Intervening against the Fed*

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Abstract

By identifying unexpected foreign exchange intervention (FXI) through deviations from estimated FXI rules, we study the interaction between US monetary policy surprises and FXI for exchange rates and stock prices across firms. We find that, without intervention, an unexpected Fed funds rate hike depreciates local currencies and decreases the stock price of firms, especially those whose debt is disproportionately denominated in US Dollars, consistent with the Global Financial Cycle literature. However, if central banks counteract by selling the US Dollar, the US monetary shock has a limited effect on the exchange rate and stock prices even for firms with US Dollar debt. These results suggest that FX interventions are a successful tool in muting the impact from the Global Financial Cycle.

Keywords: Foreign Exchange Intervention, Monetary Policy Spillovers, Exchange Rates, Dollar debt

JEL Classification Codes: E44, F31, F32, F41

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1 Introduction

The Federal Reserve is an important driver of the “Global Financial Cycle" and changes in US monetary policy can have major spillovers to the global economy. When the Fed tightens monetary policy, the US Dollar appreciates, and global stock prices as well as credit contract (Rey 2015, Miranda-Agrippino and Rey 2020). Although both academics and policymakers have signaled the first-order importance of this issue, there is limited consensus on how countries could protect themselves against this unwarranted tightening of monetary policy.

An increasingly popular policy tool among central banks are sterilized foreign exchange intervention (FXI), i.e. the purchases or sales of foreign currencies that do not involve directly changing the interest rate. Many central banks have accumulated FX reserves reaching record highs to keep their currencies depreciated.[1] However, often the benefits of a depreciated currency for boosting exports remain elusive (Gopinath et al. 2020). Instead, an increase in US Dollar debt of companies in emerging markets has raised concerns that depreciations are contractionary rather than expansionary (Maggiori et al. 2020). This raises the question of whether the accumulated reserves in the US Dollar can potentially be used to insulate themselves against an unwarranted tightening of US monetary policy, and how FX interventions can stabilize the exchange rate and the economy more broadly.

A notable example is the recent Japanese FX intervention against US Dollar. Figure 1 plots the minute-by-minute US Dollar to Japanese yen spot exchange rate on September 22, 2022. At 2pm Eastern Daylight Time on September 21, or equivalently, 3am Japan Standard Time on September 22, FOMC made an announcement to increase the Fed funds rate by 0.75 percentage points to mitigate the inflation caused by Russian war in Ukraine. The Japanese yen showed a clear depreciation trend until it reached nearly 1USD = 146JPY, the weakest level after the early 1990s. However, when the Bank of Japan intervened in the FX market by selling US Dollar and buying Japanese yen at around 5pm on the same date, the yen suddenly started appreciating and became close to 1USD = 140JPY at around 6pm.[2] The last time Japan intervened in the FX market by selling the US Dollar was in 1998. The intervention was unexpected by the market

[1]For example, the Swiss National Bank has sold franc to counter the over-valuation due to its safe-haven status and boost the export industries (Jordan 2017). Chinese foreign reserves increased from 733 billion US Dollar in July 2005 to 3.99 trillion dollar in June 2014 (Das 2019).

[2]The timing of intervention is not publicly disclosed by the Bank of Japan. The Japanese yen was bought and started appreciating at around 5:03pm JST. At 5:15pm, The Ministry of Finance announced that the intervention was carried out and a press conference was held at 6:30pm. The volume of intervention in the September 2022 was around 2.8 trillion yen or approximately 20 billion US Dollar, which was a record high.

because the Bank of Japan has kept accommodative negative interest rate policy since the global financial crisis (Duguid 2022).[3]

Despite widespread use, the effect of intervention is far from well understood from empirical perspectives, both due to data availability and endogeneity issues. Especially, a main challenge in the literature has been how to construct an exogenous shock to the exchange rate which is orthogonal to FX interventions or other macroeconomic conditions.

The contributions of this paper are twofold. Our first contribution is to develop a novel event study methodology to identify the effect of FX intervention. We exploit the US monetary shocks cleanly identified by high-frequency methods (Nakamura and Steinsson 2018a) combined with daily FX interventions data around FOMC announcements. The high-frequency monetary shocks is estimated by a change in Fed funds futures in a sufficiently narrow time windows around the FOMC announcement, so that monetary shocks are orthogonal to information revealed in this narrow window. Using this monetary surprise, we compare the responses of exchange rates and stock prices to FOMC announcements in countries that do and do not counter-intervene against the US Dollar shortly after the announcement.

To address the endogeneity concern of FXI, we identify unexpected interventions through an estimation of a FXI rule. The idea is to estimate the central banks' response of intervention to US monetary shocks as well as past exchange rate movements and intervention. The intervention implied by this rule can be interpreted as expected intervention and allows us to decompose the variance of interventions into an explained and unexplained part. Most of the explained variation is driven by whether the central bank has recently intervened in the FX market, followed by differential propensity to intervene against the Fed depending on their macro-characteristics. We then exploit the residual of the FXI rule as an unexpected exogenous intervention for identification. Our estimate shows that more than 75% of FX intervention against the US dollar cannot be explained by this FX intervention rule. This low explanatory power implies that a large component of interventions in our sample is unexpected.

Using these unexpected monetary shocks and FX intervention, we present evidence that intervening against the Fed prevents exchange rate disturbances against the US Dollar when US monetary policy surprisingly changes. When the Fed hikes rates unexpectedly and the country does not sell the US Dollar to counteract the surprise, the domestic currency depreciates against the US Dollar. However, when the domestic authority sells US Dollars and buys the domestic

[3]Another example is that Brazil sold 110 billion US Dollars in two years following Fed's taper announcement in May 2013 (Chamon et al. 2017).

currency, the domestic currency remains flat around the US monetary policy tightening.

While previous studies on FX interventions mainly focused on exchange rate only, policy-makers and academics are also interested in how FX intervention affects the economy and how the effect is heterogeneous across agents. Our second contribution is to study the effect of FX intervention on the stock market using firm-level stock price and balance sheet information. The effect on the stock market cannot simply be measured in the aggregate stock market as it masks significant heterogeneity across firms. Instead, we take a more granular approach and exploit variation in the firm-level characteristics and trace the differential response in stock return across firms. In particular, we focus on firms with US Dollar debt as they are particularly susceptible to exchange rate depreciation. Firms with a large degree of US Dollar debt see a decrease in their domestic net worth position in response to an appreciation of the US Dollar, as the value of their liabilities in domestic currency increases.

The availability of a rich corporate bond- and loan-level dataset of currency breakdowns allows us to investigate how firms with heterogeneous degrees of exchange rate exposure are affected by the FX intervention. Exploiting the heterogeneity across firms allows us to abstract from country-date specific factors that would drive the results. Instead, within the same country, we can compare firms with and without a large amount of US Dollar debt and trace their differences in stock returns. We find that firms that have a large degree of US Dollar debt are significantly more negatively affected by US monetary policy tightening if the domestic country does not intervene against the Fed. However, when the domestic authority intervenes against the Fed, stock returns of firms with a larger degree of US Dollar debt behave insignificantly differently than those of their counterparts.

These results suggest that FX interventions can be successful in stabilizing both the exchange rate and stock returns, especially for those that are highly exposed to the global financial cycle. FX interventions can make countries more insulated from the global financial cycle.

Firms that have a larger degree of US Dollar debt may be inherently different from those that do not, potentially biasing our estimates. Therefore, we further refine our identification strategy by exploiting the debt maturity structure of firms around the FOMC announcements.[4] If firms happen to have Dollar debt which matures around unexpected Fed hikes, the depreciation of local currency increases the cost of rolling over debt in terms of local currency. On the other

[4]The debt maturity identification approach follows the approach by Almeida et al. (2011) and Duval et al. (2020) that study the effect of debt maturity during the global financial crisis on firms' outcomes. More recently, this approach has been applied in the context of the US Dollar debt maturity structure around exchange rate movements by Casas et al. (2022).

hand, if the maturity is not around the monetary shocks, the increase in debt rollover cost is small. We show that when the domestic central banks intervene against the Fed policy by buying local currency in response to a tightening shock, this disproportionately benefits the firms that have US Dollar debt that matures around the FOMC announcement relative to a scenario in which the Dollar debt does not mature around the FOMC announcement. Since the debt maturity structure is orthogonal to exchange rate movements, the effect of debt repayment on stock price can potentially be interpreted causally.

Literature. Recent theories claim that interventions can affect the exchange rate and enhance welfare under imperfect financial markets (Gabaix and Maggiori 2015, Cavallino 2019, Amador et al. 2020, Jeanne and Sandri 2020, Fanelli and Straub 2021, Hassan et al. 2022). However, empirical analyses have been limited due to both endogeneity concern and data limitation. Previous empirical studies on the FX intervention, including Fatum and Hutchison (2010) and Fratzscher et al. (2019), use propensity score matching (PSM) developed by Rosenbaum and Rubin (1983). PSM calculates propensity scores from observed covariates and divides the sample into treatment and control groups using the samples with similar scores. Adler et al. (2019) uses monthly panel data to estimate the effects of FXI interventions. In contrast, our event study approach exploits daily FX data combing with US monetary surprises purely identified by a high-frequency approach (Gürkaynak et al. 2005, Gorodnichenko and Weber 2016, Nakamura and Steinsson 2018a;b, Jarociński and Karadi 2020, Bu et al. 2021). The advantage of high-frequency identification is that, by using changes in Fed funds futures in a narrow time window around FOMC announcements, it minimizes the possibility that monetary policy is affected by other macroeconomic conditions. Thus, using this high-frequency monetary shock as an unexpected shock to the exchange rate allows us to identify whether foreign exchange interventions are effective in leaning against exchange rate shocks. In terms of methodology, our paper is complementary to Kuersteiner et al. (2018), who use high-frequency FX intervention data in Colombia and regression discontinuity design to identify the surprise component of rule-based intervention. Our contribution is to use a larger set of countries and study the response to high-frequency US monetary shocks. Moreover, while previous studies have focused on the effect of FX intervention on exchange rate, we also exploit the firm- and bond-level data on currency denomination and maturity and study the effect of intervention on stock market.

