Exchange Rates and Monetary Policy Uncertainty*

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Abstract

We document that a trading strategy that is short the U.S. dollar and long other currencies exhibits significantly larger excess returns on days with scheduled Federal Open Market Committee (FOMC) announcements. We also show that these excess returns (i) are higher for currencies with higher interest rate differentials vis-à-vis the U.S.; (ii) increase with uncertainty about monetary policy; and (iii) intensify when the Federal Reserve adopts a policy of monetary easing. We interpret these excess returns as a compensation for monetary policy uncertainty within a parsimonious model of constrained financiers who intermediate global demand for currencies.

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1 Introduction

Announcements by the Federal Open Market Committee (FOMC) are among the most highly anticipated events by investors around the world. These announcements, which occur regularly at pre-specified dates, serve as the Federal Reserve's main channel for communicating its monetary policy decisions to the market. Given the close link between currency markets and monetary policy, it is only natural to expect that FOMC announcements can have large impacts on exchange rates. The active nature of the currency markets (with a daily turnover of over 5 trillion U.S. dollars), coupled with high market concentration and the participants' ability to operate with high leverage ratios means that even small price movements in this market can potentially translate into economically significant effects.

In this paper, we document that announcements by the FOMC have an economically and statistically significant impact on the excess returns of a host of different currencies vis-à-vis the U.S. dollar. By relying on high-frequency data, we document that a trading strategy that is short the U.S. dollar and long other currencies exhibits significantly larger average excess returns on days with scheduled FOMC announcements compared to all other days. We also document that the excess returns earned on announcement days (i) consist of a pre- as well as a post-announcement component; (ii) are higher for currencies with higher interest rate differentials vis-à-vis the U.S.; (iii) increase with market participants' uncertainty about monetary policy; and (iv) intensify when the Federal Reserve adopts a policy of monetary easing.

We interpret these findings through the lens of a parsimonious model of exchange rate determination in the spirit of Gabaix and Maggiori (2015), in which constrained financiers with short investment horizons intermediate global demand for currencies. These financiers can actively engage in currency trades, but have a downward-sloping demand for risk-taking, which limits their risk-bearing capacity. Such a limit can arise for a variety of reasons, such as value-at-risk constraints or agency problems. Crucially, in addition to the "fundamental risk" in global demand for and supply of currencies, financiers in our model also face "monetary policy uncertainty" due to potential future changes in interest rates.

Using this framework, we show that an increase in uncertainty regarding future interest rates in the U.S. results in higher excess returns for other currencies: the financiers are willing to engage in currency trade and bear this extra risk only if they are compensated accordingly with higher returns. As such, all else equal, an increase in monetary policy uncertainty due to an upcoming FOMC announcement results in the depreciation of foreign currencies against the U.S. dollar, coupled with an expected appreciation in the future. We also establish that the increase in excess returns in response to monetary policy uncertainty is higher for currencies with larger interest rate differentials vis-à-vis the U.S. This is due to the fact that even though an increase in the interest rate differential induces an exchange rate adjustment, financiers' risk-bearing constraints all but ensure that this adjustment does not offset the increase in the interest rate differential one-for-one, thus resulting in higher excess returns.

The fact that higher currency excess returns are meant to compensate financiers for the uncertainty in monetary policy means that such returns are materialized irrespective of the interest rates set by the Fed upon the announcement. We thus interpret the impact of monetary policy uncertainty on currency excess returns as a "pre-announcement" effect. However, the actual realization of the monetary policy shock also impacts the foreign currencies' excess returns by affecting the financiers' balance sheets, leading to what we call a "post-announcement" effect. Indeed, we show that our model predicts that an ex post adoption of an expansionary monetary policy (corresponding to an interest rate reduction by the Fed) further increases foreign currencies' excess returns.

We empirically study currency risk premia around announcement days by relying on 20 years of high-frequency data from 1994 to 2013 for the ten most traded currencies. We find that, in line with our theoretical model, a simple trading strategy that is short the U.S. dollar and long the other currencies yields significantly higher returns on announcement days compared to non-announcement days. We also document that returns earned on the eight announcement days account for a significant fraction of the currencies' yearly excess returns. Notably, the large increase in average excess returns on announcement days is not accompanied by an equally large increase in realized risk, resulting in significantly higher Sharpe ratios on announcement days.

Since investors do not typically trade only in individual currencies but rather go long and short a portfolio of currencies simultaneously, we also test our model's predictions for currency portfolios sorted based on interest rate differential vis-à-vis the U.S. Our empirical results indicate that excess returns earned on announcement days are larger for currency portfolios with higher interest rates, an observation consistent with our model. In particular, we find that a portfolio consisting of currencies with low interest rates earns an average daily return of 5.19 basis points (bps) during days when the Federal Reserve makes an announcement, compared to an average of -0.51bps on all other days. This difference becomes larger (and highly statistically significant) for the portfolio consisting of high interest rate currencies, with a daily return of 14.47bps on announcement days compared to 1.73bps on non-announcement days.

Our explanation for the large returns earned on announcement days is that they reflect a premium for heightened uncertainty about monetary policy. Using different proxies for monetary policy uncertainty (such as an implied volatility index calculated from Treasury futures options and an uncertainty measure constructed from survey forecasts about the future federal funds rate), we find that an increase in market participants' uncertainty is indeed associated with higher returns on FOMC announcement days.

We then study the intra-day pattern of returns in further detail by decomposing currency returns into their pre- and post-announcement components. To this end, we split the day into two non-overlapping time windows that fall before and after the exact time of the announcement. We find that returns earned over both windows are larger on announcement days compared to the corresponding windows on non-announcement days. We also test our model's prediction regarding the relationship between the returns earned during the post-announcement window and the stance of monetary policy by stratifying our sample into easing and tightening periods depending on the policy adopted by the Fed. Using a monetary policy indicator constructed from high-frequency data on various interest rate futures, we find that, in line with our model's prediction, post-announcement returns are higher when the Federal Reserve adopts an expansionary policy.

The observation that the stance of monetary policy and the interest rate differentials are tightly linked to currency excess returns means that trading strategies that take these factors into account should exhibit higher returns compared to the simpler strategies that do not. We leverage these observations to construct trading strategies that improve upon the simple strategy that always shorts the U.S. dollar along two dimensions. First, using the observation that post-announcement returns are lower after the adoption of a contractionary monetary policy, we reverse the simple strategy's position right after the announcement in response to a tightening, while leaving the position unchanged in response to an easing. Second, given that currency excess returns increase with the interest rate differential, we restrict this trading strategy to currencies that exhibit a positive interest rate differential vis-à-vis the U.S. These adjustments indeed result in more economically and statistically significant returns on announcement days, increasing the simple trading strategy's announcement day returns from 10.77 to 20.54bps (with a t-statistic of 4.17), coupled with an equally significant increase in the Sharpe ratio from 0.51 to 0.93.

We then test whether announcements by the Federal Reserve exert a unique impact on exchange rates, or whether similar patterns can be observed for other central bank announcements. For instance, anecdotal evidence suggests that one of the largest one-day depreciations of the Japanese yen in recent years coincides with the Bank of Japan's announcement of an expansion of its asset-purchase program (Ramage and Albanese, 2015). To test this hypothesis, we collect the exact timing of monetary policy announcements for the different countries in our sample and perform an empirical exercise similar to the one outlined above by measuring the excess returns of interest rate-sorted portfolios vis-à-vis the corresponding currencies. Using data between 1998 and 2013, we find that announcements by the Bank of Japan lead to a pattern that is virtually identical to that of FOMC announcements. We find no significant effects for the rest of the central banks in our sample.

We conclude the paper by running a series of robustness checks. First, we repeat the analysis for truncated data to ensure that our results are not driven by outliers in the sample. Second, to overcome concerns regarding the sample size, we compute small-sample standard errors through a bootstrap exercise. In another bootstrap exercise, we sample randomly from the distribution of non-announcement returns to test whether we can generate returns similar in size to those observed on announcement dates. These exercises all indicate the robustness of our main empirical findings. We also show that announcement day returns remain significant and highly profitable (with annualized Sharpe ratios of up to 0.8) even when transaction costs are taken into account by adjusting for bid-ask spreads. Finally, we document the unique role of monetary policy announcements on currency returns by showing that the significant difference between announcement and non-announcement day returns observed for FOMC announcements is not shared by other macroeconomic announcements.

Related Literature: Our paper belongs to the growing literature that documents sizable responses of various asset classes to macroeconomic announcements. For instance, Hördahl, Remolona, and Valente (2015) study high-frequency movements in bond yields around macroeconomic announcements and document strong movements not only in yields but also in bond risk premia. Similarly, Jones, Lamont, and Lumsdaine (1998) study realized bond excess returns around macroeconomic news releases about inflation and the labor market; Savor and Wilson (2013) focus on (unconditional) excess equity returns in response to inflation, labor market, and FOMC releases; Beber and Brandt (2006) use Treasury futures options to assess how the state price density changes around macroeconomic announcements; and Savor and Wilson (2014) document that systematic market risk prices risky assets (including foreign exchange portfolios) well on announcement days. Most recently, Lucca and Moench (2015) study S&P500 index returns ahead of scheduled FOMC announcements and find that announcement day returns are due to a pre-announcement drift rather than returns earned at the announcement.[1]

Even though closely related, our paper departs from this literature along several important dimensions. First, in contrast to Lucca and Moench (2015) who find that returns in the equity market are earned entirely in the 24-hour window before the announcement, we document that currency excess returns span the entire announcement day and consist of a pre- as well as a post-announcement component. Second, we find that the post-announcement returns are tightly linked to the content of the announcement, with an expansionary (contractionary) policy associated with higher (lower) returns. Finally, we provide a theoretical framework that interprets the documented pre- and post-announcement excess returns as, respectively, a compensation for intermediaries' exposure to monetary policy uncertainty prior to the announcement and the ex post impact of the monetary policy shock on their balance sheets.

Our paper is also related to the theoretical asset pricing literature that studies the interplay of market frictions and exchange rates. For example, in the context of a model of the international banking system, Bruno and Shin (2015) show that local currency appreciation results in lower credit risk and, hence, expanded bank lending capacity. Our theoretical framework is most closely related to the recent work of Gabaix and Maggiori (2015) who present a model of exchange rate determination based on capital flows in imperfect financial markets. They show that, in the presence of intermediation frictions, shocks to financiers' risk-bearing capacity affect the level and volatility of exchange rates. Given our different focus, we depart from the framework of Gabaix and Maggiori (2015) by studying a model in which financiers may be uncertain about the future path of monetary policy and show that such uncertainty plays a first-order role in determining currency excess returns on central bank announcement days.

Finally, our paper contributes to the literature linking exchange rates to monetary policy. For example, Eichenbaum and Evans (1995), Faust and Rogers (2003), Scholl and Uhlig (2008), Rogers, Scotti, and Wright (2016), and Stavrakeva and Tang (2015) among others, study the effect of monetary policy shocks extracted from high-frequency data on exchange rates in a vector autoregression framework. Different from these papers, we are mainly interested in the intra-daily return patterns

[1] In parallel, a large empirical literature, going back to Fleming and Remolona (1999) and Andersen, Bollerslev, Diebold, and Vega (2003), studies the impact of monetary policy announcements on second moments in foreign exchange markets. The main finding of this literature is that policy surprises increase realized exchange rate volatility. See Neely (2011) for a survey of this literature.

on announcement and non-announcement days, with a focus on documenting the role of monetary policy in shaping these patterns.

Outline: The rest of the paper is organized as follows. In the next section, we formulate a model of exchange rate determination around central bank announcement days. Section 3 describes the data on which we base our analysis. Our main empirical findings are presented in Section 4. Section 5 concludes. All proofs and derivations are presented in the Appendix. An Online Appendix provides additional empirical results and robustness checks.

2 Theoretical Framework

In this section, we present a parsimonious model of exchange rate determination in the spirit of Gabaix and Maggiori (2015), which forms the basis of our analysis. As the main ingredient of our model, we assume that market participants are uncertain about the future stance of monetary policy prior to central bank announcements.

2.1 Model

Consider a discrete-time economy that lasts for three periods, $t = 0, 1, 2$. The economy consists of two countries, each populated by a unit mass of investors and with its own currency. For expositional simplicity, we refer to one of the countries as the United States and to its currency as the dollar.

Investors in each country can trade a one-period, nominal risk-free bond that is denominated in their respective domestic currency. We use R_t and R_t^* to denote the interest rates in the United States and the foreign country between periods t and $t+1$, respectively. We assume that the interest rate in the U.S. is smaller than that of the foreign country in all periods. The exchange rate e_t is defined as the quantity of dollars that can be bought by one unit of the foreign currency at time t.

At any given period, investors in each country have a downward-sloping demand for assets denominated in the other country's currency. Such demand may arise due to various reasons, such as trade or portfolio flows. We assume that U.S. investors have a time t demand of f_t/e_t for assets denominated in the foreign currency, which they fund by an offsetting position $-f_t$ in dollars. We assume that f_t is drawn independently over time from a common continuous distribution function $G(\cdot)$ with bounded support $[\underline{f}, \bar{f}]$, where $\underline{f} > 0$. Similarly, foreign investors have a time t demand of $d_t e_t$ for dollar-denominated assets, funded by the offsetting position $-d_t$ in their currency, where we assume that $d_t = d > 0$ is constant over time.

In addition to the investors, the economy is populated by a unit mass of identical, risk-neutral financiers, who can trade in the domestic bonds of *both* countries. As such, the financiers' main role is to act as intermediaries between investors in the two countries by taking the other side of their currency demands, at a profit. The representative financier enters the market with no capital of her own and takes a time $t \in \{0, 1\}$ position of $-Q_t$ in dollars, funded by Q_t/e_t units of the foreign currency.

The representative financier unwinds this position at the end of period $t+1$. Consequently, her profit (expressed in dollars) at the end of the period is given by

$$V_{t+1} = \left(\frac{e_{t+1}}{e_t} R_t^* - R_t \right) Q_t, \tag{1}$$

where recall that R_t and R_t^* denote the interest rates in the U.S. and the foreign country, respectively.

