The Dollar Ahead of FOMC Target Rate Changes*

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Abstract

I find that the U.S. dollar appreciates over the two-day period before contractionary monetary policy decisions at scheduled Federal Open Market Committee (FOMC) meetings and depreciates over the two-day period before expansionary monetary policy decisions. The federal funds futures rate forecasts these dollar movements with a 22% R^2. A high federal funds futures spread three days in advance of an FOMC meeting not only predicts the target rate rise, but also predicts a rise in the dollar over the subsequent two-day period. A simple trading strategy, which exploits this predictability, exhibits a 0.93 Sharpe ratio. My findings imply that information about monetary policy changes is reflected first in the fixed income markets, and only later becomes reflected in currency markets.

JEL codes: F31, G12, G17, E52.

Keywords: exchange rates, monetary policy, federal funds futures, predictability.

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The foreign exchange (FX) market is the worlds largest financial market, with a daily trading volume of more than 5 trillion USD (Bank of International Settlements 2016). Given the size of the market, and the influence exchange rates can have for other prices, it is important to better understand FX movements. A long-standing puzzle in international economics is the difficulty of tying exchange rates to macroeconomic fundamentals, such as money supply, output, and interest rates (Engel and West 2005). Meese and Rogoff (1983) and others have found that in the short run a random walk forecasts exchange rates better than macroeconomic models, suggesting that macro-related variables are not important when forecasting currency prices.[1]

In this paper, I study how FX markets incorporate market participants' expectations of monetary policy changes prior to the scheduled meetings of the Federal Open Market Committee (FOMC). Federal funds ("fed funds") futures and U.S. money market rates rise ahead of time and signal the anticipated monetary policy change with a high accuracy. I document that the same phenomenon happens in FX markets: the dollar exchange rate (relative to a basket of other currencies) rises in the two days ahead of an FOMC meeting that announces a rate rise, and falls in the two days ahead of a rate cut. Fed funds futures markets move earlier than FX markets. My central finding is that, since 1994, a high federal funds futures spread (over the target) three days in advance of a scheduled FOMC meeting not only predicts a target rate rise, but also predicts a rise in the dollar that will take place in the subsequent two days up until the announcement. The R^2 of the latter predictive relation is 22%. Thus, information about the monetary policy change is captured first by the fed funds futures markets and is reflected only later in currency markets. I show that a currency trader can easily exploit the predictability of the dollar prior to an FOMC announcement. A simple trading strategy that *(1)* goes long the dollar two days prior to the announcement, when the fed funds futures signal a target rate rise, and *(2)* goes short the dollar two days prior to the announcement, when the futures signal a target rate cut, exhibits a 25 bps average excess return, with a 2.8 t-stat and 0.93 annualized Sharpe ratio.

My findings pose a significant puzzle for exchange rate models that rely on rational expectations. Even though the direction of the movement of the exchange rate in response to monetary policy expectations is in line with the prediction by the standard exchange rate models (e.g., Fleming 1962), the speed at which these movements occur is not aligned across the bond and exchange rate markets: bond markets incorporate information faster than exchange rate markets do. This is surprising given how liquid exchange rate markets are.

This paper contributes to the macroeconomics and finance literature in two ways. First, my findings contrast the exchange rate disconnect and predictability puzzles, as I show that mon-

[1] Obstfeld and Rogoff (2001) refer to the weak relation between the exchange rate and macroeconomic fundamentals as the "exchange rate disconnect"puzzle.

etary policy expectations signaled by the fed funds futures explain a one-fifth of the variation in currency returns prior to the scheduled FOMC meetings. Second, my results integrate fixed income and currency markets. In particular, I show that these markets absorb information about a monetary policy change at different speeds. This suggests a failure of the efficient-market hypothesis (Fama 1970) due to limited investor attention and/or a form of market segmentation, as I find that using lagged fed funds futures rates forecasts currency returns.

Standard exchange rate models (Fleming 1962; Mundell 1963; Dornbusch 1976) imply that a country with a relatively higher interest rate has a stronger currency. If the Federal Reserve (Fed) raises the target rate while other central banks keep their rates unchanged, then the returns on savings become more attractive in the U.S. than in other countries. International investments flow from other countries to the U.S., causing the dollar to appreciate. At first glance, my findings are in line with the standard exchange rate models and uncovered interest rate parity (UIP): an interest rate increase appreciates the currency. Specifically, the target rate rise in 1994–2015 is 29 bps on average and is accompanied by a 25 bps dollar appreciation in the two days leading up to the FOMC announcement. However, these macroeconomic explanations do not line up with the fact that interest rates gradually rise in the weeks preceding announced policy changes, while the dollar rises only during the two days ahead of the announcement.

According to the UIP puzzle, over short-term horizons a currency with higher interest rate tends to earn an excess return (e.g., Fama 1984). Currency risk premiums are strongly related to interest rate differentials between two countries. Lustig, Roussanov, and Verdelhan (2014) show that average interest rate differentials (between the U.S. and developed countries) forecast monthly to annual dollar excess returns. I confirm this finding for the non-pre-FOMC days, but show that average interest rate differentials *do not* forecast the dollar returns prior to the FOMC meetings, when the fed funds futures signal a policy change. Prior to these meetings, the currency predictability arises from the direction of the U.S. monetary policy expectations, signaled by the fed funds futures spreads. Thus, standard currency risk premiums cannot reconcile the pre-FOMC dollar movements.

I show that the realized currency volatility and illiquidity do not rise in the two-day pre-FOMC period. There are also no monetary policy speeches or interviews by FOMC members,[2] and only a few macroeconomic releases come out in the last days prior to the policy announcement. Market participants divine monetary policy actions several weeks prior to an FOMC announcement, as evidenced in the fixed income markets. Changes in the fed funds futures, money market, and Treasury yields are negligibly small in the two days prior to an FOMC meeting and are not predictable from the federal funds futures spreads. All these pieces of evidence indicate that the flow of new information is low in the pre-FOMC window as compared to

[2]The week before FOMC meetings is known as the blackout period.

the time of the announcement or other days. The key challenge for the risk-based explanations of the pre-FOMC dollar returns is this disconnect between the time when the dollar returns are earned and when the news is revealed.

If the pre-FOMC dollar return was a reflection of private information prior to the FOMC announcement, then it should be correlated either with the change in the federal funds futures upon the announcement [ex post monetary policy surprise, see Bernanke and Kuttner (2005)] or with the dollar's reaction to the Fed's announcement. I find that the pre-FOMC dollar return is *not* correlated with the futures or dollar changes on impact.

It is difficult to relate the predictable pre-FOMC dollar return to the notion of resolution of uncertainty. A high level of uncertainty prior to the FOMC announcement, which is resolved upon the announcement, can generate a positive pre-announcement equity premium (Ai and Bansal 2016). According to this theory, uncertainty resolves on the days with all types of scheduled monetary policy decisions, as well as on the days with scheduled macroeconomic announcements. This theory does not align with the fact that the two-day pre-FOMC dollar return depends on the direction of the anticipated target rate change (ex ante encoded in the fed funds futures), while the change in the futures is negligibly small in this pre-FOMC period. Also, I do not find positive dollar excess returns prior to the major U.S. macroeconomic announcements, such as those regarding GDP, inflation, or unemployment.

Understanding how information is incorporated in asset prices is a key question in finance. Why does the fed funds futures market lead the FX market in reflecting monetary policy information two days prior to an FOMC announcement? It is difficult to square this empirical evidence with the existing economic and asset pricing theories. I provide suggestive evidence that is consistent with the theories based on limited investor attention, investor risk aversion and/or a form market segmentation.

Interest rates rise in advance of policy changes established by the Fed. An interest rate increase leads to an appreciation of the currency. However, some investors are slow to adjust their portfolios, perhaps because it is costly to constantly monitor and gather information (Mankiw and Reis 2002; Sims 2003). Kacperczyk, Nieuwerburgh, and Veldkamp (2014) show that investors allocate their attention between signals about aggregate and idiosyncratic components of cash flows, and each time optimally focus only on the shocks that are most important for their portfolios.

Consistent with the theories on limited investor attention, currency investors may not pay enough attention to fed funds futures expectations of the Fed's policy change earlier than in the last days prior to the FOMC announcement. Two pieces of suggestive evidence support this hypothesis. First, a stale (i.e., two-week or three-week lagged) fed funds futures spread forecasts

the two-day pre-FOMC dollar return almost as well as the fed funds futures spread recorded three days prior to the announcement. Second, the number of Fed-related articles in The Wall Street Journal and *The Financial Times* rises exactly two days prior to the FOMC announcement. Thus, the two-day pre-FOMC dollar return depends on the direction of the anticipated Fed's policy change (encoded into the fed funds futures), as investors focus on monetary policy news due to the upcoming announcement, even if the news may have been available before. Finally, even if not all investors are inattentive to the market expectations of the Fed's policy change, they may not be willing to trade on this information too far ahead of the FOMC meeting to avoid exposure to shocks unrelated to the forthcoming FOMC announcement.

I provide several extensions to my main result, that the fed funds futures rates predict the two-day pre-FOMC return. First, I find a similar empirical pattern for the dollar in the 1983–1994 period: the dollar appreciates prior to the Fed's contractionary decisions and depreciates prior to expansionary decisions at the scheduled FOMC meetings. A spread of a short LIBOR rate over the target rate forecasts these pre-FOMC meeting dollar movements. Second, I show that the fed funds futures spreads forecast not only returns on the dollar index, but also returns of single currency pairs. High interest rate currencies depreciate more than low interest rate currencies do when the federal funds futures spread is high. Finally, I find that the monetary policy decisions by other central banks (including European Central Bank, Bank of England, Bank of Japan, Swiss National Bank, Bank of Canada, and Reserve Bank of Australia) are not associated with similar movements in their currencies.

My paper is also related to recent studies documenting interesting patterns in excess returns for different asset classes on the FOMC days and during the hours ahead of an FOMC announcement. Lucca and Moench (2015) document large excess returns on US. equities and other stock markets ahead and on the days of FOMC announcements. They find that about half of the realized excess stock market returns are earned during the 24-hour pre-FOMC window. The authors refer to this pre-FOMC announcement drift as a puzzle because none of risk-based theories they discuss matched empirical evidence. Savor and Wilson (2014) argue that investors demand higher returns to hold higher-beta assets on the days when investors expect to learn important information about the economy. They find that the capital asset pricing model holds on the days when employment, inflation, and FOMC releases are scheduled to be announced.Mueller, Tahbaz-Salehi, and Vedolin (2016) find that FX rates exhibit large excess returns on the days of scheduled FOMC announcements and relates the results to monetary policy uncertainty. My results complement the above-mentioned studies as I *(1)* document that the direction of the pre-FOMC dollar returns depends on the direction of the anticipated policy move (as signaled by the fed funds futures), *(2)* show that prices on one market (fixed income) forecast prices another market (foreign exchange), *(3)* focus not only on the day of the announcement, but also on the

wider window prior to the FOMC announcement,

My paper is also related to the literature on currency predictability. Meese and Rogoff (1983) find that a random walk forecasts currencies better than fundamental variables. Evans and Lyons (2005) document that FX order flow forecasts currency movements.

1. Data

My primary dataset spans the period from January 1994 through December 2015. The following subsections provide a quick overview of the data, including definitions of dollar returns, FOMC meetings, and federal funds futures.

1.1 Dollar Returns

I obtain five-minute spot mid prices over the 1994–2015 period from Olsen Associates. This dataset covers four currencies quoted against the U.S. dollar (USD): EUR (DEM before 1999), JPY, GBP, and CHF. These four currencies account for almost half of global foreign exchange market turnover (Bank of International Settlements 2016). I also use daily FX prices from WM/Reuters (WMR). This dataset covers spot and monthly forward prices for G10 currencies quoted against the USD from 1994 to 2015. WMR records mid, bid, and ask prices at 16:00 GMT, which corresponds to 11:00 EST.

The log spot prices s_t^i are quoted in units of foreign currency i per 1 USD. Thus, positive currency return stands for dollar appreciation. I write the simple currency return from $t-j$ to t as the log difference of spot prices,

$$r_{t-j\to t}^i = s_t^i - s_{t-j}^i. \tag{1}$$

I denote the forward discount as $f_{t-j}^i - s_{t-j}^i$, where f_{t-j}^i is the currency log forward price at $t-j$. I write the currency excess returns from $t-j$ to t as the difference between the spot return and the forward discount rate,

$$rx_{t-j\to t}^i = (s_t^i - s_{t-j}^i) - (f_{t-j}^i - s_{t-j}^i) = s_t^i - f_{t-j}^i. \tag{2}$$

My outputs are five-minute simple (spot) returns on the USD against the EUR, JPY, GBP, and CHF and daily 1pm-to-1pm simple and excess returns on the USD against G10 currencies (AUD, CAD, CHF, EUR, JPY, NOK, NZD, SEK, and GBP). I compute equal-weighted dollar

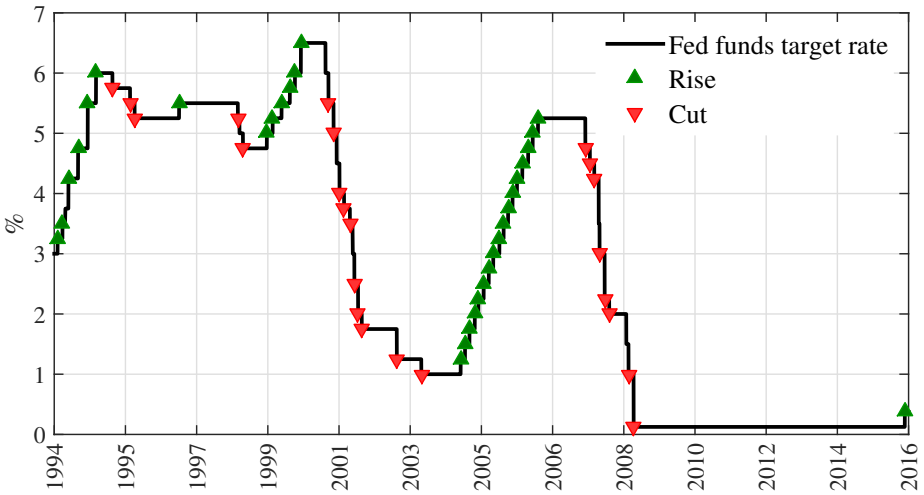

Figure 1: **Fed funds target rate and FOMC decisions.** The figure shows the Fed funds rate and Fed's decisions to raise the target rate (up-pointing triangle) or cut the target rate (down-pointing triangle) at the scheduled meetings. The sample covers 176 scheduled (31 rises, 23 cuts, 122 neutral) and 7 unscheduled announcements, from January 1994 to December 2015.

returns as:

$$DOLr_{t-j\to t} = \overline{r}^{i}_{t-j\to t}, \tag{3}$$

where the bar denotes a simple average across currencies.

Dollar excess returns are:

$$DOLrx_{t-j\to t} = \overline{rx}^{i}_{t-j\to t} = \overline{r}^{i}_{t-j\to t} - \overline{(f^{i}_{t-j} - s^{i}_{t-j})}. \tag{4}$$

The equation (4) illustrates that dollar excess returns are the difference between dollar simple returns and the average forward discount.