Both theoretical and empirical literature on exchange rate dynamics and international transmission of monetary policy mainly focuses on changes in policy interest rate, based on the

seminal work by Gali and Monacelli (2005). Especially, recent papers emphasize the special role of US Dollar in both international trade and finance. For example, Corsetti et al. (2020), Egorov and Mukhin (2020), Gopinath et al. (2020) and Mukhin (2021) consider monetary policy when the US Dollar plays a dominant role in trade. Akinci and Queralto (2019), Aoki et al. (2020), Gopinath and Stein (2021), and di Giovanni et al. (2022) study US monetary policy and corporate balance sheet risk when firms issue debt denominated in dollars. In the context of firm heterogeneity, Maggiori et al. (2020) and Salomao and Varela (2022) provide evidence that large firms issue foreign currency bond and take on currency mismatch on balance sheet, while small firms issue bonds in local currency. Amiti et al. (2014) construct a model with heterogeneous firms in exports and imports, and Rodnyansky (2019) studies the effect of competitive devaluation in such an environment. Casas et al. (2022) study the role of US Dollar borrowing for the transmission of exchange rate shocks to trade. de Ferra et al. (2020) and Guo et al. (2020) study an open economy New Keynesian model with households with heterogeneous degrees of trade and financial integration. Timmer (2018) studies the spillover of US monetary policy on corporate bond yields. However, monetary policy consists of many tools and we are not just interested in the responses of firms to interest rate changes. In contrast to most of extant studies, we study another widespread and important dimension of monetary policy, that is, sterilized FX intervention.

2 Data

2.1 Sources

We combine data from several sources. Our sample period is between 2000 and 2019, during which the data on US monetary shock and corporate balance sheet are available.

First, we collect data on sterilized FX interventions based on Fratzscher et al. (2019) and Adler et al. (2021). We use publicly available databases on central bank websites and the FRED database. Some countries do not publicly disclose the data due to secret intervention, in which case we individually contacted the central banks to be granted an access to the data. We then restricted the sample countries based on the following criteria. First, for the sake of high-frequency identification, we only use daily intervention data and exclude countries where only monthly or quarterly data is available. Second, since we study the interventions against US monetary shocks, our sample only comprises countries that intervened against US Dollar

multiple times during the sample period. The following 14 countries have available data and satisfy the above criteria: Argentina, Australia, Brazil, Chile, Colombia, Costa Rica, Georgia, Hong Kong, Japan, Mexico, Morocco, Peru, Switzerland, and Turkey.

To address the endogeneity concern of monetary policy, we use the high-frequency change in Fed funds rate (FFR) identified by Nakamura and Steinsson (2018a).[5] They estimate the changes in Fed funds futures in a 30-minute window around the FOMC announcement. We obtain daily data on the spot exchange rate and stock price from Thomson Reuters Datastream. Since Datastream reports the closing exchange rate at 4pm London time and FOMC announcement is made around 2pm Washington time, we moved the reported dates of exchange rates by one date forward so that the exchange rate on each date is reported after the FOMC announcement on the same date. Since the end-of-date stock price is released at different times in different time zones, we adjusted the dates for the stock price depending on whether the stock price is released before or after the FOMC announcement.

We use corporate balance sheet data on the Capital IQ platform provided by S&P Global Market Intelligence. Capital IQ satisfies the following three key requirements. The advantage of Capital IQ is that it provides information on the currency denomination of debt, which is not available in other databases, such as Worldscope, Compustat, and Orbis. Its Capital Structure database provides detailed information on each debt instrument held by each firm, including the principal amount due, repayment currency, and maturity. For example, Agrometal S.A.I., a manufacturing firm in Argentina, has a total outstanding debt of 5.6 million dollars in December 31, 2015. Among them, 2.2 million dollars are repaid in US Dollars and the remaining 3.4 million dollars are repaid in Argentine peso.[6] Hence, the share of dollar bond over total bond is 39 percent. Capital IQ provides annual data on corporate balance sheet after 2001. The sample is restricted to publicly listed firms as data on stock price is available.

We complement the data using a variety of sources. Firm-level data on exports and incorporation date is available on Worldscope. To measure the firms' reliance on intermediate imports in their production, we use sector-level data on import content of exports in OECD input-output tables, following Rodnyansky (2019).[7] The SIC industry code in Capital IQ is matched with

[5]The original data was updated by Miguel Acosta and Joseph Saia. The data is currently available between 2000 and 2019.

[6]Capital IQ converts the principal due of peso bond to US Dollar using the end-of-year spot exchange rate.

[7]Due to the data limitation, this paper focuses on the effect of FX intervention on firms with Dollar debt rather than exporters and importers. First, almost all Worldscope firms, especially in emerging economies, are non-exporters. Second, it is difficult to obtain a firm-level data on invoicing currency of export and import for a number of countries.

ISIC Revision 4 industry code using a conversion table in the United Nations Statistics Division. Appendix A provides details on data cleaning procedure and selection criteria for our sample of firms.

Finally, for country-level characteristics, we collected the data on monthly policy rate from the IMF Monetary and Financial Statistics. The data on GDP, inflation rate, trade balance, and unemployment rate are retrieved from World Bank database and complemented by IMF World Economic Outlook.

2.2 Summary Statistics

Table 1 provides summary statistics for Fed funds rate shocks and changes in the exchange rate and stock price.[8] We trimmed top and bottom 5% of Fed funds rate shocks and winsorized top and bottom 5% of changes in exchange rate and firms' stock price in each country so that our result is not affected by outliers.

Our sample consists of 90 FOMC announcement dates between 2000 and 2019. Row (1) shows the summary statistics for Fed funds rate shock estimated by Nakamura and Steinsson (2018a). The Fed funds rate shock is defined as the change in market expectations of the Fed funds rate over the remainder of the month in which FOMC meeting occurs. The shock is in terms of basis points and a positive value implies a tightening surprise by the Federal Reserve. As Nakamura and Steinsson (2018a) discuss, the magnitude of Fed funds rate shocks estimated by the high-frequency method is small: the standard deviation is only 1.81 basis points. This precludes us from estimating the effect on variables in a distant future: for example, output several quarters away is likely to be influenced by other macroeconomic conditions. In order to minimize this "power problem," we study the response of daily data on exchange rate, stock price, and FX intervention, which move contemporaneously with monetary shock.

Row (2) shows the summary statistics for the changes in exchange rate comparing before and after the FOMC announcement date. $e_{c,t}$ is the spot exchange rate at the end of date t in country c. The exchange rate is defined as the value of US Dollar in terms of local currency so that higher $e_{c,t}$ implies the appreciation of US Dollar or depreciation of local currency. We take the change in the logarithm of exchange rate from date $t-1$ to $t+1$. Similarly, row (3) shows the summary statistics for the change in stock price comparing before and after the FOMC announcement. $p_{i,t}$ is the stock price of firm i at the end of date t. The stock price is

[8] Table 3 shows the sample of firms, which we will discuss later in this section.

denominated in local currency. The standard deviation of exchange rate change is 0.72 percent and that of stock price return is 3.47 percent.

Table 2 shows the frequency (columns 1-3) and average amount (column 4-5) of interventions around the FOMC event dates in our sample countries. To consider the possibility that the effect of Fed funds rate shock and FX intervention accumulates over time, we consider a 5-day window after FOMC announcement dates.

We first define buying and selling intervention so that central banks buy or sell the US Dollar at least once between dates t and $t+5$, where t is the FOMC announcement date. Columns (1) and (2) report the frequency of buying and selling US Dollar interventions, which happened after 90 FOMC event dates in our sample. There is a large variation in the frequency of interventions across countries. For example, Argentina intervened 59 times by buying US Dollar and 45 times by selling it, out of total 90 event dates. In contrast, Switzerland never intervened and Turkey intervened only once around the FOMC meetings. However, the intervention happened only outside of the 5-day window around the meetings. To minimize the possibility that the intervention is affected by a myriad of other factors than US monetary shocks, our sample does not count intervention which happened outside of the 5-day window around FOMC event dates.

Column (3) reports the frequency of counteracting intervention, which is the main focus of our analysis. We define counteracting intervention as follows: if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. Intuitively, since a higher Fed funds rate depreciates the local currency, central banks can offset the depreciation by selling the US Dollar and buying the local currency. Unless otherwise stated, we will use this definition of counteracting FX intervention throughout the regression analyses in this paper.[9] We learn that not all interventions are counteracting interventions against the Fed. For example, Argentina intervened by buying US Dollar 59 times and by selling US Dollar 45 times, but only 15 times they intervened counteractingly to Fed funds rate shocks. We will study how the effects of FOMC announcements on exchange rate and stock price is different when the central banks do and do not counter-intervene against Fed funds rate shocks.

Column (4) reports the average amount of FX intervention. We take the average amount of FX net purchase of between dates t and $t+5$ over all FOMC announcement dates t. The unit is

[9]Section 4.5 defines the counteracting intervention in a different way: the central banks' average net sales of US Dollar between dates t and $t+5$ is positive when the Fed funds rate increases at date t, and vice versa when the Fed funds rate decreases. Our main results are robust to using this alternative definition.

millions of US Dollars and positive and negative values imply buying and selling US Dollars, respectively. Column (5) takes the ratio of FX intervention over GDP to take into account the difference in country size. We learn that there is a significant variation in the amount of FX intervention across countries. The average net purchase of US Dollar in a 5-day window after the announcement date ranges from 1.2×10^{-3} percent of GDP in Hong Kong to 1.9×10^{-7} percent of GDP in Japan.[10] The average net purchase of US Dollar across all countries is 6.8 million dollars and 2.9×10^{-4} percent of total GDP.

Column (6) reports the sample period when the FX intervention data are available. The availability of FX intervention data depends on countries. Especially, our sample only includes countries and time periods in which daily FX intervention data is available. We excluded time periods in which only monthly, quarterly, or annual data are available. For example, daily intervention data in Switzerland is available only until 2001.