As our main point of departure from the framework of Gabaix and Maggiori (2015), we assume that in addition to the "fundamental risk" in demand and supply of currencies — captured in our model by the uncertainty in the realization of f_t's — the financiers also face "monetary policy uncertainty" due to potential future changes in interest rates. We model the presence of this latter kind of uncertainty by assuming that, when taking their positions at $t = 0$, the financiers are uncertain about the interest rate in the U.S. between $t = 1$ and $t = 2$. More specifically, we assume that $\log(R_1)$ is a random variable drawn at $t = 1$ independently from (f_0, f_1, f_2) with mean $\mathbb{E}_0[\log(R_1)] = \log(R_0)$ and standard deviation σ_R.[2] Thus, σ_R serves as a natural proxy for the extent of U.S. monetary policy uncertainty. In particular, $\sigma_R > 0$ naturally corresponds to an FOMC announcement day, on which market participants are uncertain about the future stance of monetary policy. On the other hand, $\sigma_R = 0$ corresponds to a "normal" day with no scheduled monetary policy announcements. On such days, market participants are certain that the interest rate will remain unchanged throughout the day, in which case $R_1 = R_0$ with probability one. To simplify the derivations, we assume that the interest rate in the foreign country is deterministic and constant, that is, $R_0^* = R_1^* = R^*$. Finally, throughout the paper, we assume that the interest rate differential between the two currencies is large enough at all times, and in particular $R^* \underline{f} > R_t \overline{f}$ for $t \in \{0, 1\}$. This assumption serves as a simple sufficient condition for the financiers to short the dollar in equilibrium, that is, $Q_t \geq 0$.

An immediate implication of equation (1) is that whenever the uncovered interest rate parity (UIP) condition is not satisfied (i.e., when $\mathbb{E}_t[R_t^* e_{t+1}/e_t - R_t] \neq 0$), the representative financier wants to take infinitely large positions unless some friction limits her ability to do so. We model the presence of such intermediation frictions by assuming that the representative financier is subject to a value-at-risk constraint, whereby the likelihood that she makes negative profits cannot exceed some small $\alpha_t < 1$.[3,4] The representative financier thus faces the following problem at time $t \in \{0, 1\}$:

$$\begin{aligned} \max_{Q_t} \quad & \mathbb{E}_t[V_{t+1}] \\ \text{s.t.} \quad & \mathbb{P}_t(V_{t+1} \leq -\epsilon) \leq \alpha_t, \end{aligned} \tag{2}$$

where ϵ is some positive number arbitrarily close to zero.[5]

[2] The assumption that R_1 and f_t are drawn independently is made in the interest of tractability. Assessing the actual extent of comovements between these variables requires additional empirical work that is beyond the scope of this paper.

[3] Formally, in proving our main results, we consider the case in which $\alpha_t \to 0$.

[4] Adrian and Shin (2014) show that value-at-risk constraints similar to the one in our model can emerge as a result of a standard contracting framework with risk-shifting moral hazard.

[5] The assumption that ϵ is arbitrarily close (but not exactly equal) to zero is made for technical reasons and has no bearing on our results. In fact, we present our main results assuming that $\epsilon \to 0$.

The presence of the value-at-risk constraint effectively limits the "risk-bearing capacity" of the financiers. When α_t is close to 1, the representative financier is essentially unconstrained and can take arbitrarily large currency positions. However, if α_t is small, the constraint in (2) is tightened whenever the financier faces higher risk (for example, due to an increase in the anticipated volatility of future exchange rates or interest rates). In this sense, the value-at-risk constraint induces a downward-sloping demand curve for risk-taking by the financiers.[6]

The competitive equilibrium of the economy described above is defined in a straightforward manner. It consists of the tuple $(e_0, e_1, e_2, Q_0, Q_1)$ of exchange rates and currency positions such that (i) the representative financier chooses Q_t in order to maximize her expected profit, taking the exchange rates as given; and (ii) the net demand for dollars is equal to zero in all periods:

$$de_0 - f_0 - Q_0 = 0 \tag{3}$$

$$de_1 - f_1 + R_0 Q_0 - Q_1 = 0 \tag{4}$$

$$de_2 - f_2 + R_1 Q_1 = 0, \tag{5}$$

where recall that, whenever $\sigma_R > 0$, the realization of R_1 becomes known at $t = 1$.

2.2 Monetary Policy Uncertainty

We start our analysis by characterizing how uncertainty about the future stance of monetary policy in the U.S. impacts the foreign currency's (log) *excess returns*, defined as $\phi = \phi_1 + \phi_2$, where

$$\phi_{t+1} = \log(R^*) - \log(R_t) + \log(e_{t+1}) - \log(e_t)$$

captures the foreign currency's excess returns between periods t and $t+1$. Note that $\mathbb{E}_t[\phi_{t+1}] = 0$ is equivalent to the satisfaction of UIP between periods t and $t+1$. Since monetary policy uncertainty is resolved at $t = 1$, we can naturally interpret ϕ_1 and ϕ_2 as, respectively, the foreign currency's pre- and post-announcement excess returns. We have the following result:

Proposition 1. *An increase in monetary policy uncertainty in the U.S. increases the foreign currency's expected excess returns, that is,* $\partial \mathbb{E}_0[\phi]/\partial\sigma_R > 0$.

This proposition thus establishes that the foreign currency's excess returns are higher on FOMC announcement days compared to days with no scheduled announcements. The intuition underlying this result is that on announcement days, the financiers are uncertain about the interest rate at which they will have to refinance their position, exposing them to a risk that is above and beyond the usual fundamental risk they face on non-announcement days when $\sigma_R = 0$. Given their downward-sloping demand for risk-taking induced by the value-at-risk constraint, the financiers are willing to bear this extra risk only if they are compensated accordingly with higher returns. Put differently, the higher

[6] Gabaix and Maggiori (2015) consider an alternative specification of the model with a different constraint, whereby the financiers are subject to a limited commitment friction that intensifies with the complexity of their balance sheets. Since both our value-at-risk constraint and the limited commitment constraint of Gabaix and Maggiori induce downward-sloping demand for risk-taking by the financiers, they have similar implications for exchange rates and currency excess returns.

σ_R faced by the financiers on announcement days tightens their value-at-risk constraint in (2), thus limiting their ability to short the dollar. Consequently, for currency markets to clear, the foreign currency has to depreciate at $t = 0$, coupled with an expected appreciation at $t = 2$, thus increasing excess returns.

Our next result determines the relationship between the foreign currency's excess returns and the interest rate differential between the two countries.

Proposition 2. *The foreign currency's expected excess return increases in the foreign country's interest rate, that is,* $\partial\mathbb{E}_0[\phi]/\partial R^* > 0$. *Furthermore, the increase in excess returns in response to higher monetary policy uncertainty is larger for currencies with higher interest rates, i.e.,* $\partial^2\mathbb{E}_0[\phi]/\partial R^*\partial\sigma_R > 0$.

The first part of the above result establishes that a higher interest rate differential between the two countries leads to larger (expected) excess returns on the foreign currency position. This is due to the fact that a higher interest rate differential between the two countries makes shorting the dollar more attractive for the financiers, inducing them to take larger positions in equilibrium. This increase in the position size results in an equilibrium exchange rate adjustment. However, due to financiers' limited risk-bearing capacity, the adjustment in exchange rates does not offset the increase in interest rate differential one-for-one, thus resulting in higher excess returns.

More importantly, however, the second part of Proposition 2 establishes that the impact of monetary policy uncertainty on excess returns (characterized in Proposition 1) is not the same for all currencies. Rather, returns that are earned in compensation for higher monetary policy uncertainty are larger for currencies with higher interest rates. The model thus predicts that not only the foreign currency earns higher excess returns on FOMC announcement days relative to non-announcement days, but also that the difference between announcement and non-announcement day returns increases with the country's interest rate differential vis-à-vis the United States.

2.3 Monetary Policy Shock

Our focus thus far was on the impact of monetary policy uncertainty on excess returns. Indeed, the fact that this uncertainty is resolved at $t = 1$ means that the effects characterized in our previous results work through financiers' $t = 0$ expectations about future interest rates. As our next result, we show that in addition to these expectations-driven effects, the actual realization of the monetary policy shock also has an impact on the foreign currency's excess returns. We capture this so called "post-announcement effect" by characterizing the relationship between the realization of R_1 and the foreign currency's excess returns between $t = 1$ and $t = 2$.

Proposition 3. *An interest rate reduction by the Federal Reserve increases the foreign currency's expected post-announcement excess returns, i.e.,* $\partial\mathbb{E}_1[\phi_2]/\partial R_1 < 0$. *Moreover,* $\partial^2\mathbb{E}_1[\phi_2]/\partial R_1\partial\sigma_R < 0$.

Thus, not only the foreign currency exhibits higher excess returns on announcement days relative to non-announcement days, but also that announcement day returns are higher if, ex post, the Fed adopts a policy of monetary easing. The juxtaposition of Propositions 1 and 3 also illustrates that the composition of announcement day returns is driven by two related, but distinct factors. First, the mere possibility of a change in interest rates in the U.S. results in higher monetary policy uncertainty and, hence, higher excess returns. Second, given that the policy announcement may result in an actual change in interest rates, the foreign currency's post-announcement returns also adjust in response to the adopted policy.

3 Data

We work with tick-by-tick high-frequency data that runs from January 1, 1994 to December 31, 2013. There are eight scheduled FOMC meetings in one year. This leaves us with 160 FOMC announcement days and 4,512 trading days with no scheduled FOMC announcements. We exclude from our sample the 10 days in which the FOMC made a surprise announcement following an unscheduled meeting.

High-Frequency Currency Data: The high-frequency spot exchange rate data for Australia, Canada, Euro, Japan, New Zealand, Norway, Sweden, Switzerland, and the UK, all vis-à-vis the U.S. dollar, are from Olsen & Associates.[7] We focus on these so called "G10" currencies as they are the most heavily traded (Bank for International Settlements, 2015). The raw data consists of all interbank bid and ask indicative quotes for the exchange rates to the nearest even second. After filtering the data for outliers, the log price at each five-minute tick is obtained by linearly interpolating from the average of the log bid and log ask quotes for the two closest ticks.[8] We then calculate daily currency returns by sampling the data at 4pm Eastern Time (ET).

Spot and Forward Data: The log excess return of purchasing a foreign currency in the forward market and then selling it in the spot market after one month is given by $rx_{t+1} = fw_t - s_{t+1}$, where s_t and fw_t denote the spot and forward rates in logs, respectively. The excess return can also be stated as the log forward discount minus the change in the spot rate: $rx_{t+1} = fw_t - s_t - \Delta s_{t+1}$. Note that since covered interest rate parity (CIP) holds at daily and lower frequencies, the forward discount is equal to the interest rate differential, that is, $fw_t - s_t \approx r_t^* - r_t$, where r^* and r respectively denote the foreign and domestic nominal risk-free rates over the maturity of the contract.

To calculate currency excess returns, we combine our high-frequency spot data with the daily data for spot exchange rates and one-month forward rates (versus the U.S. dollar) obtained from BBI and WM/Reuters (via Datastream). More specifically, we use the change in exchange rates from the high-frequency data and combine it with an appropriately scaled forward discount that is extracted from the daily data assuming that the interest is earned linearly over the length of the contract.

Volatilities: To obtain measures for intra-day realized volatility, we first calculate spot FX changes sampled at five-minute intervals and obtain the realized variance over a rolling one-hour window as

[7] We use the Deutsche mark instead of the euro prior to the latter's introduction in January 1999.

[8] We follow the literature and take five-minute intervals as opposed to higher frequencies, in order to mitigate the effect of spurious serial correlation stemming from microstructure noise.

the respective sum of squared changes. We then calculate realized volatility by taking the square root of realized variance.

FOMC Announcements: For a high-frequency analysis, it is important to know exactly when FOMC decisions become known to market participants. Unlike other macroeconomic announcements that are released at very precise times, FOMC announcements are usually made around, but not precisely at, 215pm ET. We follow Fleming and Piazzesi (2005) and collect precise announcement times from the Bloomberg newswire, though, with some abuse of terminology, we use 215pm and the announcement time interchangeably.

Monetary Policy Indicator: To obtain an indicator for monetary policy shocks, we follow Gürkaynak, Sack, and Swanson (2005) and Nakamura and Steinsson (2015) and construct a composite measure of changes in fed funds and Eurodollar futures with horizons up to one year over a 30-minute window around FOMC announcements. This composite measure, which we refer to as the "monetary policy indicator" or MPI, is the first principal component of unanticipated changes in the following five interest rates: the federal funds rate immediately following the FOMC meeting, the expected federal funds rate immediately following the next FOMC meeting, and expected 3-month Eurodollar interest rates at horizons of two, three, and four quarters.

Uncertainty Indices: As our benchmark index for market participants' uncertainty about monetary policy, we use the implied volatility index extracted from one-month options on 30-year Treasury futures (akin to the VIX), which we refer to as Treasury Implied Volatility or TIV (Choi, Mueller, and Vedolin, 2016). As part of our robustness analysis, we also proxy policy uncertainty with two alternative measures: the economic policy uncertainty index of Baker, Bloom, and Davis (2016) and the cross-sectional standard deviation of forecasts constructed from surveys about the future federal funds rate available from Bloomberg.

Finally, we proxy market participants' appetite for risk and intermediaries' risk-bearing capacity by the VIX index of implied volatility from S&P500 options (Pan and Singleton, 2008; Adrian and Shin, 2010; Miranda-Agrippino and Rey, 2015), as well as the average five-year CDS spread of Citibank, JPMorgan, Bank of America, and Goldman Sachs, available from Markit. These banks, which are the four largest U.S.-based banks trading in the FX market, hold around 34% of the market share.

4 Empirical Analysis

This section contains our main empirical results, where we document that returns to a trading strategy that is short the U.S. dollar and long other currencies are on average larger on FOMC announcement days compared to all other days. We also show that the difference between announcement and non-announcement day returns (i) is larger for currencies with larger interest rate differentials vis-à-vis the U.S.; (ii) increases with various proxies of monetary policy uncertainty; and (iii) increases when the Federal Reserve adopts an expansionary monetary policy.