The results in my paper are robust to using bilateral trade-weighted or currency turnover-weighted dollar returns.

1.2 FOMC Meetings

The FOMC is the monetary-policy body of the Fed. The FOMC conducts eight scheduled meetings per year, one approximately every six weeks. The schedule of meetings for a particular year is announced ahead of time. Scheduled meetings are the focus of my paper, since I am interested in characterizing and predicting the dollar returns over the days prior to these meetings.

Starting in February 1994, the FOMC began to announce its target rate decisions after the

scheduled meetings, around 14:15 GMT.[3] In total, there have been 176 scheduled FOMC announcements from 1994–2015, including 31 contractionary (target rate rises), 23 expansionary (target rate cuts), and 122 neutral (unchanged target rate).[4] The black line on Figure 1 depicts the Fed funds target rate (taken from the FRED), while the green and red triangles represent the Fed's decisions to raise and cut (respectively) the target rate at the scheduled FOMC meetings. Starting from 2009, I use the average of the upper and lower bounds. Prior to 1994, market participants inferred FOMC actions based on the size and type of open-market operations, which were announced the day following the scheduled FOMC meeting.

1.3 Federal Funds Futures

I use daily fed funds futures (fff) from Chicago Mercantile Exchange (CME) as the main measure of market expectations several days prior to the FOMC announcement. Fed funds futures started trading on the Chicago Board of Trade in October 1988. These contracts have a face value of USD 5 million. Prices are quoted as 100 minus the daily average fed funds rate that is realized during the contract month.

I compute the target rate implied by the next-month futures j days ahead of the scheduled FOMC announcement as follows:

$$E_{t-j}^{fff}\left[FFR_t\right] = 100 - fff_{t-j}, \tag{5}$$

where FFR_t is the fed funds target rate after the FOMC announcement has occurred at t, fff_{t-j} is the price of the next-month Fed funds futures at j days prior the FOMC announcement.[5].

2. Main Results

I first show that the USD, on average, appreciates during the two-day period prior to an FOMC announcement to raise the target rate and depreciates during the two-day period prior to an

[3] Specifically, during 1994–2015 target rate announcements occurred between 14:10 and 14:20 EST, according to *Bloomberg* or *Dow Jones* newswires. See detailed timing for each FOMC announcement in Lucca and Moench (2015), Table IA.I.

[4] Over the sample period, only seven target changes took place at the unscheduled FOMC meetings: one target raise on 18 April 1994 (25 bps) and six target cuts on 15 October 1998 (-25 bps), 3 January 2001 (-50 bps), 18 April 2001 (-50 bps), 17 September 2001 (-50 bps), 22 January 2008 (-75 bps), and 8 October 2008 (-50 bps).

[5] The results are similar when I use the adjusted version of the Fed funds futures, which takes into account the exact timing of each FOMC meeting. I use the unadjusted version for the sake of simplicity. My results are also robust to accounting for a 2 basis point estimated risk premium in the next-month fff (p. 686 in Piazzesi and Swanson, 2008)

FOMC announcement to cut the target rate. I then extract the anticipated policy change from the fed funds futures three days ahead of the scheduled FOMC meetings. I show similar directional pre-FOMC dollar movements ahead of the announcements, when the policy change is ex ante predicted by the fed funds futures. Finally, I illustrate that a high fed funds futures spread over the target three days in advance of a scheduled FOMC meeting predicts a rise in the USD that will take place in the subsequent two days.

2.1 Dollar Around Realized Target Changes

I first provide an event-study graph of the cumulative dollar returns around the realized FOMC announcements. *Panel A* of Figure 2 depicts the average 5-minute cumulative dollar returns in a five-day window around 31 target raises and 23 target cuts. This graph uses ex post information on the Fed's actions and I do not take any ex ante market expectations into account.

The event window begins at 00:00 EST two days ahead of the scheduled FOMC meetings and ends at 23:55 EST two days after. *Panel A* of Figure 2 indicates that the USD on average depreciates during the two days ahead of an FOMC announcement to cut the target. The USD's downward drift begins the morning before the announcement and continues until the announcement occurs. Before 14:00 EST, the USD loses on average 32 bps (18 bps excluding two rate cuts in fall 2008). The USD drops by 10 bps over the two hours following the announcement and continues to lose an additional 5 bps until the end of the day. This downward movement in the dollar on impact is largely driven by the reaction to the few larger-than-expected rate cuts. Over the next two days, the dollar appreciates by 25 bps, close to its initial level observed two days before the announcement.

A similar, but reversed phenomenon occurs during the two days prior to an FOMC announcement to raise the target rate. Starting in the evening two days prior to the announcement, the USD begins to appreciate, rising by 25 bps by the time of announcement. The USD stays almost flat during two hours after the announcement reflecting small USD surprises to the contractionary Fed's actions. The dollar then depreciates beginning the evening of the announcement.

Panel B of Figure 2 indicates a slight 5 to 10 bps downward movement in the dollar during the two days prior to neutral FOMC actions and close to zero returns after the announcement.

Table 1 shows the results of a decomposition the USD returns around the policy moves. The table is divided into: *pre-FOMC*, 14:00 two days prior to the announcement $\rightarrow$ 14:00 on the announcement day (I denote it as $DOLr_{t-2\rightarrow t}$), *on impact*, 14:00 $\rightarrow$ 16:00 on the announcement day, and *post-FOMC*, 16:00 on the announcement day $\rightarrow$ 14:00 on the second day after

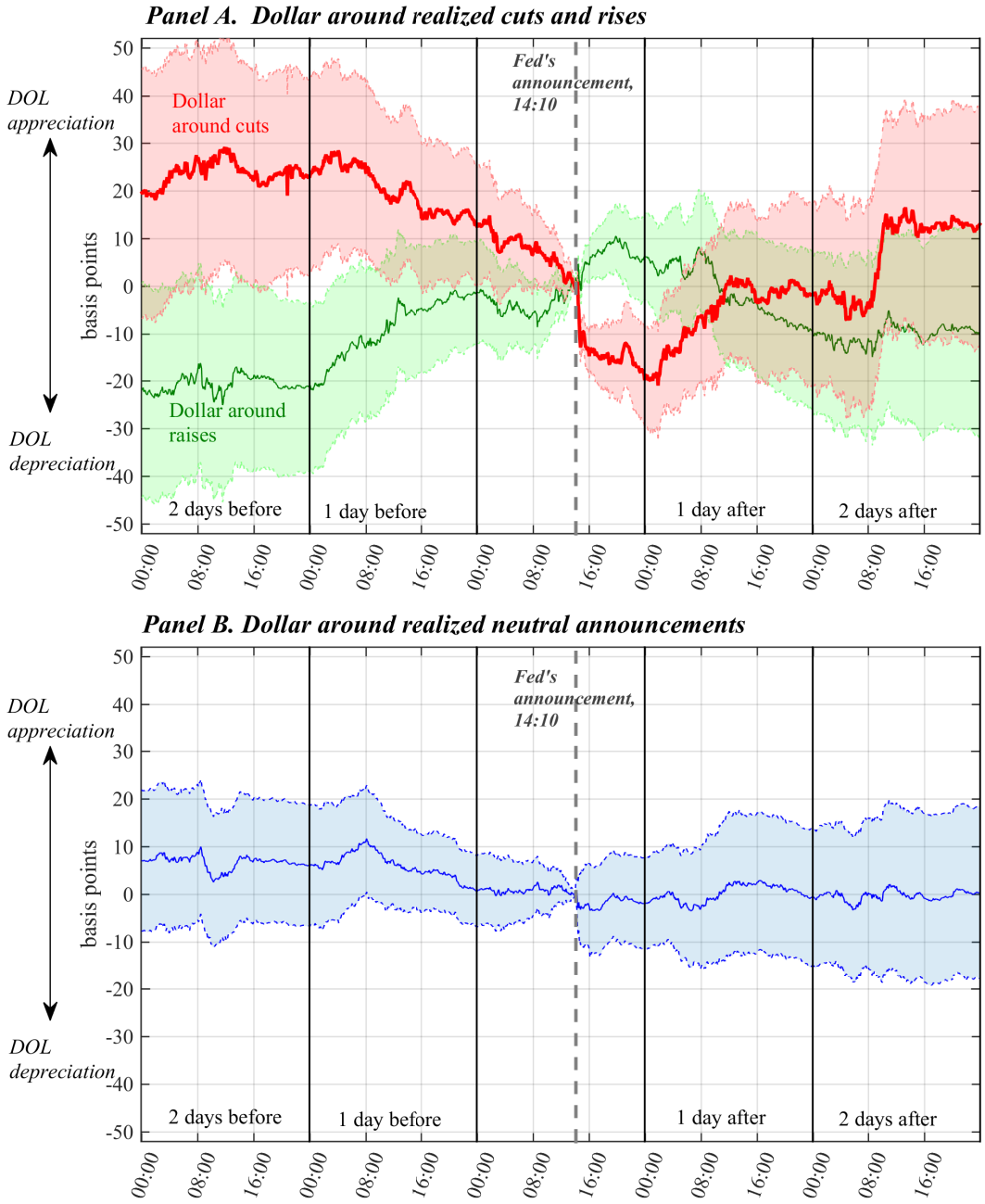

Figure 2: **Dollar around FOMC decisions.** *Panel A* shows average five-minute cumulative dollar returns around 31 target rate rises (bold/green line) and 23 target rate cuts (thin/red line). *Panel B* shows average 5-minute cumulative dollar returns around 122 neutral FOMC decisions. The dotted lines depict pointwise 90% confidence bands around the average cumulative returns returns. I cumulate the average standard error of a pre-FOMC (post-FOMC) 5-minute return and divide it by the square root of the number of considered events to derive the confidence band around cumulative returns before (after) the announcement. I normalize cumulative returns to zero before the announcement. I compute confidence bands around the cumulative returns on the left and on the right starting from the announcement. The dollar returns are equal-weighted five-minute EUR, GBP, CHF, and JPY returns versus the USD.

	Pre-FOMC		*On Impact*		*Post-FOMC*	
	$DOLr_{t-2,14:00\to t,14:00}$		$DOLr_{t,14:00\to t,16:00}$		$DOLr_{t,16:00\to t+2,16:00}$	
Panel A. Full sample, Jan 1994 – Dec 2015						
31 Rises	**24.6**	[2.21]	4.6	[0.83]	-16.0	[-1.38]
23 Cuts	**-33.2**	[-2.24]	-13.6	[-1.69]	25.8	[1.63]
Difference	**57.8**	[3.38]	18.2	[1.71]	**-41.7**	[-1.97]
Panel B. Excluding Jul 2008 – Dec 2009						
21 Cuts	**-17.9**	[-2.12]	-7.3	[-1.33]	21.0	[1.38]
Difference	**42.5**	[2.92]	11.9	[1.25]	-36.9	[-1.72]

Table 1: **Average Dollar Returns around Realized *FFR* Changes.** This table shows the average USD returns around the Fed's decisions to change the target rate. I decompose average dollar returns around the FOMC into three components: *(1) pre-FOMC*, from 14:00 two days prior to the announcement to 14:00 on the announcement day (same as $DOLr_{t-2\to t}$), *(2) on impact*, from 14:00 to 16:00 on the announcement day, and *(3) post-FOMC*, from 16:00 on the announcement day to 14:00 on the second day after the announcement. I compute average dollar returns around 31 raises and 23 cuts at the scheduled meetings between 1994 and 2015. I also compute the difference between these averages for each of three components (see "Difference"). The *t*-statistics for the averages and for a test of difference in averages are reported in brackets. Bold numbers are statistically significant at 5% level. The return numbers are expressed in basis points (simple return multiplied by 10'000).

the announcement.

Table 1 shows that the difference between the pre-FOMC USD return ahead of target rises and cuts is 58 bps and is statistically significant (*t*-stat=3.5). This difference remains significant (*t*-stat 2.9) after excluding two extreme target rate cuts in fall 2008. The pre-FOMC USD returns account for a sizeable share in the total dollar variation over 1994–2015. Excluding the two-day periods prior to the target rate raises (cuts) from my sample suggests that the USD would have been 6% weaker (10% stronger) by the end of the sample. These two-day pre-FOMC periods cover 114 days and represent less than 2% of the total number of days in my sample (3760).

The USD returns on impact are weakly significant (*t*-stat=1.7) for target cuts, but lose their significance (*t*-stat=1.3) after excluding the fall 2008 outliers, when the market saw larger-than-expected target rate cuts. The difference between USD returns for rises and cuts on impact is positive (12 bps) but statistically insignificant. The average post-FOMC USD returns are negative (-16 bps) for the rises and positive (26 bps) for the cuts, indicating about a two-thirds reversal of the respective average pre-FOMC USD returns. The difference between target rate cuts and rises has a *t*-stat of 2.0 for the full sample and 1.7 when excluding fall 2008.

In sum, Figure 2 and Table 1 illustrate that the USD on average *(1)* depreciates during the two days ahead of the realized expansionary announcements, *(2)* appreciates during the two

days ahead of realized contractionary announcements, and *(3)* reverses partially in the two days following the announcement.

How predictable are the announced policy moves in 1994–2015? Accurate signaling several days ahead of the Fed's scheduled meeting would help to predict the USD appreciation or depreciation before the announcement.

2.2 Signal of Fed's Policy Change from Fed Funds Futures

I use the target rate change implied by the next-month fed funds futures j days prior to the FOMC announcement to construct a signal of the Fed's most likely action at the upcoming announcement. I write the fed funds futures spread over the target as the difference between the expected target rate encoded into fff_{t-j} and the fed funds target rate valid at $t-j$:

$$E_{t-j}^{fff}\left[\Delta FFR_t\right] = E_{t-j}^{fff}\left[FFR_t\right] - FFR_{t-j}. \tag{6}$$

This spread signals market expectations of the monetary policy action at the upcoming FOMC announcement. I use a simple rule to extract the predicted action at $t-j$:

- If $E_{t-j}^{fff}\left[\Delta FFR_t\right] \geq 12.5$ bps, fff_{t-j} forecasts a target rate raise,
- If $E_{t-j}^{fff}\left[\Delta FFR_t\right] \leq -12.5$ bps, fff_{t-j} forecasts a target rate cut,
- If $\mid E_{t-j}^{fff}\left[\Delta FFR_t\right] \mid < 12.5$ bps, fff_{t-j} forecasts no target rate change.

I justify a 12.5 bps threshold by the fact that since 1994 the minimum size of the policy change, $\mid \Delta FFR_t \mid$, is 25 bps. If the expected target rate change as measured by $E_{t-j}^{fff}\left[\Delta FFR_t\right]$ is just a few basis points, the likelihood of a policy change at the upcoming FOMC announcement is very low. Similarly, $E_{t-j}^{fff}\left[\Delta FFR_t\right]$ being close to 25 bps signals a high likelihood of a target rate increase.[6] Increasing or reducing the 12.5 bps threshold by several basis points does not significantly affect my results.