Table 3 describes the sample of firms.[11] The table shows the total number of firms and the number of firms with Dollar debt in each country. Our sample consists of 4,088 firms in total, out of which 261 firms (6%) have Dollar debt and 431 firms (11%) are exporters.[12] The share of firms with Dollar debt is relatively large in emerging economies, while most of the Japanese firms do not issue Dollar debt as they borrow in Japanese yen (if we exclude Japanese firms, 14% of firms have Dollar debt). Among the firms with Dollar debt, only four firms are exporters.[13] Hence, our result on firms with Dollar debt is mainly driven by firms without corresponding exporting revenues: they are not naturally hedged against exchange rate depreciation.[14] The average share of Dollar debt over total debt across all firms is 53% (66% except Japan), conditioning on firms issuing positive amount of Dollar debt. Our results on FX intervention and stock market are robust even after controlling for export and import, as well as their interaction with Fed funds rate shocks.

[10] Section 4.4 shows that our main results hold even after excluding small intervention.

[11] We omitted the following countries from our sample firms. Turkey never conducted FX intervention in 5-day windows around FOMC announcement dates. In Switzerland, the daily FX intervention data is only available until 2001. In Costa Rica, Georgia, and Peru, there is very little data on corporate balance sheet.

[12] Table 3 defines firms with Dollar debt as those which issued positive amount of Dollar debt at least once during the sample period. Similarly, the exporters are defined as firms which report positive amount of export at least once during the sample period.

[13] Almost all exporters in our sample are Japanese firms which borrow in yen.

[14] Section 4.2 also controls for international sales and asset holdings, which affect firms' foreign currency revenue, and our main result does not change.

3 Results

3.1 Identification of Unexpected FX Intervention

To elaborate our identification strategy of FX intervention, we follow Fatum and Hutchison (2010) and Fratzscher et al. (2019) and estimate a central bank reaction function. The motivation is to extract the unexpected component of intervention which cannot be forecast by Fed funds rate shocks, past exchange rate movement and FX intervention before the FOMC events, and other macroeconomic conditions. This is a popular approach to deal with endogeneity of intervention in the literature.

We consider the following FX intervention rule:

$$\widetilde{FXI}_{c,t} = \alpha + \sum_{c} \beta_c (FFR_t \times country_c) + \delta Z_{c,t} + \gamma_c + \epsilon_{c,t}. \tag{1}$$

$\widetilde{FXI}_{c,t}$ is the dummy for counteracting intervention in country c on FOMC announcement date t, as discussed in Section 2.2. $\widetilde{FXI}_{c,t}$ takes 1 if the Fed funds rate increases on date t and the central banks intervene by selling the US Dollar at least once but never intervenes by buying the US Dollar between dates t and $t+5$. Similarly, $\widetilde{FXI}_{c,t}$ takes -1 if the Fed funds rate decreases on date t and the central banks intervene by buying the US Dollar at least once but never intervenes by selling the US Dollar between dates t and $t+5$. Otherwise, $\widetilde{FXI}_{c,t}$ takes zero. FFR_t is the Fed funds rate shock in terms of basis points and $country_c$ is the dummy variable for each country c. Their interaction $FFR_t \times country_c$ captures the difference in response of intervention to Fed funds rate shocks across countries. $Z_{c,t}$ is the set of controls, including the trend and standard deviation of exchange rate and the dummy for FX intervention before the FOMC event date, as well as the macroeconomic variables (lagged policy rate, GDP, CPI inflation rate, trade balance over GDP ratio, unemployment rate), and the interaction of macroeconomic variables with Fed funds rate shock. For past exchange rate movement, we took the percentage change and standard deviation of exchange rate between dates $t-1$ and $t-5$, where t is the FOMC event date. For past intervention, the dummy takes 1 if the average net purchase of US Dollars between dates $t-1$ and $t-5$ is positive, -1 if the net purchase is negative, and zero if there is no intervention.

Our choice of controls is based on previous empirical literature on FX intervention. Following Fratzscher et al. (2019), we control for the past exchange rate trend and volatility and

past interventions since they can help us predict the FX interventions. Moreover, based on Fatum and Hutchison (2010), we also controlled for macroeconomic variables, such as GDP and trade balance, since countries with different macroeconomic conditions may adopt different interventions. We use lagged macroeconomic variables to remove the simultaneity bias. We also take the interaction between the Fed funds rate shock and macro variables since countries with different macroeconomic condition can respond heterogeneously to Fed funds rate shock. We include the country fixed effect γ_c to control the difference in average exchange rate trends in each country. The standard error $\epsilon_{c,t}$ is double-clustered at country and event date levels to account for correlation in exchange rate changes in the same country and time.

The predicted counter-intervention from estimating the reaction function (1) can be interpreted as expected component of counter-intervention, in other words, component of intervention which can be explained by Fed funds rate shock, past exchange rate and intervention, and macroeconomic conditions. The residual, or the deviation from FX intervention rule, can be interpreted as unexpected component of FX intervention. We can exploit this residual as the exogenous surprise component of FX intervention.

Figure 2 graphically illustrates the result for variance decomposition from estimating Equation (1). Our estimates show that 24% of variation in counter-intervention can be explained by the set of controls ($R^2 = 0.24$), while the remaining 76% are unexplained. This low R-squared imply that a large part of FX intervention cannot be predicted by the Fed funds rate shock or other factors. If we further decompose the controls, 16% can be explained by the Fed funds rate shocks, 2% by macroeconomic variables (policy rate, GDP, CPI inflation rate, trade balance over GDP ratio, unemployment rate), 30% by the interaction between Fed funds rate shock and macro variables, 35% by past intervention, and 17% by firm fixed effect. The contribution of past exchange rate trend and volatility is almost zero so it is not displayed on the figure. This is consistent with Fratzscher et al. (2019), who show that past exchange rate has a very limited explanatory power for FX intervention.

Having shown that the variation of intervention is difficult to predict, we will use the residual from estimating Equation (1) as an unexpected component of counter-intervention. To simplify the interpretation of results in later section, we define an unexpected counter-intervention dummy $FXI_{c,t}$. If the residual from estimating Equation (1) is greater than its median in absolute value, $FXI_{c,t}$ takes one and central banks counter-intervene unexpectedly against the Fed. Otherwise, $FXI_{c,t}$ takes zero and central banks do not counter-intervene unexpectedly. We will use this

definition of unexpected counter-intervention throughout our analysis.[15]

3.2 Exchange Rates

We first study the effect of unexpected FX intervention on the exchange rate. We test whether unexpected intervention can mitigate the depreciation of exchange rate caused by US monetary tightening. Our hypothesis is as follows. When the Fed funds rate surprisingly increases, the dollar appreciates and the local currency depreciates due to the higher rate of return on dollar bond. However, when central banks intervenes in the FX market by selling the US Dollar, the Fed funds rate shock has limited effect on exchange rate depreciation. We identify this mechanism using the high-frequency monetary shock and the unexpected FX intervention identified in Section 3.1. We estimate the effect of Fed funds rate shocks on the exchange rate and compare the response in countries and dates with and without unexpected FX intervention.

For our baseline specification, we estimate the following equation:

$$\log(e_{c,t+1}) - \log(e_{c,t-1}) = \alpha + \beta FFR_t + \delta Z_{c,t} + \gamma_c + \epsilon_{c,t}. \tag{2}$$

e is the spot exchange rate between country c's local currency and the US Dollar. An increase in e represents appreciation of US Dollar or depreciation of the local currency. The dependent variable is the change in spot exchange rate between dates $t-1$ and $t+1$, where t is the FOMC announcement date. FFR_t is the Fed funds rate shock estimated by estimated by (Nakamura and Steinsson 2018a). The shock is defined as the change in Fed funds futures rate in a 30-minute window around the FOMC announcement. FFR_t is in terms of basis points and higher FFR_t represents the increase in interest rate. The coefficient β thus captures the percentage change in the level of exchange rate comparing before and after the Fed funds rate shock when the FFR increases by one basis point. $Z_{c,t}$ is the set of controls, including the trend and standard deviation of exchange rate before the event date, dummy for FX intervention before the event date, as well as lagged policy rate, GDP, inflation, trade balance over GDP ratio, unemployment rate, and their interaction with Fed funds rate shock. We include country fixed effect. The standard errors are double clustered at the country and date levels. We estimate Equation (2) separately for countries with and without unexpected counter-intervention, where the definition of unexpected counter-intervention is given in Section 3.1.

[15]Section 4.5 shows that our results are robust even if we use a different definition of unexpected counter-intervention.

Table 4, columns (1) and (2) show the results for countries without and with intervention, respectively. If the local monetary authorities do not intervene, when the Fed unexpectedly hikes interest rate, the domestic currency depreciates in a statistical significant manner (2.25% in response to 10bp surprise hike). However, if they counter-intervene in the FX market by selling the US dollar, the exchange rate remains flat around the FOMC meeting.

Next, to check the difference in exchange rate responses in countries with and without unexpected FX intervention, we run the following regression:

$$\begin{aligned}\log(e_{c,t+1}) - \log(e_{c,t-1}) = \alpha + \beta_1 FFR_t + \beta_2 FXI_{c,t} \\ + \beta_3(FFR_t \times FXI_{c,t}) + \delta Z_{c,t} + \gamma_c + \epsilon_{c,t},\end{aligned} \tag{3}$$

where $FXI_{c,t}$ is the dummy for unexpected counter-intervention defined in Section 3.1. Coefficients $\beta_{1,k}$ measures the response of exchange rate to Fed funds rate shocks in countries without counter-intervention and $\beta_{3,k}$ measures the response of exchange rate in countries with counter-intervention relative to those without counter-intervention.

Table 4, column (3) shows the result. Without intervention, a 10bp surprise hike in Fed funds rate leads to 2.01% exchange rate depreciation. However, if central banks counter-intervene by selling the US Dollar, the depreciation is smaller by 2.02% than no counter-intervention case and this difference is statistically significant. Thus, intervention offsets the exchange rate depreciation caused by Fed surprise.

To take into account the possibility that the effects of monetary shock and FX intervention accumulate over time, we reestimate Equations (2) and (3) over different time horizon. The dependent variable is changed to $\log(e_{c,t+k}) - \log(e_{c,t-1})$ $(-5 \leq k \leq 5)$, where k is the days since FOMC meeting. This measures the percentage change in exchange rate from date $t-1$ to $t+k$ when the Fed funds rate increases on date t. Other regression specification is the same as Equations (2) and (3).