4.1 Announcement vs. non-Announcement Day Returns

Individual Currencies: We begin our empirical investigation by documenting the returns of individual currencies on days with and without scheduled FOMC announcements. Table 1 presents the summary statistics of daily excess returns of the nine currencies in our sample (in bps) vis-à-vis the U.S. dollar for the entire sample (Panel A), days without FOMC announcements (Panel B), and days with scheduled announcements (Panel C). The returns are sampled at 4pm ET, which corresponds to the closing time of the stock market in New York.[9]

There are several noteworthy observations. First, focusing on the entire sample in Panel A indicates that, except for the New Zealand dollar, daily returns are on average not statistically different from zero. Summary statistics for non-announcement days, detailed in Panel B, exhibit a similar pattern: average returns are not statistically different from zero for any of the currencies. Panel C, however, indicates that announcement day returns are not only statistically different from zero for most of the currencies, but are also significantly larger than non-announcement day returns. For example, the average daily return of the Australian dollar (AUD) on announcement days is 17.28bps compared to 1.16bps on non-announcement days, amounting to a statistically significant difference of 16.12bps (with a t-statistic of 2.51). In fact, as the bottom row of Table 1 illustrates, except for the Japanese yen and the Norwegian krona, differences in announcement and non-announcement day returns are significant for all other currencies, an observation that is consistent with our model's prediction in Proposition 1. This pattern can also be seen in Figure 1, which plots the currencies' average daily returns on announcement and non-announcement days.

Second, our results indicate that most of the currency excess returns earned on announcement days are due to changes in exchange rates as opposed to the interest rate differential. In particular, line Δs in Panel C, which denotes the daily return that is earned as a consequence of changes in the foreign exchange, shows that almost the entire return on announcement days is attributable to the exchange rate change.

Third, we note that the difference between announcement and non-announcement day returns is larger for currencies that have higher interest rate differentials vis-à-vis the U.S. For example, the difference between announcement and non-announcement day returns for the Australian and New Zealand dollars, two typical investment currencies, is respectively 16.12 and 13.92bps, both of which are statistically different from zero. In contrast, the difference between announcement and non-announcement day returns of the Japanese yen, a typical funding currency, is statistically insignificant. This finding is in line with our model's prediction in Proposition 2, according to which currencies with larger interest rate differentials vis-à-vis the U.S. should exhibit larger excess returns on announcement days relative to non-announcement days. We explore this issue in further detail in what follows.

We end this discussion by noting that, according to our model, currency excess returns are closely

[9] Benchmark exchange rates available through Datastream are sampled at 4pm London time. In order to cover the most active trading period prior to the announcement, we instead focus on 4pm ET, which is when the market closes in New York. We verify that the Datastream data and our high-frequency data when sampled at 4pm London time are virtually identical.

Table 1. Summary Statistics of Individual Currency Returns

This table reports summary statistics for individual currency returns for the entire sample (Panel A), non-announcement days (Panel B), and FOMC announcement days (Panel C). "Δs" represents the return earned from the change in the foreign exchange and "SR" is the Sharpe ratio. All numbers are expressed in daily bps except for Sharpe ratios, which are annualized, taking into account the annual frequency of FOMC announcements (8/252). "diff" indicates the difference between announcement and non-announcement day returns in basis points (bps), with the corresponding t-statistic for a test of difference in means between announcement and non-announcement days reported in parentheses. Returns are sampled from 4pm to 4pm ET and cover the period January 1, 1994 to December 31, 2013.

	AUD	CAD	CHF	EUR	GBP	JPY	NOK	NZD	SEK
Panel A: Entire Sample ($n = 4{,}672$)									
mean	1.715	0.978	0.221	0.299	0.610	-1.088	0.935	2.222	0.977
t-stat	(1.47)	(1.31)	(0.21)	(0.32)	(0.74)	(-1.05)	(0.86)	(1.92)	(0.87)
Δs	0.897	0.959	0.991	0.516	0.249	0.104	0.529	1.155	0.886
skewness	-0.354	-0.054	-0.291	0.015	-0.524	0.528	-0.140	-0.354	-0.076
kurtosis	12.311	8.164	9.934	4.706	8.265	9.097	6.137	6.720	5.790
SR	0.341	0.304	0.049	0.073	0.173	-0.243	0.199	0.445	0.203
Panel B: Non-Announcement Days ($n = 4{,}512$)									
mean	1.163	0.421	-0.108	-0.050	0.155	-0.973	0.706	1.745	0.641
t-stat	(0.98)	(0.56)	(-0.10)	(-0.05)	(0.19)	(-0.92)	(0.64)	(1.49)	(0.56)
Δs	0.345	0.402	0.661	0.167	-0.206	0.217	0.299	0.679	0.551
skewness	-0.439	-0.250	-0.422	-0.049	-0.595	0.524	-0.162	-0.435	-0.133
kurtosis	12.479	6.977	9.821	4.507	8.324	9.234	6.169	6.597	5.578
SR	0.229	0.130	-0.024	-0.012	0.043	-0.214	0.148	0.346	0.131
Panel C: Announcement Days ($n = 160$)									
mean	17.283	16.692	9.507	10.136	13.452	-4.325	7.365	15.666	10.431
t-stat	(2.43)	(3.31)	(1.38)	(1.86)	(2.79)	(-0.77)	(1.20)	(2.22)	(1.77)
Δs	16.451	16.672	10.309	10.376	13.082	-3.074	7.011	14.581	10.328
skewness	1.183	2.435	1.537	1.451	0.898	0.660	0.408	1.139	1.671
kurtosis	8.218	18.220	9.441	8.164	6.106	5.188	5.183	7.808	11.615
SR	0.544	0.740	0.307	0.416	0.623	-0.173	0.269	0.497	0.396
diff	16.120	16.271	9.615	10.186	13.297	-3.351	6.659	13.920	9.789
	(2.51)	(3.96)	(1.69)	(1.96)	(2.94)	(-0.59)	(1.11)	(2.19)	(1.64)

related to exchange rate volatility (via the tightness of financiers' risk constraint). To test for this relationship, we plot the daily movement of average realized volatility of the currencies' exchange rates on announcement and non-announcement days in Figure 2. As the figure indicates, throughout most of the day, realized volatility on announcement days is low and indistinguishable from the realized volatility at corresponding times on non-announcement days. However, realized volatility spikes considerably for all currencies around the time of the announcement. Indeed, performing an F-test on the data from a one-hour window straddling the time of the announcement indicates that, for all currencies, exchange rate volatility on announcement days is larger than non-announcement days (with p-values that are virtually equal to zero).

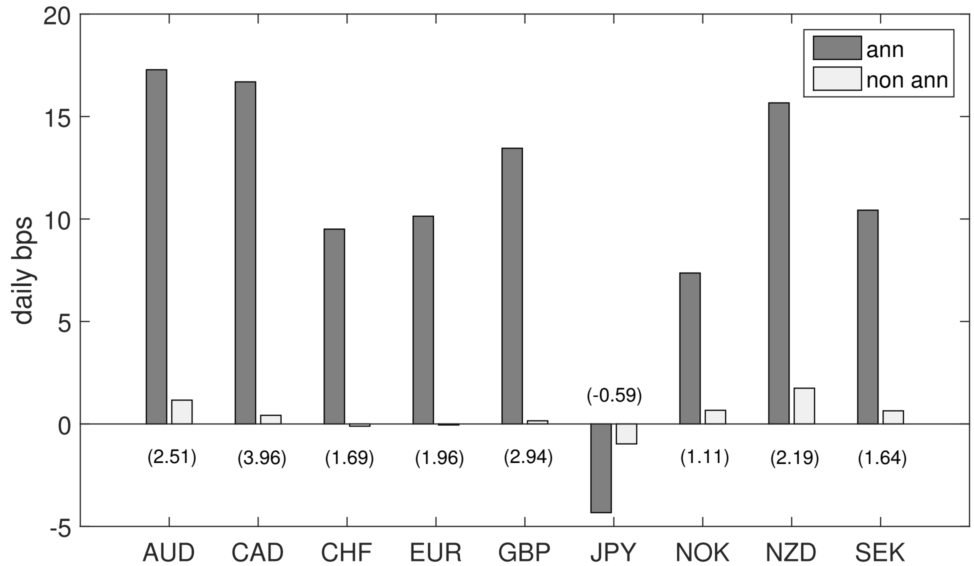

Figure 1. Currency Returns on Announcement and non-Announcement Days. The figure plots average announcement and non-announcement day returns for the currencies in our sample vis-à-vis the U.S. dollar. The numbers in parentheses report the t-statistics for the tests of difference in mean returns between announcement and non-announcement days. The data runs from January 1, 1994 to December 31, 2013.

Currency Portfolios: In the remainder of this section, we focus our attention on currency portfolios, as most traders do not invest in single currencies. In particular, in order to diversify away idiosyncratic currency risks, many traders take a long position in a number of high-interest rate currencies while shorting currencies with low interest rates (Pedersen, 2015).

Motivated by our earlier observation that currencies of countries with a positive interest rate differential vis-à-vis the U.S. exhibit larger returns on announcement days, we construct currency portfolios that are sorted on their forward discount, as is customary in the literature (see, e.g., Lustig and Verdelhan (2007) and Lustig, Roussanov, and Verdelhan (2011), among others). To this end, we allocate currencies into three portfolios based on their observed forward discounts $fw_t - s_t$, or, equivalently, their interest rate differentials at the end of each month t.[10] Portfolios are ranked in increasing interest rate order, with $\mathrm{pf1}$ and $\mathrm{pf3}$ denoting the portfolios consisting of the three currencies with the lowest and highest interest rates, respectively. We calculate daily log excess returns of individual currencies using the daily interest rate differentials and daily log exchange rate changes, assuming that the interest rate differential is earned linearly over the month. Portfolio returns are then calculated as the average of the currency excess returns in each portfolio as in Lustig, Roussanov, and Verdelhan (2011). Table 2 presents the resulting summary statistics, with dol denoting the portfolio that is short the U.S. dollar and long all other currencies.

Panel A of Table 2 presents summary statistics for average returns over our entire sample. These results confirm the well-known empirical pattern that, when averaged over all days, low interest rate currencies earn lower average returns than high interest rate currencies: in our sample, the low

[10]Recall that since covered interest rate parity holds at daily and lower frequencies, the forward discount is equal to the interest rate differential.

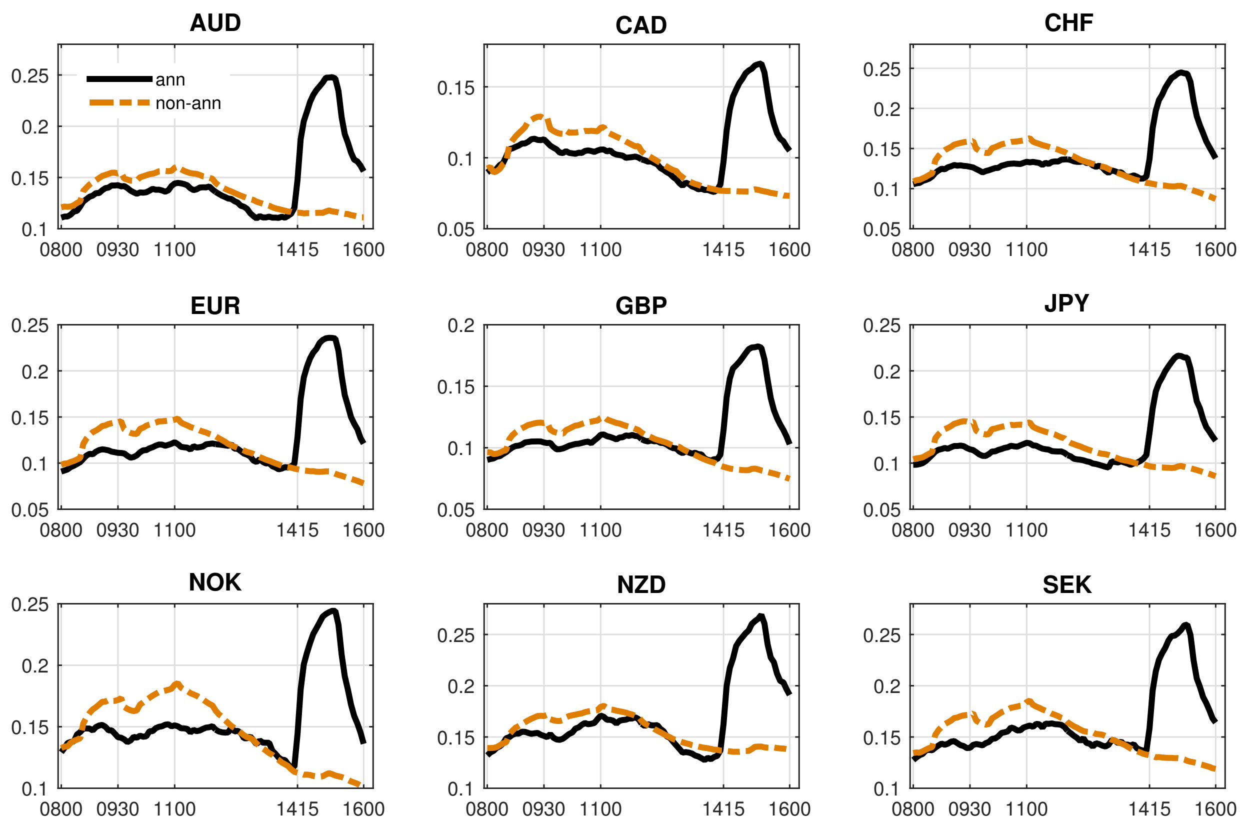

Figure 2. Foreign Exchange Realized Volatility. This figure plots average realized exchange rate volatility on FOMC announcement days (solid curve) and all other days (dashed curve). Realized volatilities are calculated from data sampled at five-minute frequency over a one-hour window and are annualized. The data runs from January 1, 1994 to December 31, 2013.

interest rate portfolio, pf1, earns a daily return of -0.31bps (with a t-statistic of -0.39), whereas the high interest rate portfolio, pf3, earns an average daily return of 2.18bps (with a t-statistic of 2.31). The dol portfolio has a daily return of 0.84bps, which is statistically insignificant (with a t-statistic of 1.14). Panel A also indicates that corresponding annualized Sharpe ratios are larger for high interest rate currencies: while pf1 only generates an annualized Sharpe ratio of -0.09, pf3 has a Sharpe ratio of 0.54.

