US Interest Rate Surprises and Currency Returns

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June 2, 2023

Abstract

Currencies that are more exposed to US monetary policy yield positive average excess returns. This result holds both for pure monetary policy shocks and for central bank information shocks, identified via sign restrictions on interest rate surprises using high-frequency data. Currency characteristics help explain the heterogeneity of these exposures across currencies and time. We then build exposure indices to gauge this effect around policy announcements. Long-short trading strategies that condition on such exposure indices display significant excess returns after controlling for dollar, carry and momentum factors.

Keywords: Foreign exchange; monetary policy shocks; central bank information shocks; interest rate differentials; carry.

JEL Classification Numbers: F31, G12, G15.

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1 Introduction

Since the global financial crisis, there has been renewed interest in understanding how monetary policy transmits across countries and drives the movement in the cross-section of asset returns worldwide. It is widely accepted that monetary policy in the US has significant spillovers to the rest of the world, generating strong co-movements of asset prices across countries (e.g., Miranda-Agrippino and Rey, 2020; Brusa et al., 2020). Nowhere is this topic more central than in the foreign exchange market, given the close link between currency movements and monetary policy in theoretical models of exchange rate determination. However, the effect of monetary policy on the cross-section of currency returns is not fully understood.[1] Do all currencies move in the *same direction* in response to US monetary policy actions? Do some currencies respond *more strongly* than others? And, whatever the answers are to the above questions, what country characteristics determine the sign and magnitude of currencies' exposures to US monetary policy?

In this paper, we provide answers to the above questions. A natural first step would be to analyze the behavior of currency returns on a tight window around monetary policy announcements (Rogers et al., 2014, 2018). However, the recent literature in macroeconomics emphasizes that central bank announcements do not only contain information about changes in monetary policy, but also information about the policymakers' reassessment of the (future) state of the economy (Nakamura and Steinsson, 2018; Jarociński and Karadi, 2020).

[1] Recent literature has focused on the factor structure of exchange rates and how this is related to expected returns; see, e.g., Lustig et al. (2011); Menkhoff et al. (2012a); Verdelhan (2018); Maurer et al. (2019); Panayotov (2020); Korsaye et al. (2021); Aloosh and Bekaert (2022); Jiang and Richmond (2023).

This literature has developed methods to disentangle pure *monetary policy shocks* —changes in the stance of policy independent of current or expected macroeconomic conditions— from simultaneous *central bank information shocks* — changes in interest rates that reveal the central bank's new assessment of future economic activity— contained in central bank announcements. In essence, the conflation of these two types of shocks in interest rate surprises may bias inference on the impact of monetary policy on asset prices. Hence, we focus on the heterogeneous impact of US monetary policy on currencies as follows. First, we decompose interest rate surprises into orthogonal monetary policy shocks and information shocks. Following Jarociński and Karadi (2020), we break down the surprise changes in interest rates around the Federal Open Market Committee's (FOMC) announcements into the two types of shocks by analyzing the comovement of interest rates and stock prices during the announcement window. Second, we regress currency returns on these two structural shocks, interacted with time-varying country characteristics to obtain an "exposure index" (EXP) for each shock and for every currency. Interacting the shocks with the currency characteristics allows for a parsimonious modeling of time-varying exposures to the shocks, following the seminal work of Shanken (1990). Finally, we evaluate the economic magnitude of these effects by building long-short portfolios that sort currencies on EXP and analyze their out-of-sample performance.

A key contribution of the paper is the disentangling of the effects on currencies of monetary policy shocks from other contemporaneous effects, particularly central bank information shocks. The separation of the two components turns out to be crucial as a positive information shock signals an improvement in economic activity, thus offsetting the impact of tightening monetary policy, whereas monetary policy shocks lead to tighter monetary policy and weaker economic activity. As an illustration of their distinct effect on exchange rates, Figure 1 reports the results of running simple univariate regressions of currency returns around the announcement window on the "total" interest rate surprises, as well as on the two shocks (pure monetary policy shocks, and central bank information shocks) separately.[2] The estimated coefficients on the different variables capture the heterogeneous response of each currency to each type of shock as well as the interest rate surprise itself, which can be thought of as a convolution of the two primitive shocks. The figure offers two takeaways.[3]

First, we find that the average response of currencies to interest rate surprises is negative and the magnitude of the response appears fairly homogeneous across currencies (red circles, Figure 1). However, the decomposition of interest rate surprises in monetary policy shocks (green triangles) and information shocks (blue squares) reveals that responses of currencies to both shocks are highly heterogeneous and generally of different signs. Specifically, foreign currencies tend to depreciate with contractionary US monetary policy shocks, which is in line with the vast literature on the effect of monetary policy on exchange rates (e.g., Kim et al., 2017; Rogers et al., 2018). In contrast, foreign currencies appreciate in response to a positive information shock. Hence, the positive information shock about the macroeconomic outlook may command

[2]We focus on exchange rates against the US dollar for the following 16 countries/regions: Australia, Brazil, Canada, Czech Republic, Euro Area, United Kingdom, Hungary, Japan, Mexico, Norway, New Zealand, Poland, Singapore, South Africa, Sweden, and Switzerland.

[3]Figure C.2 in the Internet Appendix reports the estimated country-specific average responses with 90 percent confidence interval based on Newey-West standard errors.

an offsetting effect on the accompanying rise in interest rate. As a consequence, we observe that foreign currencies can appreciate or depreciate depending on which effect dominates, and the effect is different across currencies. Overall, currencies tend to depreciate on tightening policy shocks but tend to appreciate when there are contemporaneous positive information shocks.[4]

The second takeaway is that fundamental variables, e.g. interest rate differentials, help explain the heterogeneity in the currencies' responses. To illustrate this, Figure 1 plots country-specific average responses against interest rate differentials. Despite the large difference in their average interest rate level, the Japanese yen (a safe haven currency) and the Brazilian real (a much riskier currency) react similarly to a 1% change in the US policy rate, depreciating by 4.34% and 5.11%, respectively. This surprising finding occurs because the policy rate innovations do not disentangle the monetary policy shocks from the information shocks. The impact of monetary policy on currencies is thus underestimated because the positive information shocks have offsetting effects. In fact, if we decompose the reaction to the 1% change in the US policy rate into the underlying shocks, the tightening US monetary policy shock is associated with a large (6.51%) depreciation in the Brazilian real. In contrast, the contribution of the central bank information shock is associated with around a 1.40% appreciation in the Brazilian real. On the contrary, low interest rate currencies like the Japanese yen react much less to both policy and information

[4]The currency responses on the two decomposed policy shocks are consistent with the currency excess returns decomposition in Froot and Ramadorai (2005). A contractionary US monetary policy is likely associated with lower future consumption growth, which leads to higher marginal utility, resulting in a rise in risk premia. By decomposition, increased interest rates and future expected returns could be potential drivers behind the observed dollar appreciation with tightening policy shocks. In contrast, a positive information shock about the macroeconomic outlook may be related to higher future consumption growth and lower marginal utility, indicating a decrease in risk premia. In the decomposition, reduced risk premia can lead to foreign currency appreciation. Thus, the behavior of the foreign currency on the impact of positive information shocks could be affected by the offsetting forces from both a potential reduction in risk premia and a rise in interest rates, leading to the observed heterogeneous responses.

shocks (-3.74% and -0.60%).

The above empirical observations illustrate that currencies around the world have different exposures—in terms of both sign and magnitude—to US monetary policy actions, and that these exposures appear related to currency characteristics such as the interest rate differential. Therefore, we construct a monetary policy exposure index that captures the cross-sectional and time-series differences in the sensitivities across currencies. Specifically, our regressions use the cross-product of the policy-related variables with currency characteristics linked to policy sensitivity. This approach to incorporating time variation exposure follows the seminal work by Shanken (1990), and builds on the methods of Pástor and Stambaugh (2003) and Ozdagli and Velikov (2020). The characteristics underlying the EXP index in our regressions include interest rate differentials, trend inflation differentials, the ratio of net foreign assets (NFA) over gross domestic product (GDP), the stock market beta of the currency, and a measure of "trade network centrality" that measures countries' exposure to global shocks. We show that currencies tend to be more reactive to US monetary policy if they are associated with net borrowers countries, more peripheral in the global trade network, characterized by higher average interest rates, and more exposed to aggregate equity risk.

Finally, we evaluate the economic magnitude of the monetary policy effects by building long-short portfolios that sort currencies by the EXP indices and analyze their performance. We find that the EXP index is a strong predictor of returns in the cross-section of currencies. Specifically, currencies that are more sensitive to FOMC announcements (i.e., those that perform worse when there is a tightening policy shock and those that perform better when there is a positive information shock) have significantly higher average returns than less sensitive currencies. A long-short trading strategy designed to exploit this effect achieves an annualized return of 5.27% with an annualized Sharpe Ratio of 0.72 in an out-of-sample exercise from 2009 to 2019. The strategy earns an annualized abnormal return of 3.52% even after controlling for the dollar and carry factors of Lustig et al. (2011) and for a currency momentum factor of Menkhoff et al. (2012b). Overall, the performance of the exposure strategy indicates that the effect of monetary policy is economically important even in the low interest rate environment post-2009. Thus, investors earn excess returns from holding currencies that are more sensitive to US monetary policy.

Related literature We contribute to the extensive literature on the effects of monetary policy on exchange rates. The well-known overshooting hypothesis of Dornbusch (1976) predicts that a monetary tightening leads to an impact appreciation followed by a persistent depreciation of the domestic currency. However, empirical studies (e.g. Eichenbaum and Evans, 1995; Scholl and Uhlig, 2008) document puzzling evidence of "delayed overshooting", where the domestic currency experiences a persistent (instead of immediate) appreciation. Kim et al. (2017) investigate different monetary policy regimes. They argue that the delayed overshooting puzzle is a phenomenon of the 1980s when the uncovered interest parity (UIP) failed, but it was severe enough to contaminate the entire sample period. During the post-Volcker era, exchange rates overshoot immediately on the impact of monetary policy shocks. In related work, Rogers et al. (2014, 2018) find that US monetary policy easing surprises lead to immediate dollar depreciation using intraday data. By taking a cross-sectional perspective, we contribute to this literature by not only examining the effect of monetary policy on the aggregate dollar exchange rate but also the heterogeneous responses of individual country pairs.

This paper also contributes to the literature that assesses the impact of high-frequency financial-market surprises around key monetary policy announcements on asset prices (Kuttner, 2001; Gürkaynak et al., 2005; Bernanke and Kuttner, 2005). This literature uses financial market responses to central bank announcements to identify monetary policy shocks and assess the causal impact of policy. However, Miranda-Agrippino (2016) Nakamura and Steinsson (2018) and Jarociński and Karadi (2020), among others, demonstrate that policy announcements come with central bank communication about their assesment of the economic outlook, which can bias the estimated effects of monetary policy. In this paper, we follow Jarociński and Karadi (2020) and combine high-frequency identification and sign restrictions (Faust, 1998; Canova and De Nicolo, 2002; Uhlig, 2005) to separate the monetary policy shock from the impact of the central bank information shocks. Our contribution is to investigate the purged (or simply "pure") monetary policy's effect on currencies.

The third strand of related literature uses indices based on time-varying firm characteristics to study the cross-section of stock returns. The pioneering work of Shanken (1990) allows asset betas to vary over time with the levels of the state variables using interaction terms. Similarly, Pástor and Stambaugh (2003) use stock-level characteristics to predict firms' exposure to aggregate liquidity risk, while Ozdagli and Velikov (2020) create an index of monetary policy exposure in the stock market. In the context of the currency market, Dedola et al. (2017) find no systematic pattern in country responses (e.g. in asset prices and capital flows) to US monetary policy when grouping countries by characteristics. We build on these papers to study the impact of monetary policy in the cross-section of currency returns by relying on currency fundamentals linked to the monetary policy transmission channels of exchange rates.

2 Deconstructing Interest Rate Surprises around Monetary Policy Announcements

In line with the literature, we define here the monetary policy rate *surprises* as the interest rates changes in a narrow window around FOMC announcements (e.g., Kuttner, 2001; Gürkaynak et al., 2005; Nakamura and Steinsson, 2018). To reduce reliance on any specific interest rate contract in the computation of the interest rate surprise, Nakamura and Steinsson (2018) use a composite measure of policy surprises computed as the first principal component of changes in interest rates at different maturities spanning the first year of the term structure. This measure captures not just instantaneous changes in the federal funds rate, but also "forward guidance" about interest rate changes in subsequent meetings.

While it may be tempting to use these surprises as a proxy for monetary policy shocks, the empirical macroeconomics literature has widely documented that central bank announcements can simultaneously convey information about both monetary policy and the central bank's assessment of the economic outlook (see, e.g. Miranda-Agrippino, 2016; Nakamura and Steinsson, 2018; Miranda-Agrippino and Ricco, 2021; Jarociński and Karadi, 2020, among others.). Jarociński and Karadi (2020) identify these two components from the high-frequency co-movement of stock prices and interest rates in the window around the FOMC announcement and document their different effect on macroeconomic aggregates. Their strategy is based on the recognition that a broad range of theoretical models would suggest that a pure monetary policy tightening unambiguously leads to lower stock market valuations because both the present value of future dividends declines *and* the discount rate increases. By definition, the same shock leads to an increase in interest rates. These clear sign restrictions identify a monetary policy shock through a negative co-movement between interest rates and stock price changes during the announcement. By contrast, were we to observe a positive co-movement between stock prices and interest rates during the announcement, this must reflect something in the central bank's communication that is not news about monetary policy, and that leads to a positive revision to expected future dividends as well as a higher discount rate—what the authors call a central bank information shock. These sign restrictions can be implemented as in Uhlig (2005) to produce an orthogonal decomposition of the total interest rate surprises into the contribution of the two distinct shocks.