Figure 3, panel (a) plots the estimates of β over 5-day window around the FOMC meeting. Before the FOMC meeting, there is little difference of exchange rate between countries without and with intervention. However, when the Fed hikes unexpectedly, countries which do not counter-intervene by selling the US dollar experience persistent depreciation, while those which counter-intervene do not experience depreciation.

Finally, to compare the trends of exchange rate around FOMC meetings in countries without

and with FX intervention, we reestimate Equation 3, where the dependent variable is now $\log(e_{c,t+k}) - \log(e_{c,t-1})$ $(-5 \leq k \leq 5)$. Figure 3, panel (b) shows the estimates of β_3 coefficients. The negative values imply that the exchange rate depreciates less when the central banks counter-intervene against the Fed compared to no intervention case. These results suggests that FX interventions are successful in stabilizing the exchange rate in response to unexpected monetary shocks.

3.3 Stock Market

We then study the effect of FX intervention on the stock market. One important transmission channel is driven by firms with debt denominated in US Dollars as they are particularly susceptible to exchange rate risk. We hypothesize that firms with Dollar debt benefit from unexpected FX intervention. If firms issue Dollar debt, currency depreciation increases the debt repayment in terms of local currency. If central banks do not counter-intervene against unexpected Fed hikes by selling the US Dollars, firms with dollar debt are harmed. However, if central banks counter-intervene, currency depreciation is mitigated. Hence, intervention benefits firms with US Dollar debt disproportionately more than those without Dollar debt.

To test this channel, we estimate the following baseline regression:

$$\log(p_{i,t+1}) - \log(p_{i,t-1}) = \alpha + \beta FFR_t + \delta_1 Z_{i,t} + \delta_2 Z_{ind,t} + \gamma_i + \epsilon_{i,t}. \tag{4}$$

p is the stock price of firm i at the end of date t. The stock price is denominated in local currency. The dependent variable is the percentage change stock price from date $t-1$ to $t+1$, where t is the FOMC announcement date. The coefficient β captures the percentage change in stock price when the Fed funds rate increases by one basis point. $Z_{i,t}$ is the set of firm-level controls, including the export intensity (the ratio of export over total sales), firm size (measured by total asset denominated in local currency), liquidity-to-asset ratio, and firm age. $Z_{ind,t}$ the industry-level import content of production and ind is the industry where firm i belongs to. We control for exports and imports as they can affect firms' foreign currency revenue and cost, and also control for size, liquidity, and age since they can drive the heterogeneous response of firms to monetary shocks.[16] We also include the interaction terms between the Fed funds rate shock

[16] Jeenas (2019) shows that firms with fewer liquid assets reduce investment in response to contractionary monetary shocks. Cloyne et al. (2019) show that younger firms that pay no dividend are sensitive to monetary policy.

and these controls to capture the heterogeneous response of firms with different characteristics. We take the lagged controls (except for firm age) so that the Fed funds shock does not affect the stock prices via changes in export, import, firm size, and liquidity. We include a firm fixed effect γ_i to control for the average firm response around FOMC announcements. The standard errors are double clustered at the firm and date levels. We estimate Equation (4) separately for firms with and without Dollar debt and countries with and without unexpected counter-intervention, where the definition of unexpected counter-intervention is given in Section 3.1.

Table 5, columns (1)-(4) shows the result. Columns (1) and (2) show the results for firms with Dollar debt in countries without and with unexpected FX intervention, respectively. We find that, if central banks do not counter-intervene against the Fed, an unexpected increase in Fed funds rate reduces the stock price for firms with Dollar debt in a statistically significant manner (6.6% in response to 10bp surprise hike). However, if central banks counter-intervene by selling the US Dollar, the decline in stock price is mitigated (1.9%). Columns (3) and (4) show the results for firms without Dollar debt in countries without and with FX intervention, respectively. For firms without Dollar debt, the decline in stock price is small, regardless of whether the central banks intervene or not.

Next, we test whether firms with Dollar debt shows a different response from the counterpart without Dollar debt in a statistically significant manner. We estimate the following equation:

$$\begin{aligned}\log(p_{i,t+1}) - \log(p_{i,t-1}) = \alpha + \beta_1 FFR_t + \beta_2 dollar_{i,t} + \beta_3 (FFR_t \times dollar_{i,t}) \\ + \delta_1 Z_{i,t} + \delta_2 Z_{ind,t} + \gamma_i + \epsilon_{i,t},\end{aligned} \tag{5}$$

where $dollar_{i,t}$ is the dummy variable which takes one if firm i has Dollar debt and zero otherwise.[17] Coefficient β_1 measures the response of stock return to Fed funds rate shock for firms without Dollar debt and β_3 measures the response in firms with Dollar debt relative to those without Dollar debt. When β_3 is negative, firms with Dollar debt experience larger decline in stock price than those without Dollar debt. We estimate Equation (5) separately in countries without and with FX intervention.

Table 5, columns (5) and (6) show the result for countries without and with FX intervention, respectively. Without intervention, when the Fed funds rate increases by 10bp, the decline in

[17]To simplify the interpretation of result, we focus on the extensive margin for dollar debt, that is, whether firms borrow or not in US Dollar. In Section 4.1, we also take into account the intensive margin, that is, how much firms borrow in US Dollar.

stock price for firms with dollar debt is 3.1pp larger than those without dollar debt. However, if central banks counter-intervene by selling the US Dollar, there is little difference in stock price responses between firms with and without Dollar debt.

We then study whether the effect of FX intervention is statistically large. We estimate the following equation:

$$\begin{aligned}\log(p_{i,t+1}) - \log(p_{i,t-1}) = \alpha + \beta_1 FFR_t + \beta_2 FXI_t + \beta_3 (FFR_t \times FXI_t) \\ + \delta_1 Z_{i,t} + \delta_2 Z_{ind,t} + \gamma_i + \epsilon_{i,t}. \end{aligned} \tag{6}$$

Coefficient β_1 measures the response of stock return to Fed funds rate shock in countries without counter-intervention and β_3 measures the response in countries with counter-intervention relative to those without counter-intervention. When β_3 is positive, if central banks counter-intervene, firms experience less decline in stock price than no intervention case. We estimate Equation (6) separately for firms with and without Dollar debt.

Table 5, columns (7) and (8) show the result for firms with and without Dollar debt, respectively. For firms with Dollar debt, if central banks do not counter-intervene, a 10bp increase in Fed funds rate reduces the stock price by 6.4%. However, if central banks counter-intervene, the decline in stock price is smaller by 4.7pp. For firms without Dollar debt, the effects of Fed hikes and counter-intervention is quantitatively small.

Finally, we study the triple interaction between the Fed funds rate shock, FX intervention, and Dollar debt to test whether the effect of intervention on firms with Dollar debt is larger than those without Dollar debt. We estimate the following:

$$\begin{aligned}\log(p_{i,t+1}) - \log(p_{i,t-1}) = \alpha + \beta_1 FFR_t + \beta_2 FXI_{c,t} + \beta_3 dollar_{i,t} \\ + \beta_4 (FFR_t \times dollar_{i,t}) + \beta_5 (FFR_t \times FXI_{c,t}) + \beta_6 (FXI_{c,t} \times dollar_{i,t}) \\ + \beta_7 (FFR_t \times dollar_{i,t} \times FXI_{c,t}) + \gamma_i + \gamma_{c,t} + \epsilon_{i,t}. \end{aligned} \tag{7}$$

Coefficient β_1 captures the percentage change in stock returns for firms without dollar debt in countries without counter-intervention. when the Fed funds rate increases by 1bp. β_4 captures the stock response to Fed hikes for firms with Dollar debt relative to those without Dollar debt in countries without FX intervention. β_5 captures the effect of FX intervention on firms without Dollar debt. Our coefficient of interest is β_7, which captures the difference in the effect

of intervention on firms with Dollar debt relative to those without Dollar debt. Moreover, to capture time-varying country-specific factor, we also consider country-date fixed effect $\gamma_{c,t}$.

Table 5, column (9) shows the result without including country-date fixed effect. First, comparing the second and fourth rows (β_5 and β_7), if central banks do not counter-intervene, unexpected Fed hikes reduce the stock price for firms with Dollar debt by 3.1pp relative to those without Dollar debt. However, if central banks counter-intervene, this effect on firms with Dollar debt is mitigated by 3.3pp. Next, comparing the third row (β_6) implies that, if firms do not have Dollar debt, there is little difference in stock price response to Fed hikes comparing the case with and without intervention. However, the fourth row (β_7) implies that, if firms have Dollar debt, the decline in stock price is smaller by 3.3pp when central banks intervene compared to no intervention case and firms without Dollar debt. Column (10) shows the result when including country-date fixed effect and obtains similar result to column (9). Note that FFR_t, $FXI_{c,t}$, and $FFR_t \times FXI_{c,t}$ are absorbed by the fixed effect $\gamma_{c,t}$.

These results imply that FX intervention that counteracts against Fed hikes by selling the US Dollar disproportionately benefits firms with Dollar debt relative to those without Dollar debt.

Next, to study the effect of intervention over time, we reestimate Equation (4) for firms with Dollar debt in countries without and with counteracting FX intervention. The dependent variable is now $\log(p_{i,t+k}) - \log(p_{i,t-1})$ $(-5 \leq k \leq 5)$ where t is the FOMC announcement date and k is the days since the FOMC meeting. This measures the percentage change in stock price from date $t-1$ to $t+k$ when the Fed funds rate increases by 1bp. Other regression specifications are similar to Equation (4). Figure 4, panel (a) plots the estimated coefficient β. We learn that, if countries do not counter-intervene against Fed hikes, the stock price for firms with Dollar debt decreases persistently. However, without intervention, the stock price decline is small and the effect is short-lived. To confirm that the effect of intervention is large, in panel (b), we reestimate Equation (6) over 5-day window around the FOMC meeting and plots the estimated difference-in-difference coefficient β_3. The positive value implies that, if countries counter-intervene, the stock price decline for firms with Dollar debt is small compared to the no counter-intervention case. In panels (c) and (d), we repeat the similar exercise for firms without Dollar debt. We learn that that the effects of Fed hikes and intervention on firms without Dollar debt are quantitatively small.