Next, we compare the currency portfolios' returns on announcement and non-announcement days, as documented in Panels B and C of Table 2 and depicted in Figure 3. The key observation is that, in line with the model's prediction in Propositions 1 and 2, the difference between announcement and non-announcement day returns is positive and increasing in the interest rate differential. For instance, the average daily return on the low interest rate portfolio is 5.19bps on announcement days compared to -0.51bps on non-announcement days. This 5.70bps difference is positive but not statistically significant (with a t-statistic of 1.31). However, the average daily return of the high interest rate currency portfolio grows from 1.73bps on non-announcement days to 14.47bps on announcement days, a 12.74bps difference that is significantly different from zero (with a

Table 2. Summary Statistics of Currency Portfolio Returns

This table reports summary statistics of currency portfolios for the entire sample (Panel A), non-announcement days (Panel B), and FOMC announcement days (Panel C). Portfolios are sorted according to their interest rate differentials, with $\mathrm{pf1}$ ($\mathrm{pf3}$) denoting the portfolio with the lowest (highest) interest rate differential vis-à-vis the U.S. "dol" denotes the portfolio that is short the U.S. dollar and long all other currencies. "Δs" represents the return earned from the change in the foreign exchange and "SR" is the Sharpe ratio. All numbers are expressed in daily bps except for Sharpe ratios, which are annualized, taking into account the annual frequency of FOMC announcements (8/252). "diff" indicates the difference between announcement and non-announcement day returns in basis points (bps), with the corresponding t-statistic for a test of difference in means between announcement and non-announcement days reported in parentheses. Returns are sampled from 4pm to 4pm ET and cover the period January 1, 1994 to December 31, 2013.

	pf1	pf2	pf3	dol
Panel A: Entire Sample ($n = 4{,}672$)				
mean	-0.307	0.638	2.183	0.838
t-stat	(-0.39)	(0.82)	(2.31)	(1.14)
skewness	0.226	-0.028	-0.366	0.017
kurtosis	6.059	6.980	8.695	5.874
SR	-0.090	0.189	0.537	0.265
Panel B: Non-Announcement Days ($n = 4{,}512$)				
mean	-0.509	0.194	1.730	0.472
t-stat	(-0.64)	(0.24)	(1.81)	(0.64)
skewness	0.156	-0.115	-0.461	-0.100
kurtosis	5.941	6.711	8.629	5.471
SR	-0.148	0.057	0.421	0.148
Panel C: Announcement Days ($n = 160$)				
mean	5.187	12.656	14.465	10.769
t-stat	(1.06)	(2.65)	(2.49)	(2.27)
skewness	1.489	1.545	1.305	1.756
kurtosis	7.235	10.174	8.384	9.621
SR	0.238	0.593	0.556	0.508
diff	5.696	12.462	12.735	10.298
	(1.31)	(2.90)	(2.45)	(2.55)

t-statistic of 2.45). We also note that unlike the unconditional average taken over the entire sample (as presented in Panel A of Table 2), the dol portfolio features a large and statistically significant return on announcement days (10.77bps, with a t-statistic of 2.27), whereas the return on non-announcement days is insignificant, with a t-statistic of 0.64. The difference of 10.30bps between the announcement and non-announcement day returns is highly statistically different from zero with a t-statistic of 2.55.

These observations illustrate that a sizable portion of the currency portfolios' average yearly returns is earned on FOMC announcement days. For instance, the average yearly return on the high interest rate portfolio is $252 \times 2.183 = 550$bps, of which 21% (or $8 \times 14.465 = 116$bps) is earned on the eight FOMC announcement days. For the dol portfolio, we find that 41% of the entire annual return is earned on announcement days. Notably, this large increase in average returns on announcement

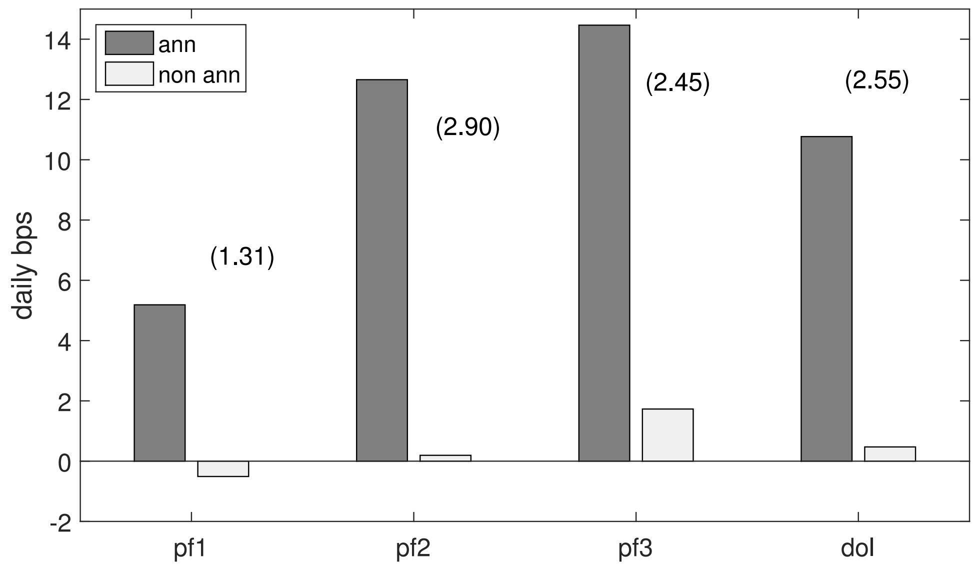

Figure 3. Currency Portfolio Returns on Announcement and non-Announcement Days. The figure plots average announcement and non-announcement day returns for portfolios sorted according to interest rate differentials vis-à-vis the U.S., with pf1 (pf3) denoting the portfolio with the lowest (highest) interest rate differential. dol denotes the portfolio that is short the U.S. dollar and long all other currencies. The numbers in parentheses report the t-statistics for the tests of difference in mean returns between announcement and non-announcement days. The data runs from January 1, 1994 to December 31, 2013.

days is not accompanied by an equally large increase in realized risk, as annualized Sharpe ratios are significantly larger on announcement days.[11] We also note that even though announcement day Sharpe ratios are comparable to those of some of the established currency trading strategies, it is well-known that carry trades feature negative skewness (Brunnermeier, Nagel, and Pedersen, 2008; Jurek, 2014; Daniel, Hodrick, and Lu, 2016). In contrast, the relatively high Sharpe ratios of pf3 and dol on announcement days are accompanied by returns that are positively skewed.

4.2 Time-Series Analysis

We continue our investigation of currency excess returns around FOMC announcements by taking a time-series perspective. This approach enables us to test our model's theoretical predictions in further detail and study the potential determinants of announcement day returns more formally.

We start by documenting how monetary policy uncertainty and the realization of monetary policy shocks shape currency excess returns on announcement days. As our benchmark regression, we regress each currency portfolio's excess returns on a dummy variable that takes the value of one on announcement days and zero otherwise:

$$rx_{t+1} = \alpha_0 + \alpha_1 \times \text{Announcement Dummy}_t + \epsilon_{t+1}. \quad (6)$$

[11] Annualized Sharpe ratios are obtained by adjusting daily values for the yearly frequency of FOMC announcements (eight out of 252 trading days). Thus, the adjustment factors for announcement and non-announcement day Sharpe ratios are $\sqrt{8}$ and $\sqrt{244}$, respectively.

Table 3. Currency Portfolio Returns Time-Series Regressions

This table reports the results of time-series regressions of interest rate-sorted currency portfolios. The dependent variable is the portfolios' excess returns from 4pm to 4pm ET. The announcement dummy takes the value of one on days when the FOMC makes an announcement and zero otherwise. "TIV" is the standardized (that is, demeaned and scaled by the corresponding sample standard deviation) Treasury Implied Volatility index extracted from one-month options on 30-year Treasury futures. "MPI" is Nakamura and Steinsson's (2015) indicator of monetary policy shock. Data runs from January 1, 1994 to December 31, 2013. Numbers in parentheses denote Newey and West (1987) t-statistics.

	pf1	pf2	pf3	dol
Panel A: Baseline Regression				
constant	-0.502	0.212	1.747	0.486
	(-0.62)	(0.27)	(1.82)	(0.65)
ann dummy	5.689	12.444	12.718	10.283
	(1.31)	(2.89)	(2.45)	(2.55)
Adj. R^2	0.02%	0.16%	0.11%	0.12%
Panel B: Monetary Policy Uncertainty				
constant	-0.504	0.215	1.750	0.487
	(-0.63)	(0.27)	(1.83)	(0.65)
ann dummy	6.818	13.669	14.662	11.716
	(1.56)	(3.16)	(2.82)	(2.90)
TIV	0.436	-0.718	-0.814	-0.365
	(0.54)	(-0.90)	(-0.85)	(-0.49)
TIV $\times$ ann dummy	10.896	13.054	20.384	14.778
	(2.47)	(3.00)	(3.88)	(3.62)
Adj. R^2	0.12%	0.31%	0.39%	0.36%
Panel C: Monetary Policy Shock				
constant	-0.502	0.212	1.747	0.486
	(-0.62)	(0.27)	(1.82)	(0.65)
ann dummy	7.059	13.736	14.369	11.721
	(1.62)	(3.19)	(2.77)	(2.91)
MPI $\times$ ann dummy	3.888	3.667	4.688	4.081
	(4.66)	(4.45)	(4.72)	(5.29)
Adj. R^2	0.46%	0.56%	0.56%	0.69%

In this regression, the intercept α_0 measures the corresponding portfolio's mean return on non-announcement days, while α_1 measures the spread between announcement and non-announcement days' mean returns.

The results, reported in Panel A of Table 3, mirror those in Table 2, with positive coefficients for the announcement dummy for all portfolios. Furthermore, except for the low interest rate portfolio, the spread between announcement and non-announcement day returns is significant for all portfolios, with $\alpha_1 = 12.72$ (t-statistic of 2.45) for the high interest rate portfolio. The estimates for the intercept α_0 are not significant except for $\mathrm{pf3}$, implying that there is little return to be earned on non-announcement days. Similarly, for the dol portfolio, the announcement dummy ($\alpha_1 = 10.28$) is statistically significant whereas the intercept is not. These results thus confirm our model's main prediction that currency excess returns are on average higher on announcement days. Also recall that according to our model, the difference between announcement and non-announcement day returns should increase with the currency portfolios' interest rate differential vis-à-vis the U.S. (Proposition 2). Indeed, we find that the estimated coefficients increase from 5.69 for pf1 to 12.72 for pf3.

Next, we turn to testing our model's other prediction that larger currency excess returns on announcement days are in response to the presence of monetary policy uncertainty (Proposition 1). To check whether higher announcement day returns are indeed associated with higher monetary policy uncertainty, we regress currency excess returns on the announcement dummy interacted with the (standardized) implied volatility index TIV, which serves as a proxy for monetary policy uncertainty:

$$rx_{t+1} = \alpha_0 + \alpha_1 \times \text{Ann Dummy}_t + \alpha_2 \times \text{TIV}_t + \alpha_3 \times \text{Ann Dummy}_t \times \text{TIV}_t + \epsilon_{t+1}. \tag{7}$$

In this regression, we are mainly interested in coefficient α_3, which measures the additional return one can earn on announcement days relative to non-announcement days as TIV increases. The results are reported in Panel B of Table 3. We find that all estimated coefficients for the interaction term are statistically significant at the 1% level and carry the expected positive sign, indicating that higher uncertainty is indeed associated with a larger spread between announcement and non-announcement day excess returns. Interestingly, monetary policy uncertainty does not seem to matter for currency returns outside of announcement days as manifested by the insignificant estimates for α_2.

Finally, we test for the relationship between currency excess returns and the realization of the monetary policy shock at the announcement. Recall that according to Proposition 3, the difference between returns on announcement and non-announcement days should increase (decrease) if the Fed adopts a policy of monetary easing (tightening). To test for this prediction, we regress currency returns on the announcement dummy interacted with the monetary policy indicator of Nakamura and Steinsson (2015). This indicator, which we refer to as MPI, is obtained by extracting the principal component of changes in various interest rate futures, with a positive value corresponding to an expansionary change in policy. Our rationale for relying on such an indicator, as opposed to the change in the federal funds rate announced by the FOMC, is twofold. First, within our sample of 160 announcements, the federal funds rate was changed on only 52 occasions (corresponding to 30 and 22 rate hikes and reductions, respectively), thus leaving us with too small of a sample. In contrast, by relying on the MPI, we can identify, respectively, 59 and 101 episodes of easing and tightening of policy. Second, given its overnight nature, changes in the federal funds rate are incapable of capturing any longer term changes in (expected) interest rates as a result of the FOMC announcement. In contrast, such potential changes are better reflected in the MPI due to its longer horizon nature.

Panel C of Table 3 reports the results. Estimated coefficients are positive and highly statistically significant for all portfolios with t-statistics ranging between 4.45 and 5.29. These results thus indicate that, consistent with the predictions of Proposition 3, the adoption of an expansionary policy by the Fed increases the spread between announcement and non-announcement day returns.

4.2.1 Pre- and Post-Announcement Returns

One of the key predictions of our model is that currency excess returns consist of pre- and post-announcement components. To test this prediction and explore the intra-day patterns of returns, we decompose daily returns by sampling the data at 215pm and 4pm and calculate currency returns over two non-overlapping time windows: (i) from 4pm on any given day to 215pm the following day and (ii) from 215pm to 4pm on the same day. We then separately regress the returns earned over each time window on an announcement dummy in a regression akin to (6). With some abuse of terminology, we refer to the 4pm–215pm and 215pm–4pm time windows as the pre- and post-announcement windows, respectively.

The results are summarized in Table 4, where Panels B and C report the corresponding numbers for pre- and post-announcement windows, respectively. As a reference, we also reproduce in Panel A the results of our baseline regression for the entire day (from Table 3). The positive and significant estimates for the announcement dummy indicate that, except for $\mathrm{pf1}$'s returns during the pre-announcement window, the pre- and post-announcement components of all portfolios are larger on announcement days compared to the corresponding windows on non-announcement days (at the 10% level). For instance, the estimated coefficients for the dol portfolio over the pre-announcement window indicates 7.89bps higher returns on announcement days compared to the same time window on all other days (with an associated t-statistic of 2.02). Similarly, dol's returns during the post-announcement window of 215pm–4pm are 2.39bps (t-statistic of 2.32) higher on announcement days than on non-announcement days.