2.1 High-Frequency Monetary Policy Surprises

Our policy rate surprise uses an updated version of the data for "policy news shocks" in Nakamura and Steinsson (2018). Over the period from January 1996 to March 2014, we use the data available on Emi Nakamura's website.[5] We extend the original series to July 2019 following the same methodology, using

[5] https://eml.berkeley.edu/~enakamura/papers.html.

the first principal component of the change in five interest rates.

The first of these rate changes is the change in market expectations of the federal funds rate over the remainder of the month in which the FOMC meeting occurs. To construct this variable, we use data on the price of the federal funds futures for the month in question. The second variable used in constructing the policy rate surprise is the change in the expected federal funds rate at the time of the next scheduled FOMC meeting. The last three variables used are the change in the price of three eurodollar futures at the time of the FOMC announcements. We use eurodollar futures at horizons of one, two, and three quarters in the future. We collect the tick-by-tick transaction prices from TickWrite. The scale of the policy news shock is arbitrary. Consistent with Nakamura and Steinsson (2018), we rescale it such that its effect on the one-year nominal Treasury yield is equal to one. The unit of policy rate surprise is in percentage points.

2.2 Estimation of a VAR with Policy Rate Surprise

Similar to Jarociński and Karadi (2020), we separate monetary policy shocks from contemporaneous information shocks by analyzing the high-frequency co-movement of our policy rate surprises measure and stock prices in the same 30-minute window around the policy announcement. Consider the structural vector autoregression (SVAR) with the following form:

$$A_0 m_t = \varepsilon_t, \tag{1}$$

where m_t is a 2×1 vector of two high-frequency policy surprise variables observed at time t, including the composite interest rate surprise and the S&P

500 stock market index;[6] ε_t is a 2×1 vector of structural shocks; and A_0 is an invertible 2×2 matrix of parameters. The vector ε_t is Gaussian with mean zero and covariance matrix I_2, which is a 2×2 identity matrix.

If we pre-multiply by A_0^{-1}, the reduced-form representation is $m_t = u_t$, where $u_t = A_0^{-1}\varepsilon_t$.[7] The reduced-form interest rate and stock price surprises, u_t are correlated and do not have an economic interpretation, whereas the primitive shocks ε_t are orthogonal and will be interpreted as monetary policy and central bank information shocks.

2.3 High-Frequency Identification and Sign Restrictions

We combine high-frequency identification and sign restrictions in order to identify the structural shocks of interest in the baseline VAR model. Empirically, our two policy surprise variables in vector m_t are both measured in a narrow window of 30 minutes around the announcement. Thus, high-frequency identification allows us to make the assumption that the announcement surprises m_t are affected only by the two shocks (the monetary policy shocks and information shocks) and not by other shocks.

We further use sign restrictions, assuming that a pure monetary policy shock is associated with a positive rate change surprise and a drop in stock prices. In contrast, we assume that a central bank information shock is associated with a positive rate change surprise and an increase in stock prices. Thus,

[6] Our measure of the stock price surprise is the change in the S&P500 futures. We collect the tick-by-tick high-frequency futures data from TickWrite. The change is between 10 minutes before and 20 minutes after the announcement. The price change is in percentage.

[7] Thus, the baseline model is a VAR with a restriction that m_t does not depend on the lags of m_t and has zero mean. These restrictions are reasonable as each observation represents one meeting occurring approximately every six weeks, and there is no reason to expect serial correlation from one meeting to the next or a systematic bias on policy surprises

we assign any negative co-movement shocks as the monetary policy shocks, and any positive co-movement shocks as the central bank information shocks. Orthogonality is a standard requirement of structural shocks. The above framework models the surprises m_t as linear combinations of structural shocks, and the contribution of the two shocks adds up to the total interest rate surprise.

3 Empirical Approach

In this section, we describe how we construct monetary policy exposure indices using the interaction of currency fundamentals with policy-related variables. We show that fundamentals help explain currencies' heterogeneous responses to monetary policy and information shocks. We then discuss the construction of exposure portfolios.

3.1 Estimation of Time-Varying Exposure

We allow for the responses of currencies to monetary policy and information shocks to vary both in the cross-section and in the time series. To do so, we model the shock exposures as a function of time-varying currency characteristics. Specifically, we run panel regressions of the characteristics interacted with the shocks, in a similar spirit to what is done by Pástor and Stambaugh (2003) and Ozdagli and Velikov (2020) in different contexts. Our main specification is

$$r_{it} = \sum_{k=1}^{n} \beta_k Z_{it}^k + \theta_i \text{Shocks}_t + \sum_{k=1}^{n} \gamma_k Z_{it}^k \times \text{Shocks}_t + \text{Country}_i + \text{Meeting}_t + \varepsilon_{it}, \quad (2)$$

where i is the currency identifier, t is the date of the scheduled FOMC meeting, r_{it} is the intraday currency spot return in the 30-minute window surrounding the FOMC press releases,[8] and Shocks_t is one of the structural shocks defined in the previous section.[9] We define exchange rates as units of US dollars per unit of foreign currency such that an increase in spot indicates an appreciation of the foreign currency. The variable Z_{it}^k is the k-th currency characteristic that can help capture the exposure of a currency to monetary policy. The variables Country_i and Meeting_t are country and meeting fixed effects.

Using the coefficient estimates $\hat{\theta}_i$ and $\hat{\gamma}_k$ from Equation (2), our currency exposure (EXP) indices can be estimated as

$$\text{EXP}_{it}^X = \hat{\theta}_i^X + \sum_{k=1}^{n} \hat{\gamma}_k^X \times Z_{it}^k, \tag{3}$$

where $X \in \{\text{MP}, \text{Info}, \text{Rate}\}$ refers to the monetary policy shocks, the information shocks, and the interest rate surprises. The resulting exposure indices capture differences in the sensitivity to interest rate surprises, MP shocks and Info shocks across currencies and over time. The indices are based not only on country-specific responses but also on the contribution of each characteristic: the interaction terms model the time-varying component of the currency response as a function of currency characteristics, whereas the coefficient θ_i captures the average response of each country's spot rate changes to shocks.

[8] We collect minute-by-minute spot exchange rate quotes from January 1996 to March 2019 from Refinitiv Tick History. Our measure of the currency response to policy announcements is the percentage change in the spot rate between 10 minutes before and 20 minutes after the announcement.

[9] We also run an analogous regression using the rates innovations instead of the structural shocks to highlight the importance of the shocks decomposition.

Positive interest rate surprises around central bank announcements can have different impact on asset returns, depending on what information they convey; i.e., asset prices may react differently to positive rates innovations associated with different structural shocks. Positive Info shocks indicate positive economic outlooks, i.e. a good state of the world where marginal utility is low; currencies that yield high returns in good times are riskier. By contrast, positive MP shocks are expected to induce lower future consumption growth, and hence higher marginal utility; thus currencies that depreciate more in these bad times are riskier. This is why the monetary policy risk premium detected in asset returns can be positive or negative, depending on which of these shocks dominate (Ozdagli and Velikov, 2020).

Put another way, when the US interest rate goes up due to Info shocks, this is associated with a good state of the world (marginal utility is low) and foreign currencies tend to appreciate (with the exception of safe haven currencies such as the Japanese yen and the Swiss franc, which depreciate). When the US interest rate rate goes up due to MP shocks, this is associated with a bad state of the world (marginal utility is high) and all foreign currencies tend to depreciate.

This implies that the exposure index measuring the sensitivity of currencies to shocks is a direct measure of the magnitude of currencies reaction, i.e. their level of appreciation (depreciation), to states of the world where marginal utility is low (high). The exposure differs across currencies, time, and shocks.

3.2 Currency Fundamentals

To estimate Equation (2) we consider five currency fundamentals that may be linked to the monetary policy transmission mechanisms and policy sensitivity of currency spot rates: interest rate differentials, trend CPI inflation differentials, the ratio of net foreign assets (NFA) over GDP, the US stock market beta of the currency, and a measure of "trade network centrality" that measures countries' exposure to global shocks. We collect data for currency characteristics from a number of sources. We provide here only a high-level description, but Appendix A and B.2 contain more details.

The NFA/GDP ratio is an updated version of the Lane and Milesi-Ferretti (2018) dataset, kindly provided by Gian Maria Milesi-Ferretti. To splice the Euro Area before 1999, we use the ratio of aggregated NFA and GDP of all euro area countries.

We splice the trade network centrality data of Richmond (2019), available on Robert Richmond's website until 2016[10] with our updated data to 2019. Our updated series follows the original methodology and uses bilateral trade data from the International Monetary Fund's Direction of Trade Statistics. GDP data in US dollars are from the World Bank's World Development Indicators.

For each currency, we collect from Bloomberg a mixture of -IBOR rates, swap rates on interbank deposits, and implied yields to supply the daily interest rate data. Table C.2 lists the Bloomberg tickers. We interpolate the daily interest rate data to fill missing data and use a 20-day moving average to deal with outliers. For the euro area, we use the interest rate of Germany before 1999.

[10] https://robertjrichmond.com/Data.html.

We estimate trend CPI inflation differentials by relying on a measure of trend inflation proposed by Cieslak and Povala (2015), calculated for different countries using CPI indexes from the International Monetary Fund's IFS.

We construct the monthly US equity beta for each currency similarly to Lilley and Rinaldi (2020). To make sure that the conditional equity beta captures long-term currency characteristics, at the end of every month, we regress the daily log appreciation of each currency on the daily log return of S&P 500 futures using rolling five-year windows. The futures data are sampled at the daily close of the stock market in New York.

Table 1 reports the time-series average of the five country characteristic variables (fundamentals) along with the country-specific policy exposure. Figure C.3 visualizes the relationship between these fundamentals and the sensitivity by reporting the cross-sectional correlation between characteristics and responsiveness to shocks.

3.3 Construction of Portfolios Sorted by Exposure Indices

We start by exploring the asset pricing implications of monetary policy by performing a univariate sort on our policy exposure indices. We construct exposure indices to rate changes, pure policy shocks and central bank information shocks separately. At the end of every month, we sort currencies by at least 1-month lagged characteristics. Specifically, for annual data (NFA and trade centrality) we create monthly series by keeping end-of-period data constant until a new observation becomes available. Then, for each one of the three measures of monetary policy surprises, we construct the currency-specific exposure index using the lagged characteristics and the corresponding sets of coefficients estimation results from Equation (2).

In order to generate portfolio results that are out-of-sample, we proceed as follows. We estimate Equation (2) over the sample period from January 1996 to December 2008. We then use the estimates obtained to compute the exposure index, as defined in Equation (3), for each country and for each shock. The time and cross sectional variation of these exposure indices out of sample are then driven only by the variation in the country characteristics, keeping the coefficients constant and conditioning only on data available at the time of sorting.

At the end of each month, we form five portfolios based on each of the three exposure indices and these portfolios are held for one month. The one fifth of all available currencies in a given month that has the lowest exposure index value is allocated to Portfolio 1 (denoted "Low"), the next fifth is allocated to Portfolio 2, and so on, and the one fifth of all currencies with the highest exposure index value is allocated to Portfolio 5 (denoted "High"). Finally, we also analyze a portfolio that is long the most sensitive currencies (highest exposure index) and short in the least sensitive currencies (lowest exposure index). However, recall from the discussion explaining the Exposure index in Equation (3) that the high exposure to Info shocks is associated with a good state of the world, whereas high exposure to MP shocks and Interest rate surprises is associated with a bad state of the world. Hence, we take the Low-minus-High portfolio when the sorting signal is the exposure index to rate changes or policy shocks, whereas we take the opposite, High-minus-Low portfolio when we sort on the exposure index to positive information shock.

We denote the above-mentioned long-short portfolios as per their sorting signal. Thus, the long-short exposure portfolios to rate changes, pure policy shocks, and central bank information shocks are denoted as "Rate", "MP", and "Info" portfolios, respectively. We also construct an aggregated monetary policy exposure portfolio, denoted "Mix", by combining the MP and Info portfolios using an inverse volatility weighting scheme. Specifically, we compute the daily volatility of the MP and Info strategies using rolling five-year windows. The portfolio Mix is then constructed by allocating to the MP and Info portfolios with weights that are inversely proportional to their respective rolling volatility (scaling the weights to add up to one). An important feature of these long-short portfolios is that the long and short sides of the portfolio always have the same number of currencies.

In addition to the benchmark results with equal weights, we also report returns of rank portfolios, where weights are proportional to signal strength. Similar to the long-short portfolio construction, we sort the monetary policy rate surprise and shock exposure indices in descending order and the information shock exposure index in ascending order so that we allocate the most sensitive currencies to the largest rank. Similar to Asness et al. (2013), the weights are

$$\begin{aligned} w_{i,t}^{Rank} &= c_t\Big(\mathrm{rank}(\mathrm{EXP}_{it}^X) - \mathrm{med}\{\mathrm{rank}(\mathrm{EXP}_{it}^X)\}\Big), \\ \text{where} \quad c_t &= \frac{2}{\sum \Big|\mathrm{rank}(\mathrm{EXP}_{it}^X) - \mathrm{med}\{\mathrm{rank}(\mathrm{EXP}_{it}^X)\}\Big|}. \end{aligned} \tag{4}$$

The term c_t is a scaling factor such that the absolute sum of all portfolio weights equals two so that we are one dollar long and one dollar short as in the long-short portfolio case. The term $\mathrm{med}\{\mathrm{rank}(\mathrm{EXP}_{it}^X)\}$ indicates the median of the rank of the exposure index at time t. We take no position in the median exposure currency. Given this construction, the rank exposure portfolios are also long-short portfolios with no direct dollar exposure.