Finally, to compare the effect of intervention on firms with and without Dollar debt, we

reestimate Equation (7) over 5-day window around FOMC meetings, where the dependent variable is $\log(p_{i,t+k}) - \log(p_{i,t-1})$ $(-5 \leq k \leq 5)$. Figure 5 plots shows the difference-in-difference coefficient β_7. The positive value implies that, if central banks counter-intervene against Fed hikes, firms with Dollar debt experience less decline in stock price than those without Dollar debt, and the effect of intervention is persistent over time.

The main implication of our analysis is that FX intervention can stabilize not only exchange rate but also stock market. The effect of intervention is heterogeneous across firms: in particular, intervention that counteracts against unexpected Fed hikes disproportionately benefits firms with Dollar debt.

3.3.1 Debt Maturity

To further refine our identification strategy, we use the firms' debt maturity structure. If firms happen to have Dollar debt whose maturity is around unexpected Fed hikes, the cost of rolling over debt increases. However, if the debt does not mature around the FOMC event, the effect rollover cost is small. Hence, FX intervention that counteracts against Fed hikes should disproportionately benefits firms with Dollar debt that matures around the FOMC announcement dates. Since the maturity structure is exogenous to exchange rate movement, the stock price response can potentially be interpreted in a causal way.

To test this hypothesis, we divide the Dollar debt into maturing and non-maturing Dollar debt. Maturing Dollar debt is defined as the debt whose repayment currency is US Dollar and which matures within one-year window around (six months before or after) the FOMC announcement date. Non-maturing Dollar debt is defined as the Dollar debt which does not mature within one-year window around the announcement. We limit the sample to firms with Dollar debt and compare the stock return of firms with maturing and non-maturing Dollar debt.

In Table 6, columns (1)-(4), we estimate Equation (4) for firms with and without maturing Dollar debt and in countries with and without counter-intervention, respectively. Columns (1) and (2) show the result for firms with maturing Dollar debt. Without intervention, 10bp increase in Fed funds rate reduces stock price by 15pp. However, if central banks intervene, the decline of stock price is mitigated to 9.7pp. Columns (3) and (4) show that, if firms only have non-maturing Dollar debt, the stock price decline is quantitatively smaller than the firms with maturing Dollar debt, regardless of whether countries intervene or not.

We then set up a dummy $dollar^m_{i,t}$ which takes one if firms have maturing Dollar debt and

zero otherwise. Using this dummy, columns (5) and (6) estimate Equation (5) separately for countries without with intervention, respectively. Without intervention, firms with maturing Dollar debt experiences larger decline in stock price than those with non-maturing Dollar debt when the Fed hikes (column 5). However, if central bank intervenes, the difference in stock price decline becomes small (column 6). Columns (7) and (8) estimate Equation 6 separately for firms with maturing and non-maturing Dollar debt, respectively. The effect of intervention on mitigating the stock price decline is larger when firms have maturing Dollar debt (column 7) than those with non-maturing Dollar debt (column 8). Column (9) estimate Equation 7 using the dummy $dollar^m_{i,t}$ for maturing Dollar debt and confirms that the effect of intervention on firms with maturing Dollar debt is larger in a statistically significant manner. Column (10) includes country-date fixed effect and obtains a similar result. These results suggests that FX intervention that counteracts against unexpected Fed hikes is particularly beneficial for firms with Dollar debt which matures around FOMC announcement date.

4 Robustness Checks

This section provides robustness checks, including intensive and extensive margins of Dollar debt, additional control variables, different exchange rate regimes, size of FX intervention, and alternative definition for unexpected counteracting FX intervention.

4.1 Intensive and Extensive Margins of Dollar debt

In the baseline results on stock prices, the firms' borrowing decision in Dollar debt was expressed in a 0-1 binary dummy variable for simplicity. However, in reality, the effect of intervention may depend not only on whether firms borrow or not (extensive margin) but also on how much they borrow in Dollars (extensive margin). Firms with large degree of Dollar debt would be more exposed to currency risk than those with small degree of Dollar debt. To test this intensive margin, we take the percentage share of Dollar debt over total debt. We standardize the Dollar debt share so that one point increase in the Dollar debt share corresponds to one standard deviation to simplify the interpretation.

Columns (1) and (2) estimate Equation 5 using the Dollar debt share for $dollar_{i,t}$ instead of 0-1 dummy. Columns (1) and (2) show the result in countries without and with counter-intervention, respectively. If central banks do not counter-intervene, when firms' Dollar debt

share increases by one standard deviation, a 10bp Fed funds hike leads to 0.43% larger decline in stock price. However, if central banks intervene, the stock response of firms with large degree of Dollar debt is not significantly different from those with small degree of Dollar debt. Next, columns (3) and (4) estimate Equation (7) using the Dollar debt share $dollar_{i,t}$. Column (3) shows that, if firms' Dollar debt share is larger by one standard deviation, the effect of intervention on mitigating the stock price decline is larger by 0.44pp, compared to no intervention case. In column (4), we also include a country-date fixed effect and obtain a similar result.

These results imply that counter-intervention against the Fed is beneficial especially for firms with large share of Dollar debt compared to those with small share of Dollar debt.

4.2 Controlling for International Sales and Asset Holdings

In the baseline results on stock prices, we controlled for export and import because they affect firms' foreign currency revenue and cost. There are other factors that potentially affect firms' foreign currency revenue include international sales and international asset, as firms with international sales or asset may benefit from domestic currency depreciation. To address this issue, we use firm-level data on international sales and asset holdings available in Worldscope.

Table 8 reproduces Table 5 after controlling for international asset over total asset ratio, international sales over total sales ratio, and their interaction with Fed funds rate shock. We obtain a similar result to the benchmark case even after controlling international sales and asset. Without intervention, an unexpected Fed hike leads to large decline in stock price for firms with Dollar debt compared to those without Dollar debt. However, if central banks counter-intervene by selling US Dollar, stock price for firms with Dollar debt does not decline compared to those without Dollar debt.

4.3 Different Exchange Rate Regimes

In this section, we consider the difference in exchange rate regime across countries. Countries with fixed exchange rate regimes, such as Hong Kong, keep their exchange rate fixed by definition, and those with flexible regimes face larger exchange rate fluctuations. We will test whether counteracting FX intervention is effective even after limiting the sample to countries to relatively flexible exchange rate regimes.

We used monthly data on exchange rate regimes provided by Ilzetzki et al. (2019), since the effect of monetary and exchange rate policies can be heterogeneous across countries with different exchange rate regimes. They classify the exchange rate regimes into fifteen categories and larger category implies more flexible exchange rate regime. Following Wiriadinata (2021), we define 5% moving band, managed floating regime, or more flexible exchange rate regimes as relatively flexible regimes (category 12 or higher in Ilzetzki et al. (2019)), and 2% moving band or less flexible regimes as relatively fixed regimes (category 11 or lower). Around 60% of country-date observations in our sample are under relatively flexible regimes and 40% are under relatively fixed regimes.

Table 9a reproduces Table 4 after limiting the sample to countries with relatively flexible exchange rate regimes. We obtain a similar result to the benchmark. Countries that do not intervene experience exchange rate depreciation after unexpected Fed hikes. However, if countries intervene, the effect on exchange rate is small. Next, Table 9b reproduces Table 5 after limiting the sample to firms in countries with relatively flexible exchange rate regimes. Without intervention, Fed surprise hikes reduce stock price for firms with Dollar debt. However, if central banks intervene, the stock price remains flat.

4.4 Size of FX Intervention

Our baseline analysis whether central banks counter-intervened against unexpected Fed hikes or not. However, as shown in Table 2, the size of intervention is significantly different across countries. We will test whether our main result holds even if we focus on large intervention and exclude small intervention.

For each country and FOMC event date, we first calculate the average net purchase of US Dollar between t and $t+5$, where t is the FOMC event date. We then define large and small interventions if the average net purchase is larger and smaller than 25 percentile in absolute value, respectively. We then exclude small intervention from our sample. Tables 10a and 10b replicate Tables 4 and 5, respectively without small intervention and confirms that the results for both exchange rate and stock price are similar to the benchmark case.

4.5 Alternative Definition for Unexpected Counter-Intervention

Finally, we study different criteria for unexpected counteracting FX intervention. First, in the benchmark case, counteracting intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t + 5$, and vice versa when the Fed funds rate decreases. Then, we estimating equation 1 and defined unexpected counter-intervention if the residual is larger than its median in absolute value.

We will try two alternative definitions for unexpected counter-intervention. First, we define counter-intervention so that the central banks' average net sales of US Dollar between dates t and $t + 5$ is positive when the Fed funds rate increases on date t, and vice versa when the Fed funds rate decreases. Tables 11b and 11b report the result for exchange rate and stock price, respectively under this mean criteria for counter-intervention. Second, we adopt an alternative criteria for identifying unexpected intervention. The unexpected counter-intervention is defined as unexpected if the residual from estimating Equation (1) is larger than 75 percentile in absolute value. This criteria is more strict than the benchmark using the median criteria since the intervention is not identified as being unexpected unless the residual is sufficiently large. Tables 12b and 12b report the result for exchange rate and stock price, respectively under this 75-percentile criteria for unexpected intervention. In both cases, the results are qualitatively similar to the benchmark case.

5 Conclusion

This paper develops a novel event-study methodology to identify the causal effect of FX intervention. We use a cleanly identified high-frequency US monetary shock and study the response comparing countries with and without intervention. We show that, if central banks do not counter-intervene against the Fed funds hikes by selling the US Dollar, the domestic currency depreciates against the dollar and funds rate depreciates the exchange rate and reduces the stock price of firms with Dollar debt. However, if central banks intervene, the effects on exchange rate and stock market are limited. Our results suggest that FX intervention is successful in stabilizing both the exchange rate and the stock market, especially for firms that are exposed to global financial cycle.

In future research, it would be interesting to study the macroeconomic implications of

FX intervention. This would require a counterfactual exercise using a full-fledged general equilibrium framework. For example, Gabaix and Maggiori (2015) show that the intervention is effective when the international financial market is imperfect. Based on their framework, it would be interesting to introduce firms with Dollar debt as well as export and import, and study issues including the interaction between monetary and exchange rate policies, the relationship between intervention and invoicing currency of trade (producer currency, local currency, or dollar pricing) and finance (US Dollar debt), and cooperative and non-cooperative interventions.