Comparing the three panels of Table 4 side-by-side also provides a clear decomposition of the portfolios' daily returns earned over the two time windows. For instance, focusing on $\mathrm{pf3}$, the table illustrates that (when compared to non-announcement days) out of the 12.72bps additional returns earned on announcement days, 9.48bps are earned over the pre-announcement window, with the remaining 3.24bps earned over the post-announcement window.

4.2.2 Pre-Announcement Returns and Monetary Policy Uncertainty

Recall from Section 2 that, according to our model, the excess returns earned prior to the announcement are in response to the presence of higher monetary policy uncertainty on announcement days. We test for this prediction by re-running regression (7) while replacing the entire day returns as the left-hand side variable with the returns earned over the pre-announcement window (4pm–215pm). The results are presented in Table 5. Similar to the results for the full day returns reported in Panel B of Table 3, the estimated coefficient for the announcement dummy interacted with TIV (which serves as our proxy for monetary policy uncertainty) is positive and

Table 4. Pre- and Post-Announcement Returns

This table reports the results of time-series regressions of interest rate-sorted currency portfolios for different time windows. The dependent variable is the portfolios' excess returns from 4pm to 4pm (Panel A), from 4pm to 215pm (Panel B), and from 215pm to 4pm (Panel C). The announcement dummy takes the value of one on days when the FOMC makes an announcement and zero otherwise. Data runs from January 1, 1994 to December 31, 2013. Numbers in parentheses denote Newey and West (1987) t-statistics.

	pf1	pf2	pf3	dol
Panel A: Entire Day (4pm–4pm)				
constant	-0.502	0.212	1.747	0.486
	(-0.62)	(0.27)	(1.82)	(0.65)
ann dummy	5.689	12.444	12.718	10.283
	(1.31)	(2.89)	(2.45)	(2.55)
Adj. R^2	0.02%	0.16%	0.11%	0.12%
Panel B: Pre-Announcement Window (4pm–215pm)				
constant	-0.613	-0.457	1.360	0.135
	(-0.77)	(-0.59)	(1.48)	(0.19)
ann dummy	3.806	10.415	9.484	7.894
	(0.89)	(2.49)	(1.91)	(2.02)
Adj. R^2	0.00%	0.11%	0.06%	0.07%
Panel C: Post-Announcement Window (215pm–4pm)				
constant	0.111	0.673	0.391	0.394
	(0.61)	(3.43)	(1.40)	(2.07)
ann dummy	1.881	2.028	3.237	2.387
	(1.90)	(1.92)	(2.15)	(2.32)
Adj. R^2	0.06%	0.06%	0.08%	0.09%

significant for all portfolios (with t-statistics ranging from 2.24 to 3.45). Furthermore, as reflected by the insignificant estimates for TIV, we find that monetary policy uncertainty does not matter for currency returns on non-announcement days.

4.2.3 Post-Announcement Returns and the Monetary Policy Shock

Besides the decomposition of returns into their pre- and post-announcement components, our model also predicts that returns over the post-announcement window are tightly linked to the realization of the monetary policy shock at the announcement. In particular, recall from Proposition 3 that the adoption of a policy of monetary easing should result in a further increase in excess returns after the announcement. We explore the determinants of post-announcement returns by formally testing this relationship in our sample.

As a first exercise, we restrict our attention to announcement days only and calculate average returns during the post-announcement window conditional on whether the monetary shock

Table 5. Monetary Policy Uncertainty and Pre-Announcement Returns

This table reports the results of time-series regressions of interest rate-sorted currency portfolios for the pre-announcement window. The dependent variable is the portfolios' excess returns from 4pm to 215pm. The announcement dummy takes the value of one on days when the FOMC makes an announcement and zero otherwise. "TIV" is the standardized Treasury Implied Volatility index extracted from one-month options on 30-year Treasury futures. Data runs from January 1, 1994 to December 31, 2013. Numbers in parentheses denote Newey and West (1987) t-statistics.

	pf1	pf2	pf3	dol
constant	-0.614	-0.453	1.363	0.136
	(-0.77)	(-0.59)	(1.49)	(0.19)
ann dummy	4.822	11.397	11.114	9.106
	(1.12)	(2.71)	(2.23)	(2.32)
TIV	0.473	-1.133	-0.914	-0.503
	(0.60)	(-1.46)	(-1.00)	(-0.70)
TIV $\times$ ann dummy	9.723	11.048	17.337	12.698
	(2.24)	(2.60)	(3.45)	(3.21)
Adj. R^2	0.08%	0.23%	0.27%	0.24%

was expansionary or contractionary. In particular, we divide announcement days into two separate categories conditional on the sign of our monetary policy indicator, with a positive MPI corresponding to a policy of monetary easing. Figure 4 presents the results. As the figure indicates, returns over the post-announcement window are positive and significant for all portfolios whenever the Fed adopts a policy of monetary easing (with returns ranging from 18.33bps with a t-statistic of 3.90 for $\mathrm{pf1}$ to 24.32bps with a t-statistic of 4.30 for $\mathrm{pf3}$). We also find that returns are negative and significant during tightening periods with returns ranging from -6.55bps to -8.46bps. Thus, in line with our theoretical model, we can conclude that an expansionary policy results in positive returns post-announcement, whereas a contractionary policy leads to negative average returns.

In a second exercise, we study how the realization of monetary policy shock impacts *the difference* between announcement and non-announcement day returns over the post-announcement window. To this end, we regress the currency portfolios' returns earned over the post-announcement window on the announcement dummy interacted with the MPI, akin to the results presented in Panel C of Table 3 for the entire day. The results are reported in Table 6, where all estimated coefficients are positive and highly statistically different from zero. Thus, in line with our model's prediction, we find that the difference between announcement and non-announcement day returns over the post-announcement window is higher the more expansionary the adopted policy is.[12]

4.3 Trading Strategies

Our results thus far illustrate that a simple trading strategy that is short the U.S. dollar and long other currencies (i) exhibits high excess returns on FOMC announcement days; (ii) earns higher returns if

[12] We performed the same set of exercises for individual currencies, finding a similar pattern. The details are provided in the online appendix.

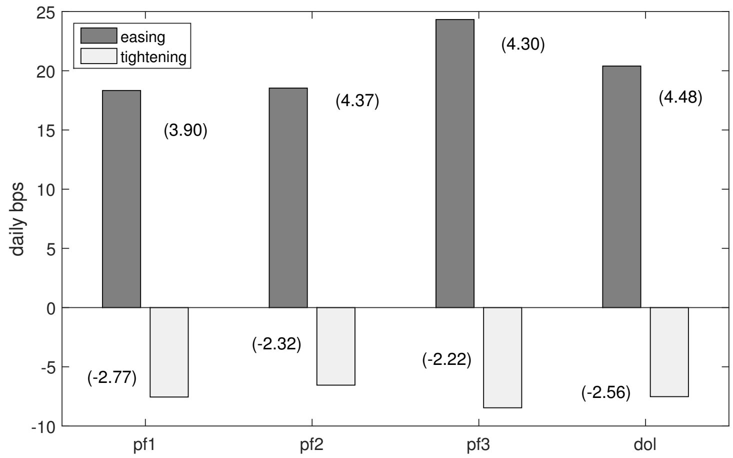

Figure 4. Post-Announcement Returns Following Monetary Easing and Tightening. This figure plots average announcement day returns over the post-announcement window (215pm–4pm) conditional on the sign of the realized monetary policy shock at the announcement. Monetary easing and tightening are defined using Nakamura and Steinsson's (2015) indicator of monetary policy shock. The numbers in parentheses report the t-statistics for the test of zero mean. The data runs from January 1, 1994 to December 31, 2013.

the interest rate differential is larger; and (iii) results in larger returns over the post-announcement window if the Federal Reserve adopts a policy of monetary easing.

Taken together, these observations imply that the simple trading strategies we have thus far focused on can be improved along two dimensions. First, the fact that the stance of monetary policy at the announcement is tightly linked to the post-announcement returns means that a trading strategy that responds accordingly to the content of the announcement should exhibit higher returns compared to the simpler strategies that do not. One such strategy, which we label $\mathrm{S1}$, shorts the U.S. dollar and goes long all other currencies at 4pm the day before the announcement and keeps the portfolio until 4pm on the day of the announcement if the Federal Reserve adopts an expansionary policy. If, however, the Federal Reserve tightens the policy, the strategy reverses the trade right after the announcement by going long the U.S. dollar and shorting the basket of all other currencies.

Second, the observation that the interest rate differential plays a key role in determining announcement day returns means that $\mathrm{S1}$ can be further improved if we only apply the strategy to currencies of countries that have a positive interest rate differential vis-à-vis the U.S., a strategy that we label $\mathrm{S2}$.

The summary statistics for announcement day returns of these trading strategies are summarized in Table 7. We note that average returns are indeed larger than those reported in Table 2: $\mathrm{S1}$ and $\mathrm{S2}$ generate average returns of 19.49 and 22.54bps, respectively, compared to 14.47 and 10.77bps for $\mathrm{pf3}$ and dol portfolios. Furthermore, these returns are not only highly statistically significant (as indicated by the corresponding t-statistics), but also exhibit very large Sharpe ratios, increasing from approximately 0.5 for $\mathrm{pf3}$ and dol to over 0.9 for either of the improved currency strategies. These Sharpe ratios are of similar orders of magnitude as the dollar carry strategy of Lustig, Roussanov, and Verdelhan (2014) for an extended dataset of currencies, which exploits the time variation in interest rate differentials vis-à-vis the U.S. However, in addition to the high returns and large Sharpe ratios

Table 6. Monetary Policy Shock and Post-Announcement Returns

This table reports the results of time-series regressions of interest rate-sorted currency portfolios for the post-announcement window. The dependent variable is the portfolios' excess returns from 215pm to 4pm. The announcement dummy takes the value of one on days when the FOMC makes an announcement and zero otherwise. "MPI" is Nakamura and Steinsson's (2015) indicator of monetary policy shock. Data runs from January 1, 1994 to December 31, 2013. Numbers in parentheses denote Newey and West (1987) t-statistics.

	pf1	pf2	pf3	dol
constant	0.111	0.673	0.391	0.394
	(0.62)	(3.48)	(1.42)	(2.11)
ann dummy	2.792	2.848	4.186	3.280
	(2.87)	(2.72)	(2.80)	(3.24)
MPI $\times$ ann dummy	2.586	2.327	2.695	2.536
	(13.88)	(11.61)	(9.42)	(13.07)
Adj. R^2	4.00%	2.84%	1.92%	3.60%

obtained on announcement days, the improved strategies $S1$ and $S2$ also exhibit positive skewness, a feature that is in contrast with the negative skewness observed for most of the well-known currency trading strategies (Daniel, Hodrick, and Lu, 2016).

Finally, comparing announcement day returns in the FX market to their counterparts in the equity market suggests that even though the former are smaller on average, the two are quite similar in terms of Sharpe ratios. In particular, we calculate pre-announcement returns in the equity market as in Lucca and Moench (2015) for an extended dataset ending in 2013 and find an average daily return of approximately 40bps with an associated annualized Sharpe ratio of 1.04. While announcement returns in the FX market are smaller — the average return for $S2$ is 22bps — the currency strategies exhibit Sharpe ratios that are comparable to the ones in the equity market.

4.4 Announcements by Other Central Banks

One natural question is whether announcements by other central banks have implications for currency returns that are similar to the patterns we document for FOMC announcements.

To answer this question, we collect announcement dates for the central banks of Australia, England, Japan, New Zealand, and Switzerland either from Bloomberg (if available) or from the webpages of the corresponding central banks.[13] We then re-base all exchange rates into the local currency of interest, assuming there are no violations of triangular arbitrage. We then build three portfolios based on interest rate differentials vis-à-vis the respective country and re-run the same exercise as we did for FOMC announcements. We do not find any significant effects for other central bank announcements except for the Bank of Japan.[14] In what follows, we first discuss Japan's

[13] The remaining countries have either a very short history or a small number of scheduled announcements, making any meaningful statistical analysis impossible. For example, Bank of Canada only started a fixed announcement schedule from 2001 onwards and Norges Bank only met once per year until 2007.

[14] In contrast, Brusa, Savor, and Wilson (2016) document that there are no effects on global stock market indices from

Table 7. Summary Statistics for Currency Strategies

This table reports summary statistics of currency returns on announcement days for two currency strategies. Strategy "S1" shorts the U.S. dollar and goes long the other currencies at 4pm the day before the announcement. It then continues the trading strategy post-announcement in case of monetary easing, whereas it goes long in the U.S. dollar and short in the other currencies after the announcement in case of monetary tightening. "S2" is the same strategy but only using currencies that exhibit a positive interest rate differential vis-à-vis the United States. The sample covers January 1, 1994 to December 31, 2013. All numbers are expressed in daily returns (in bps) except for Sharpe ratios, which are annualized.

	S1	S2
mean	19.485	22.538
t-stat	(4.11)	(4.17)
skewness	1.759	1.612
kurtosis	8.762	8.293
SR	0.920	0.933

monetary policy in more detail and then present the results.

The Bank of Japan (BoJ) Policy Board meets once or twice a month for two days to discuss economic developments inside and outside of the country. During these Monetary Policy Meetings, the members produce a guideline for money market operations in inter-meeting periods, which is written in terms of a target for the uncollateralized overnight call rate (the policy interest rate that corresponds to the federal funds rate in the U.S.). This is the base rate that is charged when banks that are part of the system provide one another with loans with a short maturity, usually a maturity of one day (overnight). The uncollateralized call rate was lowered to virtually zero in February/March 1999, and with the exception of a brief interest rate increase in the fall of 2000, the rate has since remained at the zero lower bound.