In Figure 3, I plot the size of the expected target change three days in advance of each scheduled FOMC meetings (black bars) along with the realized target change at the scheduled FOMC meeting at t. Fed funds futures are wrong about the future policy move only five times in the 176 scheduled meetings in 1994–2015. All of these occasions happened in the early part

[6] I do not define the likelihood of the target change as $E_{t-j}^{fff}\left[\Delta FFR_t\right]$ divided by 25, because the expected target change might exceed 25 bps. This would translate into the probability of the target rate raise in excess of 100%, but in fact might only reflect that futures predict a target change of an amount greater than 25 bps. Note that we do not know the exact size of the realized target rate (25, 50, or 75 bps) change ex ante.

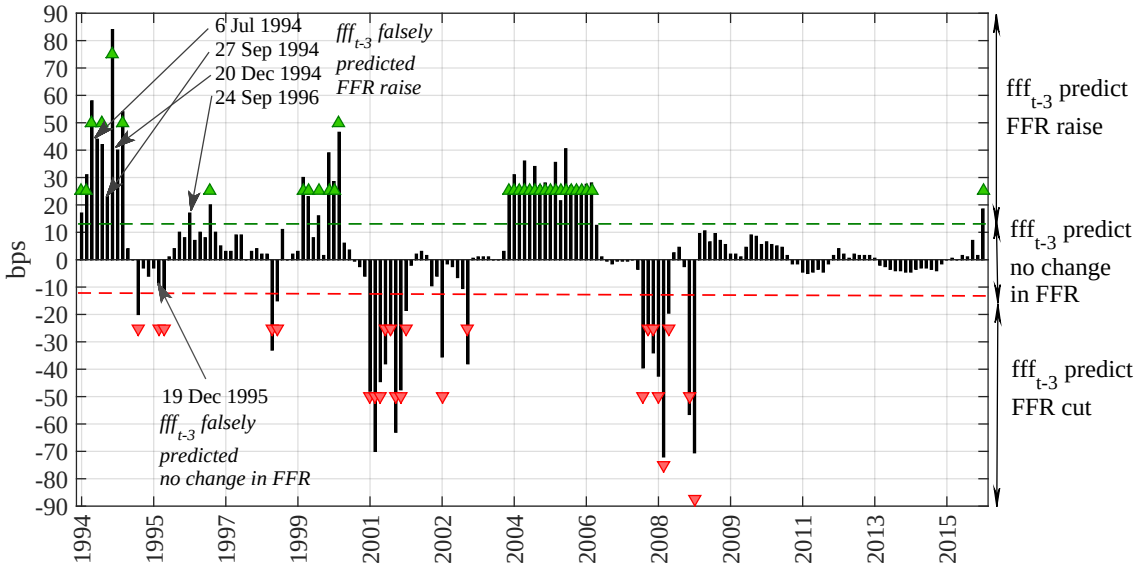

Figure 3: FFR **change encoded into the fed funds futures at** $t-3$ **and realized** FFR **change.** In the figure, I plot $E^{fff}_{t-j}[\Delta FFR_t]$ (black bars) along with the realized target rate changes at the announcement (raises in green, cuts in red). The target rate change expected by fff_{t-3} is caluclated using equation (6). The sample covers 176 scheduled FOMC announcements over 1994–2015.

of the sample: four false predictions of a target rate increase in 1994–1996 (no change realized) and one false prediction of no target rate change in 1995 (target cut realized).[7] Prior to most policy changes, the fed funds futures spread is well above the 12.5 bps threshold, indicating that accuracy of the predictions based on fff_{t-3} is high.

In the Appendix, I show that $E^{fff}_{t-3}[\Delta FFR_t]$ predicts both the size and the direction of the realized FFR change with a 74% and 88% R^2, respectively. I also show that 3-, and 6-month fed funds futures are almost as predictive of the target rate as the next month futures, while the spreads of the LIBOR and Treasury yields are less predictive of the policy change.

2.3 Dollar Ahead of Target Rate Changes, which are Predicted by Fed Funds Futures

I extract the policy change expectations three days prior to each scheduled FOMC meeting. I then plot the average cumulative USD returns around the predicted target rate raises and cuts. Policy change expectations barely change in the last two days prior to the FOMC announcement.

[7]The false target rate increase predictions happened ahead of the following meetings: 6 July 1994 (target stayed at 4.25%), 27 September 1994 (4.75%), 20 December 1994 (5.5%), 24 September 1995 (5.25%). Three days prior to these FOMC meetings, the futures spreads over the target were 43, 23, 41, 16 bps, respectively, well above the 12.5 bps threshold. The Fed unexpectedly cut the target rate on 19 December 1995. Three days ahead of this decision, the futures spread was -10 bps, thus not low enough to signal a cut.

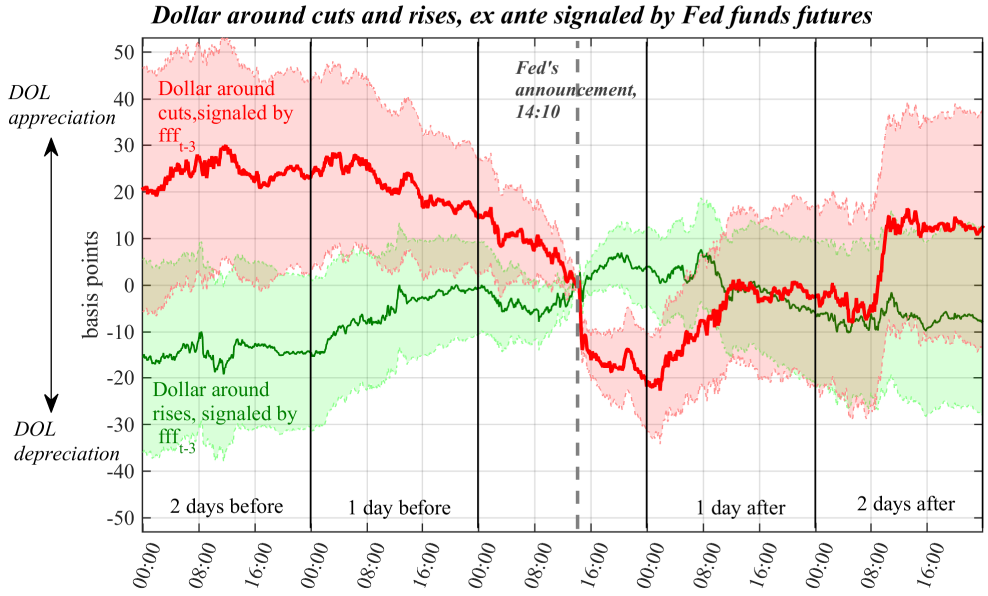

Figure 4: **Dollar Around FOMC Target Rate Changes, ex ante Signaled by the Fed Funds Futures.** The figure shows average 5-minute cumulative dollar returns around 35 target rate rises, *ex ante* predicted by the fed funds futures (bold/green line) and 22 target rate cuts, *ex ante* predicted by the fed funds futures (thin/red line). See details on the construction of the dollar returns and confidence bands in the caption to Figure 2. The sample is January 1994 – December 2015.

If the efficient-market hypothesis holds, the USD returns should be on average zero as soon as we control for the ex ante expectations of the target rate change. However, Figure 4 illustrates that the dynamics of the USD returns is almost identical to *Panel A* of Figure 2. The USD moves in the direction of an anticipated policy change, even though it has been already priced in the fed funds futures markets.

The dollar goes up on average by 20 bps during the two days prior to the FOMC announcement, when futures signal a target rise. The dollar drops, on average, by 32 bps prior to the announcement when the fed funds futures signal a target rate cut. These numbers are slightly smaller than the dollar returns ahead of the realized target rate rise (25 bps) and cut (33 bps). This is not surprising given that the fed funds futures are inaccurate only five times in signaling the direction of the policy move.

How do the pre-FOMC dollar returns, $DOLr_{t-2\to t}$, look across different FOMC announcements? In Figure 5, I plot the time-series of the two-day dollar returns prior to rate raises (*Panel A*) and rate cuts (*Panel B*), which are ex ante signaled by the fed funds futures. The dollar goes up prior to 22 out of 35 (63%) of signaled rises and goes down prior to 13 out of 22 signaled cuts (60%).

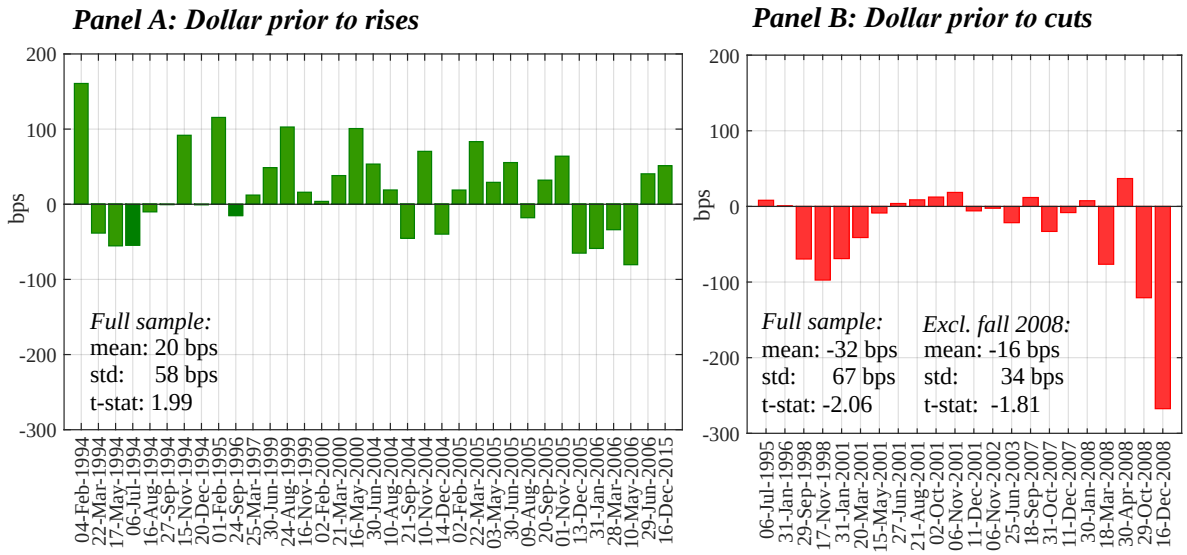

Figure 5: **Dollar Two-day Returns Ahead of the Rate Moves, Signaled by the Fed Funds Futures.** *Panel A* shows $DOLr_{t-2\to t}$ ahead of 35 announcements, when the fff_{t-3} signals a target rate rise ($E^{fff}_{t-3}[\Delta FFR_t] \geq 12.5$ bps). *Panel B* shows $DOLr_{t-2\to t}$ ahead of 22 announcements, when the fff_{t-3} signals a target rate cut ($E^{fff}_{t-3}[\Delta FFR_t] \leq -12.5$ bps).

There are two obvious outliers in Figure 5. The rate cuts in fall 2008 (by 50 bps on 29 October 2008 and by 87.5 bps on 16 December 2008) were accompanied by a sharp dollar fall in the 48 hours prior to the announcements (by 265 bps and 155 bps). Removing these two extreme observations reduces the mean dollar return ahead of cuts to from 32 to 16 bps and reduces its t-stat from 2 to marginally significant 1.8.

The difference between $DOLr_{t-2\to t}$ prior to the rate rises and cuts is 52 bps (36 bps excluding the recent financial crisis). This difference is statistically significant at 1% level (t-stat=3.1). These two series of returns combined effectively represent the long leg and minus short leg of a tradable strategy based on the signal encoded into fff_{t-3}. I discuss the profitability of this strategy and compare it with the other FX strategies in Section 2.5.

I document my finding more formally by running simple regressions of daily (2pm-to-2pm) dollar simple and excess returns with the pre-FOMC dummies:[8]

$$DOLr_t = \alpha + \beta D_t + \varepsilon_t \tag{7}$$

$$DOLrx_t = \alpha + \beta D_t + \varepsilon_t \tag{8}$$

[8]To construct daily excess returns, I use daily one-week forward discounts divided by 5. These series are recorded at 1 pm.

	D^{fff}_{rise}		D^{fff}_{cut}		$D^{fff}_{rise} - D^{fff}_{cut}$	
Panel A. Full sample, Jan 1994 – Dec 2015						
$DOLr_t$	**10.1**	[2.03]	**-16.2**	[-2.08]	**12.4**	[2.88]
$DOLrx_t$	**10.3**	[2.08]	**-16.3**	[-2.09]	**12.5**	[2.92]
Panel B. Excluding Jul 2008 – Dec 2009						
$DOLr_t$	**10.1**	[2.03]	-8.1	[-1.73]	**9.3**	[2.61]
$DOLrx_t$	**10.3**	[2.08]	-8.1	[-1.75]	**9.4**	[2.66]

Table 2: **Dollar Returns with the pre-FOMC Dummies.** The regressions are $DOLr_t = \alpha + \beta D_t + \varepsilon_t$ and $DOLrx_t = \alpha + \beta D_t + \varepsilon_t$, where where D_t is a pre-FOMC dummy variable, which takes D^{fff}_{rise} (equal to one on the two days ahead of 35 announcements, when the fff_{t-3} signals a target rate rise, and is zero otherwise), D^{fff}_{cut} (equal to one on the two days ahead of 22 announcements, when the fff_{t-3} signals a target rate cut, and is zero otherwise), or $D^{fff}_{rise} - D^{fff}_{cut}$. t-statistics are shown in brackets. They are based on the standard errors, robust to conditional heteroscedasticity and serial correlation up to two lags as in Newey and West (1987). Bold numbers are statistically significant at 5% level. The full sample covers 5760 days.

where D_t is a pre-FOMC dummy variable, which takes D^{fff}_{rise} (equal to one on the two days ahead of 35 announcements, when the fff_{t-3} signals a target rate rise, and is zero otherwise), D^{fff}_{cut} (equal to one on the two days ahead of 22 announcements, when the fff_{t-3} signals a target rate cut, and is zero otherwise), or $D^{fff}_{rise} - D^{fff}_{cut}$. Table 2 reports the results from running these dummy regressions. Firstly, the coefficients in front of D^{fff}_{rise} and D^{fff}_{cut} are half of those reported for the means of two-day returns in Table 5. The dollar goes up by 10 bps per day during the two days prior to the announcement when fff_{t-3} signals a target rate rise. The dollar goes down by 16 bps per day (8 bps excluding the recent financial crisis) during the two days prior to the announcement when fff_{t-3} signals a target rate cut. The difference between the two dummies, 12 bps, effectively represents daily returns from being long the dollar ahead of rises and short the dollar ahead of the cuts, when both are signaled with fff_{t-3}.

Second, the results for the dollar excess returns in Table 2 are almost identical to the results for the simple returns, reflecting that only a tiny part of the returns comes from the interest rate differentials. On average, the daily expectations of currency depreciation or appreciation as encoded into the currency forward discounts (interest rate differentials between the U.S. and foreign countries) are negligibly small in their magnitude to account for the observed pre-FOMC announcement dollar return. Specifically, these expectations are on average below 1 bps for the two-day pre-FOMC announcement period.