Appendix

A Data Construction

This section provides the data definition and cleaning procedure. the firm-level data on fundamentals and balance sheet, the data definition and cleaning procedure follow the standard literature on monetary policy and corporate balance sheet risk, for example Ottonello and Winberry (2020). The cleaning procedure of Capital IQ data follows Kim et al. (2020).

A.1 Data Definition

- *Leverage:* the ratio of total debt over total asset.
- *Share of Dollar debt:* the ratio of total due amount of Dollar debt (the sum of due amounts of debt instruments whose repayment currency is U.S. Dollar) over the total due amount of debt denominated in all currencies.
- *Size:* the total asset which is denominated in local currency and deflated by consumer price index (CPI).
- *Liquidity:* the ratio of cash and short-term investments over total asset.
- *Age:* years after the incorporation date.
- *Export intensity:* the ratio of export over total sales.
- *Import content of production:* the imports content of exports, defined as the contribution of imports for the production of goods and services.

A.2 Data Cleaning Procedure

We only use data of publicly listed firms as the data on stock price is available. The sample only includes ultimate corporate parents which are headquartered in each country. Moreover, the sample excludes the following:

- Firm-year observations which do not report balance sheet information.
- Firm-year observations which do not report the currency composition of debt.

- Each control, including total asset, principal due, tangible asset, liquidity, and long-term investment, belongs to top or bottom 1% in each country.
- Leverage belongs to top 1% in each country.
- Financial firms (SIC industry code: 6000-6999).
- Government institution.
- Firm-year observations in which the sum of cash and cash equivalents and tangible assets is greater than the total asset.
- Firm-year observations in which the difference between the total asset and the sum of total liability and equity is greater than 10,000 U.S. Dollar.
- Firm-year observations in which the difference between the sum of principal dues of all individual debt instruments, which is available in the detailed financial statement, and the total principal due of debt, which is available in the main financial statement, is greater than 100,000 U.S. Dollar.
- Firm-year observations in which the sum of due amounts of Dollar debt in the detailed financial statement is greater than the total due amounts in the main financial statement.

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Table 1: Summary Statistics: FFR shock, exchange rate, and stock price

	Mean	Med	S.D.	p5	p95	Obs
(1) FFR shock (basis point)	0.015	-0.48	1.81	-3.1	3.75	90
(2) Exchange rate (% change, $\log(e_{c,t+1}) - \log(e_{c,t-1})$)	0.04	0	0.72	-1.37	1.29	876
(3) Stock price (% change, $\log(p_{i,t+1}) - \log(p_{i,t-1})$)	0.02	0	3.47	-5.60	5.70	124,589

Note: t is the FOMC announcement date. $e_{c,t+1}$ is the exchange rate in country c at date $t+1$. Higher $e_{c,t+1}$ implies the appreciation of US Dollar or depreciation of local currency. $p_{i,t+1}$ is the stock price of firm i at date $t+1$. The stock price is in terms of local currency. Observations are the number of FOMC announcement dates (row 1), country times FOMC announcement dates (row 2), and firm times FOMC announcement dates (row 3).

Table 2: Interventions around FOMC event dates

Country	Frequency			Ave. Net Purchese of USD		Periods
	Buy USD	Sell USD	Counter	Millions USD	% GDP ($\times 10^{-4}$)	
	(1)	(2)	(3)	(4)	(5)	(6)
Argentina	59	45	15	11	2.9	2003-2019
Australia	0	2	2	-0.7	-0.094	2000-2019
Brazil	11	1	8	19	1.2	2009-2019
Chile	6	0	4	0.01	0.0062	2008-2019
Colombia	34	2	18	5.6	2.3	2000-2019
Costa Rica	34	32	3	0.61	2.1	2006-2019
Georgia	9	12	15	0.21	2.3	2009-2019
Hong Kong	83	58	13	26	12	2000-2019
Japan	4	0	1	0.0094	0.0019	2000-2019
Mexico	0	24	7	-17	-1.6	2000-2011
Morocco	0	1	0	-6.7	-7.81	2018
Peru	72	51	26	6.6	4.7	2000-2019
Switzerland	0	0	0	-0.45	-0.094	2000-2001
Turkey	1	1	0	2.3	0.34	2002-2019
Total	313	229	112	6.8	2.9	2000-2019

Note: Columns (1) and (2) show the frequencies of buying and selling intervention. Buying intervention implies that central banks buy US Dollar at least once between date t and $t+5$, where t is the FOMC announcement date, and selling intervention is defined similarly. Column (3) shows the frequency of counter-intervention, defined so that the central bank sells US Dollar at least once and never buys US Dollar between the dates t and $t+5$ when the Fed funds rate increases at date t, and vice versa when the Fed funds rate decreases. Column (4) shows the average amount of net purchase of US Dollar between date t and $t+5$ over all FOMC announcement dates t. Column (5) shows the average ratio of net purchase of US Dollar over GDP. The positive and negative values imply buying and selling US Dollar, respectively. Column (6) shows the sample period when the data on FX intervention is available.

Table 3: Sample Firms

Country	Total	Dollar Debt	Country	Total	Dollar Debt
Argentina	34	25	Hong Kong	480	42
Australia	1190	126	Japan	2216	4
Brazil	68	21	Mexico	48	33
Chile	3	1	Morocco	28	0
Colombia	22	9	Total	4088	261

Note: The table shows the number of all firms and firms with Dollar debt in each country. For firms with Dollar debt, the table shows the number of firms which issued Dollar debt at least once during the sample period.

Table 4: Exchange Rate: Baseline Regression

	Exchange rate depreciation $(\log(e_{c,t+5}) - \log(e_{c,t-1}))$		
	(1)	(2)	(3)
FFR shock	0.225***	0.00446	0.201**
	(0.0690)	(0.0213)	(0.0724)
Intervention			0.266
			(0.155)
FFR shock × Intervention			-0.202**
			(0.0724)
Observations	418	417	836
R-squared	0.108	0.0833	0.0840
Intervention	No	Yes	Both
Fixed Effects	Country	Country	Country
Clusters	Country, Date	Country, Date	Country, Date

Note: Columns (1) and (2) report the estimated coefficient from Equation (2) in countries without and with unexpected counter-intervention, respectively. Column (3) report the estimated coefficients from Equation (3). The dependent variable is the percentage change in spot exchange rate from date $t-1$ to $t+5$, where t is the FOMC announcement date. An increase in e implies the appreciation of US Dollar or depreciation of local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. Standard errors are in parentheses. Standard errors are double clustered at the country and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 5: Stock Price: Baseline Regression

	Change in stock price $(\log(p_{i,t+1}) - \log(p_{i,t-1}))$									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FFR shock	-0.666***	-0.196*	-0.0937**	-0.151**	-0.0964**	-0.157**	-0.648***	-0.0933**	-0.0959**	0
	(0.119)	(0.102)	(0.0450)	(0.0575)	(0.0449)	(0.0609)	(0.118)	(0.0449)	(0.0447)	(.)
FFR shock × Dollar Debt					-0.316***	0.00475			-0.319***	-0.263***
					(0.0869)	(0.0433)			(0.0836)	(0.0697)
FFR shock × Intervention							0.470***	-0.0334	-0.0401	0
							(0.130)	(0.0831)	(0.0796)	(.)
FFR shock × Intervention × Dollar Debt									0.337***	0.242***
									(0.0910)	(0.0672)
Observations	1926	1258	103155	9915	105114	11178	3206	113534	116754	116754
R-squared	0.0930	0.115	0.0317	0.209	0.0314	0.195	0.0909	0.0335	0.0332	0.0865
Dollar Debt	Yes	Yes	No	No	Both	Both	Yes	No	Both	Both
Intervention	No	Yes	No	Yes	No	Yes	Both	Both	Both	Both
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Date FE	No	No	No	No	No	No	No	No	No	Yes
Clusters	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date

Note: Columns (1)-(4) report the estimated coefficient from Equation (4). Column (1) reports the result for firms with Dollar debt and countries without FX intervention. Column (2) reports the result for firms with Dollar debt and countries with FX intervention. Column (3) reports the result for firms without Dollar debt and countries without FX intervention. Column (4) reports the result for firms without Dollar debt and countries without FX intervention. Columns (5) and (6) report the estimated coefficients from Equation (5) for countries without and with FX intervention, respectively. Columns (7) and (8) report the estimated coefficients from Equation (6) for firms with and without Dollar debt, respectively. Columns (9) and (10) report the estimated coefficients from Equation (7) with and without country-date fixed effect, respectively. The dependent variable is the percentage change in stock price from date $t-1$ to $t+1$, where t is the FOMC announcement date. The stock price is denominated in local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. We controlled for export intensity, import content of production, total asset, liquidity-to-asset ratio, firm age, and their interaction with Fed funds rate shock. Standard errors are in parentheses. Standard errors are double clustered at the firm and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 6: Stock Price: Debt Maturity

	Change in stock price ($\log(p_{i,t+1}) - \log(p_{i,t-1})$)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FFR shock	-1.533***	-0.975***	-0.654***	-0.191*	-0.619***	-0.195*	-1.494***	-0.621***	-0.599***	0
	(0.334)	(0.325)	(0.135)	(0.100)	(0.118)	(0.0985)	(0.346)	(0.135)	(0.118)	(.)
FFR shock × Maturing Dollar Debt					-0.467***	-0.0266			-0.494***	-0.448***
					(0.101)	(0.167)			(0.105)	(0.144)
FFR shock × Intervention							0.744	0.450***	0.421***	0
							(0.595)	(0.144)	(0.129)	(.)
FFR shock × Maturing Dollar Debt × Intervention									0.489**	0.430*
									(0.244)	(0.257)
Observations	161	72	1752	1176	1926	1258	243	2948	3206	3155
R-squared	0.400	0.290	0.0966	0.120	0.0959	0.115	0.373	0.0952	0.0936	0.204
Maturing Dollar Debt	Yes	Yes	No	No	Both	Both	Yes	No	Both	Both
Intervention	No	Yes	No	Yes	No	Yes	Both	Both	Both	Both
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Date FE	No	No	No	No	No	No	No	No	No	Yes
Clusters	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date