The monetary policy decisions are announced right after the meeting with the minutes released about a month later. It is important to note that in addition to setting the interest rate, BoJ's monetary policy announcements entail two other measures: (i) setting the target (reserves) of commercial banks at the BoJ in excess of required reserves; and (ii) setting the size of outright purchases of long-term government bonds, private equity, and debt, such as asset-backed securities. These announcements also include the BoJ's collective outlook on the economy as well as guidance about future monetary policy decisions.[15]

Monetary Policy Meeting dates are available from the webpage of Bank of Japan since 1998. Spring 1998 coincides with the year the BoJ gained independence from the government in its policy making decisions and member appointments. To test for announcement day effects, we re-base all exchange rates vis-à-vis the Japanese yen and sort the currencies into three different portfolios based on their interest rate differentials. The results are presented in Table 8.

The findings are strikingly similar to the ones for the Federal Reserve. On days with a BoJ announcement, the average daily return on the low interest rate portfolio is 12.47bps, compared to

announcements by central banks other than the Fed, arguing that the Fed exerts a unique impact on global equity prices.

[15] See Kuttner (2014) for an excellent overview of Japan's monetary policy.

Table 8. Announcements by the Bank of Japan

This table reports summary statistics of currency portfolios for the entire sample (Panel A), days without an announcement by the BoJ (Panel B), and BoJ announcement days (Panel C). Announcement days are when the BoJ releases its interest rate decisions. Portfolios are sorted according to their interest rate differentials, with pf1 (pf3) denoting the portfolio with the lowest (highest) interest rate differential vis-à-vis Japan. "jpy" denotes the portfolio that is short the Japanese yen and long all other currencies. "SR" is the Sharpe ratio. All numbers are expressed in daily bps except for Sharpe ratios, which are annualized, taking into account the annual frequency of BoJ announcements (15/252). "diff" indicates the difference between announcement and non-announcement day returns in basis points (bps), with the corresponding t-statistic for a test of difference in means between announcement and non-announcement days reported in parentheses.

	pf1	pf2	pf3	jpy
Panel A: Entire Sample ($n = 3{,}997$)				
mean	0.410	1.657	3.340	1.802
t-stat	(0.39)	(1.47)	(2.58)	(1.64)
skewness	-0.498	-0.663	-0.593	-0.641
kurtosis	8.246	10.138	11.572	10.438
SR	0.088	0.330	0.579	0.369
Panel B: Non-Announcement Days ($n = 3{,}765$)				
mean	-0.039	1.191	2.823	1.325
t-stat	(-0.05)	(1.32)	(2.71)	(1.50)
skewness	-0.512	-0.684	-0.619	-0.663
kurtosis	8.427	10.361	11.737	10.641
SR	-0.008	0.230	0.474	0.263
Panel C: Announcement Days ($n = 232$)				
mean	12.467	14.040	17.592	14.699
t-stat	(2.23)	(2.37)	(2.76)	(2.60)
skewness	-0.159	-0.157	0.265	-0.062
kurtosis	3.849	4.508	5.860	4.895
SR	1.067	1.133	1.320	1.242
diff	12.506	12.849	14.769	13.375
	(2.20)	(2.13)	(2.27)	(2.32)

-0.04bps on non-announcement days. This 12.51bps is significantly different from zero, with a t-statistic of 2.20. For the high interest rate currency portfolio, the average announcement day return is 17.59bps compared to 2.82bps on non-announcement days; a 14.77bps difference that is significantly different from zero (t-statistic of 2.27). In a pattern mirroring that of the FOMC announcements, the large increases in average returns on BoJ announcement days is not accompanied by an equally large increase in realized risk, as annualized Sharpe ratios are large and economically significant, ranging from 1.07 for pf1 to 1.32 for pf3.

These observations indicate that similar to the results for the U.S., a sizable portion of the portfolios' average yearly returns is earned on the BoJ announcement days. For instance, the average yearly return on pf3 is $3.34 \times 252 = 842$bps of which 31% (or $15 \times 17.59 = 264$bps) are earned on the 15 announcement days. Similarly, for the portfolio that is long all currencies and short the Japanese yen (reported in the last column in Table 8), announcement day returns account for 49% of the annualized premium (14.70bps $\times$ $15/1.80$bps $\times$ 252).

We end this discussion by noting that the similarity between the results for the BoJ and the FOMC should not be considered surprising, as the Japanese yen serves as one of the most prominent funding currencies. In fact, this similarity is in line with our model's prediction, according to which a higher interest rate differential between the funding and investment currencies leads to a larger difference between returns on announcement and non-announcement days.

4.5 Robustness

We conclude this section by running several robustness checks. First, we redo our analysis by using alternative proxies for market participants' uncertainty about monetary policy. Second, we check the impact of transaction costs on the returns. Third, we redo the analysis for truncated data to ensure that our results are not driven by outliers in the sample. Fourth, in a pair of bootstrap exercises, we compute small-sample standard errors (to overcome concerns about sample size) and sample randomly from the distribution of non-announcement returns (to test whether one can generate returns similar in size to those observed on announcement dates). Finally, we check whether other macroeconomic announcements result in similarly large returns as the ones documented for FOMC announcements.

4.5.1 Alternative Measures of Uncertainty

As our first set of robustness checks, we verify that the positive relationship between monetary policy uncertainty and currency excess returns on announcement days we documented above is not driven by our specific choice of uncertainty measure.

In Table 9, we summarize the estimated coefficients from re-running regression (7) using two alternative measures of policy uncertainty: Baker et al.'s (2016) economic policy uncertainty index (EPU) and the cross-sectional standard deviation of forecasts constructed from surveys about the future federal funds rate available from Bloomberg (DiB FF). As the table suggests, similar to our results in Panel B of Table 3, the estimated coefficients on the interaction term (that is, α_3 in equation (7)) are positive and mostly significant.

To test our model's prediction that excess returns increase with exchange rate volatility, we regress portfolio excess returns on the announcement dummy interacted with the realized exchange rate volatility sampled from the high-frequency data at 215pm. The estimated coefficients, also presented in Table 9, are all positive and highly significant, as expected.

Finally, we regress each portfolio's excess returns on the announcement dummy interacted with the VIX index of implied volatility of S&P500 options, which serves as a proxy for market participants' aversion to risk (Pan and Singleton, 2008; Adrian and Shin, 2010). As expected, the corresponding coefficients are all positive and significant. We also replicate this exercise, replacing VIX with the average CDS spreads of the four largest U.S.-based banks active in the FX market. The positive and

Table 9. Alternative Measures of Uncertainty

This table reports the results of time-series regressions of interest rate-sorted currency portfolios on various explanatory variables akin to equation (7). "pf1" and "pf3" denote the portfolios with the lowest and highest interest rate differential vis-à-vis the U.S., respectively. "dol" denotes the portfolio that is short the U.S. dollar and long all other currencies. The dependent variable is the portfolios' excess returns from 4pm to 4pm ET. The announcement dummy takes the value of one on days when the FOMC makes an announcement and zero otherwise. "EPU" is the economic policy uncertainty index of Baker et al. (2016); "DiB FF" is the cross-sectional standard deviation of forecasts constructed from surveys about the future federal funds rate available from Bloomberg; "RV" is realized exchange rate volatility measured over a two-hour window around the time of an FOMC announcement; "VIX" is S&P500 implied volatility; and "CDS" is the average five-year CDS spread of Citibank, JPMorgan, Bank of America, and Goldman Sachs. "EPU", "RV", "VIX", and "CDS" are demeaned and scaled by their respective sample standard deviations. For brevity, the table only reports estimated coefficient for the interaction term. Data runs from January 1, 1994 to December 31, 2013 for all regressions except for the CDS regressions which run from April 1, 2001 to December 31, 2010. Newey and West (1987) t-statistics are in parentheses.

	pf1					pf2				
EPU × ann dummy	6.531					6.073				
	(1.94)					(1.83)				
DiB FF × ann dummy		0.231					0.419			
		(1.49)					(2.73)			
RV × ann dummy			18.161					23.713		
			(4.17)					(5.25)		
VIX × ann dummy				17.900					20.845	
				(4.10)					(4.84)	
CDS × ann dummy					8.206					11.943
					(1.54)					(1.99)
constant	-0.502	-0.508	-0.712	-0.502	0.579	0.206	0.275	-0.047	0.214	0.936
	(-0.62)	(-0.63)	(-0.86)	(-0.62)	(0.60)	(0.26)	(0.35)	(-0.06)	(0.27)	(0.86)
Adj. R^2	0.06%	0.03%	0.41%	0.33%	0.17%	0.19%	0.14%	1.00%	1.03%	0.44%
	pf3					dol				
EPU × ann dummy	6.111					6.238				
	(1.53)					(2.01)				
DiB FF × ann dummy		0.468					0.373			
		(2.53)					(2.60)			
RV × ann dummy			32.490					24.788		
			(5.87)					(5.88)		
VIX × ann dummy				28.113					22.286	
				(5.42)					(5.53)	
CDS × ann dummy					17.680					12.610
					(2.33)					(2.25)
constant	1.757	1.776	1.405	1.750	2.870	0.487	0.514	0.215	0.488	1.462
	(1.83)	(1.86)	(1.34)	(1.83)	(2.08)	(0.65)	(0.69)	(0.27)	(0.66)	(1.43)
Adj. R^2	0.14%	0.12%	1.08%	1.27%	0.33%	0.17%	0.12%	1.03%	1.05%	0.41%

Table 10. Currency Portfolio Returns Net Transaction Costs on Announcement Days

This table reports summary statistics of currency portfolios' returns on announcement days net of transaction costs. Portfolios are sorted according to their interest rate differentials, with "pf1" and "pf3" denoting the portfolio with the lowest and highest interest rate differential vis-à-vis the U.S., respectively. "dol" denotes the portfolio that is short the U.S. dollar and long all other currencies. "S1" and "S2" are the improved trading strategies constructed in Subsection 4.3. "bootstrap CI" indicates the 95% bootstrapped confidence interval. "SR" is the Sharpe ratio. All numbers are expressed in daily bps except for Sharpe ratios, which are annualized, taking into account the annual frequency of FOMC announcements (8/252). Returns are sampled from 4pm to 4pm ET and cover the period January 1, 1994 to December 31, 2013.

	pf1	pf2	pf3	dol	S1	S2
mean	2.129	9.671	12.246	8.015	15.708	19.154
t-stat	(0.44)	(2.02)	(2.10)	(1.69)	(3.29)	(3.50)
bootstrap CI	[-7.16 , 11.97]	[0.75 , 19.37]	[1.13 , 23.83]	[0.07 , 17.58]	[6.83 , 25.35]	[8.85 , 30.40]
skewness	1.490	1.544	1.306	1.761	1.750	1.571
kurtosis	7.183	10.101	8.307	9.567	8.655	8.038
SR	0.097	0.451	0.470	0.377	0.735	0.783

significant coefficients on the interaction term documented in Table 9 indicate that excess returns increase when spreads widen.

4.5.2 Transaction Costs

To account for possible transaction costs, we construct the portfolios' net returns on announcement days by adjusting for bid-ask spreads. The net excess return of a currency that enters a portfolio at t and exits at $t+1$ is computed as $rx_{t+1}^{\text{long}} = fw_t^{\text{bid}} - s_{t+1}^{\text{ask}}$ for a long position and $rx_{t+1}^{\text{short}} = -fw_t^{\text{ask}} + s_{t+1}^{\text{bid}}$ for a short position.

The results are reported in Table 10. As the table indicates, even though mean returns are lower than those reported in Panel C of Table 2, our results remain qualitatively the same: mean returns are increasing in interest rate differentials and are significant for all portfolios except for pf1 (as illustrated by asymptotic t-statistics as well as bootstrap confidence intervals). For instance, average announcement day returns for pf2 and pf3 are 9.67bps and 12.24bps, respectively, both of which are statistically significant at the 5% level. As expected, the average returns of the improved trading strategies S1 and S2 are even higher and more statistically significant.

4.5.3 Truncated Data

Given that currency returns occasionally experience large crashes and some announcements are more anticipated than others, one may suspect that our results are driven by a few outliers. To test for the sensitivity of our results to such outliers, we study announcement and non-announcement day returns after discarding the top and bottom percentiles of the data. The results are reported in Table 11. We find virtually no distinction between the means and standard deviations of truncated and non-truncated samples (reported in Table 2) across interest rate-sorted portfolios,

Table 11. Summary Statistics for Currency Portfolio Returns for Truncated Data

This table reports summary statistics of currency portfolios for non-announcement (Panel A) and announcement days (Panel B) for a truncated sample after removing the the bottom and top 1% of the sample. Portfolios are sorted according to their interest rate differentials, with "pf1" and "pf3" denoting the portfolio with the lowest and highest interest rate differential vis-à-vis the U.S., respectively. "dol" denotes the portfolio that is short the U.S. dollar and long all other currencies. "SR" is the Sharpe ratio. All numbers are expressed in daily bps except for Sharpe ratios, which are annualized, taking into account the annual frequency of FOMC announcements (8/252). "diff" indicates the difference between announcement and non-announcement day returns in basis points (bps), with the corresponding t-statistic for a test of difference in means between announcement and non-announcement days reported in parentheses. Returns are sampled from 4pm to 4pm ET and cover the period January 1, 1994 to December 31, 2013.

	pf1	pf2	pf3	dol
Panel A: Non-Announcement Days ($n = 4,421$)				
mean	-0.508	0.202	1.947	0.537
t-stat	(-0.67)	(0.27)	(2.22)	(0.77)
skewness	0.131	-0.136	-0.193	-0.034
kurtosis	3.280	3.533	4.088	3.485
SR	-0.156	0.063	0.516	0.179
Panel B: Announcement Days ($n = 157$)				
mean	4.817	13.387	13.520	10.800
t-stat	(1.00)	(2.94)	(2.45)	(2.35)
skewness	1.361	1.230	1.262	1.705
kurtosis	6.617	7.582	7.116	8.869
SR	0.224	0.657	0.549	0.525
diff	5.325	13.185	11.573	10.262
	(1.29)	(3.26)	(2.43)	(2.69)

thus indicating that our results are not driven by a few outliers.