Third, the average return on the other days as indicated by the constant (unreported) is 0.5 bps and is statistically insignificant. The standard deviation of the daily dollar returns in the

pre-FOMC days is 60 bps (53 bps excluding the recent financial crisis), only slightly larger than their standard deviation in all other days, 51 bps.

Finally, I do several bootstrap exercises to account for the small number of observations in my sample and to check the sensitivity of my results to the outliers. First, I draw with replacement a return series of length corresponding to the number of signaled target rate rises (35) from the observed distribution of the dollar returns prior to signaled target rate rises in the full 1994–2015 sample, and a series of length 5,646 from the observed distribution of non-FOMC returns. Then I reestimate my dummy regression (8) and find that the bootstrapped coefficients and their standard errors (unreported) are similar to my regression results in Table 2. Second, I draw with replacement from the distribution of non-FOMC announcement returns a time series of length equal to the number of signaled target rises (35). I find that the probability of observing a mean greater than 10 bps is close to zero. The results for the signaled target rate cuts are similar.

In summary, I find that *(1)* a fed funds futures spread above 12.5 bps three days in advance of a scheduled FOMC meeting predicts a target rate rise, and also predicts a rise in the dollar that will take place in the subsequent two days, *(2)* a fed funds futures spread below 12.5 bps predicts a target rate cut, and also predicts a drop in the dollar that will take place in the subsequent two days.

2.4 Predicting the pre-FOMC Dollar Returns with the Fed Funds Futures

This far I have used a rigid rule to predict the dollar returns up until the FOMC announcement. Now I test the predictive ability of a continuous version of the fed funds futures spread prior to the FOMC announcement and in the other days:

$$DOLrx_{t-2\to t} = \alpha + \beta E_{t-3}^{fff}\left[\Delta FFR_t\right] + \varepsilon_{t-2\to t}, \tag{9}$$

where t stands for the day of FOMC, PPI, GDP, unemployment announcement, and all other days. The dates of macroannouncements are from *Bloomberg* and available for 1997–2015.[9]

Table 3 shows the results. A high fed funds futures spread three days in advance of a scheduled FOMC meeting forecasts a rise in the dollar (t-stat=2.8, R^2=7.6%). The predictability comes entirely from the FOMC meetings, when fff_{t-3} signals a policy change. For these 57 meetings, the R^2 rises to 21.8%, the coefficient is 2.8 and the t-stat is 2.7. A one basis point higher expected change in the policy rate predicts a 0.8 bps rise in the dollar over the follow-

[9] I use the first announcement of the quarterly GDP data and do not use the dates when the revisions are announced. Since all macroannouncements come out at 8:30 EST, I use the dollar return from 8:00 two days prior to the scheduled macroannouncement to 8:00 on the day of announcement.

	$E_{t-3}^{fff}[\Delta FFR_t]$	t-stat	R^2	N days
Panel A. Prior to the FOMC announcements				
All FOMC ann.	**0.80**	[2.82]	7.6	176
fff_{t-3} signal a policy change	**0.80**	[2.70]	21.8	57
fff_{t-3} signal no policy change	0.16	[0.11]	0.0	118
Panel B. Prior to other days				
GDP ann.	1.15	[1.79]	5.8	74
PPI ann.	0.45	[0.90]	1.1	192
Unempl. ann.	0.55	[1.89]	2.1	192
All other days	0.13	[1.15]	0.1	2879

Table 3: **Predicting Dollar Returns with Fed Fund Futures Spread Ahead of Different Days.** The table shows results from running $DOLrx_{t-2\to t} = \alpha + \beta E_{t-3}^{fff}[\Delta FFR_t] + \varepsilon_{t-2\to t}$. Each time I predict the dollar returns ahead of the events. The dollar returns in *Panel A* are from 14:00 EST two days prior to the FOMC ann. to 14:00 EST on the day of announcement. The dollar returns in *Panel B* are from 8:00 two days prior to macroannouncements to 8:00 EST on the day of announcement. All macroannouncement. are released at 08:30 EST. The sample for the FOMC announcements runs from 1994–2015. The sample for macroannouncement runs from 1997 to 2015. The number of events used in each regression are in the last column. t-statistics are shown in brackets. They are based on the standard errors, robust to conditional heteroscedasticity and serial correlation up to two lags as in Newey and West (1987). Bold numbers are statistically significant at the 5% level. The R^2 are in percent.

ing two days up until the announcement. Removing two outliers due to recent financial crisis reduces the R^2 to 12.2% and the slope coefficient to 0.5, while the t-stat remains unchanged at 2.7 (unreported). The fed funds futures spreads have no predictive power for the dollar (zero R^2), when they do not signal a target change (i.e., when $\mid E_{t-3}^{fff}[\Delta FFR_t] \mid$ is below a 12.5 bps threshold).

I illustrate my central result, that the fed fund futures predict the pre-FOMC announcement dollar returns, in Figure 6. *Panel A* uses 57 announcements, when the futures markets expect a policy change. *Panel B* uses all 176 scheduled announcements. The fed funds futures spread over the target three days prior to the FOMC announcement (*y-axis*) predicts the subsequent two-day dollar excess return (*x-axis*). The up- and down-pointing and green triangles highlight the observations for the signaled target rate rise and cut..

I also study the predictive ability of the fed funds futures spreads for the dollar excess returns ahead of the other scheduled announcements. The results in *Panel B* of Table 3 indicate that the spreads have some predictive power for the dollar returns prior to the GDP (t-stat 1.79) and unemployment (t-stat 1.89) announcements. The R^2 of 5.8% and 2.1% is much smaller than for the days when the policy change is predicted by the fed funds futures. The slope coefficient

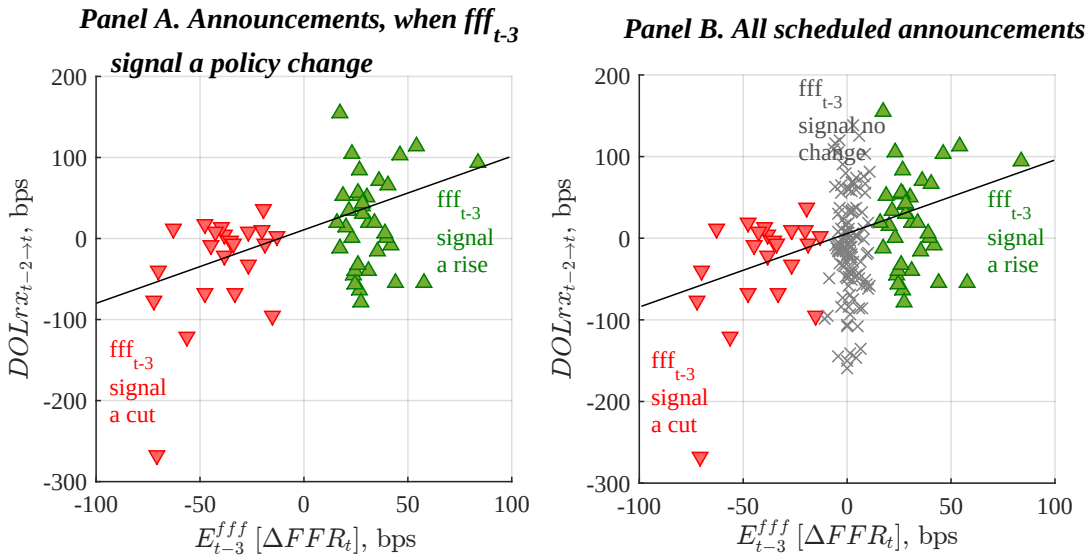

Figure 6: **Fed funds futures predict the dollar return.** The figure plots fed funds futures spread over the target three days prior to the FOMC announcement (*y-axis*) against the subsequent two-day dollar excess return (*x-axis*). *Panel A* uses 57 FOMC announcements, for which $\mid E_{t-3}^{fff}[\Delta FFR_t] \mid \geq 12.5$ bps. *Panel B* uses all 176 scheduled FOMC announcements. See first two lines of Table 3 for the corresponding regression results.

for all the other days (last line) is also positive, but insignificant.

2.5 The Pre-FOMC Dollar Strategy

In this subsection, I examine an implementable trading strategy based on the fed funds futures three days prior to an FOMC announcement. Specifically, the strategy goes long the dollar if $E_{t-3}^{fff}[\Delta FFR_t] \geq 12.5$ bps and goes short the dollar if $E_{t-3}^{fff}[\Delta FFR_t] \leq -12.5$.

Figure 7 shows the cumulative returns from such a strategy for 1994–2014, see solid line. In the strategy, trading occurs 57 times: 35 times long and 22 times short the dollar during the two days prior to the FOMC announcement, when the fed funds futures signal a target change. Overall, a position is held 114 days or 5 days per year (23 years in my sample). The mean strategy return is 25 bps, and the standard deviation is 61 bps. I calculate the strategy's annualized Sharpe ratio as $SR = Mean \times \sqrt{5}/Std = 25 \times \sqrt{5}/60 = 0.93$. The Sharpe ratio of the pre-FOMC announcement dollar strategy is comparable to the Sharpe ratios of the main existing strategies on the currency market: carry trade (0.70), dollar carry trade (0.66), momentum (0.52), and value (0.60).[10]

[10]See the following studies documenting the profitability of the currency strategies: Lustig, Roussanov, and Verdelhan (2011, 2014), Menkhoff, Sarno, Schmeling, and Schrimpf (2012), Asness, Moskowitz, and Pedersen

The t-stat of the strategy is 2.8, well above a 95% confidence level. Excluding two sharp target rate cuts in fall 2008 reduces the pre-FOMC announcement strategy return to 20 bps, while the standard deviation goes down to 50 bps. The t-stat of such truncated strategy is 2.66.

In Figure 7, strategy return reduces to 15 bps after accounting for transaction costs (see dashed line). Sharpe ratio of the strategy goes down to 0.57. Transaction costs are sizeable in the first half of the sample: from 1994 to 2002 the average cost of buying/selling the dollar against most liquid currencies was 5–10 bps, consuming almost one-half of the strategy return. FX liquidity improved substantially in early 2000s, when effective cost of USD trading reduced to 1–3 bps.[11] In the second half of the sample, transaction costs constitute less than 20% of the strategy return.

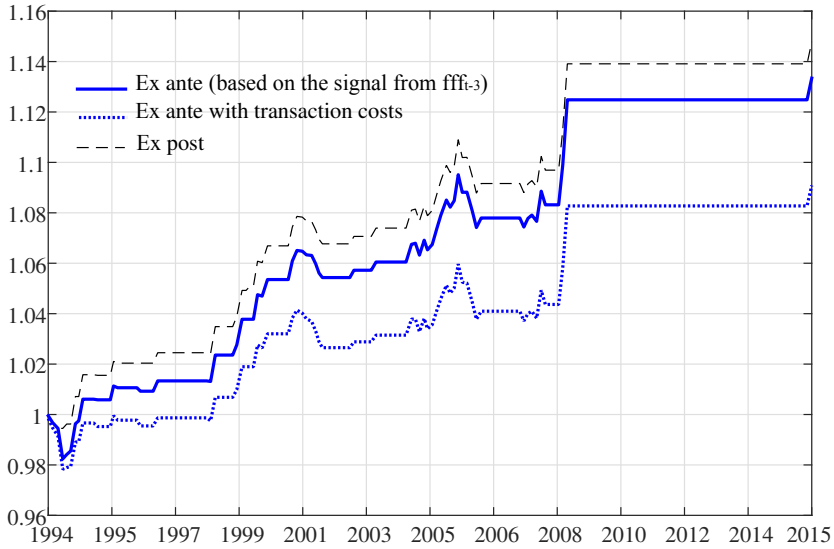

Figure 7: **Cumulative Dollar Returns on the Pre-FOMC Announcement Strategy.** The figure shows the dollar returns from trading the dollar ahead of the scheduled FOMC meetings. Solid (blue) line shows cumulative returns from the implementable strategy from trading 57 times (114 days) ahead of the FOMC meetings, when the target change is signaled with the federal funds futures (i.e., when $\mid E_{t-3}^{fff}\left[\Delta FFR_t\right] \mid \geq$ 12.5 bps). The dashed (blue) line accounts for the transaction costs in this ex ante startegy. The dotted (black) line shows cumulative dollar returns from the unimplementable startegy from trading 54 times (108 days) ahead of (ex post) realized FOMC target changes. The sample period is 1994 – 2015.

I illustrate how this simple strategy works with a recent target rise on at 14:15 on Wednesday, 16 December 2015. At the market close on Friday, 11 December 2015, the fed funds futures spread was 31 bps, 18.5 bps above the target rate (average between 25 bps upper and 0 bps

(2012), and Karnaukh (2015).

[11] Karnaukh, Ranaldo, and Söderlind (2015) study the time-series and cross-sectional variation in the currency liquidity over 1991–2012.

lower bound). Buying the dollar Monday afternoon and selling it Wednesday afternoon results into 51 bps profit, 48 bps net after transaction costs. Taking into account that even an individual FX investor can take leverage ratios of up to 100 to 1 (or trade on a 1% margin), the potential profits from such trading are huge: an investment of USD \$100 and 100 to 1 leverage ratio implies USD $10'000 \times 1.0051 = 10'051$, a 51% profit on a 2-day investment.

Knowing in advance the outcome of an FOMC announcement, would have improved the strategy returns to 28 bps (see thin dotted line on Figure 7). In other words, those five times, when the fed funds futures signaled an incorrect prediction of the target rate change, reduced the overall profit from the pre-FOMC announcement dollar trade by only 3 bps. Notably, the *ex ante* (implementable) and *ex post* (unimplementable) strategies are identical starting from 1997. This reflects the Fed's efforts to provide more forward guidance to the market and, thus, the fed fund futures have an excellent ability to forecast the direction of the policy changes from 1997–2015.

In this section I documented central result of my paper: the expected policy change information contained in the fed funds futures three days prior to the FOMC announcement predicts the subsequent two-day movement in the dollar up until the announcement with a 22% R^2. Thus, information about the monetary policy change is captured first by the fed funds futures markets and is reflected only later in currency markets. This finding is surprising given how liquid exchange rate markets are.

3. Potential Explanations

First, I discuss how my result lines up with the standard exchange rate models. According to the UIP puzzle (e.g., Fama 1984), high interest rate country tends to have the higher expected return in the short run. I investigate whether interest rate differentials can forecast the pre-FOMC dollar return. I then discuss risk-based explanations. Finally, I discuss behavioral explanations based on limited investor attention and/or form of market segmentation.

3.1 Standard Exchange Rate Models

Standard exchange rate models (Fleming 1962; Mundell 1963; Dornbusch 1976) imply that a country with a relatively higher interest rate has lower risk premium and stronger currency. If the Fed raises the target rate while other central banks keep their rates unchanged, then the returns on savings becomes more attractive in the U.S. than in other countries. International investments flow from other countries to the U.S. causing the dollar to appreciate. At first

glance, my findings are in line with the standard exchange rate models and uncovered interest rate parity (UIP): an interest rate increase appreciates the currency. Specifically, I find that the target rate rise is (on average) 29 bps from 1994–2015 and is accompanied by a 25 (on average) bps dollar appreciation in the two days pre-FOMC period. However, these macroeconomic explanations do not line up with the fact that interest rates rise gradually over several weeks leading to the announced changes, while the dollar rises only in the last two days prior to the announcement.

