponding variables in the two tables are the same, which implies that $\gamma^i \delta^i_{\omega x^*} > 0$ and $\gamma^i \delta^i_{\omega x} > 0$ for each i. Therefore, all the potential omitted variables considered indeed contribute for the estimator to be upward bias. Moreover, $\sum_i \gamma^i \delta^i_{\omega x^*}$ and $\sum_i \gamma^i \delta^i_{\omega x}$ are very close to the correction of the bias seen in the last two columns of table 5.

Table D.2. Correlation of Potential Omitted Variables with Policy Rate Surprises

	ΔVIX		Δ 2Y Yield		WTI		IJC Surprise	
PRS Intraday	0.013		0.011		-0.63***		-0.075	
	(0.01)		(0.04)		(0.24)		(0.09)	
PRS Daily		0.019*		0.024		-0.65***		-0.11
		(0.01)		(0.05)		(0.22)		(0.08)
Constant	-0.18	-0.18	-0.44	-0.43	69.0***	69.0***	-1.26*	-1.28*
	(0.16)	(0.16)	(0.34)	(0.34)	(2.45)	(2.44)	(0.72)	(0.72)
Observations	86	86	86	86	86	86	86	86
R-squared	0.00	0.01	0.00	0.00	0.04	0.05	0.01	0.02

Notes: This table shows the coefficient estimates in regressions of different dependent variables on intraday (PRS Intraday) and daily (PRS Daily) changes in the 3-month swap rate. The dependent variables are the daily change in the VIX, the daily change in the 2-year U.S. Treasury yield, the WTI crude oil price and the surprise in releases of U.S. initial jobless claims (*IJC Surprise*). Daily changes are calculated around monetary policy announcements; intraday changes are calculated from 10 minutes before to 20 minutes after an announcement. The sample includes all regular monetary policy announcements from January 2011 to November 2021. Figures are expressed in basis points. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

E Supplementary Table

Table E.1. 10-Year Yield Response to Policy Rate Surprises and Omitted Variables

	Daily Change in 10-Year Yield			
PRS Intraday	0.55***		0.50***	
	(0.12)		(0.11)	
PRS Daily		0.56***		0.50***
		(0.12)		(0.12)
ΔVIX			0.74**	0.65*
			(0.34)	(0.36)
Δ 2Y Yield			0.86***	0.81***
			(0.22)	(0.22)
WTI Price			-0.020**	-0.018**
			(0.0087)	(0.0086)
IJC Surprise			-0.054	-0.029
			(0.072)	(0.069)
Observations	70	70	70	70
R-squared	0.39	0.41	0.56	0.56

Notes: This table shows the coefficient estimates in regressions of daily changes in the 10-year yield on intraday (PRS Intraday) and daily (PRS Daily) changes in the 3-month swap rate, controlling for potential omitted variables. The control variables are the daily change in the VIX, the daily change in the 2-year U.S. Treasury yield, the WTI crude oil price and the surprise in releases of U.S. initial jobless claims (*IJC Surprise*). Daily changes are calculated around monetary policy announcements; intraday changes are calculated from 10 minutes before to 20 minutes after an announcement. The sample includes all regular monetary policy announcements from January 2011 to November 2021. Figures 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.