4.5.4 Bootstrapped Standard Errors and Random Sampling

Bootstrapped standard errors: A natural concern for the results reported in Table 3 is that, due to the small number of announcement days (160), asymptotic theory may not provide a good approximation for the distribution of the estimates. We address this concern with a bootstrap exercise, in which we compute the small-sample standard errors and confidence intervals of the point estimates in our baseline regression. In particular, we draw with replacement from the empirical distribution of returns on all days, run regression (6), and store the estimated coefficients for each portfolio. The resulting distributions have means that are virtually the same as the estimated coefficients for α_1 reported in Panel A of Table 3, with bootstrapped confidence intervals that never encompass zero, except for pf1.

Table 12. Bootstrap Exercise for Currency Portfolios

This table reports the likelihood of observing an average return as large as average announcement day returns in a sample drawn from the empirical distribution of returns on non-announcement days. Portfolios are sorted according to their interest rate differentials, with "pf1" and "pf3" denoting the portfolio with the lowest and highest interest rate differential vis-à-vis the U.S., respectively. "dol" denotes the portfolio that is short the U.S. dollar and long all other currencies. "entire day", "pre-ann", and "post-ann" correspond to 4pm–4pm, 4pm–215pm, and 215pm–4pm time windows, respectively. Data runs from January 1, 1994 to December 31, 2013.

	Before Transaction Costs				Ex Transaction Costs			
	pf1	pf2	pf3	dol	pf1	pf2	pf3	dol
entire day	9.13%	0.16%	0.58%	0.46%	9.31%	0.16%	0.58%	0.48%
pre-ann.	18.48%	0.56%	2.48%	2.00%	18.41%	0.56%	2.48%	2.07%
post-ann.	1.53%	2.05%	1.19%	0.60%	2.48%	3.05%	1.37%	0.88%

Random Sampling from non-Announcement Day Distribution: In another bootstrap exercise, we assess the likelihood of observing an average return as large as average announcement day returns in a sample drawn from the empirical distribution of returns on all other days. More specifically, we draw with replacement a time-series with length equal to the number of announcement days (160) from the empirical distribution of non-announcement day returns. Table 12 reports the associated likelihoods for the entire day and the pre- and post-announcement windows. It is evident that, except for the total and pre-announcement returns of pf1, all values are below 5%, indicating that the likelihood of earning equally large returns on non-announcement days as on announcement days is small. The table also illustrates that this pattern remains unchanged whether or not transactions costs are taken into account.

4.5.5 Other Macroeconomic Announcements

Are other macroeconomic announcements able to generate equally large returns as those earned on FOMC announcement days? To answer this question, we consider three major U.S. macroeconomic news releases: total non-farm payroll employment, the Producer Price Index, and the Consumer Price Index, all published by the Bureau of Labor Statistics (BLS).[16] We build the corresponding announcement day dummy variables and re-run regression (6) for each of these announcements separately.

The results are reported in Table 13. As the table indicates, the difference between announcement and non-announcement day returns is never statistically different from zero for any of the announcements or interest rate-sorted portfolios. This evidence thus suggests that monetary policy announcements by the Federal Reserve have a unique impact on currency returns that is not shared

[16] We choose these macroeconomic variables as they are more likely to be linked to monetary policy. In unreported results, we also check for other important macroeconomic news announcements such as initial claims for unemployment insurance, the Institute for Supply Management's manufacturing index, and housing starts. We do not find any significant results.

Table 13. Currency Portfolio Returns for Other Macroeconomic Announcements

This table reports excess returns on announcement and non-announcement days for non-farm payroll employment, CPI, and PPI. Portfolios are sorted according to their interest rate differential, with pf1 (pf3) denoting the portfolio with the lowest (highest) interest rate differential vis-à-vis the United States. "dol" denotes the portfolio that is short the U.S. dollar and long all other currencies. "diff" indicates the difference between announcement and non-announcement day returns in basis points (bps), with the corresponding t-statistic for a test of difference in means between announcement and non-announcement days reported in parentheses. The sample covers January 1, 1994 to December 31, 2013.

	Non-Farm Payroll				Consumer Price Index				Producer Price Index			
	pf1	pf2	pf3	dol	pf1	pf2	pf3	dol	pf1	pf2	pf3	dol
Ann.	-6.523	1.824	4.783	0.028	2.220	2.316	3.292	2.609	3.708	5.311	6.861	5.293
	(-1.60)	(0.46)	(1.12)	(0.01)	(0.56)	(0.59)	(0.66)	(0.68)	(1.00)	(1.62)	(1.75)	(1.66)
Non.	-0.386	0.497	2.459	0.857	-0.336	0.818	2.351	0.945	-0.446	0.478	2.127	0.719
	(-0.47)	(0.62)	(2.54)	(1.14)	(-0.41)	(1.02)	(2.43)	(1.25)	(-0.55)	(0.59)	(2.20)	(0.96)
diff	-6.137	1.327	2.324	-0.829	2.556	1.498	0.940	1.665	4.154	4.833	4.734	4.574
	(-1.48)	(0.33)	(0.53)	(-0.22)	(0.63)	(0.38)	(0.19)	(0.43)	(1.10)	(1.43)	(1.17)	(1.40)

by other macroeconomic announcements.

5 Conclusions

In this paper we document that returns to a strategy that is short the U.S. dollar and long other currencies are on average an order of magnitude larger on days that the FOMC makes a monetary policy announcement compared to non-announcement days. This difference is increasing in the forward discount of the currency and becomes larger when the Fed adopts a policy of monetary easing. Moreover, using different proxies of monetary policy uncertainty, we find that currency returns increase when uncertainty is higher.

We interpret these observations through the lens of a minimalistic model of exchange rate determination in imperfect financial markets. Exchange rates in our model are determined by the risk-bearing capacity of financiers who intermediate global demand for currencies. Within this framework, we show that an increase in monetary policy uncertainty due to an impending FOMC announcement increases foreign currencies' excess returns as a compensation to financiers who bear this extra risk. We also show that, consistent with our empirical results, these risk premia are increasing in the foreign currency's interest rate differential vis-à-vis the U.S. Finally, our model predicts that the actual realization of the monetary policy shock at the announcement impacts currency excess returns, with an expansionary (contractionary) policy resulting in higher (lower) returns, a prediction that is in line with what we document empirically.

Appendix: Proofs and Derivations

Throughout the proofs, we use G to denote the common cumulative distribution function of f_t, while using F to denote the standardized (i.e., demeaned and normalized) distribution of $\log(R_1)$. For notational simplicity, we use H to denote the distribution of $f_1 + R_1^{-1}G^{-1}(\alpha_1)$. Note that this distribution can be explicitly expressed in terms of F and G.

Lemma 1. *The representative financier's equilibrium positions are given by*

$$Q_0 = \frac{R^{*2}H^{-1}(\alpha_0) - R_0 f_0(1+R^*)}{R_0\left(1+R^*+R^{*2}\right)} \tag{8}$$

$$Q_1 = \frac{R^*G^{-1}(\alpha_1) + R_1(R_0Q_0 - f_1)}{R_1(R^*+1)}, \tag{9}$$

where $H(x) = \mathbb{P}(f_1 + R_1^{-1}G^{-1}(\alpha_1) \leq x)$.

Proof. Recall from (2) that at period $t \in \{0, 1\}$, the representative financier maximizes her expected profits $\mathbb{E}_t[V_{t+1}]$, subject to the value-at-risk constraint $\mathbb{P}_t(V_{t+1} \leq -\epsilon) \leq \alpha_t$, while taking the exchange rates as given. Suppose that $R^*\mathbb{E}_t[e_{t+1}] > R_te_t$, a statement that we will verify later. Under this assumption, the financier chooses as large of a Q_t as possible. At the same time, it is immediate that increasing Q_t tightens the financier's value-at-risk constraint, which means that the constraint has to bind in equilibrium. Thus, as $\epsilon \to 0$, we have

$$\mathbb{P}_t\left(R^*e_{t+1} \leq R_te_t\right) = \alpha_t. \tag{10}$$

Setting $t = 1$ and replacing for the exchange rates in the above equation from the market clearing conditions (4) and (5) implies that

$$\mathbb{P}\left(f_2 \leq R_1Q_1 + R_1(f_1 + Q_1 - R_0Q_0)/R^*\right) = \alpha_1.$$

Replacing the left-hand side of the above equation with $G(R_1Q_1 + R_1(f_1+Q_1-R_0Q_0)/R^*)$ and solving for Q_1 leads to (9). To verify that Q_1 is indeed positive, note that $R^*G^{-1}(\alpha_1) \geq R^*\underline{f} \geq R_1f_1$. Thus, Q_1 is positive as long as Q_0 is positive, which we verify below.

To obtain the expression for Q_0 in equation (8), set $t = 0$ in (10), replace Q_1 from (9) in terms of Q_0, and substitute for e_0 and e_1 from the market clearing conditions (3) and (4). Following these steps implies that

$$\mathbb{P}\left(f_1 + R_1^{-1}G^{-1}(\alpha_1) \leq R_0Q_0 + R_0(R^*+1)(f_0+Q_0)/R^{*2}\right) = \alpha_0.$$

Replacing the left-hand side of the above equation with $H\left(R_0Q_0 + R_0(R^*+1)(f_0+Q_0)/R^{*2}\right)$ and solving for Q_0 thus leads to (8). To verify that $Q_0 \geq 0$, note that $H^{-1}(0) \geq \underline{f}(1+1/R^*)$, which alongside the assumption that $R^*\underline{f} > R_t\overline{f}$ guarantees that $R^{*2}H^{-1}(\alpha_0) > R_0f_0(1+R^*)$.

The proof is complete once we verify that $\Delta_t = R^*\mathbb{E}_t[e_{t+1}] - R_te_t$ is indeed positive in equilibrium.

Replacing for e_1, e_2, Q_0, and Q_1 from equations (4), (5), (8), and (9) implies that

$$\Delta_1 = R^* \mathbb{E}_1[e_2] - R_1 e_1 = R^* d^{-1} \Big(\mathbb{E}_1[f_2] - G^{-1}(\alpha_1) \Big). \tag{11}$$

It is immediate that the right-hand side of the above equality is positive for small enough values of α_1. In fact, it is simply sufficient for α_1 to be smaller than $G(\mathbb{E}[f_2]) = \mathbb{P}(f_2 \leq \mathbb{E}_1[f_2])$. Similarly, replacing for e_0 and e_1, from the market clearing conditions (3) and (4) implies that

$$\Delta_0 = R^* \mathbb{E}_0[e_1] - R_0 e_0 = \frac{R^{*2} d^{-1}}{R^* + 1} \Big(\mathbb{E}_0[f_1] + \mathbb{E}_0[R_1^{-1}] G^{-1}(\alpha_1) - H^{-1}(\alpha_0) \Big), \tag{12}$$

which is positive for small enough values of α_0, thus completing the proof. □

Lemma 2. *Q_0 and Q_1 are decreasing in σ_R.*

Proof. Recall from equation (9) that Q_1 is increasing in Q_0, which is itself increasing in $H^{-1}(\alpha_0)$, as is evident from (8). Therefore, it is sufficient to prove that $H^{-1}(\alpha_0)$ is decreasing in σ_R.

To this end, let $F(r)$ denote the probability that $\log(R_1)$ is r standard deviations above its mean; that is, $F(r) = \mathbb{P}(\log R_1 \leq \log R_0 + r\sigma_R)$, where recall that by assumption, $\mathbb{E}_0[\log(R_1)] = \log(R_0)$. Therefore, if $\tilde{F}(x) = \mathbb{P}(R_1^{-1} \leq x)$ denotes the cumulative distribution function of R_1^{-1}, we have

$$\tilde{F}(x) = \mathbb{P}\left(\log R_1 \geq -\log x\right) = 1 - F\left(\frac{-1}{\sigma_R} \log\left(R_0 x\right)\right). \tag{13}$$

On the other hand, the fact that R_1 and f_2 are independent implies that

$$H(x) = \mathbb{P}(f_1 + R_1^{-1} G^{-1}(\alpha_1) \leq x) = \int_{\underline{f}}^{\min\{\overline{f}, x\}} \tilde{F}\left(\frac{x - y}{G^{-1}(\alpha_1)}\right) dG(y).$$

Setting $x = H^{-1}(\alpha_0)$ and using (13) to replace $\tilde{F}$ in terms of F, we obtain

$$\int_{\underline{f}}^{\min\{H^{-1}(\alpha_0), \overline{f}\}} \left[1 - F\left(\frac{1}{\sigma_R} \log\left(\frac{G^{-1}(\alpha_1)}{R_0(H^{-1}(\alpha_0) - y)}\right)\right)\right] dG(y) = \alpha_0. \tag{14}$$

Differentiating both sides with respect to σ_R and using the Leibniz integral rule leads to

$$\int_{\underline{f}}^{\min\{H^{-1}(\alpha_0), \overline{f}\}} \frac{\partial}{\partial \sigma_R} F\left(\frac{1}{\sigma_R} \log\left(\frac{G^{-1}(\alpha_1)}{R_0(H^{-1}(\alpha_0) - y)}\right)\right) dG(y) = 0, \tag{15}$$

for all σ_R, where recall that even though $H^{-1}(\alpha_0)$ depends on the extent of monetary policy uncertainty, α_0 is a fixed parameter of the model that is independent of σ_R.