Finally, while we re-balance the exposure portfolios at the monthly frequency, we track the daily portfolio excess returns given that we have the daily currency excess returns available. We obtain daily quotes on one-, three-, and six-month forward exchange rates from a number of sources because of data quality considerations. Our main source is JP Morgan; when data are missing, we rely on two other sources, Bloomberg and WMR via DataStream.[11] Currency excess returns are the daily excess returns of a US-based investor holding foreign currency via IMM-dated forward contracts. Appendix B.1 provides details on the excess return computation.

4 Empirical Results

4.1 Country-Specific Response to Monetary Policy

Table 2 reports estimates from the baseline panel regression in Equation (2). All variables are scaled by their standard deviation to ease the interpretation of the coefficients' estimates. Columns 1 to 3 report how different characteristics capture the exposure of exchange rates to policy rate changes, monetary policy, and information shocks, respectively. We focus our discussion below mainly on Columns 2 (MP shocks) and 3 (Info shocks).

[11]While quoted exchange rates at monthly frequency from WMR or Bloomberg seem to be more prevalent in recent academic studies due to their relatively long historical coverage and the focus on monthly analysis, they seem to contain apparent errors when sampled at daily frequency. For example, the daily interest rate differentials that can be implied by forward and spot quotes contain many unreasonable outliers for a number of currency pairs. Hence, we prefer to use quotes from JP Morgan, which do not present these issues.

The signs of the coefficients on the interaction terms with the currency characteristics have a clear economic intuition. For example, with respect to the NFA/GDP ratio and its effect on the responsiveness to policy tightening shocks, a positive coefficient (0.165) in Column 2 means that countries with higher NFA/GDP ratios (net lenders) are less responsive (i.e., depreciate less). Instead, positive information shocks lead to foreign currency appreciation; thus, the negative coefficient (-0.124) in Column 3 also indicates that countries with higher NFA/GDP ratios (net lenders) are less reactive. In other words, currencies of net debtor countries tend to be more responsive than those of net lender countries. This finding seems consistent with the notion that net debtor countries offer high returns to compensate investors willing to finance negative external imbalances as their currencies tend to depreciate in bad times (Gabaix and Maggiori, 2015; Della Corte et al., 2016).

The estimates also show that central countries (as measured by their trade centrality), tend to be less exposed to monetary policy. As tightening shocks depreciate the foreign currency, a positive coefficient (0.227) in Column 2 indicates that central countries depreciate less. In Column 3, a negative coefficient (-0.234) indicates that central countries appreciate less (or can even depreciate) when there is a positive shock to the future US economic outlook. Thus, central countries seem to be a good hedge against adverse shocks and tend to respond less to monetary policy shocks. This observation seems consistent with the prediction in Richmond (2019) that central countries are a good hedge against global consumption risk.

Lustig et al. (2011) and Menkhoff et al. (2012a) argue that a US investor loads up on global risk by investing in high interest rate currencies and borrowing in low interest rate currencies. Aligning with this argument, we find that the coefficient on the interest rate differential is significant and positive in Column 3, indicating a stronger appreciation of high-rate currencies to positive information shocks. However, its effect weakens in Column 2, meaning that interest rate differentials do not add incremental value in capturing the policy shock exposure of currency after controlling for other characteristics.

We include countries' inflation differentials in the regression because Engel et al. (2022) argue that inflation differentials are an appropriate measure of monetary policy stance and a more persistent predictor of excess returns than the interest rate differential, especially post-2009. Thus, currency inflation differentials may pick up the policy sensitivity of a currency in a mechanism similar to the interest rate differential. In our pre-2009 regressions in Table 2, however, the estimated coefficients on inflation differentials are not statistically significant.

Currencies' equity beta is another crucial determinant of currency sensitivity. Lilley and Rinaldi (2020) document an increase in the conditional equity beta of currencies after 2009. They argue that while the spreads in interest rates across currencies were compressed following the global financial crisis, exchange rates needed to adjust to compensate investors through expected appreciation when risk premia increase. In other words, we expect high equity-beta currencies to be more exposed to fluctuations in the future economic outlook. Indeed, the coefficient of 0.133 in Column 3 indicates that if a currency's historical equity beta is high, then the currency tends to appreciate more with positive central bank information shocks.

Overall, the results in this section show that US policy shocks have a larger impact on currencies of countries that are net borrowers, more peripheral in the global trade network, characterized by higher interest rates, and on currencies with higher equity beta. These characteristics are, therefore, important for our understanding of the heterogeneity of currencies' exposures to US monetary policy.

4.2 Returns to the Exposure Portfolios

In this section, we present empirical results regarding the performance and characteristics of currency policy exposure strategies and portfolio exposure to other currency risk factors.

4.2.1 Portfolio sorted on EXP

We report the performance for portfolios sorted on the three currency exposure indices in Table 3 exclusively for the out-of-sample period, which is from January 2009 to July 2019. Panel A shows that sorting currencies based on their exposure to the policy rate surprise does not lead to any clear pattern in the portfolio excess returns or Sharpe Ratio. This observation is in line with our earlier discussion that the impact of policy rate surprises may be poorly estimated because the coexisting monetary policy shocks and information shocks move the foreign currencies in opposite directions.

The cross-section of portfolios returns sorted on the exposure to the two decomposed shocks (MP and Info) present different results. In Panel B (sorting on MP shocks), average returns are decreasing in EXP^{MP}, from 4.67% for the Low portfolio PL (with average $\mathrm{EXP}^{MP} = -1.46$) to -0.85% for the High portfolio PH (with average $\text{EXP}^{MP} = -0.41$). As tightening monetary policy shocks lead to foreign currency depreciation, currencies with smaller (i.e., more negative) exposure index to policy shocks are more sensitive (e.g., those that are in PL). In contrast, Panel C (sorting on Info shocks) shows that average returns are increasing in currency exposure to the positive information shocks from -1.92% for the PL portfolio (with average $\text{EXP}^{Info} = -0.17$) to 3.47% for the PH portfolio (with average $\text{EXP}^{Info} = 0.67$). Positive information shocks lead to foreign currency appreciation; thus, currencies with higher exposure index to information shocks are more sensitive (e.g., those that are in PH).

In Panel D, we combine the Low EXP^{MP} portfolio with the High EXP^{Info} portfolio using inverse volatility weights to measure the aggregated High central bank exposure portfolio (PH in Mix). Accordingly, a measure for the aggregated Low central bank exposure portfolio (PL in Mix) would combine the High EXP^{MP} portfolio with the Low EXP^{Info} portfolio. Accordingly, average returns are increasing from -1.36% in PL to 3.98% in PH.

These findings further clarify the discussion in Section 3.1. The exposure indices directly capture the magnitude of currencies reactions, i.e., their level of appreciation (depreciation) to positive information shocks (monetary policy shocks). Therefore, investors who wish to gain exposures to monetary policy shocks should take the Low-minus-High (LmH) EXP^{MP} portfolio, which go long currencies that depreciate the most and short currencies that depreciate the least on impact of tightening monetary policy shocks. On the contrary, they should take the High-minus-Low (HmL) EXP^{Info} portfolio to load up on exposure to information shocks by going long (short) the currencies that appreciate the most (least) on impact of positive information shocks. In other words, both the LmH EXP^{MP} portfolio and the HmL EXP^{Info} portfolio go long the most sensitive currencies and short the least sensitive currencies. Also, we can interpret the long-short Mix portfolio that aggregates the LmH MP and HmL Info portfolios as a strategy that exposes investors positively to both *tightening* monetary policy shocks and *positive* information shocks.

4.2.2 Long-Short Policy Exposure Strategies

Table 4 reports descriptive statistics for the excess returns of long-short portfolios. Specifically, the first four columns show the equally weighted LmH (or HmL) portfolios, whereas the next four columns present the rank-weighted portfolio results. We also report the carry trade portfolio performance for comparison. The portfolio performance is analyzed along a battery of statistics, including annualized average excess returns, standard deviation, and Sharpe Ratio.

Panel A focuses on the out-of-sample period from January 2009 to July 2019. Rate changes exposure portfolios (Rate) have economically small and statistically insignificant annualized average excess return of 1.52% for the equally weighted portfolio and 1.74% for the rank-weighted portfolio. For comparison, the standard carry portfolio also delivers an insignificant average excess return of 3.40% with a modest Sharpe Ratio of 0.35 in the same time period.

We then inspect the results for the exposure strategies when we purge the impact of central bank information shocks from the policy rate surprises. We show that exposure strategies based on the two decomposed shocks deliver more appealing returns and Sharpe ratios than those portfolios based on the rate changes exposure or carry trade. Specifically, the equally weighted MP and Info portfolios deliver economically significant and positive excess returns of 5.39% ($t = 2.57$) and 5.24% ($t = 2.03$) per annum with annualized Sharpe Ratio of 0.69 and 0.61, respectively. The excess return is slightly weaker in the rank-weighted MP and Info portfolios, but their Sharpe ratios are both sizable (0.51 and 0.61).

The Mix portfolios aggregate the MP and Info portfolio with inverse volatility weights and generate positive and significant excess return of 5.27% for the equally weighted portfolio and 3.58% for the rank-weighted portfolio. Another natural question that the Mix strategies help to answer is how different the exposure portfolios constructed from the two decomposed shocks are. We start by analyzing the diversification benefits of the performance of the Mix portfolio. We observe some diversification benefit in the equally weighted Mix portfolio, which displays a Sharpe Ratio of 0.72. Figure 2 reports the cumulative log excess returns of the portfolios. We can see that the MP and Info portfolios present a clear divergence in the early 2000s. Also, the long-short MP and Info exposure portfolios have a relatively stable correlation (around 0.60) as shown in Table C.4. In addition, the two shocks generate distinct portfolio compositions as shown in Table C.6. Indeed, the MP and Info portfolios take the opposite position in several currencies (e.g., Mexican peso and Norwegian krone).

4.2.3 The In-Sample Results

For completeness, we also illustrate the portfolio results for the in-sample calibration period, which is from February 1996 to December 2008 in Panel B of Table 4. The findings are consistent with the out-of-sample results and even stronger. There is a low and insignificant excess return of 1.78% per annum associated with the equally weighted Rate portfolio, which does not distinguish currencies exposure to the offsetting tightening monetary policy and positive information shocks. The two decomposed shocks portfolios—equally weighted MP and Info—perform substantially better with economically significant and positive excess returns of 8.56% and 8.49% per annum and annualized Sharpe Ratio of 0.96 and 0.79. The Sharpe Ratio of the equally weighted Mix portfolio is 0.98. The risk-adjusted performance of the exposure strategies are therefore similar to (only slightly lower than) that of a standard version of the carry trade, which has a Sharpe Ratio of 1.08 during the pre-crisis period.

4.2.4 Portfolio Exposure to other Currency Risk Factors

Next, we explore how the exposure strategies relate to some well-established common factors in the currency market: the dollar factor, the carry trade strategy, and the short-term (one-month) currency momentum strategy. In this section, we will focus on the out-of-sample period from January 2009 to July 2019.

In Table 5, we test the hypothesis that the excess returns for the cross-section of EXP-sorted portfolios are jointly equal to zero after controlling for the dollar, carry and momentum factors, using the test of Gibbons et al. (1989). The null hypothesis of zero alpha is rejected at the one percent significance level with t-statistics over three for both the dollar-carry two-factor model and dollar-carry-momentum three-factor model, and both for the cross-section of MP and Info portfolios. The hypothesis is also rejected at the 5 percent level for the aggregate Mix portfolios. These results suggest that factor models based on the dollar, carry, and momentum factors cannot fully price the cross-section of exposure portfolios.

Then, we run time-series spanning regressions of returns to the long-short equally weighted and rank-weighted portfolios on returns to dollar, carry, and momentum risk factors. Estimated coefficients are shown in Table 6 with t-statistics based on the Newey-West robust standard errors reported in parenthesis.[12] Using the three-factor model, the slope coefficient estimates on the dollar and carry factors for the MP portfolios are positive and statistically significant. However, the momentum factor is statistically insignificantfor MP portfolios, and the R^2 is only about 50%.

The returns to Info strategies load heavily on the carry factor with a beta of about 0.74 for the equally weighted and 0.57 for the rank-weighted portfolio but are essentially uncorrelated with the dollar and momentum factor. This result is unsurprising as interest rate differentials contribute significantly to the information shocks exposure index. The resulting aggregate monetary policy strategies, Mix, have moderate exposure to both the dollar and carry factors but remain uncorrelated with the momentum factor. Furthermore, the alphas are statistically different from zero for MP, Info and Mix strategies and are economically sizeable (3.84% for MP, 2.90% for Info and 3.36% for Mix per annum). Overall, the evidence suggests that monetary policy exposure portfolios are related but different from the tradable dollar and carry factors, and they are essentially unrelated to the momentum factor.

[12] We also report in the upper part of the table results from regressions on only dollar and carry (i.e. excluding the momentum factor) for completeness, but we focus our discussion below on the results from the richer three-factor model, reported in the bottom part of the table.