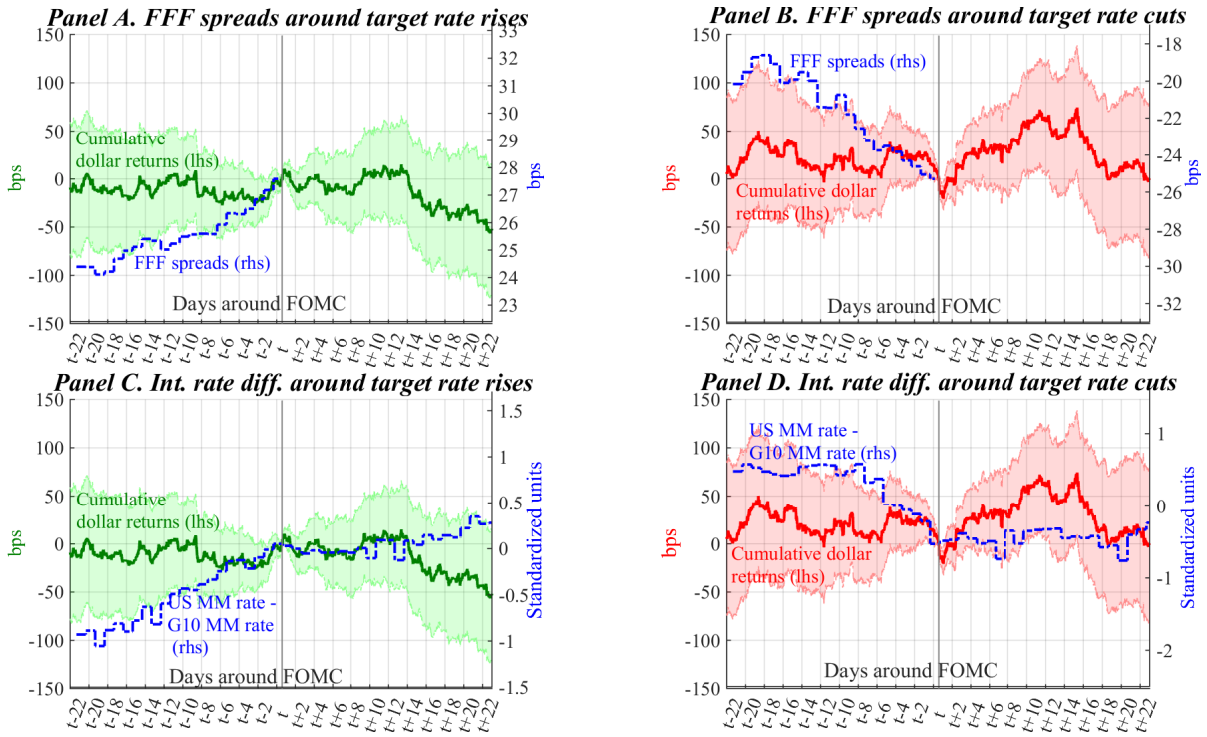

Figure 8: **FFF spreads, interest rate differentials, and the dollar cumulative returns during a month around target rate changes.** The solid line depics average cumulative dollar returns during a month before and after the FOMC announcement (t). I standardize the fed funds futures spread (dotted line) by the size of the realized policy change (25/50/75 bps) before computing the average spread across the announcements. I standardize interest rate differentials (dotted line) across all announcements to have mean zero and unit standard deviation before computing the average. See caption to Figure 2 for the details on the standard errors around average cumulative returns.

Figure 8 plots the average (across the announcements) fed funds futures spreads and interest rate differentials around the *realized* target rate raises (*Panel A* and *C*) and cuts (*Panel B* and *D*), see dotted lines. Solid bold line plots with the cumulative 5-minute dollar returns, standardized to zero at the time of announcement. The figure covers a month (22 trading days) prior and after the FOMC announcement.

This figure has three messages. First, both fed funds futures spreads and interest rate dif-

ferentials move in the direction of the realized policy move during a month prior to the FOMC meetings. In other words, fixed income markets become more certain about the Fed's most likely action. Fed funds futures spread and interest rate differentials rise gradually over a month prior to the FOMC meeting. The rise in the interest rate differentials is entirely driven by the rise in the U.S. interest rate as G10 interest rate does not change on average prior to the FOMC announcement.[12]

Second and most importantly, the dynamics of fed fund futures spread and interest rate differentials does not line up with the dynamics of the dollar earlier than in the last two days prior to the FOMC announcement. The dollar returns are not statistically different from zero over a month prior to the announcement and a t-stat for the difference between $DOLr_{t-22\to t-2}$ prior to the target rate rises and cuts is -0.7. The correlations between $DOLr_{t-j\to t-3}$ and changes in futures spreads $E^{fff}_{t-j\to t-3}[\Delta FFR_t]$ (for $j = 22, 12, 7$ days) are close to zero.

Third, the futures spread is already 25 bps three weeks prior to the target rate raise (see *Panel A*), well above a 12.5 bps threshold. Similarly, the futures spread is -20 bps three weeks prior to the target rate cut (see *Panel B*), well below a 12.5 bps threshold. This illustrates that the futures market has already determined the most likely Fed's decision well ahead of time, and not just three days prior to the FOMC announcement.

My findings pose a significant puzzle for exchange rate models that rely on rational expectations. Even though the direction of the movement of the exchange rate in response to monetary policy expectations is in line with the prediction by the standard exchange rate models, the speed at which these movements occur is not aligned across the bond and exchange rate markets: bond markets incorporate information faster than exchange rate markets do. This evidence also suggests a failure of the efficient-market hypothesis.

3.2 Uncovered Interest Rate Puzzle and Currency Risk Premiums

The uncovered interest rate puzzle finds that over short horizons when the interest rate (one country relative to another) is higher than average, the short-term deposits of high-interest rate currency tend to earn an excess return (Fama 1984). A risk-based explanation of this anomaly requires that the short-term deposits in the high-interest rate country are relatively riskier and therefore incorporate an expected excess return as a reward for risk-bearing. The ex-ante risk premium is time-varying and covary with the currency forward discounts (or interest rate dif-

[12]This evidence is suggestive of a presence of risk premium during the weeks prior to the announcement. In fact, fff_{t-15} or fff_{t-10} do predict their own returns and government bonds returns over the next three or two weeks up until the announcement. The macroannouncements, policy speeches and other world shocks which (might) come out during this time are the most likely source of this risk premium.

ferentials).[13]

Do currency forward discounts forecast the dollar returns prior to the FOMC announcement or the predictive power steams from the fed funds futures spreads? I show that currency forward discounts do forecast dollar returns in normal days but do *not* forecast the dollar returns prior to the FOMC meetings when a policy change is signaled with fff_{t-3}. Prior to these meetings all the predictability comes from the fed funds futures spreads. I then show the predictive power of the futures spreads for G10 and a larger cross-section of pre-FOMC dollar returns. I find that high interest rate currencies depreciate more than low interest rate currencies, when the fed funds futures spread is high.

I run the regressions of the dollar excess returns on the average currency forward discount[14]:

$$DOLrx_{t-2\to t} = \alpha + \beta\overline{(f^i_{t-3} - s^i_{t-3})} + \varepsilon_{t-2\to t}. \tag{10}$$

Table 4 (*Panel A*) shows the results from running these predictive regressions ahead of the FOMC announcements and in all other days. First, currency forward discounts negatively predict the dollar returns in the ordinary days (-1.96 t-stat). This result illustrates the UIP failure for the dollar returns: on average, a higher foreign interest rate than in the U.S. (positive forward discount) predicts foreign currency appreciation (negative dollar returns). Lustig, Roussanov, and Verdelhan (2014) document a similar predictability result for the monthly to annual dollar excess returns.

Second, currency forward discounts predict the dollar returns prior to the FOMC announcements, when fff_{t-3} signals no policy change (3.1 t-stat, 7.5% R^2). Third, currency forward discounts have zero predictive power for the dollar returns prior to the FOMC announcements fff_{t-3} signals a monetary policy change (-0.2 t-stat, 0.1% R^2).[15]

Now I add the fed funds futures spread to these predictive regressions:

$$DOLrx_{t-2\to t} = \alpha + \beta\overline{(f^i_{t-3} - s^i_{t-3})} + \gamma E^{fff}_{t-3}\left[\Delta FFR_t\right] + \varepsilon_{t-2\to t} \tag{11}$$

Panel B of Table 4 shows that the fed funds futures spread enters the regression with a positive significant coefficient for all FOMC announcements (line (1)) and for the announcements,

[13]Currency forward discount are equal to interest rate differentials, if the covered interest rate parity holds. I observe the deviations from CIP only since mid-2008. Only 3 out of 54 target rate changes occurred after mid-2008. Thus, using forward discounts instead of interest rate differentials does affect my results.

[14]I use the average forward discount across G10 countries. Using the average forward discount across EUR, CHF, GBP, JPY (exchange rates which are used to compute the equal-weighted dollar) gives similar results.

[15]These regression results are almost identical for simple dollar returns, except for the slope coefficient being not significant for all other days (-1.3 t-stat). Also, currency forward discounts do not predict the *post-FOMC* dollar returns.

Panel A. $DOLrx_{t-2\to t} = \alpha + \beta\overline{(f^i_{t-3} - s^i_{t-3})} + \varepsilon_{t-2\to t}$			
	β	t-stat	R^2
All FOMC ann.	**-9.03**	[-2.28]	3.8
fff_{t-3} signal a policy change	-1.13	[-0.15]	0.1
fff_{t-3} signal no policy change	**-12.71**	[-3.11]	7.5
All other days	**-1.98**	[-1.96]	0.1

Panel B. $DOLrx_{t-2\to t} = \alpha + \beta\overline{(f^i_{t-3} - s^i_{t-3})} + \gamma E^{fff}_{t-3}\left[\Delta FFR_t\right] + \varepsilon_{t-2\to t}$					
	β	t-stat	γ	t-stat	R^2
All FOMC ann.	-6.42	[-1.64]	**0.71**	[2.47]	9.4
fff_{t-3} signal a policy change	6.88	[1.05]	**0.89**	[2.81]	23.8
fff_{t-3} signal no policy change	**-13.30**	[-3.10]	-0.76	[-0.54]	7.8
All other days	-1.78	[-1.74]	0.10	[0.90]	0.2

Table 4: **Predicting Dollar Returns with Average Currency Forward Discount and Fed Funds Futures Spreads.** I run the predictive regression of the dollar returns ahead of the FOMC announcements and in the other days. The number of events used in each regression can be found in the last column of Table 3. t-statistics are shown in brackets. Bold numbers are statistically significant at 5% level. The R^2 are in percent.

when fff_{t-3} signal a policy change (line (1a)). The fed funds futures spread does not have a predictive power in all other days.

How is it that the fed funds futures spreads predict the dollar returns when the currency forward discounts do not? Let us assume that the UIP holds. Both spreads would predict the dollar returns in a similar way if the times when the Fed is adopting the monetary policy easing (tightening) always coincide with the times when the world interest rate is below (above) the U.S. interest rate (i.e. both $\overline{(f^i_{t-3} - s^i_{t-3})}$ and $E^{fff}_{t-3}\left[\Delta FFR_t\right]$ have the same sign). However, this is not always the case. The periods of the Fed's monetary policy tightening in 1999 and second half of 2005–2006 were the times when the average G10 interest rate was below the U.S. one ($E^{fff}_{t-3}\left[\Delta FFR_t\right] > 0$, but $\overline{(f^i_{t-3} - s^i_{t-3})} < 0$). Similarly, in 2001 and 2008 the Fed adopted monetary policy easing in the times when the U.S. interest rate was lower than the rest of the world ($E^{fff}_{t-3}\left[\Delta FFR_t\right] < 0$, but $\overline{(f^i_{t-3} - s^i_{t-3})} > 0$). Most of these periods correspond to the second part of the monetary policy easing or tightening cycle.[16]

[16] See Figure 14 in Appendix for the plot of the Fed funds rate and G10 average interest rate. For instance, lets look at the two last cuts of the Fed's 2001–2003 easing cycle. The G10 interest rate was at 3%, more than 1% higher than in the US, i.e. $\overline{(f^i_{t-3} - s^i_{t-3})} > 0$. Prior to the corresponding FOMC meetings (6 Nov 2002 and 25 Jun 2003), the fed funds futures markets predicted a cut: $E^{fff}_{t-3}\left[\Delta FFR_t\right]$ equal to -35 bps and -38 bps, well below a -12.5 bps threshold. Thus the two spreads had opposite signs. The dollar went down in the two days prior to these FOMC meetings, thus following the prediction from the futures markets.

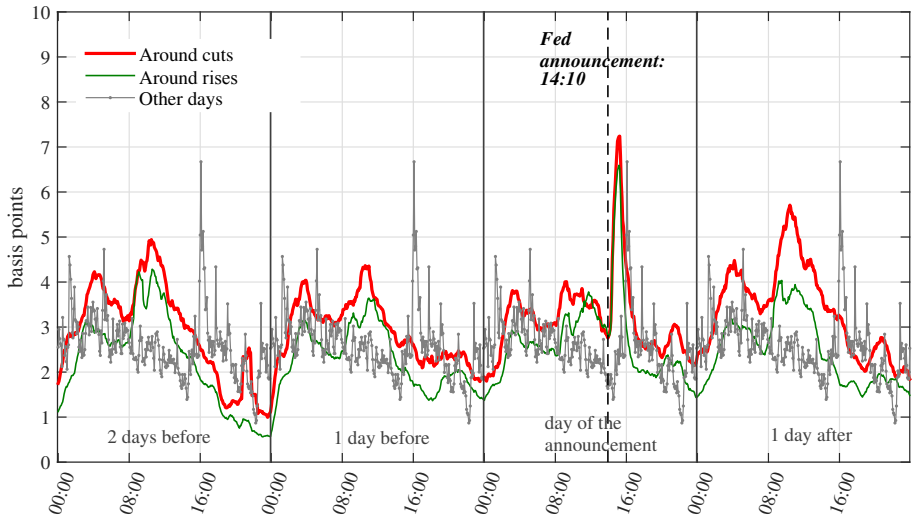

Figure 9: **Realized volatility around target rate cuts and rises and in the other days.** The figure depicts 5-minute FX realized volatility, computed as a 1-hour rolling average of absolute 5-minute dollar returns. The realized volatility is averaged across the EUR, AUD, GBP, CHF, JPY, and CAD rates vs USD.

If we were to assume always a failure of the forward premium puzzle (as for any other day, see last line of Table 4), then $\overline{(f^i_{t-3} - s^i_{t-3})}$ and $E^{fff}_{t-3}[\Delta FFR_t]$ would always need to have the opposite sign. However, this is not true for the first part of the monetary policy easing and tightening cycles.

To sum up, currency forward discounts do not help to forecast the dollar excess returns prior to the FOMC announcements, when the fff_{t-3} signal a policy change. All the predictability ahead of those days comes from the fed funds futures spreads.