Now, suppose that $H^{-1}(\alpha_0)$ is increasing in σ_R for some constellation of parameters. Under such an assumption, the integrand in (15) would be negative, as a higher σ_R would only decrease $\frac{1}{\sigma_R} \log\left(\frac{G^{-1}(\alpha_1)}{R_0(H^{-1}(\alpha_0) - y)}\right)$. But this violates equation (15), which requires the integral to be equal to zero. Therefore, $H^{-1}(\alpha_0)$ is decreasing in σ_R for all σ_R. □

Proof of Proposition 1 Recall that the foreign currency's total expected excess return is given by

$$\begin{aligned}\mathbb{E}_0[\phi] &= 2\log(R^*) - \mathbb{E}_0[\log(R_1)] - \log(R_0) + \mathbb{E}_0[\log(e_2)] - \log(e_0) \\ &= 2\log(R^*) - 2\log(R_0) + \mathbb{E}_0[\log(f_2 - R_1Q_1)] - \log(f_0 + Q_0)\end{aligned}$$

where we are replacing for e_0 and e_2 from the market clearing conditions (3) and (5) and using the fact that $\mathbb{E}_0[\log(R_1)] = \log(R_0)$. On the other hand, recall from Lemma 2 that Q_0 and Q_1 are decreasing in σ_R, thus implying that the right-hand side of the above expression is increasing in σ_R. □

Proof of Proposition 2 Market clearing conditions (3) and (5) imply that the foreign currency's total excess returns are given by

$$\phi = \log\left(\frac{R^{*2}(f_2 - R_1Q_1)}{R_1R_0(f_0 + Q_0)}\right).$$

Replacing for Q_0 and Q_1 from (8) and (9) leads to

$$\phi = \log\left(1 + \frac{R^{*2} + R^* + 1}{R_0f_0 + H^{-1}(\alpha_0)}\left(\frac{f_2 - G^{-1}(\alpha_1)}{R_1} + \frac{f_1 + R_1^{-1}G^{-1}(\alpha_1) - H^{-1}(\alpha_0)}{R^* + 1}\right)\right),$$

thus implying that

$$\mathbb{E}_0[\phi] = \frac{R^{*2} + R^* + 1}{R_0f_0 + H^{-1}(\alpha_0)}\left(\mathbb{E}_0[R_1^{-1}]\left(\mathbb{E}_0[f_2] - G^{-1}(\alpha_1)\right) + \frac{\mathbb{E}_0[f_1] + \mathbb{E}_0[R_1^{-1}]G^{-1}(\alpha_1) - H^{-1}(\alpha_0)}{R^* + 1}\right)$$

up to a first-order approximation. Now the fact that $\Delta_0 = \mathbb{E}_0[f_1] + \mathbb{E}_0[R_1^{-1}]G^{-1}(\alpha_1) - H^{-1}(\alpha_0)$ and $\Delta_1 = \mathbb{E}_0[f_2] - G^{-1}(\alpha_1)$ given in (12) and (11) are positive guarantees that $\mathbb{E}_0[\phi]$ is increasing in R^*. In particular,

$$\frac{\partial\mathbb{E}_0[\phi]}{\partial R^*} = \frac{\Delta_1(2R^* + 1)\mathbb{E}_0[R_1^{-1}]}{R_0f_0 + H^{-1}(\alpha_0)} + \frac{\Delta_0R^{*2}(R^* + 2)}{(R^* + 1)^2(R_0f_0 + H^{-1}(\alpha_0))}, \tag{16}$$

which is always positive.

To prove the second statement, note that the first term on the right-hand side of (16) is decreasing in $H^{-1}(\alpha_0)$, which is itself decreasing in σ_R (as proved in Lemma 2). Consequently, the first-term on the right-hand side of (16) is increasing in σ_R. As for the second term, note that its denominator is increasing in $H^{-1}(\alpha_0)$, whereas Δ_0 defined in (12) is decreasing in $H^{-1}(\alpha_0)$. As a result, the second term on the right-hand side of (16) is also decreasing in $H^{-1}(\alpha_0)$ and hence increasing in σ_R. Taken together, these observations imply that $\partial^2\mathbb{E}_0[\phi]/\partial R^*\partial\sigma_R$ is positive. □

Proof of Proposition 3 Recall that, by definition, $\phi_2 = \log(R^* e_2) - \log(R_1 e_1)$. Replacing for e_1 and e_2 from the market clearing conditions (4) and (5) implies that

$$\phi_2 = \log\left(1 + \frac{(R^*+1)(f_2 - G^{-1}(\alpha_1))}{G^{-1}(\alpha_1) + R_1(f_1 - R_0 Q_0)}\right),$$

where we are also using (9) to replace Q_1 in terms of Q_0. Therefore,

$$\mathbb{E}_1[\phi_2] = \frac{(R^*+1)(\mathbb{E}_1[f_2] - G^{-1}(\alpha_1))}{G^{-1}(\alpha_1) + R_1(f_1 - R_0 Q_0)} \tag{17}$$

up to a first-order approximation. Recall from the proof of Lemma 1 that $\Delta_1 = \mathbb{E}_1[f_2] - G^{-1}(\alpha_1)$ is positive. Therefore, $\mathbb{E}_1[\phi_2]$ is decreasing in R_1 as long as $f_1 > R_0 Q_0$. To verify this inequality, note that

$$f_1 - R_0 Q_0 = \frac{1}{R^{*2} + R^* + 1}\Big(f_1(R^{*2} + R^* + 1) + R_0 f_0 (1 + R^*) - R^{*2} H^{-1}(\alpha_0)\Big),$$

where we are using equation (8). It is now immediate that the right-hand side of the above equation is positive for small enough values of α_0, thus establishing $\mathbb{E}_1[\phi_2]$ is decreasing in R_1.

To prove the second statement, note that (17) implies

$$\frac{\partial \mathbb{E}_1[\phi_2]}{\partial R_1} = \frac{(R^*+1)(\mathbb{E}_1[f_2] - G^{-1}(\alpha_1))(R_0 Q_0 - f_1)}{\left(G^{-1}(\alpha_1) + R_1 f_1 - R_1 R_0 Q_0\right)^2}.$$

Furthermore, recall from Lemma 2 that Q_0 is decreasing in σ_R. Therefore, it is immediate that increasing σ_R reduces the numerator while increasing the denominator, thus implying that the right-hand side of the above equality is decreasing in σ_R. □

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A Online Appendix: Individual Currencies

This appendix reproduces the paper's main tables for the individual currencies in our sample.

Pre- and Post-Announcement Returns Table A1 reports the results of regressing individual currency returns on the announcement dummy, over three different time windows: the entire day (4pm–4pm), the pre-announcement window (4pm–215pm), and the post-announcement window (215pm–4pm). The results for the entire day, reported in Panel A, are in line with those presented in Table 1 in the main body of the paper: the difference between announcement and non-announcement day returns is statistically different from zero for all currencies except for the Japanese yen and the Norwegian krona. Panels B and C report the estimated coefficients for the announcement dummy for returns over the pre- and post-announcement windows, respectively. As the table indicates (and consistent with our results for interest rate-sorted portfolios in Table 4), the difference between announcement and non-announcement day returns is positive and significant for a majority of the individual currencies over both time windows.

Post-Announcement Returns and Monetary Policy Table A2 provides the results of regressing individual currencies' returns over the post-announcement window on the announcement dummy interacted with our indicator of monetary policy shock. Recall that by Proposition 3, the difference between announcement and non-announcement day returns over the post-announcement window should increase if the Fed adopts an expansionary policy. As the results illustrate, all estimated coefficients are positive and significant as expected. These results are also consistent with the corresponding results for interest rate-sorted portfolios reported in Table 6.

Transaction Costs Table A3 reports the summary statistics of individual currencies' returns after taking transaction costs into account by adjusting for bid-ask spreads. We note that the numbers are similar to those reported in Table 1 in the main body of the paper: except for the Swedish krona, all currencies that exhibit a significant return before adjusting for transaction costs have positive and significant returns after the adjustment.

Bootstrap Exercise Table A4 replicates the bootstrap exercise in Table 12 for the individual currencies in our sample. In particular, we draw with replacement a time-series with length equal to the number of announcement days (160) from the empirical distribution of non-announcement day returns and report the probability of observing a mean greater than the corresponding value on announcement days. We note that most probabilities are below 10%, except for Japanese yen and Norwegian Krona, which are the two currencies that do not exhibit a significant difference between

Table A1. Pre- and Post-Announcement Returns of Individual Currencies

This table reports the results of time-series regressions of individual currency returns for different time windows. The dependent variable is the currencies' excess return from 4pm to 4pm (Panel A), from 4pm to 215pm (Panel B), and from 215pm to 4pm (Panel C). The announcement dummy takes the value of one on days when the FOMC makes an announcement and zero otherwise. Data runs from January 1, 1994 to December 31, 2013. Numbers in parentheses denote Newey and West (1987) t-statistics.

	AUD	CAD	CHF	EUR	GBP	JPY	NOK	NZD	SEK
				Panel A: Entire Day (4pm–4pm)					
constant	1.163	0.421	-0.108	-0.050	0.155	-0.973	0.677	1.745	0.641
	(0.98)	(0.55)	(-0.10)	(-0.05)	(0.19)	(-0.92)	(0.61)	(1.48)	(0.56)
ann dummy	16.120	16.271	9.615	10.186	13.297	-3.351	6.688	13.920	9.789
	(2.51)	(3.96)	(1.69)	(1.96)	(2.95)	(-0.59)	(1.12)	(2.19)	(1.64)
Adj. R^2	0.11%	0.31%	0.04%	0.06%	0.16%	-0.01%	0.01%	0.08%	0.03%
				Panel B: Pre-Announcement Window (4pm–215pm)					
constant	0.527	0.093	-0.715	-0.583	-0.696	-0.522	0.131	1.686	0.275
	(0.46)	(0.13)	(-0.69)	(-0.62)	(-0.84)	(-0.50)	(0.12)	(1.50)	(0.25)
ann dummy	11.002	11.601	6.700	8.207	13.766	-1.979	3.446	11.203	7.215
	(1.79)	(2.92)	(1.19)	(1.62)	(3.08)	(-0.35)	(0.59)	(1.84)	(1.20)
Adj. R^2	0.05%	0.16%	0.01%	0.03%	0.18%	-0.02%	-0.01%	0.05%	0.01%
				Panel C: Post-Announcement Window (215pm–4pm)					
constant	0.635	0.328	0.606	0.533	0.851	-0.452	0.545	0.059	0.367
	(1.87)	(1.54)	(2.55)	(2.30)	(4.28)	(-1.90)	(1.99)	(0.16)	(1.32)
ann dummy	5.118	4.670	2.915	1.979	-0.470	-1.373	3.243	2.717	2.574
	(2.78)	(4.08)	(2.27)	(1.58)	(-0.44)	(-1.07)	(2.19)	(1.38)	(1.72)
Adj. R^2	0.14%	0.33%	0.09%	0.03%	-0.02%	0.00%	0.08%	0.02%	0.04%

announcement and non-announcement returns as in Table 1 in the main body of the paper. This pattern remains unchanged whether or not transactions costs are taken into account.

Table A2. Monetary Policy Shock and Post-Announcement Returns of Individual Currencies

This table reports the results of time-series regressions of individual currency returns for the post-announcement window. The dependent variable is the currencies' excess return from 215pm to 4pm. The announcement dummy takes a value of one on days when the FOMC makes an announcement and zero otherwise. "MPI" is Nakamura and Steinsson's (2015) indicator of monetary policy shock. Data runs from January 1, 1994 to December 31, 2013. Numbers in parentheses denote Newey and West (1987) t-statistics.

	AUD	CAD	CHF	EUR	GBP	JPY	NOK	NZD	SEK
constant	0.635	0.328	0.606	0.533	0.851	-0.452	0.545	0.059	0.367
	(1.88)	(1.55)	(2.60)	(2.35)	(4.35)	(-1.91)	(2.01)	(0.16)	(1.33)
ann dummy	5.966	5.187	4.068	3.100	0.437	-0.665	4.308	3.531	3.484
	(3.25)	(4.54)	(3.23)	(2.52)	(0.41)	(-0.52)	(2.94)	(1.80)	(2.34)
MPI $\times$ ann dummy	2.409	1.468	3.273	3.182	2.573	2.010	3.022	2.309	2.583
	(6.85)	(6.70)	(13.55)	(13.50)	(12.67)	(8.20)	(10.77)	(6.13)	(9.05)
Adj. R^2	1.12%	1.26%	3.85%	3.77%	3.29%	1.40%	2.48%	0.80%	1.74%

Table A3. Summary Statistics of Individual Currency Returns Net Transaction Costs

This table reports summary statistics of individual currency returns on announcement days net of transaction costs. Boot CI indicates bootstrapped 95% confidence intervals, and SR is the Sharpe ratio. All numbers are expressed in daily bps except for Sharpe ratios, which are annualized taking into account the annual frequency of FOMC announcements (8/252). Returns are sampled from 4pm to 4pm ET and cover the period January 1, 1994 to December 31, 2013.

	AUD	CAD	CHF	EUR	GBP	JPY	NOK	NZD	SEK
mean	17.256	14.042	7.320	9.653	12.502	-7.191	0.390	14.949	5.751
t-stat	(2.42)	(2.78)	(1.06)	(1.76)	(2.58)	(-1.29)	(0.06)	(2.11)	(0.96)
boot CI	[5.22 28.93]	[6.09 22.64]	[-3.29 19.52]	[0.68 19.21]	[4.25 20.35]	[-16.11 2.58]	[-9.11 10.10]	[4.29 27.39]	[-3.37 16.39]
skewness	8.210	18.287	9.456	8.146	6.169	5.236	5.062	7.787	11.474
kurtosis	1.177	2.469	1.545	1.442	0.919	0.700	0.436	1.133	1.666
SR	0.542	0.623	0.237	0.396	0.580	-0.289	0.014	0.474	0.216

Table A4. Bootstrap Exercise for Individual Currencies

This table reports the likelihood of observing an average return as large as average announcement day returns in a sample drawn from the empirical distribution of returns on non-announcement days for the G10 currencies. "entire day", "pre-ann", and "post-ann" correspond to 4pm–4pm, 4pm–215pm, and 215pm–4pm time windows, respectively. Data runs from January 1, 1994 to December 31, 2013.

	AUD	CAD	CHF	EUR	GBP	JPY	NOK	NZD	SEK
Panel A: Before Transaction Costs									
entire day	0.40%	0.00%	3.40%	4.20%	0.00%	70.00%	12.40%	1.20%	5.00%
pre-ann.	3.40%	0.20%	11.40%	6.00%	0.00%	61.00%	26.80%	3.80%	11.60%
post-ann.	0.00%	0.00%	0.20%	4.00%	0.67%	88.20%	1.40%	5.60%	3.00%
Panel B: Ex Transaction Costs									
entire day	1.20%	0.00%	3.60%	1.60%	0.20%	70.40%	10.00%	1.80%	5.40%
pre-ann.	4.20%	0.00%	10.20%	3.60%	0.20%	62.20%	24.40%	3.20%	11.00%
post-ann.	1.00%	0.00%	0.40%	4.40%	0.69%	88.80%	2.20%	6.60%	4.80%