5 Conclusion

This paper studies the heterogeneous impact of US monetary policy on currencies around the world. First, to distill the pure monetary policy effect on currencies, we do not use surprises in interest rate changes, which contain information that goes beyond monetary policy shocks. Instead, we separate pure monetary policy shocks from the contemporaneous information shocks by analyzing the co-movement of interest rates and stock prices in a narrow policy announcement window. We use simple univariate regression to illustrate the monetary policy and information shocks' offsetting effect on currencies. Currencies tend to depreciate on tightening policy shocks but tend to appreciate when there are contemporaneous positive information shocks. We also document that fundamental variables like interest rate differentials help explain currencies' heterogeneous responses in the cross-section.

Motivated by these two findings, we construct an "exposure index" that captures the cross-sectional and time-series difference in policy sensitivity across currencies. Our regressions use the interaction terms of the different structural shocks with currency characteristics linked to policy sensitivity. The resulting exposure indices show that currencies tend to be more reactive to US monetary policy if they are associated with net borrowers countries, peripheral in the global trade network, characterized by higher interest rates, and more exposed to equity risk. Therefore, the heterogeneity of currencies' exposures to US monetary policy is understandable in terms of simple economic characteristics.

To evaluate the economic magnitude of the monetary policy effects, we build long-short portfolios that sort currency on the different exposure indices and analyze their behavior. We find that currencies that are more sensitive to US monetary policy announcements (i.e. those that react more negatively when there is a tightening policy shock and those that react more positively when there is a positive information shock) earn significantly higher average returns than less sensitive currencies. An aggregate policy exposure strategy designed to exploit this effect achieves an annualized return of 5.27% with an annualized Sharpe Ratio of 0.72 from 2009 to 2019. While the returns moderately load on the dollar and carry factors, the strategy continues to generate a significant annualized excess return of 3.52% controlling for the common currency factors after the global financial crisis. The exposure strategy performance implies that the effect of monetary policy is economically important, both pre-2009 and post-2009, with different interest rate regimes. Thus, investors are compensated for holding currencies that are more exposed to US monetary policy.

Table 1: Estimated Country-Specific Responsiveness

This table reports the country's average response to different monetary policy-related variables and average country characteristics. Panel A reports the θ_i for each country estimated from the individual univariate regression $r_{i,t} = \mu_i + \theta_i \text{Shocks}_t + \varepsilon_{it}$, where i is the currency identifier, t is the date of the scheduled FOMC meeting, and r_{it} is the intraday currency spot return in the 30-minute window surrounding the FOMC press releases. Shocks_t is one of the structural shocks or innovations of interest: (1) policy rate changes, (2) purged policy shocks, and (3) central bank information shocks, respectively. A positive surprise/shock is tightening. Note that we scale the estimated θ_i of the purged policy shocks and central bank information shocks with their variance contribution factors reported in Table C.1. We report t-statistics based on the Newey-West standard errors with optimal lags in parentheses. Panel B reports country-specific time-series averages for the five characteristic variables. The sample period is 01/1996-07/2019.

	Panel A: Average Responsiveness			Panel B: Average Characteristics				
Country	Rate Changes	MP Shocks	Info Shocks	NFA/GDP	Trade Centrality	Interest Rate Diff	Inflation Diff	Equity Beta
Australia	-7.38	-7.92	0.54	-0.54	0.35	1.81	0.41	0.15
	(-5.10)	(-5.32)	(0.68)					
New Zealand	-6.87	-7.68	0.81	-0.73	0.10	2.36	0.12	0.15
	(-4.45)	(-4.99)	(0.97)					
Norway	-6.44	-6.46	0.02	0.76	0.26	0.87	-0.08	0.05
	(-4.05)	(-4.00)	(0.02)					
Hungary	-6.21	-6.75	0.53	-0.79	0.24	5.35	7.82	0.14
	(-4.58)	(-5.17)	(0.50)					
Sweden	-6.21	-6.64	0.43	-0.18	0.37	-0.27	-0.51	0.06
	(-4.39)	(-4.26)	(0.49)					
Poland	-5.90	-7.01	1.12	-0.47	0.34	5.30	3.80	0.13
	(-3.47)	(-4.01)	(1.27)					
Euro Area	-5.85	-5.84	-0.01	-0.13	0.77	-0.66	-0.57	0.00
	(-4.55)	(-4.34)	(-0.01)					
South Africa	-5.78	-6.64	0.87	-0.13	0.20	6.57	4.56	0.22
	(-3.88)	(-5.40)	(1.51)					
Czech Republic	-5.52	-5.95	0.43	-0.25	0.30	1.20	2.60	0.06
	(-4.13)	(-4.11)	(0.51)					
Switzerland	-5.43	-4.81	-0.62	1.11	0.51	-1.83	-1.48	-0.07
	(-4.16)	(-3.92)	(-0.92)					
Brazil	-5.11	-6.51	1.40	-0.32	0.23	13.06	4.93	0.24
	(-4.21)	(-5.97)	(2.80)					
United Kingdom	-4.78	-5.00	0.22	-0.08	0.83	0.67	0.01	0.02
	(-4.35)	(-4.06)	(0.34)					
Canada	-4.39	-4.97	0.58	-0.09	0.61	0.03	-0.38	0.13
	(-4.67)	(-5.61)	(1.34)					
Japan	-4.34	-3.74	-0.60	0.42	0.66	-2.42	-2.28	-0.12
	(-3.60)	(-2.99)	(-1.35)					
Mexico	-3.33	-4.88	1.56	-0.41	0.48	7.99	7.04	0.23
	(-3.32)	(-5.13)	(3.53)					
Singapore	-1.94	-2.28	0.34	1.93	0.93	-1.01	-0.90	0.05
	(-2.88)	(-4.21)	(1.25)					

Table 2: Monetary Policy Exposure Estimation

This table reports estimates from panel regressions estimated at the FOMC meeting-currency level. The regression follows $r_{it} = \sum_{k=1}^{n} \beta_k Z_{it}^k + \theta_i \text{Shocks}_t + \sum_{k=1}^{n} \gamma_k Z_{it}^k \times \text{Shocks}_t + \text{Country}_i + \text{Meeting}_t + \varepsilon_{it}$, where i is the currency identifier, t is the date of the scheduled FOMC meeting, r_{it} is the intraday currency spot return in the 30-minute window surrounding the FOMC press releases, and Shocks_t is one of the structural shocks or innovations of interest: policy rate changes in Model (1), policy shocks in Model (2), and information shocks in Model (3). The variable Z_{it}^k is the k-th currency characteristic that can help capture the exposure of a currency to monetary policy. The variables Country_i and Meeting_t are country and meeting fixed effects. All variables are scaled by their standard deviation to accommodate the interpretation. The sample period covers scheduled FOMC meetings between 1996/01 and 12/2008. The t-statistics based on the time-clustered standard errors are in parentheses.

Model:	(1) Rate Changes	(2) MP Shocks	(3) Info Shocks
Variables			
NFA/GDP × Rate Changes	0.171		
	(1.884)		
Trade Centrality × Rate Changes	0.070		
	(0.515)		
Interest Rate Diff × Rate Changes	0.030		
	(0.436)		
Inflation Diff × Rate Changes	-0.152		
	(-1.123)		
Equity Beta × Rate Changes	-0.090		
	(-1.315)		
NFA/GDP × MP Shocks		0.165	
		(1.977)	
Trade Centrality × MP Shocks		0.227	
		(1.699)	
Interest Rate Diff × MP Shocks		-0.039	
		(-0.760)	
Inflation Diff × MP Shocks		-0.084	
		(-0.669)	
Equity Beta × MP Shocks		-0.111	
		(-1.199)	
NFA/GDP × Info Shocks			-0.124
			(-1.550)
Trade Centrality × Info Shocks			-0.240
			(-2.068)
Interest Rate Diff × Info Shocks			0.109
			(1.686)
Inflation Diff × Info Shocks			-0.095
			(-0.932)
Equity Beta × Info Shocks			0.133
			(2.630)
Controls: Currency Characteristics	Yes	Yes	Yes
Fixed-effects			
Time	Yes	Yes	Yes
CountryNames	Yes	Yes	Yes
Varying Slopes			
RawRatePC (CountryNames)	Yes		
MPShocks (CountryNames)		Yes	
InfoShocks (CountryNames)			Yes
Fit statistics			
Observations	1,448	1,448	1,448
Adjusted R^2	0.665	0.686	0.656
Within Adjusted R^2	0.014	0.025	0.017

Table 3: Currency Portfolio Cross-Section Performance

This table reports descriptive statistics for the set of sorted portfolios based on currencies' exposures to monetary policy rate changes, MP shocks, and Info shocks. We report the ex-ante average exposure indices. At the end of each month, we re-balance five portfolios based on one of the exposure indices, and these portfolios are held for one month. The one-fifth of all available currencies in a given month that has the lowest exposure index value is allocated to the first portfolio (denoted "PL"), the next fifth is allocated to portfolio 2, and so on, and the currencies with the largest exposure index value are allocated to the fifth portfolio (denoted "PH"). We report results for cross-sectional portfolios PL, P2, ..., and PH; as well as long-short portfolios (L/S) and rank portfolios (RW) that are long in the most sensitive currencies and short in the least sensitive currencies. As discussed in the section 3.3, we take the Low-minus-High portfolio when the sorting signal is the exposure index to rate changes or policy shocks, whereas we take the opposite High-minus-Low portfolio when we sort on the exposure index to positive information shock. Panel D reports the aggregate portfolios combining the MP and Info portfolios using inverse volatility weights. Note that the returns of the PL for the aggregate Mix portfolio combine the PH of the MP portfolio and the PL of the Info portfolio and so on so that the portfolios are combined along their level of sensitivity. Mean returns, return volatility, and Sharpe Ratio are annualized. We report t-statistics based on Newey-West standard errors with optimal lags in parentheses. The sample period is between 01/2009-07/2019.

	PL	P2	P3	P4	PH
Panel A: Rate Changes Exposure Portfolios					
Mean EXP_t^{MP}	-1.31	-1.13	-1.00	-0.85	-0.36
Mean Return	1.87	0.51	-0.10	-0.68	0.28
Std. Dev	11.00	10.65	10.35	8.88	6.67
Sharpe Ratio	0.17	0.05	-0.01	-0.08	0.04
Panel B: Monetary Policy Shocks Exposure Portfolios					
Mean EXP_t^{MP}	-1.46	-1.23	-1.07	-0.89	-0.41
Mean Return	4.67	0.38	-1.57	-0.33	-0.85
Std. Dev	11.35	11.77	9.60	8.80	6.47
Sharpe Ratio	0.41	0.03	-0.16	-0.04	-0.13
Panel C: Information Shocks Exposure Portfolios					
Mean EXP_t^{Info}	-0.17	0.20	0.38	0.53	0.67
Mean Return	-1.92	-0.15	-1.56	2.55	3.47
Std. Dev	7.43	8.04	10.18	11.22	11.46
Sharpe Ratio	-0.26	-0.02	-0.15	0.23	0.30
Panel D: Mix Central Bank Exposure Portfolios					
Mean Return	-1.36	-0.24	-1.59	1.45	3.98
Std. Dev	6.57	8.22	9.74	11.06	11.04
Sharpe Ratio	-0.21	-0.03	-0.16	0.13	0.36

Table 4: Returns to Currency Monetary Policy Exposure Strategies

This table reports descriptive statistics for currency portfolios based on exposures to different monetary policy shocks. We report results for the long-short portfolio where we sort currencies into five bins based on the exposure indices in Panel A, and the corresponding rank-weighted portfolio in Panel B. The exposure indices measure foreign currency's sensitivity to (1) policy rate changes (Rate), (2) pure monetary policy shocks (MP), and (3) central bank information shocks (Info). We also report results for an inverse volatility weighted aggregate portfolio of MP and Info, denoted Mix. We compare the monetary policy exposure portfolio with the carry risk factors. Excess returns are monthly and are defined such that positive numbers mean a positive return on holding the foreign currency. Mean returns, return volatility, and Sharpe Ratio are annualized. Also shown are the return skewness, kurtosis, auto-regressive coefficient, maximum and minimum monthly return, and the number of months with positive and negative returns. The sample period is between 02/1996-12/2008 for in-sample and 01/2009-07/2019 for out-of-sample.