Note: We define maturing Dollar debt as the debt whose repayment currency is in US Dollar and which matures within 1-year window around FOMC announcement, and non-maturing Dollar debt as the Dollar debt which does not mature within 1-year window around FOMC announcement. We limit the sample to firms with Dollar debt. Columns (1)-(4) report the estimated coefficient from Equation (4). Column (1) reports the result for firms with maturing maturing Dollar debt and countries without FX intervention. Column (2) reports the result for firms with maturing Dollar debt and countries with FX intervention. Column (3) reports the result for firms without maturing Dollar debt and countries without FX intervention. Column (4) reports the result for firms without maturing Dollar debt and countries without FX intervention. Columns (5) and (6) report the estimated coefficients from Equation (5) for countries without and with FX intervention, respectively. Columns (7) and (8) report the estimated coefficients from Equation (6) for firms with and without maturing Dollar debt, respectively. Columns (9) and (10) report the estimated coefficients from Equation (7) with and without country-date fixed effect, respectively. The dependent variable is the percentage change in stock price from date $t-1$ to $t+1$, where t is the FOMC announcement date. The stock price is denominated in local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. We controlled for export intensity, import content of production, total asset, liquidity-to-asset ratio, firm age, and their interaction with Fed funds rate shock. Standard errors are in parentheses. Standard errors are double clustered at the firm and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 7: Stock Price: Intensive Margin

	Change in stock price ($\log(p_{i,t+1}) - \log(p_{i,t-1})$)			
	(1)	(2)	(3)	(4)
FFR shock	-0.103**	-0.157***	-0.103**	0
	(0.0461)	(0.0593)	(0.0458)	(.)
FFR shock × Dollar Debt	-0.0433***	0.000252	-0.0436***	-0.0363***
	(0.0117)	(0.00988)	(0.0115)	(0.00960)
FFR shock × Intervention			-0.0323	0
			(0.0801)	(.)
FFR shock × Dollar Debt × Intervention			0.0448***	0.0349***
			(0.0102)	(0.00660)
Observations	105114	11178	116754	116754
R-squared	0.0314	0.194	0.0332	0.0865
Dollar Debt	Both	Both	Both	Both
Intervention	No	Yes	Both	Both
Firm FE	Yes	Yes	Yes	Yes
Country × Date FE	No	No	No	No
Clusters	Firm, Date	Firm, Date	Firm, Date	Firm, Date

Note: We use the standardized share of Dollar debt over total debt as an independent variable. Columns (1) and (1) report the estimated coefficients from Equation (5) for countries without and with FX intervention, respectively. Columns (3) and (4) report the estimated coefficients from Equation (7) with and without country-date fixed effect, respectively. The dependent variable is the percentage change in stock price from date $t-1$ to $t+1$, where t is the FOMC announcement date. The stock price is denominated in local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. We controlled for export intensity, import content of production, total asset, liquidity-to-asset ratio, firm age, and their interaction with Fed funds rate shock. Standard errors are in parentheses. Standard errors are double clustered at the firm and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 8: Stock Price: Controlling for International Asset and Sales

	Change in stock price ($\log(p_{i,t+1}) - \log(p_{i,t-1})$)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FFR shock	-0.717***	-0.196	-0.0888**	-0.121*	-0.0922**	-0.126**	-0.690***	-0.0883**	-0.0917**	0
	(0.112)	(0.128)	(0.0442)	(0.0620)	(0.0439)	(0.0567)	(0.106)	(0.0440)	(0.0436)	(.)
FFR shock × Dollar Debt					-0.332***	-0.0245			-0.333***	-0.277***
					(0.0842)	(0.0561)			(0.0804)	(0.0706)
FFR shock × Intervention							0.492***	0.00879	-0.00236	0
							(0.153)	(0.0875)	(0.0803)	(.)
FFR shock × Intervention × Dollar Debt									0.336***	0.249***
									(0.0917)	(0.0690)
Observations	1843	974	100333	7134	102206	8112	2835	107927	110775	110775
R-squared	0.101	0.115	0.0323	0.280	0.0320	0.255	0.0970	0.0344	0.0340	0.0895
Dollar Debt	Yes	Yes	No	No	Both	Both	Yes	No	Both	Both
Intervention	No	Yes	No	Yes	No	Yes	Both	Both	Both	Both
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Date FE	No	No	No	No	No	No	No	No	No	Yes
Clusters	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date

Note: Columns (1)-(4) report the estimated coefficient from Equation (4). Column (1) reports the result for firms with Dollar debt and countries without FX intervention. Column (2) reports the result for firms with Dollar debt and countries with FX intervention. Column (3) reports the result for firms without Dollar debt and countries without FX intervention. Column (4) reports the result for firms without Dollar debt and countries without FX intervention. Columns (5) and (6) report the estimated coefficients from Equation (5) for countries without and with FX intervention, respectively. Columns (7) and (8) report the estimated coefficients from Equation (6) for firms with and without Dollar debt, respectively. Columns (9) and (10) report the estimated coefficients from Equation (7) with and without country-date fixed effect, respectively. The dependent variable is the percentage change in stock price from date $t-1$ to $t+1$, where t is the FOMC announcement date. The stock price is denominated in local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. We controlled for export intensity, import content of production, total asset, liquidity-to-asset ratio, firm age, international asset-to-total asset ratio, international sales-to-total sales ratio, and their interaction with Fed funds rate shock. Standard errors are in parentheses. Standard errors are double clustered at the firm and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 9a: Exchange Rate: Flexible Exchange Rate Regime

	Exchange rate depreciation $(\log(e_{c,t+5}) - \log(e_{c,t-1}))$		
	(1)	(2)	(3)
FFR shock	0.241***	-0.0242	0.288***
	(0.0729)	(0.0489)	(0.0715)
Intervention			0.487
			(0.438)
FFR shock × Intervention			-0.286**
			(0.105)
Observations	319	242	563
R-squared	0.110	0.107	0.0889
Intervention	No	Yes	Both
Fixed Effects	Country	Country	Country
Clusters	Country, Date	Country, Date	Country, Date

Note: We limit the sample to firms in countries with relatively flexible exchange rate regimes. We use exchange rate regime by Ilzetzki et al. (2019). We define 5% moving band, managed floating regime, or more flexible exchange rate regimes as relatively flexible regimes (category 12 or higher), and 2% moving band or less flexible regimes as relatively fixed regimes (category 11 or lower). Columns (1) and (2) report the estimated coefficient from Equation (2) in countries without and with unexpected counter-intervention, respectively. Column (3) report the estimated coefficients from Equation (3). The dependent variable is the percentage change in spot exchange rate from date $t-1$ to $t+5$, where t is the FOMC announcement date. An increase in e implies the appreciation of US Dollar or depreciation of local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. Standard errors are in parentheses. Standard errors are double clustered at the country and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 9b: Stock Price: Flexible Exchange Rate Regimes

	Change in stock price ($\log(p_{i,t+1}) - \log(p_{i,t-1})$)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FFR shock	-0.671***	-0.0906	-0.0938**	0.00285	-0.0962**	-0.0412	-0.652***	-0.0933**	-0.0956**	0
	(0.121)	(0.201)	(0.0450)	(0.0933)	(0.0449)	(0.0855)	(0.116)	(0.0449)	(0.0447)	(.)
FFR shock × Dollar Debt					-0.323***	0.00993			-0.329***	-0.273***
					(0.0893)	(0.0631)			(0.0861)	(0.0721)
FFR shock × Intervention							0.580**	0.0552	0.0325	0
							(0.244)	(0.117)	(0.115)	(.)
FFR shock × Intervention × Dollar Debt									0.415***	0.304***
									(0.123)	(0.0890)
Observations	1815	754	102917	5321	104762	6081	2592	108706	111311	111311
R-squared	0.0940	0.105	0.0317	0.299	0.0314	0.276	0.0925	0.0312	0.0308	0.0839
Dollar Debt	Yes	Yes	No	No	Both	Both	Yes	No	Both	Both
Intervention	No	Yes	No	Yes	No	Yes	Both	Both	Both	Both
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Date FE	No	No	No	No	No	No	No	No	No	No
Clusters	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date

Note: We limit the sample to firms in countries with relatively flexible exchange rate regimes. We use exchange rate regime by Ilzetzki et al. (2019). We define 5% moving band, managed floating regime, or more flexible exchange rate regimes as relatively flexible regimes (category 12 or higher), and 2% moving band or less flexible regimes as relatively fixed regimes (category 11 or lower). Columns (1)-(4) report the estimated coefficient from Equation (4). Column (1) reports the result for firms with Dollar debt and countries without FX intervention. Column (2) reports the result for firms with Dollar debt and countries with FX intervention. Column (3) reports the result for firms without Dollar debt and countries without FX intervention. Column (4) reports the result for firms without Dollar debt and countries without FX intervention. Columns (5) and (6) report the estimated coefficients from Equation (5) for countries without and with FX intervention, respectively. Columns (7) and (8) report the estimated coefficients from Equation (6) for firms with and without Dollar debt, respectively. Columns (9) and (10) report the estimated coefficients from Equation (7) with and without country-date fixed effect, respectively. The dependent variable is the percentage change in stock price from date $t-1$ to $t+1$, where t is the FOMC announcement date. The stock price is denominated in local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. We controlled for export intensity, import content of production, total asset, liquidity-to-asset ratio, firm age, and their interaction with Fed funds rate shock. Standard errors are in parentheses. Standard errors are double clustered at the firm and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 10a: Exchange Rate: Large Intervention

	Exchange rate depreciation $(\log(e_{c,t+5}) - \log(e_{c,t-1}))$		
	(1)	(2)	(3)
FFR shock	0.220***	-0.0145	0.197**
	(0.0662)	(0.0285)	(0.0674)
Intervention			0.212
			(0.161)
FFR shock × Intervention			-0.204**
			(0.0786)
Observations	395	346	742
R-squared	0.112	0.102	0.102
Intervention	No	Yes	Both
Fixed Effects	Country	Country	Country
Clusters	Country, Date	Country, Date	Country, Date