3.3 Other risk-based explanations

Excess returns are earned as compensation for undiversifiable risk, according to the standard asset pricing theory. There is a one-week blackout period prior to the FOMC announcement, meaning the FOMC members refrain from providing monetary policy information through speeches and interviews. However, investors might aggregate other information in the 48-hour pre-FOMC window. I consider potential sources of risk premiums prior to the FOMC: volatility, illiquidity, and release of macroeconomic announcements.

Changes in Volatility and Illiquidity

Let us look at the realized volatility and bid-ask spreads in the days around the FOMC announcement. Since these measures are proportional to the information flow in the large set of

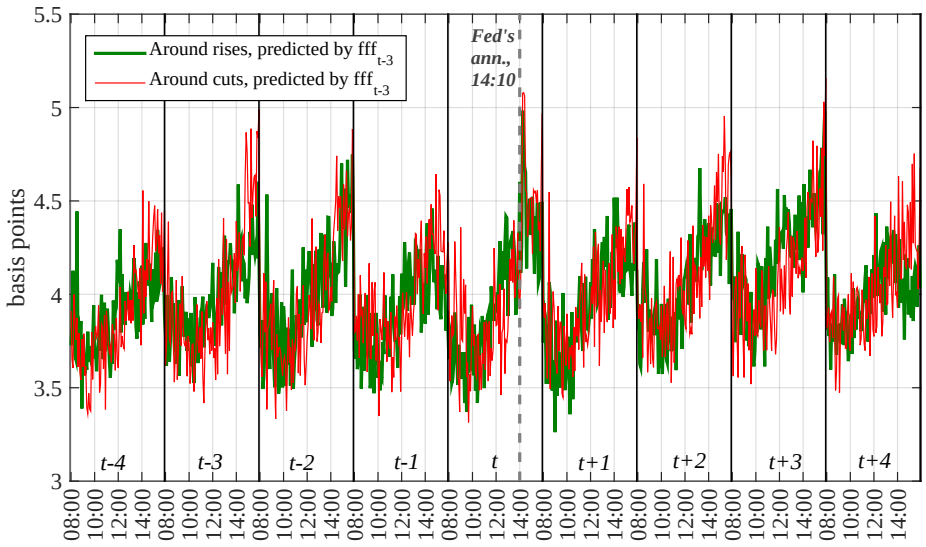

Figure 10: **Dollar illiquidity around target rate cuts and rises and in the other days.** The figure depicts average standardized 5-minute bid-ask spreads around 35 target rate rises and 22 target rate cuts, predicted by the fed funds futures. The bid-ask spreads are averaged across the EUR, AUD, GBP, and CAD rates vs USD.

models (e.g. Ross 1989), a spike in either volatility or illiquidity prior to the FOMC announcement would indicate a rise in the flow of information, for example, due to media commentaries. Figure 9 plots the rolling 1-hour realized dollar volatility (sum of the squared 5-minute returns), while Figure 10 plots 5-minute standardized dollar bid-ask spreads in several days around target rate rises and cuts. The 5-minute dollar bid-ask spreads are from *Olsen Associates* and are averaged across the EUR, AUD, GBP, and CAD rates vs USD. These two figures illustrate that both realized volatility and liquidity jump right after the announcement. However, both measures are not abnormally higher in the two days prior to the announcement. The realized volatility and bid-asks in the two-day pre-FOMC period are just as in other days of my sample.

Levels of Volatility and Illiquidity

I run single regressions of pre-FOMC returns on factors F_{t-3} capturing (1) levels of FX realized volatility, measured from the 5-minute dollar returns, (2) uncertainty about the future exchange rate level, measured by the implied volatility from 1-month currency options, (3) uncertainty about future yields (*MOVE* index), measured by the implied volatility from Treasury options, (4) stock market uncertainty (*VIX* index), measured by the implied volatility from stock index options, (5) dollar illiquidity, measured as average bid-ask spread across four FX pairs used to construct the dollar index. The option volatility data is from *Bloomberg*. For easier tractability, I standardize all right-hand side variables to have zero mean and unit standard

deviation.

Table 8 in the Appendix shows that only levels of FX realized volatility negatively predict the pre-FOMC dollar return (with a 4.9% R^2), but it looses significance, when I control for $E_{t-3}^{fff}[\Delta FFR_t]$. None of the remaining volatility or illiquidity measures can predict the pre-FOMC dollar return.

Macroannouncements

Another source of information might come from the macroannouncements which are released in a 48-hour pre-FOMC window. A positive GDP or unemployment report can make market participants more certain about the Fed's most likely policy move and thus boost the pre-FOMC dollar return. I use *Bloomberg* to collect all macroannouncements in the two-day pre-FOMC window. There are only cases when an important macroannouncement came out in a 48-hour period prior to the target rate change. Excluding those observations leaves my predictive results marginally unchanged, thus suggesting that macroannouncements do not drive the pre-FOMC dollar return.

Private Information

If the pre-FOMC dollar return was a reflection of private information prior to the FOMC, then it would have been correlated either with the change in the federal funds futures upon the announcement (*ex post* monetary policy surprise, see Bernanke and Kuttner 2005) or with the dollar immediate reaction to to the Fed's announcement. I find that the pre-FOMC dollar return has close to zero correlation with the futures or dollar return on impact.

Can the pre-FOMC dollar return can help to predict the target rate change on top of the information contained in the fed funds futures? The answer is no. Adding $DOLr_{t-2\to t}$ to the regression of the target rate change on the ex ante fed funds futures spread does not help to predict the policy move. These pieces of evidence lead me to conclude that the two-day pre-FOMC dollar movement does not reflect new (possibly, private) information about the future policy change.

Resolution of Uncertainty

A high level of uncertainty prior to the FOMC which is resolved upon the announcement generates a positive pre-announcement equity premium (Ai and Bansal 2016). According to this theory, uncertainty resolves on the days of all types of monetary policy decisions (target rate rises, cuts, neutral decisions) as well as on the days of macroeconomic announcements. It is difficult to reconcile this theory with the fact the pre-FOMC dollar return depends on the direction of the expected policy change, ex ante encoded in the fed funds futures. Also, I do not find positive dollar excess returns prior to the main U.S. macroannouncements, such as GDP,

inflation, or unemployment.

To sum up, the flow of new information is low in the two-day pre-FOMC window as compared to the time of the announcement or other days. The key challenge for the risk-based explanations of excess dollar returns in the two-day pre-FOMC period is the disconnect between the time when the returns are earned and when the news is revealed. Neither standard nor alternative risk-based explanations provide coherent justifications why the two-day pre-FOMC dollar return depends on the direction of an anticipated policy move, as ex ante signaled by the fed funds futures.

3.4 Behavioral Explanations

In the days prior to the scheduled FOMC announcement, the fed funds futures market leads the FX market in reflecting the expectations of the Fed's policy changes. I discuss behavioral explanations for my finding, including infrequent portfolio rebalancing, limited investor attention, and investor risk aversion.

Froot and Thaler (1990), p. 188, write: *"Consider as an example, the hypothesis that at least some investors are slow in responding to changes in the interest rate differential. It may be that these investors need some time to think about trades before executing them, or that they simply cannot respond quickly to recent information... While changes in nominal interest rates have differential instantaneous effects on the exchange rate across different exchange-rate models, most of these models predict that an increase in the dollar real interest rate should lead to instantaneous dollar appreciation. If only part of this appreciation occurs immediately, and the rest takes some time, then we might expect the exchange rate to appreciate in the period subsequent to an increase in the interest rate differential."*

Bacchetta and van Wincoop (2010) argue that making infrequent portfolio decisions is optimal as the welfare gain from active currency management is smaller than the corresponding fees. They show that infrequent portfolio decisions lead to a delayed impact of interest rate shocks on exchange rates. Furthermore, market participation is time-varying due to slow-moving capital (Duffie 2010). Infrequent portflolio rebalancing coupled with market segmentation may rationalize why information gets faster into fed funds futures markets than into currency markets. However, these theories do not explain why would investors decide to rebalance their portfolios exactly in the last days prior to the FOMC announcement.

Interest rates rise in advance of policy changes established by the Federal Reserve. An interest rate increase leads to an appreciation of the currency. However, some investors are slow to adjust their portfolios, perhaps because it is costly to monitor and gather information constantly (Mankiw and Reis 2002; Sims 2003). Kacperczyk, Nieuwerburgh, and Veldkamp (2014) show

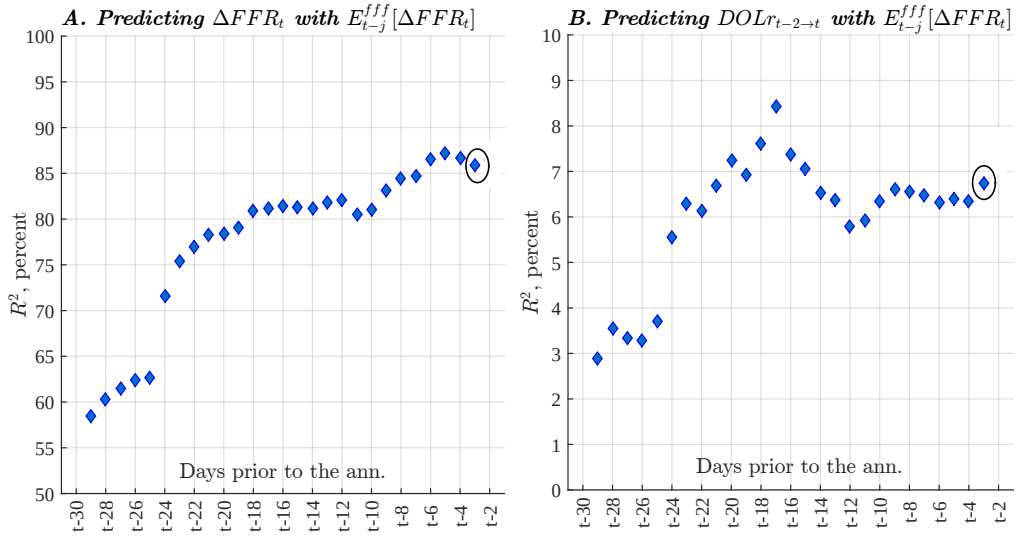

Figure 11: **Predicting with stale fed funds futures spreads.** The figure depicts the R^2 from predicting the target rate change (*Panel A*) and the two-day pre-FOMC dollar return (*Panel B*) with the fed funds futures spreads recorded on different days during a month prior to the FOMC announcement (see x-axis). The diamond point in the circle in *Panel A* (*Panel B*) is the R^2 from the regression of ΔFFR_t ($DOLr_{t-2\to t}$) on $E^{fff}_{t-3}[\Delta FFR_t]$. The sample is 176 scheduled FOMC announcements from 1994–2015.

that investors allocate their attention between signals about aggregate and idiosyncratic components of cash flows, and at each time optimally focus on shocks that are most important for returns. Consistent with the theories on limited investor attention, a set of currency investors may not pay enough attention to fed funds futures expectations of the Fed's policy change earlier than in the last days prior to the FOMC announcement.

Two pieces of suggestive evidence support this hypothesis. First, stale (i.e., two-week or three-week lagged) fed funds futures spread forecasts the two-day pre-FOMC dollar return almost as well as the fed funds futures spread recorded three days prior to the announcement. Figure 11 illustrates this by plotting the R^2 from the regressions of the target rate change (*Panel A*) and the two-day pre-FOMC dollar return (*Panel B*) on the fed funds futures spreads recorded on different days during a month prior to the FOMC announcement. The R^2 from using either $E^{fff}_{t-20}[\Delta FFR_t]$ or $E^{fff}_{t-3}[\Delta FFR_t]$ to forecast the two-day pre-FOMC dollar returns are equal to 7%. This evidence suggests that the dollar reacts to the old information already contained in the fed funds futures prices.

Second, the number of Fed-related articles in *The Wall Street Journal* and *The Financial Times* increases exactly two days prior to the FOMC announcement. Lucca and Moench (2015) illustrate this in Figure IA.6 of their Internet Appendix. Thus, the two-day pre-FOMC dollar

return depends on the direction of the anticipated Fed's policy change (encoded into the fed funds futures), as investors focus on monetary policy news, even if the news may have been available before. A price reaction to stale information is also found in equity markets. For instance, Tetlock (2011) show that stale firm-specific news predict future returns, indicating that investors trade based on media articles which contain old information.

Market commentaries admit the presence of increased investor attention to monetary policy expectations in the last days prior to the FOMC announcement. As an example, *Dow Jones Commodities Service* writes on 19 Sep 2005, a day before the Fed's decision to raise the target: *"In addition to the support the dollar was getting versus the euro, it has been broadly helped by the wide expectation that Fed policy makers will raise interest rates when they meet Tuesday."*

To sum up, I provide suggestive evidence that investor inattention earlier than two days prior to the FOMC announcement might drive the dollar predictability in the last days leading to the FOMC announcement. However, it remains unclear why bond markets do not exhibit similar pre-FOMC movements (see subsection 4.3).

A positive return on the two-day pre-FOMC dollar strategy might reflect higher risk aversion of currency investors earlier than in the last days prior to the FOMC announcement. Supposedly, most of currency traders pay attention to the most likely policy change as signaled by the fed fund futures well in advance of the FOMC announcement. These traders expect that the Fed's target rate increase will cause dollar appreciation.[17] However, they decide to wait until the last days prior to the FOMC announcement in order to avoid an exposure to the U.S. and foreign shocks which might affect the dollar but which are unrelated to the Fed's policy change. A higher uncertainty with respect to the Fed's decision coupled with potentially myopic preferences of currency investors might decentivize them to buy the dollar earlier than in the last days prior to the announcement. Higher risk aversion to buy the dollar earlier than in the last hours prior to the announcement is exemplified by the following quote by *Dow Jones Insitutional News* two hours prior to the Fed's announcement to raise the target on 16 December 2015: *"Market positioning for the dollar may have moved closer to neutral the past few weeks, but many short-euro wagers remained. Now some investors are shedding positions as FOMC-meeting risks have passed."*

[17] Such belief is in line with the standard exchange rate models and is consistent with an empirical evidence of the positive contemporaneous correlation between the dollar return and shock to the fed funds futures on impact: a higher than expected target rate change is associated with the dollar rise.

4. Extensions and Robustness

I provide various extensions and robustness checks of my main findings. I first show that the pre-FOMC announcement USD returns depend on the direction of monetary policy expectations signaled with short money market rates in 1983–1994 period. Then I show that the fed fund futures can predict single currency returns. I then illustrate that bond returns do not depend on the direction of monetary policy expectations in the two-day pre-FOMC announcement period. Finally, I show that currency returns are not predictable prior to the target rate changes by other Central Banks.

4.1 Pre-1994 Period

Have the dollar returns exhibited similar dynamics prior to the scheduled FOMC meetings before 1994? In short, yes it did.

Prior to 1994, market participants inferred FOMC actions based on the size and type of open-market operations, which were announced the day following the scheduled FOMC meeting. I collect historical scheduled FOMC meetings from the Fed's web-site[18] and match them with the target rate from the *FRED*. If I observe a target rate change on a day or during three days following the day with a scheduled meeting, I assume that the Fed has adopted a policy change on that meeting.