	Equally Weighted L/S EXP Strategies				Rank-Weighted L/S EXP Strategies				
	Rate	MP	Info	Mix	Rate	MP	Info	Mix	Carry
Panel A: 01/2009-07/2019									
Mean	1.52	5.39	5.24	5.27	1.74	3.19	4.08	3.58	3.40
t	(0.71)	(2.57)	(2.03)	(2.45)	(1.12)	(1.71)	(2.01)	(1.92)	(1.06)
Median	0.56	5.20	4.28	5.15	1.64	2.65	4.52	2.27	3.52
Std. Dev	7.92	7.83	8.65	7.32	5.75	6.25	6.69	6.08	9.85
Sharpe Ratio	0.19	0.69	0.61	0.72	0.30	0.51	0.61	0.59	0.35
Skewness	0.02	-0.12	0.15	-0.09	-0.06	-0.12	0.04	-0.12	-0.02
Kurtosis	2.90	2.94	3.68	3.44	2.88	2.75	3.51	3.11	3.46
AC1	-0.12	-0.12	-0.03	-0.07	-0.11	-0.08	0.00	-0.03	-0.03
Max	5.38	5.88	8.63	6.35	3.80	3.87	5.43	4.63	7.87
Min	-7.09	-6.07	-6.56	-6.10	-4.72	-4.37	-5.94	-5.16	-8.70
Pos	66	75	76	73	70	68	73	68	67
Neg	61	52	51	54	57	59	54	59	60
Panel B: 02/1996-12/2008									
Mean	1.78	8.56	8.49	8.49	1.99	6.08	7.40	6.65	12.13
t	(0.68)	(3.22)	(2.44)	(3.03)	(1.03)	(3.21)	(2.85)	(3.35)	(3.46)
Median	2.18	12.66	13.78	10.99	3.88	7.20	11.85	9.51	13.63
Std. Dev	8.72	8.89	10.75	8.69	6.50	6.32	8.41	6.36	11.25
Sharpe Ratio	0.20	0.96	0.79	0.98	0.31	0.96	0.88	1.05	1.08
Skewness	0.09	-0.37	-0.27	-0.32	-0.03	-0.30	-0.37	-0.29	-0.12
Kurtosis	3.47	3.55	3.21	3.81	3.51	4.00	2.99	3.70	3.46
AC1	0.08	0.10	0.19	0.19	0.08	0.16	0.17	0.21	0.19
Max	8.79	7.38	9.67	8.47	5.82	5.56	6.74	6.09	11.22
Min	-7.34	-7.34	-8.06	-7.68	-6.40	-6.11	-7.20	-5.54	-8.36
Pos	82	101	98	101	85	101	96	103	102
Neg	73	54	57	54	70	54	59	52	53

Table 5: Time-Series Asset Pricing Tests of Exposure-Sorted Portfolios

This table reports results from time-series asset pricing tests of the five exposure-sorted portfolios across different monetary policy instruments on FX asset pricing models. The factor models include a two-factor model of the dollar and carry factors; and a three-factor model of the currency market that includes the dollar, carry, and short-term momentum. All panels report Gibbons et al. (1989) (GRS) F-statistic on the joint significance of the alphas under each asset pricing model from the time-series regressions, the p-value of the F-statistic, the annualized average absolute alpha (in percent), the average time-series R^2, and the cross-sectional R^2 of average returns on the predicted expected return from each model. The sample period is between 01/2009-07/2019.

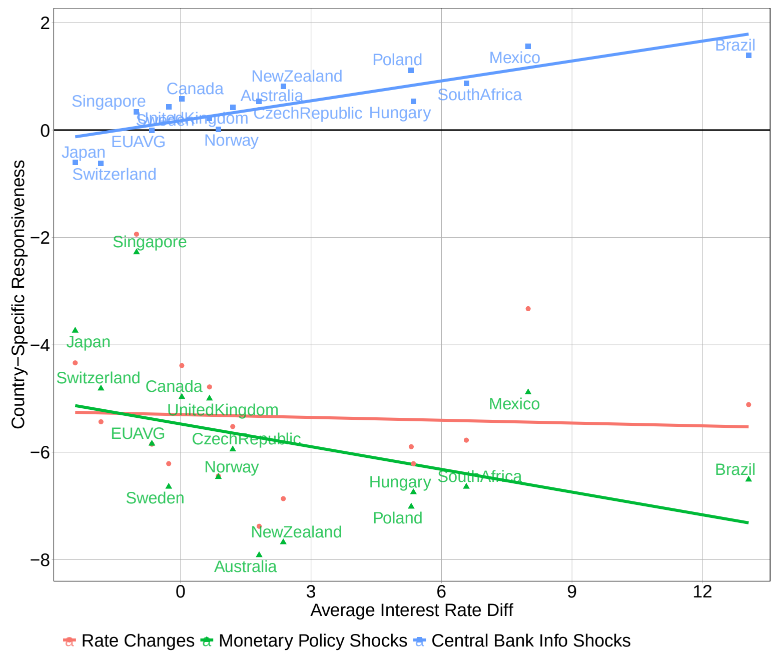
Asset Pricing Models	GRS F-statistics	p-val	Average $\|\alpha\|$	Average Time-Series R^2	Cross-Sectional R^2
Panel A: Rate Changes Exposure Portfolios					
Dollar, Carry	0.87	0.50	0.59	0.84	0.07
Dollar, Carry, Momentum	0.65	0.66	0.53	0.84	0.44
Panel B: Monetary Policy Shocks Exposure Portfolios					
Dollar, Carry	3.72	0.00	1.37	0.84	0.52
Dollar, Carry, Momentum	3.49	0.01	1.27	0.84	0.76
Panel C: Information Shocks Exposure Portfolios					
Dollar, Carry	3.34	0.01	1.33	0.87	0.70
Dollar, Carry, Momentum	3.61	0.00	1.40	0.87	0.66
Panel D: Mix Central Bank Exposure Portfolios					
Dollar, Carry	2.94	0.02	1.21	0.90	0.77
Dollar, Carry, Momentum	2.65	0.03	1.25	0.90	0.84

Table 6: Exposure Portfolios and FX Risk Factors

This table reports exposure regression results for long-short portfolios in Panel A and rank portfolios in Panel B. The dependent variables in Panel A and B are the excess return of an exposure portfolio based on different EXP indices. We consider exposure portfolios sorted on currencies' heterogeneous sensitivities to policy rate changes (Rate), purged policy shocks (MP), and information shocks (Info). Also reported are the results for an aggregated portfolio combining the MP and Info portfolios, denoted as Mix. As for factors in the regressions, we include excess returns to the dollar risk factor, carry trade factor, and currency short-term momentum. Alphas are annualized and in percent. We report t-statistics based on Newey-West standard errors with optimal lags in parentheses. The sample period is between 01/2009-07/2019.

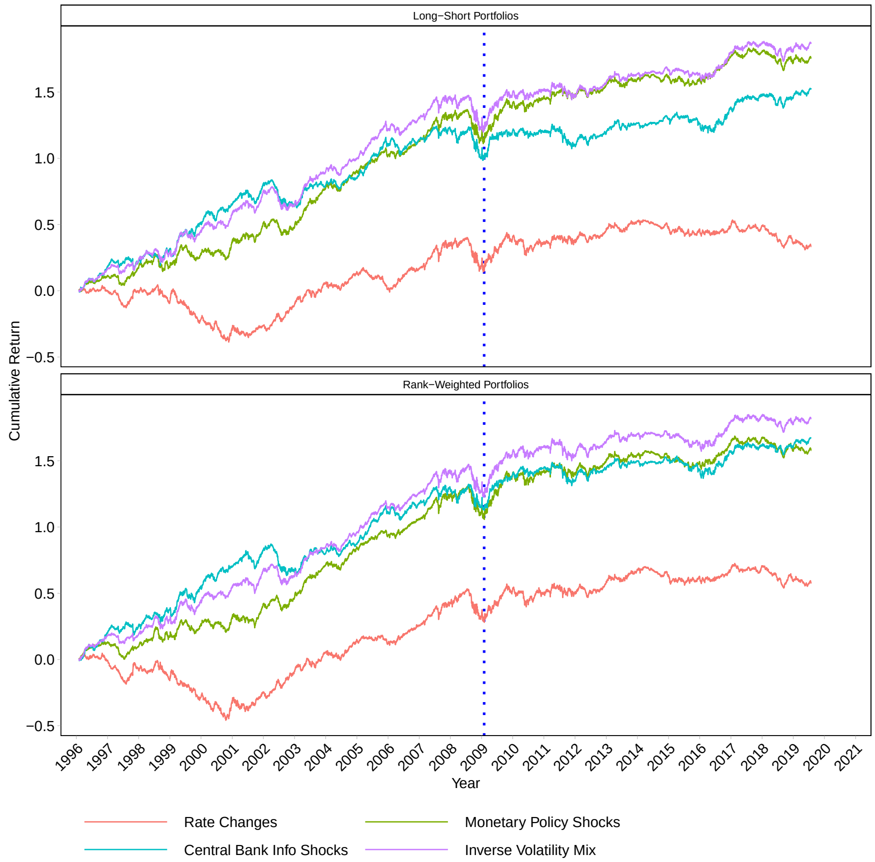
	Rate	MP	Info	Mix	Rate	MP	Info	Mix
	Panal A: Equally Weighted L/S EXP Strategies				Panal B: Rank-Weighted L/S EXP Strategies			
Two-Factor model: Dollar, Carry								
α	1.054	4.284	2.741	3.523	1.208	2.123	2.143	2.115
	(0.686)	(2.996)	(1.909)	(3.202)	(1.075)	(2.090)	(2.415)	(2.570)
Dollar	0.521	0.412	−0.008	0.215	0.360	0.341	0.053	0.204
	(9.204)	(6.701)	(−0.137)	(4.580)	(9.282)	(9.882)	(1.214)	(6.085)
Carry	0.079	0.280	0.735	0.488	0.118	0.275	0.564	0.409
	(0.826)	(2.919)	(12.359)	(6.996)	(1.793)	(4.601)	(16.576)	(9.329)
Observations	127	127	127	127	127	127	127	127
Adjusted R^2	0.396	0.502	0.688	0.672	0.455	0.633	0.753	0.729
Three-Factor Model: Dollar, Carry, Momentum								
α	0.455	3.837	2.900	3.362	0.990	2.069	2.325	2.175
	(0.272)	(2.657)	(2.022)	(3.064)	(0.792)	(1.929)	(2.354)	(2.555)
Dollar	0.510	0.404	−0.005	0.212	0.356	0.340	0.056	0.205
	(9.561)	(6.812)	(−0.077)	(4.560)	(9.663)	(9.855)	(1.302)	(6.162)
Carry	0.075	0.277	0.736	0.488	0.117	0.275	0.565	0.409
	(0.799)	(2.928)	(13.090)	(7.058)	(1.795)	(4.587)	(16.540)	(9.316)
Momentum	−0.092	−0.069	0.025	−0.025	−0.034	−0.008	0.028	0.009
	(−1.579)	(−1.338)	(0.505)	(−0.699)	(−0.901)	(−0.255)	(0.826)	(0.357)
Observations	127	127	127	127	127	127	127	127
Adjusted R^2	0.401	0.504	0.686	0.670	0.454	0.630	0.752	0.727

Figure 1: Country-Specific Responsiveness to Shocks and Characteristics



This figure plots the country-specific responsiveness to monetary policy-related variables against the time-series average of currency interest rate differentials. The country's average response to monetary policy is estimated from the individual univariate regression $r_{i,t} = \mu_i + \theta_i \text{Shocks}_t + \varepsilon_{it}$, where i is the currency identifier, t is the date of the scheduled FOMC meeting, and r_{it} is the intraday currency spot return in the 30-minute window surrounding the FOMC press releases. Shocks_t is one of the structural shocks or innovations of interest: (1) policy rate changes, (2) purged monetary policy shocks, and (3) central bank information shocks, respectively. A positive surprise/shock is tightening. Note that we scale the estimated θ_i of the purged policy shocks and central bank information shocks with their variance contribution factors reported in Table C.1. The scaled estimates of θ_i capture the policy exposure for each currency and are reported on the y-axis against their average interest rate differentials. The sample period is 1996/01-07/2019.

Figure 2: Cumulative Log Return to Exposure-Sorted Portfolios



This figure shows cumulative daily log excess returns accruing to exposure portfolios constructed by sorting currencies based on their exposure to the policy rate changes, purged monetary policy shocks, and information shocks, respectively. We also report the results for an aggregate monetary policy exposure portfolio (Mix) using the inverse volatility weighted policy and information shock exposure strategies. The dashed line denotes the beginning of the out-of-sample period in January 2009. The portfolios are adjusted to have ex-post volatility of 10% per annum.

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Online Appendix to "Currency Returns and Interest Rate Surprises: It's All in the Shocks"

by Juan Antolin-Diaz, Gino Cenedese, Shangqi Han, Lucio Sarno

Contents

A Monetary Policy Transmission Mechanism

In order to create policy exposure indices, we interact policy-related variables with currency characteristics that are linked to monetary policy sensitivity of currency exchange rate in the previous literature. In this section, we propose the following currency characteristics that are linked to monetary policy transmission mechanisms and policy sensitivity of exchange rates.

Net foreign asset We expect the currency of countries with a higher level of external liabilities to be more exposed to US monetary policy. Intuitively, with debt contracts denominated in the US dollar, contractionary US monetary policy which leads to an appreciation of the US dollar results in the dollar debt burden of debtor countries increasing. Since their assets are typically denominated in domestic currency and so do not increase in value, there is a resulting deterioration in the country's balance sheet (Mishkin, 2014).

In Gabaix and Maggiori (2015), the model predicts that exchange rates are jointly determined by global imbalance and financiers' risk-bearing capacity. In their set-up, a financial disruption, by reducing financiers' risk-bearing capacity, generates an immediate currency depreciation and an expectation of future appreciation to incentives financiers to sustain the imbalance. Empirically, Della Corte et al. (2016) show that net debtor countries need to offer a currency risk premium to compensate investors who are willing to finance negative external imbalances as their currencies tend to depreciate in bad times. Thus, net borrower countries are expected to be more sensitive (depreciated more) to tightening US policy shocks compared to net lenders.

Global trade centrality We expect the currency of the central country, who has strong trade linkages with countries that are important for the output of tradable goods, to be less sensitive to the US monetary policy surprise. Richmond (2019)'s model on trade network proposed that central countries will be more exposed to common global risk, and thus their currencies are a good hedge against global consumption risk.

Countries' differential exposure to global shocks leads to variation in their real exchange rates (RERs), where RERs are simply the relative price of countries' consumption bundles.[1] Therefore, when a country experiences a bad shock, the price of its consumption bundle will increase relative to a country that experienced a less severe shock. For example, if the U.S. receives a negative consumption shock that increases the price of its consumption basket relative to Mexico's, the dollar will appreciate relative to the peso.

As a result, central (peripheral) countries' currencies appreciate in high (low) marginal utility states so that they are a good hedge against global consumption risk. This results in central countries having low interest rates and currency risk premia, indicating that central country currencies are less sensitive to the US monetary policy surprise.

Interest rate differentials Currency carry may capture the monetary policy sensitivity of a currency in multiple ways. For example, carry is a strong predictor of currency excess returns (Lustig et al., 2011). A US investor loads up on global risk by investing in high interest rate currencies and borrowing in low interest rate currencies. On the other hand, Mueller et al. (2017) illustrate a theoretical model and show that a rise in monetary policy uncertainty in the US increases the foreign currency's expected excess return. This increase in excess return in response to higher monetary policy uncertainty is larger for currencies with higher interest rates. In other words, we expect currencies with higher interest rates to be more sensitive to monetary policy.

Inflation differentials Engel et al. (2022) find evidence that year-on-year inflation rate differentials consistently predict currency excess returns while the relationship between interest rates and currency excess returns is not stable over time. The paper estimates the "Fama Puzzle" regression with the year-on-year inflation differentials and found a consistent negative relationship between excess return and inflation differentials. They

[1] The definition of RER here is such that a lower RER means a stronger dollar and, consequently, a lower valuation level of the foreign currency.

propose that the inflation differentials are a stronger measure of monetary policy stance and a better predictor of excess returns than the interest rate differential, even prior to the financial crisis. Thus, currency inflation differentials may pick up the policy sensitivity of a currency in a mechanism similar to interest rate differential.

Equity beta Another useful measure of currency risk in the post-crisis period is the conditional equity beta. Lilley and Rinaldi (2020) suggest that, in the period prior to the crisis, central banks of the riskier currencies (e.g. AUD, NZD) were found to hike policy rates most aggressively when risk premia increased (US equity price decline), which means the goal of exchange rate smoothing take precedence than easing monetary condition. However, the responsiveness of interest rate spread to risk premia decreased largely after the crisis. Thus, exchange rates are adjusted to compensate investors through expected appreciation when risk premia increases, which leads to an increase in the conditional equity beta. Without movement in interest rate spread, riskier currencies that have high equity beta would be more sensitive to US monetary policy.

B Data

B.1 Currency Returns

High-Frequency Currency Spot Returns We focus on the commonly traded currencies for the following countries or areas: Australia, Brazil, Canada, Switzerland, Czech Republic, Euro Area, United Kingdom, Hungary, Japan, Mexico, Norway, New Zealand, Sweden, Singapore, South Africa, and Poland.

For each of the aforementioned currencies, we collect tick-by-tick high-frequency spot rate data from Tick History. Our measure of the currency response to policy shocks is the change in the spot rate between 10 minutes before and 20 minutes after the announcement. The spot rate change is in percentage.

Daily Currency Excess Returns The data for daily spot exchange rates and one-, three-, and six-month forward exchange rates cover the same sample period as above and are mainly obtained from JPMorgan Data Query, where missing data are appropriately filled with data from Bloomberg and WMR Reuters via DataStream.

At any pricing date t, we can buy a forward with maturity on the next IMM date that is further than 14 calendar days in the future. We choose to roll two weeks before the IMM date to simulate what is actually done on average. Then, the daily excess returns earned from trading day t to trading day $t+1$ can be calculated from the ratio of the nearest IMM-dated forward price on the trading day $t+1$ to the same nearest IMM-dated forward price on the trading day t, except the roll-day. Mathematically,

$$R_{t,t+1} = \frac{F_{t+1}^{m-1}}{F_t^m}$$

where the superscript denotes the number of days to the nearest IMM-dated maturity, F_t^m denotes the IMM-dated forward price on the day t, F_{t+1}^{m-1} denotes the price of the same IMM-dated forward contract on the day $t+1$ (with one less day to maturity). Also, we must form roll-day returns from the ratio of the nearest IMM-dated price on the roll day to the second-nearest IMM-dated price of the previous pricing date.

Hence, we must model the returns from IMM-dated forwards with respect to these IMM-dated maturities. However, our data is for fixed maturity, meaning that, for each pricing date, the forward settlement date is different (market conventions are all applied[2]). To estimate the returns derived from the contract we hold, we must interpolate between the fixed maturities. We perform simple linear interpolation on the forward prices to arrive at IMM-dated forward prices.

[2] We compute one, three, and six-month maturities by first calculating the spot settlement dates, adding the appropriate number of months to the date, keeping the day of the month the same, unless this would exceed the number of days in the month, in which case it is set to the last day of the month. If the forward settlement date lands on a weekend or a holiday, then it is advanced to the following business day. If, in advancing the date we would be in the next month, then instead we adjust the date to the last date in the month that is a business day. If the spot settlement falls on the last business day of the month, then the forward settlement date must also lie on the last business day of the month.

B.2 Currency Characteristics

The currency-level characteristics we discuss in the paper include the NFA-to-GDP ratio, trade centrality, interest rate differential, inflation differential, and equity beta.

The NFA/GDP ratio is an updated version of the Lane and Milesi-Ferretti (2018) dataset kindly provided by Gian Maria Milesi-Ferretti. For the Euro Area, we use the average of core euro countries: Austria, Belgium, Finland, France, Germany, and the Netherlands.

We splice the trade network centrality data of Richmond (2019), available on Robert Richmond's website until 2016[3] with our updated data to 2019. Our updated data follows the original methodology and uses bilateral trade data from the International Monetary Fund's Direction of Trade Statistics. GDP data in US dollars are from the World Bank's World Development Indicators.

For each currency, we collect from Bloomberg a mixture of -IBOR rates, swap rates on interbank deposits, and implied yields to supply the daily interest rate data. Table C.2 lists the Bloomberg tickers. We interpolate the daily interest rate data to fill missing data and use a 20-day moving average to deal with outliers. For the euro area, we use the interest rate of Germany before 1999.

We estimate trend CPI inflation differentials by relying on a measure of trend inflation proposed by Cieslak and Povala (2015) and calculated for different countries using CPI indexes from the International Monetary Fund's IFS. Specifically,

$$\tau_t^{CPI} = (1-v)\sum_{i=0}^{t-1} v^i \pi_{t-i}$$

where $\pi_t = ln\frac{CPI_t}{CPI_{t-1}}$ is the year-over-year inflation at monthly sampling. We calibrate the v parameter to be 0.987. In the early sample, if there is any year-over-year inflation above 10% we just use the actual year-over-year inflation and we only switch to the moving

[3] https://robertjrichmond.com/Data.html.

average as it goes below 10% (and we initialize at 10% in this case). We never go back to the actual inflation in the later period even if it goes above 10%.

We construct the monthly US equity beta for each currency similarly to Lilley and Rinaldi (2020). To make sure that the conditional equity beta captures long-term currency characteristics, at the end of every month, we regress the daily log appreciation of each currency on the daily log return of the S&P 500 futures using rolling five-year windows. The futures data are sampled at the daily close of the stock market in New York.

C Additional Tables and Figures

Table C.1: Country-Specific High-Frequency Data Summary Statistics

This table reports summary statistics of available spot return data by country. We report the number of available data and the corresponding variance (in basis points) of the shocks. We also report the variance decomposition of the policy rate changes (RC) into the percentage contribution from the purged policy (MP) shocks and central bank information (Info) shocks. The scaling regression estimates used for the MP and Info shocks are also reported. The sample period is 01/1996-07/2019 for Panel A and 01/1996-12/2008 for Panel B.

	Variance (bps)			Variance Contribution (%)			Scaling Regression			
Country	RC	MP	Info	MP	Info	Covariance Term	N	Intercept	MP	Info
Panel A: sample period 01/1996-07/2019										
Australia	9.99	7.07	2.92	70.77	29.23	0.00	189	0	0.03	0.02
Brazil	10.09	7.15	2.91	70.88	28.86	0.26	186	0	0.03	0.02
Canada	9.99	7.07	2.92	70.77	29.23	0.00	189	0	0.03	0.02
Czech Republic	9.99	7.07	2.92	70.77	29.23	0.00	189	0	0.03	0.02
Euro Area	9.99	7.07	2.92	70.77	29.23	0.00	189	0	0.03	0.02
Hungary	9.99	7.07	2.92	70.77	29.23	0.00	189	0	0.03	0.02
Japan	9.99	7.07	2.92	70.77	29.23	0.00	189	0	0.03	0.02
Mexico	10.13	7.17	2.91	70.80	28.75	0.45	186	0	0.03	0.02
New Zealand	9.99	7.07	2.92	70.77	29.23	0.00	189	0	0.03	0.02
Norway	10.04	7.10	2.93	70.76	29.20	0.03	188	0	0.03	0.02
Poland	10.04	7.10	2.93	70.76	29.20	0.03	188	0	0.03	0.02
Singapore	10.04	7.10	2.93	70.76	29.20	0.03	188	0	0.03	0.02
South Africa	10.04	7.10	2.93	70.76	29.20	0.03	188	0	0.03	0.02
Sweden	10.04	7.10	2.93	70.76	29.20	0.03	188	0	0.03	0.02
Switzerland	9.99	7.07	2.92	70.77	29.23	0.00	189	0	0.03	0.02
United Kingdom	9.99	7.07	2.92	70.77	29.23	0.00	189	0	0.03	0.02
Panel B: sample period 01/1996-12/2008										
Australia	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
Brazil	15.88	11.59	4.20	72.98	26.46	0.56	102	0	0.04	0.02
Canada	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
CzechRepublic	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
EUAVG	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
Hungary	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
Japan	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
Mexico	15.88	11.59	4.20	72.98	26.46	0.56	102	0	0.04	0.02
NewZealand	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
Norway	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
Poland	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
Singapore	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
SouthAfrica	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
Sweden	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
Switzerland	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02
UnitedKingdom	15.60	11.39	4.22	72.97	27.03	0.00	104	0	0.04	0.02

Table C.2: Bloomberg Tickers

This table reports the Bloomberg tickers used to calculate interest rate differentials. The tickers of type 'xxxx3M Curncy' are implied yields, the 'Index' tickers are -IBOR rates, and all others are swaps on interbank rates.

Currency	Ticker
AUD	ADBB3M Curncy
BRL	PREDI90 Index
CAD	CDOR03 Index
CHF	SF0003M Index
CZK	PRIB03M Index
DEM	FD0003M Index
EUR	EUR003M Index
GBP	BP0003M Index
HUF	BUBOR03M Index
JPY	JY0003M Index
MXN	MPSWC Curncy
NOK	NIBOR3M Index
NZD	NDBB3M Curncy
PLN	WIBO3M Index
SEK	STIB3M Index
SGD	SORF3M Index
USD	US0003M Index
ZAR	JIBA3M Index

Table C.3: Estimated Country-Specific Responsiveness (Pre-2009)

This table reports the country's average response to different monetary policy-related variables and average country characteristics. Panel A reports the θ_i for each country estimated from the individual univariate regression $r_{i,t} = \mu_i + \theta_i \text{Shocks}_t + \varepsilon_{it}$, where i is the currency identifier, t is the date of the scheduled FOMC meeting, and r_{it} is the intraday currency spot return in the 30-minute window surrounding the FOMC press releases. Shocks_t is one of the structural shocks or innovations of interest: (1) policy rate changes, (2) purged policy shocks, and (3) central bank information shocks, respectively. A positive surprise/shock is tightening. Note that we scale the estimated θ_i of the purged policy shocks and central bank information shocks with their variance contribution factors reported in Table C.1. We report t-statistics based on the Newey-West standard errors with optimal lags in parentheses. Panel B reports country-specific time-series averages for the five characteristic variables. The sample period is 01/1996-12/2008.