Between 1982 and 1993, the Fed announced only one-third (31) of target rate changes at the scheduled meetings, while two-third (64) of target rate changes were made during intermeeting periods, i.e. outside the pre-specified schedule of FOMC meetings. Among 31 policy changes at the scheduled meetings, there are 16 raises and 15 cuts. Among 64 intermeeting policy changes, there are 27 raises and 37 cuts. The pre-1994 period is interesting not only because I can check whether my results hold out-of-sample (even though under a different policy regime), but it also gives a chance to compare the dynamics of the dollar between the target rate changes at the scheduled and unscheduled FOMC meetings.

Figure 12 plots average daily cumulative dollar returns during 20 days before and 20 days after the target rate raises and cuts at the scheduled meetings (*Panel A* and *B*) and at the unscheduled meetings (*Panel C* and *D*).

The figure has four messages. First, prior to 1994 we observe the same phenomenon as for the recent sample: the dollar tends to go up during several days prior to the target rate raises (see *Panel A*) and to go down prior to the target rate cuts (see *Panel B*). The two-day

[18] https://www.federalreserve.gov/monetarypolicy/fomc_historical.htm

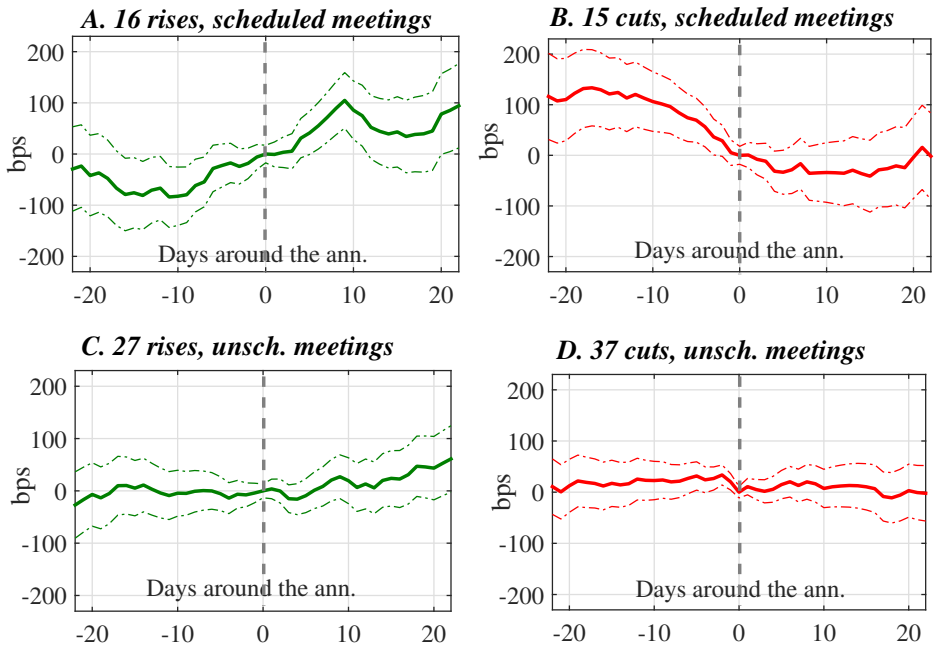

Figure 12: **Pre-1994: Dollar Cumulative Returns Around Target Rate Changes.** The dashed lines are 90% confidence bands around average cumulative returns. The sample covers 31 target changes at the scheduled meetings and 64 target rate changes at during intermeeting periods, September 1982–December 1993.

pre-FOMC dollar return is 24 bps (1.7 t-stat) prior to the raises and -37 bps (-2.8 t-stat) prior to the cuts. The difference between the two averages is statistically significant and the magnitudes are very similar to the ones observed in the last twenty two years. Second, the pre-FOMC drift in the dollar for the scheduled meetings is longer-lasting: on average the dollar goes up by 84 bps (2.7 t-stat) over two weeks prior to the target rate raises and by 114 bps (-7.1 t-stat) over two weeks prior to the target rate cuts. Third, the dollar does not revert after the scheduled announcements. The dollar keeps appreciating after the raises and depreciating after the cuts. Finally, the dollar is on average flat during around the unscheduled announcements to raise the target rate. The dollar goes down by 27 bps (-1.9 t-stat) during the two days prior to unscheduled announcements to cut the target rate.

How predictable are these movements in the dollar prior to 1994? Since the fed funds futures started being traded only from 1988, I use 1-month Libor spread over the target as a proxy for monetary policy expectations. I regress the two-day pre-FOMC return on the Libor spread recorded three days prior to the scheduled FOMC meetings. I run this regression for all 90 scheduled meetings from Sep 1982–Dec 1993. The slope coefficient is positive and statistically significant at 10% level (1.7 t-stat), the R^2 is 2.4%. The R^2 is three times smaller than in the predictive regression with the fed funds spread for all 176 scheduled meetings from 1994–2014

(see (1) in Table 3). The Libor spread has more power to predict the 10-day pre-FOMC return: a 2.2 t-stat and a 3.6% R^2.

Weaker dollar predictability in the pre-1994 period might be explained by poor predictability of the Fed's policy changes in this period. I regress the target rate changes at the scheduled meetings on the Libor spread recorded three days prior to the announcement and find a 18% R^2 (the slope coefficient has 2.6 t-stat). This R^2 is much lower than a 80% R^2 observed in the 1994–2014 period.

To sum up, we observe a similar phenomenon prior to the scheduled meetings from 1982–1993 as for the 1994–2015 period: the dollar appreciates during several days prior to a tightening policy move and depreciates during several days prior to an expansionary policy move. Money market rates spreads have lower predictability for the pre-FOMC dollar return, supposedly because the Fed's policy changes are less predictable in this period.

4.2 Predicting Single Currency Returns

Throughout the paper I focus on the predictability of the equal-weighted dollar returns. Now I assess the predictability of the excess returns of single exchange rates. Specifically, I run the following regressions of pre-FOMC dollar excess returns versus each G10 currency

$$rx^i_{t-2\to t} = \alpha + \beta E^{fff}_{t-3}\left[\Delta FFR_t\right] + \varepsilon_{t-2\to t} \tag{12}$$

$$rx^i_{t-2\to t} = \alpha + \beta E^{fff}_{t-3}\left[\Delta FFR_t\right] + \gamma\overline{(f^i_{t-3} - s^i_{t-3})} + \varepsilon_{t-2\to t} \tag{13}$$

Positive FX return stands for the dollar appreciation versus the foreign currency.

Table 5 reports the results from these predictive regressions. *Panel A* shows that a high fed funds futures spread significantly (at 5% confidence level) forecasts the dollar appreciation for four out of nine FX pairs. For three other FX pairs the t-stats indicate 10% significance, and only JPY has an insignificant coefficient. The R^2 vary from 7 to 20%, when excluding JPY.

Typical high interest rate currencies (AUD and NZD) have the largest loadings on the fed funds futures spread (1.2 and 1.48). This implies that these currencies tend to appreciate (depreciate) more than lower interest rate currencies prior to the *FFR* cuts (raises). The cross-sectional correlation between these slope coefficients and time-series averages of the respective currency interest rate differentials is 78%.

I do not have daily or intraday FX order flow data to determine whether investors indeed quit the dollar and buy higher interest rate currencies prior to the FOMC announcement. However, this evidence is consistent with the standard intuition that capital flows from lower-yielding to

	Panel A.			*Panel B.*				
	$E_{t-3}^{fff}[\Delta FFR_t]$	t-stat	R^2	$E_{t-3}^{fff}[\Delta FFR_t]$	t-stat	$\overline{(f_{t-3}^i - s_{t-3}^i)}$	t-stat	R^2
AUD	1.21	[1.75]	10.7	1.24	[1.82]	2.48	[0.53]	10.8
CAD	0.66	[1.69]	9.3	0.66	[1.74]	0.43	[0.10]	9.3
CHF	**0.79**	[2.08]	14.1	0.66	[1.62]	-10.81	[-1.41]	17.3
EUR	**0.94**	[2.30]	19.4	**0.85**	[2.00]	-7.06	[-0.93]	20.7
JPY	0.30	[0.94]	1.6	0.27	[0.84]	-1.71	[-0.25]	1.7
NOK	0.59	[1.89]	6.9	0.60	[1.76]	0.70	[0.09]	6.9
NZD	**1.48**	[2.21]	17.8	**1.46**	[2.20]	-1.57	[-0.23]	17.8
SEK	0.64	[1.76]	7.1	0.60	[1.67]	-2.62	[-0.46]	7.2
GBP	**1.01**	[2.06]	15.9	**1.00**	[2.01]	-1.11	[-0.19]	16.0

Table 5: **Predicting Individual Currency Dollar Returns with the Fed Funds Futures Spread and Currency Forward Discounts.** *Panel A.* $rx_{t-2\to t}^i = \alpha + \beta E_{t-3}^{fff}[\Delta FFR_t] + \varepsilon_{t-2\to t}$. *Panel B.* $rx_{t-2\to t}^i = \alpha + \beta E_{t-3}^{fff}[\Delta FFR_t] + \gamma\overline{(f_{t-3}^i - s_{t-3}^i)} + \varepsilon_{t-2\to t}$. I run the regressions prior to the FOMC announcements, for which the futures spread *ex ante* signal a policy change (i.e. when $\mid E_{t-3}^{fff}[\Delta FFR_t] \mid > 12.5$ bps). The returns are versus USD. Positive return corresponds to the USD appreciation versus the foreign currency. t-statistics are shown in brackets. Bold numbers are statistically significant at 5% level. The R^2 are in percent.

higher-yielding currencies, exemplified by the following quote from the *The Wall Street Journal* on 26 June 2003, the day after a 25 bps target rate cut: *"Prior to the Federal Open Market Committee's announcement of a reduction of 0.25 percentage point in the federal-funds target rate, the dollar had slipped sharply on a flurry of last-minute positioning that sent a slew of currencies to highs for the day against the dollar. Some investors had shifted to higher-yielding currencies such as sterling and the Canadian, Australian and New Zealand dollars to guard against a more aggressive 0.50-percentage-point cut that would have further widened interest-rate differentials and made dollar-denominated assets even less attractive."*

Panel B of Table 5 adds average forward discount to the regression. Neither of the slope coefficients are positive and the increases in R^2 as compared with *Panel A* are small.

I also run regressions (12) for the set of 38 currencies, using a sample of daily exchange rates from Lustig, Roussanov, and Verdelhan, 2014. The cross-sectional correlation between the fed funds futures slope coefficient and average forward discount is 27%, significant at 10% level. Figure 13 illustrates this cross-sectional relationship.[19] To sum up, in the two-day pre-FOMC period high interest rate currencies depreciate more than low interest rate currencies, when the fed funds futures spread is high.

[19]The fed funds futures spread does not have the predictive power for the *HML* factor (difference between the currency returns of high and low interest rate currencies) from Lustig, Roussanov, and Verdelhan (2011).

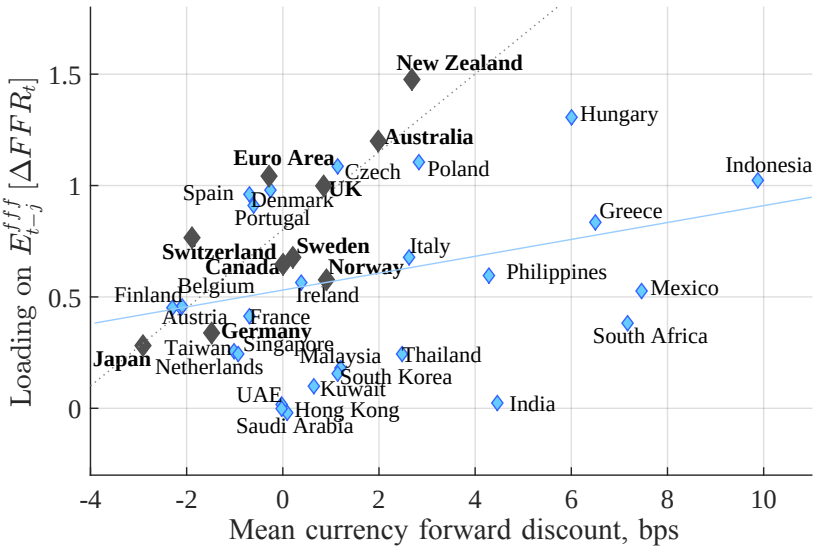

Figure 13: **Mean currency forward discount versus the loading on the fed funds futures spread.** This figure plots the times series means of the currency forward discounts versus the loadings of the respective pre-FOMC dollar return on the fed funds futures spread from regression (12). A solid line shows a linear cross-sectoonal fit for 38 currencies, a dashed line shows a linear cross-sectional fit for G10 currencies.

4.3 Pre-FOMC Fixed Income Returns

Do fed funds futures spreads predict their own return or the changes in other interest rates in the pre-FOMC window? If so, this would suggest a presence of the risk premia. I run the regressions $ret_{t-3\to t-1} = \alpha + \beta E^{fff}_{t-3}[\Delta FFR_t] + \varepsilon_{t-3\to t-1}$, where $ret_{t-3\to t-1}$ is the return on the fed funds futures contracts, T-bills and Treasury bonds. I use *CRSP* to extract the price data on the on-the-run 3-month and 6-month T-bills prior to the announcement.[20]. As for the bonds, I use the continuous series of one year through ten year yields from the *FRED* and transform them to the returns. I do not have high-frequency data on these yields, so I use their returns from three days prior to the FOMC announcement to 1 day prior to the announcement, both of which are captured at 16:00 EST. Table 6 shows that neither of these fixed income pre-FOMC returns is predicted by the futures spread. The only exception is a 1-year bond with a -0.05 coefficient significant at 10% level.[21]

Fixed income instruments are the most sensitive assets to the monetary policy news. The evidence that the fed funds futures do not predict their own returns and returns of other fixed

[20]This avoids technical rises in the yield due to rolling maturity, if I were to use the interpolated continuous series.

[21]Currency forward spreads also do not predict the fixed income pre-FOMC returns (unreported).

		$E_{t-3}^{fff}[\Delta FFR_t]$	t-stat	R^2
1	Next-month fff	0.03	[0.95]	4.6
2	3M fff	0.42	[0.10]	0.0
3	3m T-bill	-0.20	[-0.23]	0.1
4	6m T-bill	-0.48	[-0.40]	0.4
5	1Y bond	-0.05	[-1.91]	9.4
6	2Y bond	-0.03	[-0.43]	0.5
7	3Y bond	-0.02	[-0.20]	0.1
8	5Y bond	0.06	[0.32]	0.2
9	10Y bond	0.76	[1.34]	3.1

Table 6: **Predicting pre-FOMC Fixed Income Returns with the Fed Fund Futures Spread.** The table shows results from running $ret_{t-3\to t-1} = \alpha + \beta E_{t-3}^{fff}[\Delta FFR_t] + \varepsilon_{t-3\to t-1}$, where $ret_{t-3\to t-1}$ stands for a return of each fixed income instrument from three days prior to the announcement to one day prior to the announcement. t-statistics are shown in brackets. Bold numbers are statistically significant at 5% level. The R^2 are in percent.

income instruments is suggestive that there is no monetary policy risk premia in these assets in the two-day pre FOMC period. It is hard to reconcile this evidence with a potential presence of risk premia in the FX market.