	Panel A: Average Responsiveness			Panel B: Average Characteristics				
Country	Rate Changes	MP Shocks	Info Shocks	NFA/GDP	Trade Centrality	Interest Rate Diff	Inflation Diff	Equity Beta
Australia	-5.38	-5.58	0.20	-0.53	0.30	1.50	0.35	0.02
	(-4.51)	(-4.01)	(0.28)					
New Zealand	-4.56	-4.78	0.22	-0.79	0.10	2.72	0.12	0.03
	(-4.06)	(-3.63)	(0.33)					
Norway	-4.29	-3.87	-0.41	0.32	0.27	0.74	-0.10	-0.08
	(-3.51)	(-2.76)	(-0.70)					
Sweden	-4.17	-3.99	-0.18	-0.26	0.38	-0.39	-0.28	-0.05
	(-3.83)	(-3.29)	(-0.29)					
Euro Area	-3.93	-3.49	-0.44	-0.09	0.71	-0.85	-0.69	-0.10
	(-4.01)	(-3.34)	(-0.83)					
Hungary	-3.81	-3.73	-0.08	-0.75	0.21	7.53	11.28	-0.03
	(-3.41)	(-3.60)	(-0.11)					
Brazil	-3.65	-4.69	1.04	-0.34	0.18	16.10	5.55	0.13
	(-3.32)	(-4.21)	(2.31)					
Czech Republic	-3.51	-3.40	-0.11	-0.15	0.23	2.03	4.10	-0.04
	(-3.53)	(-3.52)	(-0.23)					
Switzerland	-3.44	-2.74	-0.70	1.09	0.46	-2.50	-1.36	-0.14
	(-3.42)	(-2.89)	(-1.64)					
Poland	-3.31	-3.58	0.27	-0.35	0.25	7.89	6.00	0.01
	(-2.81)	(-3.18)	(0.74)					
United Kingdom	-3.27	-2.97	-0.30	-0.04	0.85	1.26	-0.06	-0.06
	(-3.71)	(-3.07)	(-0.73)					
South Africa	-3.25	-3.65	0.40	-0.18	0.18	7.25	5.23	0.04
	(-3.95)	(-4.78)	(1.09)					
Canada	-2.86	-3.26	0.40	-0.18	0.65	-0.28	-0.44	0.05
	(-4.50)	(-5.07)	(1.24)					
Japan	-2.50	-1.62	-0.88	0.29	0.59	-3.86	-2.48	-0.06
	(-3.03)	(-2.11)	(-2.94)					
Mexico	-1.75	-2.47	0.72	-0.38	0.43	10.84	9.88	0.11
	(-3.22)	(-5.63)	(2.90)					
Singapore	-0.60	-0.77	0.16	1.86	0.95	-1.77	-1.49	0.00
	(-2.73)	(-4.29)	(1.16)					

Table C.4: Currency Portfolio Return Correlation Matrix

This table reports return correlation among currency portfolios based on exposures to different monetary policy-related variables and currency risk factors. We report results for the long-short portfolios constructed by sorting currencies into five bins based on the cross-section of signals in Panel A, and the corresponding rank-weighted portfolio in Panel B. Signals are foreign currency's exposures to 1) policy rate changes (Rate), 2) pure monetary policy shocks (MP), 3) central bank information shocks (Info). We also report results for inverse volatility weighted portfolios of MP and Info, as well as the carry trade strategy. The sample period is between 02/1996-12/2008 for in-sample and 01/2009-07/2019 for out-of-sample.

	02/1996-12/2008						01/2009-07/2019					
	Rate	MP	Info	Mix	Carry	Momentum	Rate	MP	Info	Mix	Carry	Momentum
Panel A: L/S Portfolios												
Rate	1.00						1.00					
MP	0.58	1.00					0.89	1.00				
Info	-0.10	0.58	1.00				0.43	0.60	1.00			
Mix	0.26	0.88	0.90	1.00			0.75	0.90	0.89	1.00		
Carry	0.13	0.69	0.85	0.87	1.00		0.40	0.60	0.83	0.79	1.00	
Momentum	0.01	0.17	0.09	0.14	0.15	1.00	-0.19	-0.18	-0.07	-0.14	-0.11	1.00
Dollar	0.52	0.42	-0.01	0.21	0.14	0.11	0.63	0.65	0.43	0.60	0.53	-0.15
Panel B: Rank-Weighted Portfolios												
Rate	1.00						1.00					
MP	0.67	1.00					0.94	1.00				
Info	-0.13	0.55	1.00				0.60	0.77	1.00			
Mix	0.31	0.88	0.88	1.00			0.82	0.94	0.94	1.00		
Carry	0.10	0.67	0.85	0.87	1.00		0.49	0.69	0.87	0.82	1.00	
Momentum	0.03	0.21	0.10	0.18	0.15	1.00	-0.15	-0.13	-0.06	-0.10	-0.11	1.00
Dollar	0.54	0.48	-0.05	0.24	0.14	0.11	0.66	0.71	0.51	0.65	0.53	-0.15

Table C.5: Currency Composition: Carry Trade and MP Exposure Portfolios

This table reports the currency composition of the five portfolios sorted based on rate changes exposure (Panel A), MP shocks exposure (Panel B), Info shocks exposure portfolios (Panel C), and the cross-section of the carry trade (Panel D) portfolios. We report the top five currencies entering each portfolio. The portfolios are re-balanced monthly. The sample period is between 02/1996-12/2008 for in-sample and 01/2009-07/2019 for out-of-sample.

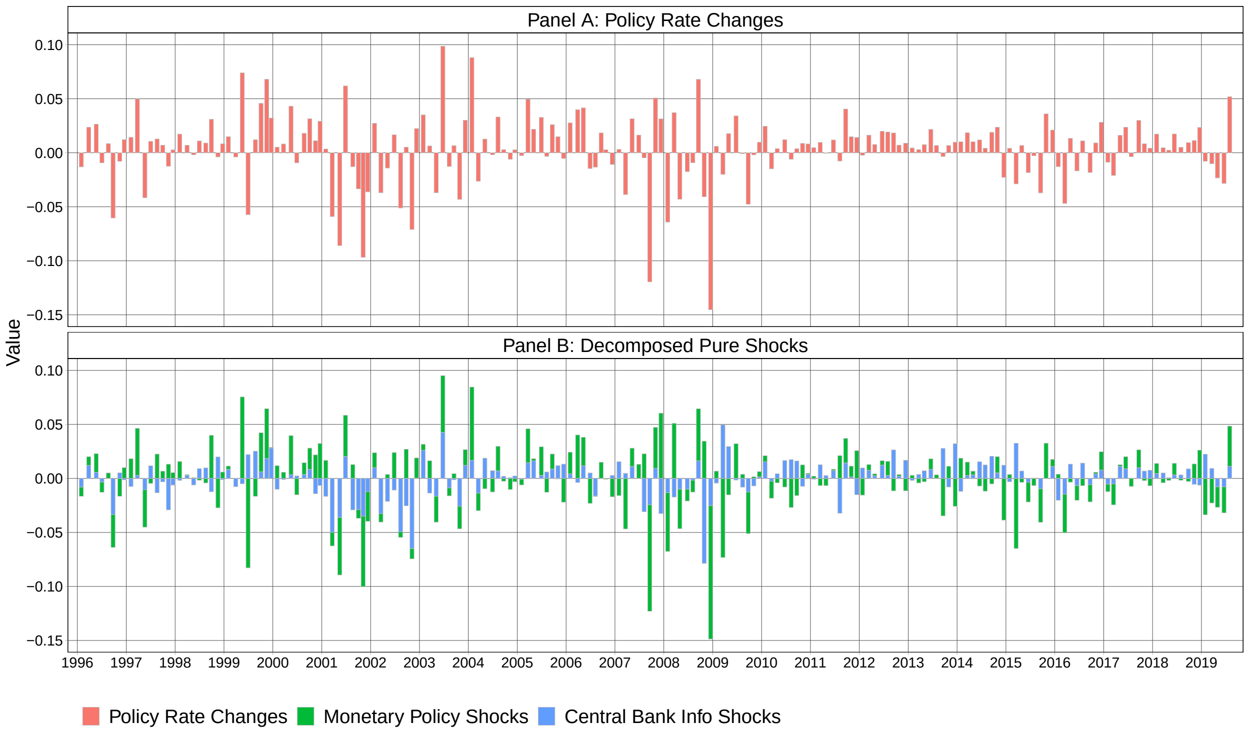
	02/1996-12/2008					01/2009-07/2019				
	Rank1	Rank2	Rank3	Rank4	Rank5	Rank1	Rank2	Rank3	Rank4	Rank5
Panel A: Rate Changes Exposure Portfolios										
P1	AUD	NOK	PLN	NZD	BRL	AUD	NZD	PLN	BRL	SEK
P2	SEK	PLN	NZD	HUF	NOK	EUAVG	SEK	ZAR	PLN	HUF
P3	EUAVG	HUF	CHF	CZK	GBP	ZAR	GBP	HUF	BRL	NOK
P4	CAD	ZAR	GBP	JPY	CHF	CAD	CZK	CHF	GBP	HUF
P5	SGD	MXN	JPY	CAD	ZAR	SGD	MXN	JPY	AUD	NZD
Panel B: Monetary Policy Shocks Exposure Portfolios										
P1	AUD	NZD	BRL	PLN	NOK	AUD	NZD	BRL	SEK	PLN
P2	NOK	SEK	PLN	HUF	BRL	HUF	SEK	PLN	ZAR	NOK
P3	EUAVG	HUF	CAD	ZAR	CZK	EUAVG	CAD	NOK	ZAR	PLN
P4	GBP	CHF	CAD	CZK	ZAR	CHF	CZK	GBP	CAD	NOK
P5	SGD	JPY	MXN	CHF	GBP	SGD	JPY	MXN	CZK	CHF
Panel C: Information Shocks Exposure Portfolios										
P1	CHF	JPY	NOK	EUAVG	GBP	JPY	CHF	NOK	EUAVG	SGD
P2	EUAVG	NOK	SEK	CZK	ZAR	EUAVG	GBP	NOK	SGD	CZK
P3	GBP	CZK	PLN	ZAR	HUF	SEK	CAD	CZK	PLN	SGD
P4	AUD	NZD	HUF	CAD	PLN	AUD	NZD	CAD	BRL	MXN
P5	BRL	MXN	SGD	NZD	CAD	ZAR	MXN	HUF	NZD	BRL
Panel D: Carry Trade Portfolios										
P1	JPY	CHF	SGD	EUAVG	CZK	CHF	JPY	EUAVG	SEK	SGD
P2	EUAVG	SEK	CAD	CZK	NOK	GBP	CZK	JPY	EUAVG	SEK
P3	GBP	AUD	CAD	SEK	PLN	NOK	CAD	NZD	SGD	SEK
P4	NZD	HUF	ZAR	AUD	MXN	AUD	PLN	MXN	NZD	CAD
P5	BRL	MXN	ZAR	HUF	PLN	ZAR	BRL	MXN	HUF	NZD
Panel E: Short-Term Momentum Portfolios										
P1	JPY	ZAR	CHF	MXN	AUD	JPY	BRL	ZAR	MXN	GBP
P2	EUAVG	SEK	CHF	SGD	NOK	EUAVG	CZK	CHF	NOK	SEK
P3	SGD	EUAVG	GBP	HUF	NOK	CHF	EUAVG	SGD	NOK	AUD
P4	NZD	PLN	CAD	NOK	AUD	CAD	AUD	SGD	SEK	CZK
P5	MXN	BRL	PLN	ZAR	HUF	BRL	ZAR	JPY	MXN	NZD

Table C.6: Average Rank Weights

This table reports the average rank portfolio weights for the exposure portfolios and the carry trade portfolios.

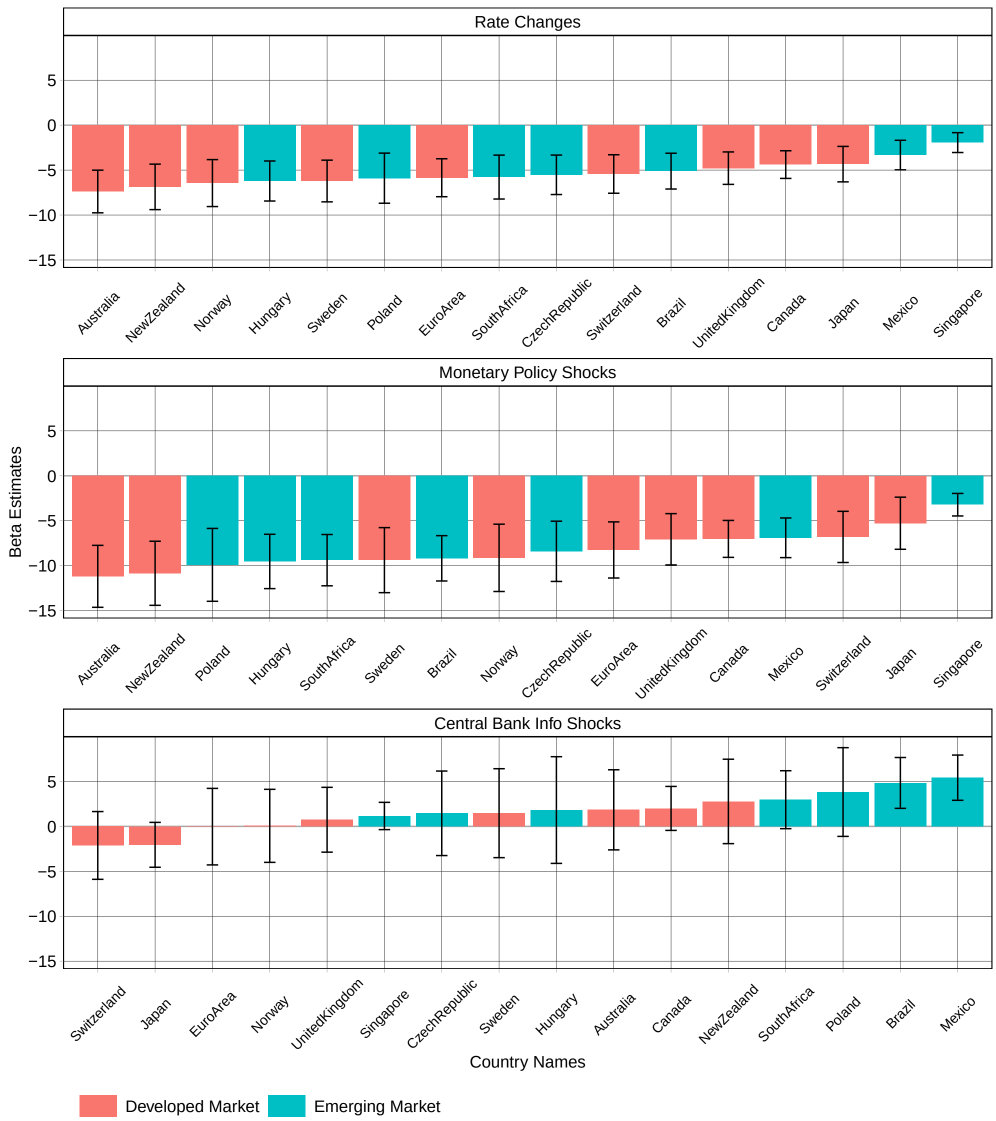
	02/1996-12/2008					01/2009-07/2019			
	Rate	MP	Info	Carry		Rate	MP	Info	Carry
JPY	-0.17	-0.21	-0.21	-0.25	CHF	-0.08	-0.14	-0.20	-0.23
CHF	-0.01	-0.12	-0.21	-0.20	JPY	-0.22	-0.23	-0.23	-0.18
SGD	-0.24	-0.24	0.06	-0.15	EUR	0.10	-0.01	-0.13	-0.14
EUR	0.03	-0.02	-0.12	-0.11	SEK	0.13	0.12	-0.03	-0.12
SEK	0.11	0.08	-0.08	-0.08	SGD	-0.22	-0.20	-0.06	-0.09
CAD	-0.13	-0.06	0.12	-0.07	GBP	-0.02	-0.05	-0.08	-0.09
CZK	-0.01	-0.03	-0.03	-0.04	CZK	-0.08	-0.10	-0.06	-0.06
NOK	0.18	0.10	-0.16	-0.01	CAD	-0.12	-0.03	0.06	-0.02
GBP	-0.07	-0.11	-0.07	0.02	NOK	0.01	0.01	-0.16	0.01
AUD	0.24	0.24	0.09	0.03	PLN	0.13	0.09	0.03	0.08
NZD	0.14	0.17	0.11	0.09	HUF	-0.01	0.06	0.16	0.08
PLN	0.16	0.17	0.08	0.11	NZD	0.19	0.19	0.14	0.09
HUF	0.04	0.06	0.03	0.15	AUD	0.23	0.23	0.11	0.10
ZAR	-0.08	-0.05	0.00	0.17	MXN	-0.17	-0.15	0.19	0.16
MXN	-0.21	-0.13	0.19	0.18	ZAR	0.05	0.08	0.18	0.19
BRL	0.06	0.18	0.21	0.23	BRL	0.07	0.13	0.09	0.22

Figure C.1: Surprises and Shocks Measured Over Time



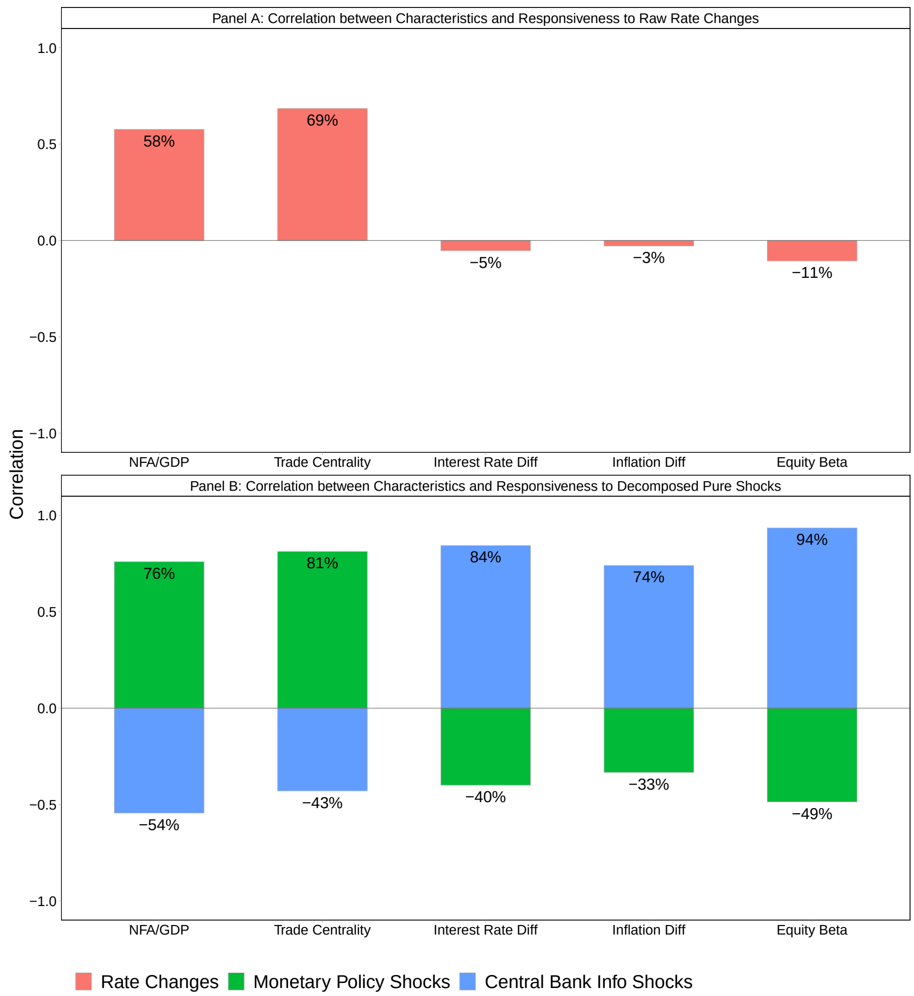
This figure reports the monetary policy-related variables measured over time. By analyzing the co-movement of interest rates and stock prices in a narrow policy announcement window, we decompose policy rate changes around the Federal Open Market Committee (FOMC) announcements into purged monetary policy and central bank information shocks.

Figure C.2: Country-Specific Responsiveness to Shocks



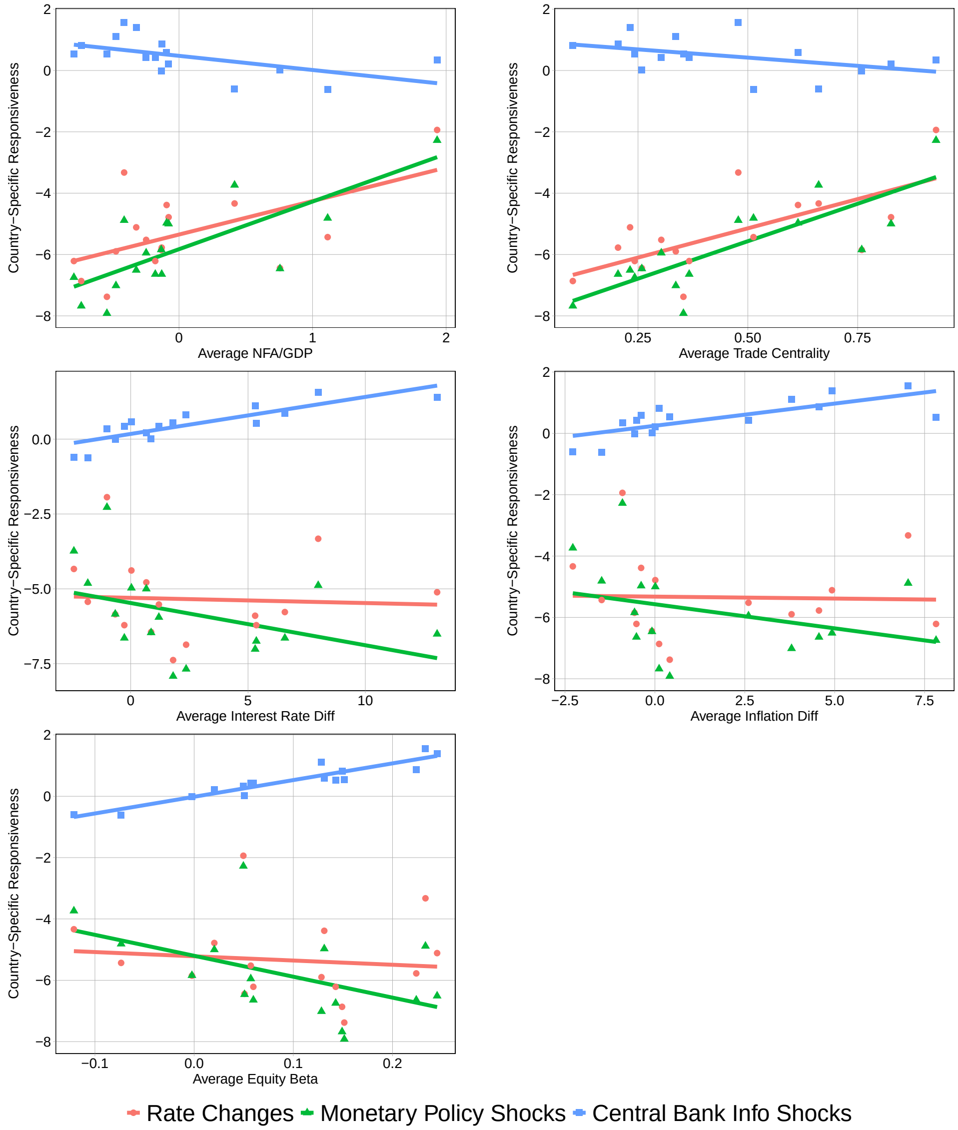
This figure plots the country-specific responsiveness to monetary policy-related variables. The country's average response to different monetary policy-related news measures is estimated from the individual univariate regression. We report the estimated beta and their 90 percent confidence interval based on Newey-West standard errors with optimal lags. The sample period is between 1996/01-07/2019.

Figure C.3: Cross-Sectional Correlation between Average Characteristics and Responsiveness to Shocks



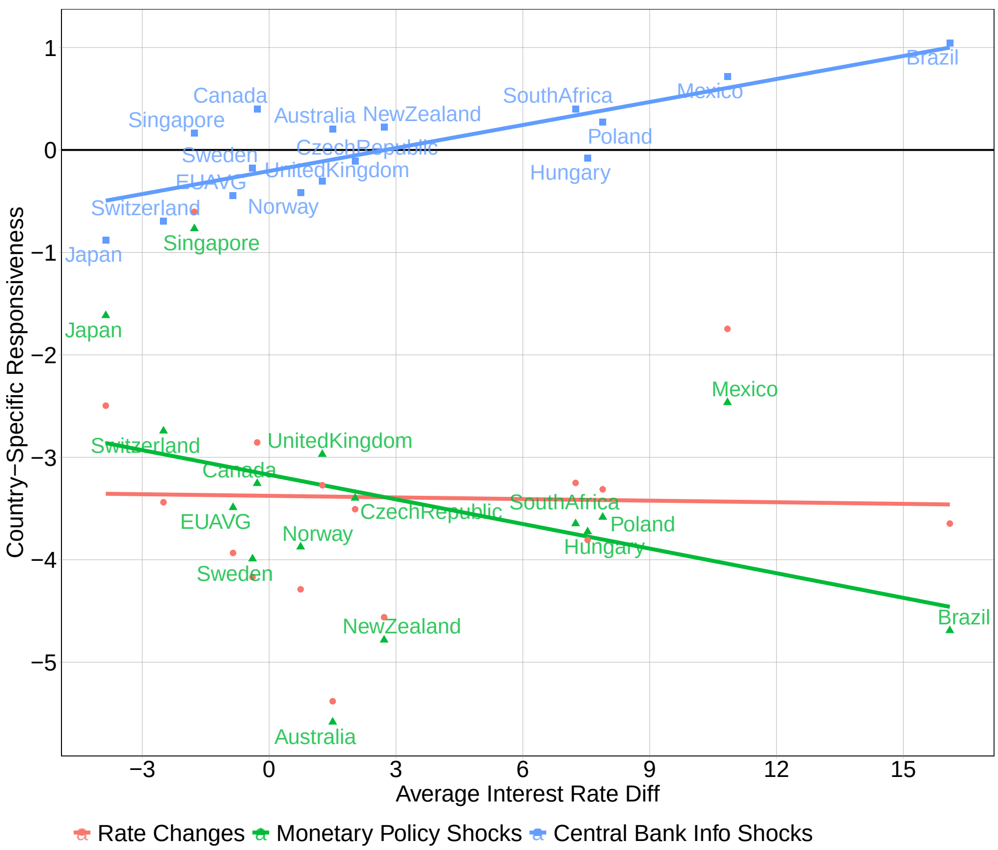
This figure reports the cross-sectional correlation between the time-series average of currency characteristics and the effect of monetary policy-related variables on individual countries. The country's average response to different monetary policy-related news measures is estimated from the individual univariate regression. The sample period is between 1996/01-07/2019.

Figure C.4: Country-Specific Responsiveness to Shocks and Characteristics



This figure plots the country-specific responsiveness to monetary policy-related variables against the time-series average of different currency characteristics. The country's average response to different monetary policy-related news measures is estimated from the individual univariate regression. The sample period is between 1996/01-07/2019.

Figure C.5: Country-Specific Responsiveness to Shocks and Characteristics (Pre-2009)



This figure plots the country-specific responsiveness to monetary policy-related variables against the time-series average of currency interest rate differentials. The country's average response to monetary policy is estimated from the individual univariate regression $r_{i,t} = \mu_i + \theta_i \text{Shocks}_t + \varepsilon_{it}$, where i is the currency identifier, t is the date of the scheduled FOMC meeting, and r_{it} is the intraday currency spot return in the 30-minute window surrounding the FOMC press releases. Shocks_t is one of the structural shocks or innovations of interest: 1) policy rate changes, (2) purged policy shocks, and (3) central bank information shocks, respectively. A positive surprise/shock is tightening. Note that we scale the estimated θ_i of the purged policy shocks and central bank information shocks with their variance contribution factors reported in Table C.1. The scaled estimates of θ_i capture the policy exposure for each currency and is reported on the y-axis against their average interest rate differentials. The sample period is between 1996/01-12/2008.

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