Finally, I find that the correlation between the contemporaneous change in the fed funds futures, $E_{t-3\to t-1}^{fff}[\Delta FFR_t]$ and the pre-FOMC dollar return (across the announcements for which the futures encode the target rate change) is 18% and is statistically significant. While indicating that a positive dollar return is associated with market participants becoming more hawkish prior to the announcement, it is not clear why rises in the futures spreads earlier than three days prior to the FOMC are not associated with the dollar appreciation (recall *Panel A* of Figure 8). Also, the level of the fed fund futures spread, $E_{t-3}^{fff}[\Delta FFR_t]$, drives out $E_{t-3\to t-1}^{fff}[\Delta FFR_t]$ in the regression of the pre-FOMC dollar return.

4.4 Recent Change in the Fed Funds Futures

I investigate whether a recent change in monetary policy expectations, $E_{t-k\to t-3}^{fff}[\Delta FFR_t]$ (I run k from 10 to 4), can help to predict the pre-FOMC dollar return. It might be that the dollar pre-FOMC return is a reflection of a recent *change* in the expectations, rather than a reaction to the *level* of expectations formed by market participants prior to the announcement. I find that $E_{t-k\to t-3}^{fff}[\Delta FFR_t]$ alone explain up to 10% of variation in the pre-FOMC dollar returns for some k, but only marginally contribute to the R^2 as soon as I include $E_{t-3}^{fff}[\Delta FFR_t]$. The maximum improvement in the R^2 from my baseline 22% result comes from adding the most

recent change in the expectations, $E^{fff}_{t-4\to t-3}[\Delta FFR_t]$. It enters the regression with a 1.7 t-stat and increases the R^2 to 24%.

4.5 Longer-term Monetary Policy Expectations

I test whether long-term market expectations of future Fed policy, measured with the level and slope of Treasury yields can predict the pre-FOMC dollar return. I extract the first two principal components from the cross-section of daily one through ten year Treasury yields from the *FRED* to construct the level and slope factors. I find that none of these two factors has predictive power for the pre-FOMC dollar return.

4.6 Unscheduled Meetings

What happened with the dollar prior to the unscheduled FOMC meetings? Only seven target rate changes took place at the unscheduled FOMC meetings: one raise in 1994, one cut in 1998, three cuts in 2001, and two cuts in 2008. The dollar depreciated during the two days prior to an unscheduled raise. The dollar also depreciated prior to five out of six unscheduled cuts. The number of these events is too small to draw any conclusions.

4.7 Monetary Policy Expectations in Other Countries

It might be that monetary policy expectations in other countries or their difference with the U.S. monetary policy expectations matter for the dollar returns prior to the FOMC announcement. For instance, if the Fed is adopting monetary policy tightening, the pre-FOMC dollar return might depend on whether other Central Banks are also planning to raise the policy rates in the nearest future and how hawkish are other Central Banks as compared to the Fed.

Since not all G10 countries have the futures markets for their target rates, I collect their 1-month LIBOR interest rates and target rates (TR) from Bloomberg.[22] I proxy the foreign monetary policy expectations with the average money market spreads, $\overline{E^{Libor}_{t-3}\left[\Delta TR^i_t\right]}$, i.e. the average difference between the LIBOR and target rate across the G10 currencies. I exclude fall 2008 due to the presence of huge credit risk premium in the money market rates.

I run predictive regressions of the dollar pre-FOMC returns with $\overline{E^{Libor}_{t-3}\left[\Delta TR^i_t\right]}$ and the difference between $\overline{E^{Libor}_{t-3}\left[\Delta TR^i_t\right]}$ and $E^{fff}_{t-3}[\Delta FFR_t]$ and find that neither foreign monetary

[22] In the case of the U.S., 1-month LIBOR interest rate spreads predict the target change almost as well as the fed funds futures spread for the period prior to the financial crisis, when money market yields had a large credit risk component.

policy expectations, nor their difference with the U.S. monetary policy expectations *does not* help to forecast the pre-FOMC dollar returns. The result for average monetary policy expectations across EUR, GBP, CHF, and JPY is similar.

4.8 Target Rate Changes by other Central Banks

I investigate whether currency returns of other countries can be predicted prior to the target rate changes made by their Central Banks. I collect the exact dates of policy actions for G10 countries from *Bloomberg*. For each country, I use the spread of 1-month rate over the target rate, $E_{t-3}^{Libor}[\Delta TR_t]$, to measure the policy expectations three days prior to the announcements of their Central Banks. Then I run predictive regressions of the two-day currency pre-announcement returns on $E_{t-3}^{Libor}[\Delta TR_t]$. I find close to zero R^2 and insignificant t-stats, suggesting that other contries' monetary policy expectations (encoded into the Libor rates) do not predict their home currency returns prior to the target rate changes.

5. Conclusion

Understanding how different asset markets incorporate information is a key question in finance. I find that the fed funds futures market leads the foreign exchange market in reflecting the information about monetary policy change. A high fed funds futures spread several days in advance of a scheduled FOMC meeting not only predicts the target rise, but also predicts the rise in the dollar that will take place in the subsequent days up until the announcement. A simple trading strategy that exploits this predictability exhibits a 0.93 annualized Sharpe ratio, which reduces 0.57 after accounting for transaction costs. The pre-FOMC announcement dollar returns account for a sizeable share in the total variation of the dollar over 1994–2015. Excluding the two-day periods prior to the target rate raises (cuts) from my sample suggests that the dollar would have been 6% weaker (10% stronger). Notably, these two-day pre-FOMC periods cover less than 2% of the total number of days in my sample.

I find that the pre-FOMC dollar returns depend on the direction of monetary policy expectations both in the post-1994 sample (when the Fed has explicitly announced the target rate change at a scheduled meeting) and in the 1983–1993 sample (when investors learned about the Fed's policy action indirectly through open market operations). I cannot reconcile my findings with the standard asset pricing and economic theories. A key challenge is to explain the fact that the speed at which currency prices respond to monetary policy expectations is not aligned across the bond and exchange rate markets: bond markets incorporate information faster then the exchange rate markets do. This finding is surprising given how liquid exchange rate mar-

kets are. Thus, my results suggest a failure of the efficient-markets hypothesis due to investor inattention, slow-moving capital and/or a form of market segmentation.

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Appendix

	Federal funds futures [1]–[3]			Money market rates [4]–[7]				Treasury yields [8]–[13]						Eff rate	Com paper
	NextM	3M	6M	1W	1M	3M	6M	3M	6M	1Y	2Y	5Y	10Y	ON	1M
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]
Panel A. $Direction_{\Delta i_t} = \alpha + \beta \bar{y}_{t-3} + \varepsilon_t$, *1994–2015 (N=176)*															
b	**2.2**	**1.6**	**1.0**	**1.9**	0.5	0.4	0.3	**1.3**	**1.2**	**0.8**	**0.5**	**0.2**	**0.1**	**1.8**	**1.0**
t	[11.6]	[11.3]	[9.6]	[4.3]	[1.3]	[1.3]	[1.7]	[9.9]	[11.1]	[9.3]	[8.0]	[3.8]	[2.0]	[4.8]	[2.1]
R^2,%	74	73	66	31	7	7	11	58	64	49	34	10	3	14	18
Panel B. $\Delta i_t = \alpha + \beta \bar{y}_{t-3} + \varepsilon_t$, *1994–2015, N=176*															
b	**0.9**	**0.6**	**0.4**	**0.8**	0.2	0.1	0.1	**0.5**	**0.5**	**0.3**	**0.2**	**0.1**	**0.0**	**0.8**	**0.4**
t	[24.3]	[16.4]	[11.8]	[4.9]	[1.0]	[0.9]	[1.2]	[10.4]	[14.4]	[11.5]	[8.1]	[4.1]	[2.4]	[6.0]	[2.1]
R^2,%	88	82	69	37	6	5	8	66	70	55	39	13	4	21	24
Panel C. $Direction_{\Delta i_t} = \alpha + \beta \bar{y}_{t-3} + \varepsilon_t$, *1994–2007, N=122*															
b	**2.4**	**1.7**	**0.9**	**3.2**	**1.6**	**1.6**	**1.3**	**1.6**	**1.2**	**0.8**	**0.5**	**0.2**	**0.1**	**2.5**	**1.9**
t	[10.1]	[9.9]	[8.7]	[11.6]	[3.8]	[8.2]	[8.8]	[11.1]	[9.7]	[7.9]	[7.0]	[3.9]	[2.6]	[3.4]	[5.6]
R^2,%	75	73	65	57	36	52	60	62	65	49	34	13	6	14	38
Panel D. $\Delta i_t = \alpha + \beta \bar{y}_{t-3} + \varepsilon_t$, *1994–2007, N=122*															
b	**0.9**	**0.6**	**0.3**	**1.1**	**0.6**	**0.6**	**0.5**	**0.5**	**0.4**	**0.3**	**0.2**	**0.1**	**0.0**	**0.8**	**0.8**
t	[23.8]	[16.9]	[12.3]	[12.9]	[4.1]	[9.9]	[14.2]	[9.2]	[13.4]	[11.2]	[7.9]	[4.1]	[2.7]	[3.0]	[6.0]
R^2,%	87	81	71	59	43	61	68	65	71	57	40	16	8	12	48

Table 7: **Predicting the direction and size of the target rate change.** The dependent variable in *Panel A* and *C* is the direction of target change, $\{1, -1, 0\}$ for up/down/neutral decision. The dependent variable in *Panel B* and *D* is the target rate change itself. The independent variables are the spreads of various money market expectations measures (federal funds futures rate, money market rates, treasury yields, effective rate, and commercial paper rate) over the target three days ahead of the scheduled FOMC meeting. *Panel A* and *B* run the regressions for the full sample, 1994–2015, 176 scheduled announcements. *Panel C* and *D* run the regressions for 1994–2007, 122 scheduled announcements. Full sample is 176 scheduled meetings, January 1994 – December 2015. *t*-statistics are in brackets. They are based on the standard errors, robust to conditional heteroscedasticity and serial correlation up to one lag as in Newey and West (1987). Bold numbers are statistically significant at the 5% level.

		Panel A			*Panel B*						
	right-hand var.	β		R^2	β		γ		δ		R^2
(1)	FX realized vol	**-11.83**	[-2.20]	4.9	**0.42**	[2.07]	-7.44	[-1.55]	0.12	[0.96]	15.1
(2)	FX implied vol	-7.52	[-0.88]	2.0	**0.42**	[2.05]	-0.59	[-0.08]	**0.33**	[2.06]	17.0
(3)	Treasuries implied vol	-10.32	[-1.32]	3.7	**0.52**	[2.34]	-2.12	[-0.21]	-0.07	[-0.31]	13.0
(4)	Stock implied vol	-6.79	[-0.84]	1.6	**0.59**	[2.40]	9.36	[0.91]	0.23	[1.14]	16.3
(5)	FX illiquidity	3.61	[0.48]	0.5	**0.50**	[2.76]	-0.47	[-0.07]	0.14	[0.77]	13.5
(6)	$E_{t-3}^{fff}\ [\Delta FFR_t]$	**0.52**	[2.69]	12.7							

Table 8: **Pre-FOMC Dollar Return and Levels of Volatility and Illiquidity.**
Panel A: $DOLr_{t-2\to t} = \alpha + \beta F_{t-3} + \varepsilon_{t-2\to t}$. *Panel B*: $DOLr_{t-2\to t} = \alpha + \beta E_{t-3}^{fff}\ [\Delta FFR_t] + \gamma F_{t-3} + \delta E_{t-3}^{fff}\ [\Delta FFR_t] \times F_{t-3} + \varepsilon_{t-2\to t}$. All right-hand side variables except for the fed funds futures spread, $E_{t-3}^{fff}\ [\Delta FFR_t]$, are standardized to have zero mean and unit standard deviation. Bold numbers are statistically significant at 5% level. The R^2 are in percent. The sample consists of FOMC announcements, when the target change is *ex ante* encode with the federal funds futures (i.e. when $\mid E_{t-3}^{fff}\ [\Delta FFR_t] \mid \geq$ 12.5 bps) and excludes two outlier target cuts in fall 2008 (29 Oct 2008 and 16 Dec 2008). Number of such announcements is 55.

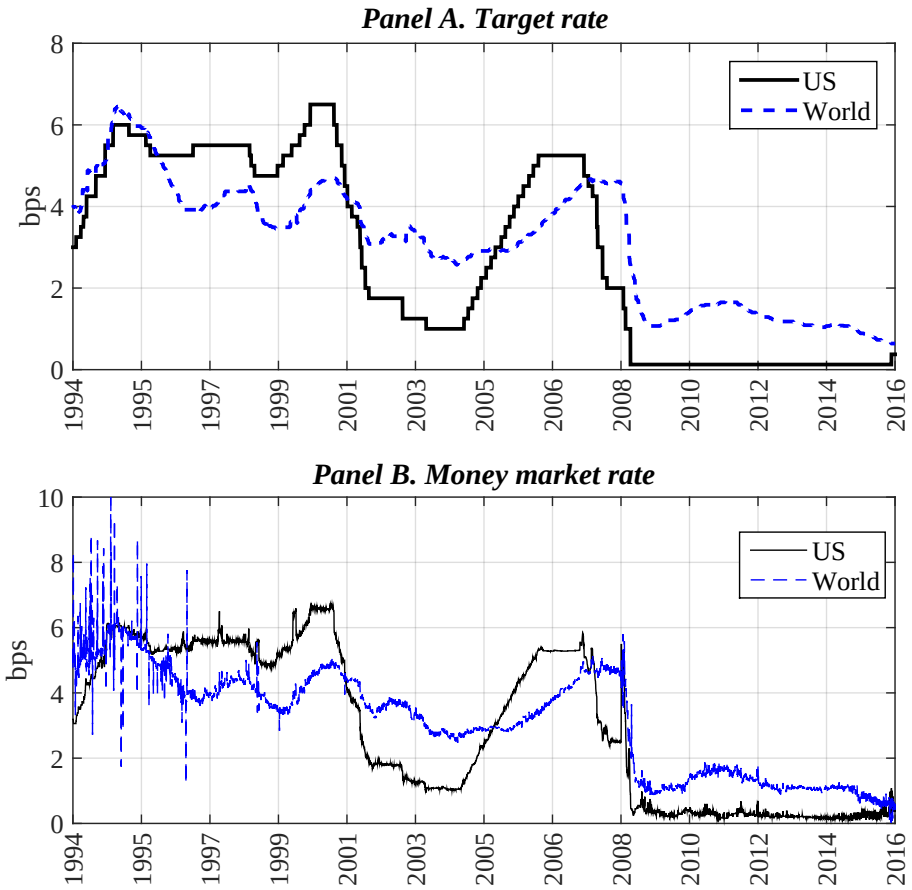

Figure 14: **Interest Rates in the US and in G10 countries.** The world interest rate is the average across the G10 countries interest rates (excluding the U.S.).