Note: We define large and small interventions so that the average net purchase of US Dollar between dates t and $t+5$ is larger than 25 percentile in absolute value. We exclude countries and dates with small intervention from the sample. Columns (1) and (2) report the estimated coefficient from Equation (2) in countries without and with unexpected counter-intervention, respectively. Column (3) report the estimated coefficients from Equation (3). The dependent variable is the percentage change in spot exchange rate from date $t-1$ to $t+5$, where t is the FOMC announcement date. An increase in e implies the appreciation of US Dollar or depreciation of local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. Standard errors are in parentheses. Standard errors are double clustered at the country and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 10b: Stock Price: Large Intervention

	Change in stock price ($\log(p_{i,t+1}) - \log(p_{i,t-1})$)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FFR shock	-0.666***	-0.140	-0.0937**	0.00812	-0.0964**	-0.0179	-0.646***	-0.0934**	-0.0960**	0
	(0.119)	(0.157)	(0.0450)	(0.0760)	(0.0449)	(0.0656)	(0.116)	(0.0449)	(0.0448)	(.)
FFR shock × Dollar Debt					-0.316***	-0.0173			-0.314***	-0.260***
					(0.0869)	(0.0716)			(0.0835)	(0.0698)
FFR shock × Intervention							0.522**	0.0418	0.0221	0
							(0.203)	(0.112)	(0.111)	(.)
FFR shock × Intervention × Dollar Debt									0.357***	0.269***
									(0.0989)	(0.0852)
Observations	1926	1018	103155	4639	105114	5662	2966	108165	111145	111145
R-squared	0.0930	0.147	0.0317	0.214	0.0314	0.198	0.0943	0.0335	0.0333	0.0864
Dollar Debt	Yes	Yes	No	No	Both	Both	Yes	No	Both	Both
Intervention	No	Yes	No	Yes	No	Yes	Both	Both	Both	Both
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Date FE	No	No	No	No	No	No	No	No	No	No
Clusters	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date

Note: We define large and small interventions so that the average net purchase of US Dollar between dates t and $t+5$ is larger than 25 percentile in absolute value. We exclude countries and dates with small intervention from the sample. Columns (1)-(4) report the estimated coefficient from Equation (4). Column (1) reports the result for firms with Dollar debt and countries without FX intervention. Column (2) reports the result for firms with Dollar debt and countries with FX intervention. Column (3) reports the result for firms without Dollar debt and countries without FX intervention. Column (4) reports the result for firms without Dollar debt and countries without FX intervention. Columns (5) and (6) report the estimated coefficients from Equation (5) for countries without and with FX intervention, respectively. Columns (7) and (8) report the estimated coefficients from Equation (6) for firms with and without Dollar debt, respectively. Columns (9) and (10) report the estimated coefficients from Equation (7) with and without country-date fixed effect, respectively. The dependent variable is the percentage change in stock price from date $t-1$ to $t+1$, where t is the FOMC announcement date. The stock price is denominated in local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. We controlled for export intensity, import content of production, total asset, liquidity-to-asset ratio, firm age, and their interaction with Fed funds rate shock. Standard errors are in parentheses. Standard errors are double clustered at the firm and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 11a: Exchange Rate: Mean Criteria for Counter-Intervention

	Exchange rate depreciation $(\log(e_{c,t+5}) - \log(e_{c,t-1}))$		
	(1)	(2)	(3)
FFR shock	0.162***	0.0338	0.146**
	(0.0472)	(0.0268)	(0.0489)
Intervention			0.181
			(0.168)
FFR shock × Intervention			-0.117**
			(0.0439)
Observations	418	417	836
R-squared	0.0873	0.103	0.0743
Intervention	No	Yes	Both
Fixed Effects	Country	Country	Country
Clusters	Country, Date	Country, Date	Country, Date

Note: Columns (1) and (2) report the estimated coefficient from Equation (2) in countries without and with unexpected counter-intervention, respectively. Column (3) report the estimated coefficients from Equation (3). The dependent variable is the percentage change in spot exchange rate from date $t-1$ to $t+5$, where t is the FOMC announcement date. An increase in e implies the appreciation of US Dollar or depreciation of local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, the Fed funds rate increases on date t, the central banks' average net sales of US Dollar between dates t and $t+5$ is positive, and vice versa when the Fed funds rate decreases Standard errors are in parentheses. Standard errors are double clustered at the country and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 11b: Stock Price: Mean Criteria for Counter-Intervention

	Change in stock price $(\log(p_{i,t+1}) - \log(p_{i,t-1}))$									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FFR shock	-0.650***	-0.147	-0.0907**	-0.0801	-0.0947**	-0.0875	-0.574***	-0.0929**	-0.0975**	0
	(0.126)	(0.146)	(0.0445)	(0.0672)	(0.0445)	(0.0615)	(0.132)	(0.0447)	(0.0446)	(.)
FFR shock × Dollar Debt					-0.270***	-0.0189			-0.252***	-0.213***
					(0.0753)	(0.0655)			(0.0764)	(0.0685)
FFR shock × Intervention							0.471**	-0.130	-0.110	0
							(0.195)	(0.0871)	(0.0776)	(.)
FFR shock × Intervention × Dollar Debt									0.314***	0.205**
									(0.0968)	(0.0790)
Observations	2101	1081	105103	7848	107236	8937	3206	113534	116754	116754
R-squared	0.0934	0.117	0.0343	0.205	0.0339	0.189	0.0861	0.0334	0.0330	0.0864
Dollar Debt	Yes	Yes	No	No	Both	Both	Yes	No	Both	Both
Intervention	No	Yes	No	Yes	No	Yes	Both	Both	Both	Both
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Date FE	No	No	No	No	No	No	No	No	No	Yes
Clusters	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date

Note: Columns (1)-(4) report the estimated coefficient from Equation (4). Column (1) reports the result for firms with Dollar debt and countries without FX intervention. Column (2) reports the result for firms with Dollar debt and countries with FX intervention. Column (3) reports the result for firms without Dollar debt and countries without FX intervention. Column (4) reports the result for firms without Dollar debt and countries without FX intervention. Columns (5) and (6) report the estimated coefficients from Equation (5) for countries without and with FX intervention, respectively. Columns (7) and (8) report the estimated coefficients from Equation (6) for firms with and without Dollar debt, respectively. Columns (9) and (10) report the estimated coefficients from Equation (7) with and without country-date fixed effect, respectively. The dependent variable is the percentage change in stock price from date $t-1$ to $t+1$, where t is the FOMC announcement date. The stock price is denominated in local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that the central banks' average net sales of US Dollar between dates t and $t+5$ is positive when the Fed funds rate increases on date t, and vice versa when the Fed funds rate decreases We controlled for export intensity, import content of production, total asset, liquidity-to-asset ratio, firm age, and their interaction with Fed funds rate shock. Standard errors are in parentheses. Standard errors are double clustered at the firm and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 12a: Exchange Rate: 75-Percentile Criteria for Unexpected Counter-Intervention

	Exchange rate depreciation $(\log(e_{c,t+5}) - \log(e_{c,t-1}))$		
	(1)	(2)	(3)
FFR shock	0.142***	-0.0201	0.121**
	(0.0371)	(0.0605)	(0.0410)
Intervention			-0.0465
			(0.162)
FFR shock × Intervention			-0.150*
			(0.0759)
Observations	627	208	836
R-squared	0.0691	0.242	0.0705
Intervention	No	Yes	Both
Fixed Effects	Country	Country	Country
Clusters	Country, Date	Country, Date	Country, Date

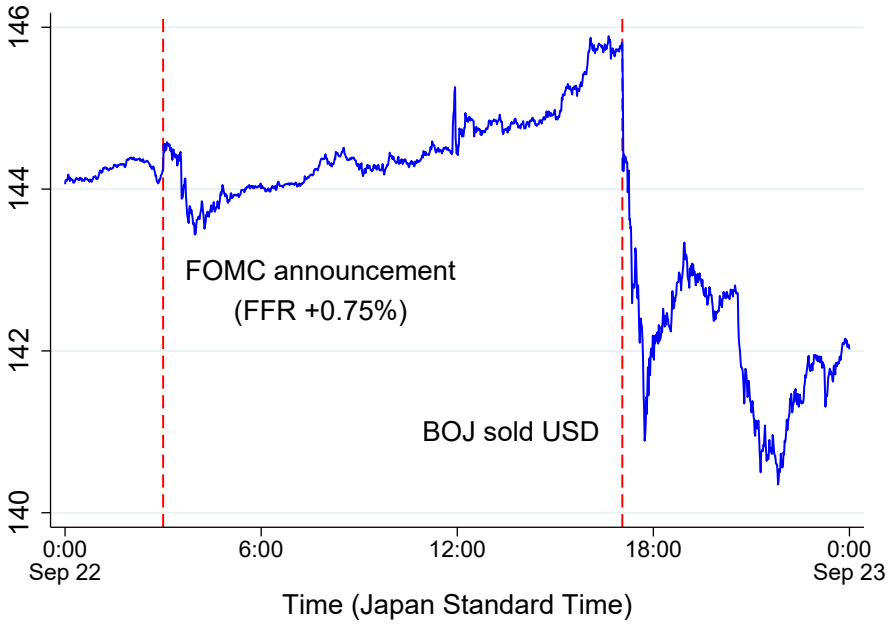
Note: Columns (1) and (2) report the estimated coefficient from Equation (2) in countries without and with unexpected counter-intervention, respectively. Column (3) report the estimated coefficients from Equation (3). The dependent variable is the percentage change in spot exchange rate from date $t-1$ to $t+5$, where t is the FOMC announcement date. An increase in e implies the appreciation of US Dollar or depreciation of local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. The counter-intervention is defined as unexpected if the residual from estimating Equation (1) is larger than 75 percentile in absolute value. Standard errors are in parentheses. Standard errors are double clustered at the country and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Table 12b: Stock Price: 75-Percentile Criteria for Unexpected Counter-Intervention

	Change in stock price ($\log(p_{i,t+1}) - \log(p_{i,t-1})$)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FFR shock	-0.595***	0.0179	-0.0989**	-0.111	-0.104**	-0.0664	-0.533***	-0.0998**	-0.105**	0
	(0.121)	(0.155)	(0.0451)	(0.101)	(0.0456)	(0.0962)	(0.126)	(0.0447)	(0.0451)	(.)
FFR shock × Dollar Debt					-0.231***	0.00938			-0.207***	-0.188***
					(0.0663)	(0.0689)			(0.0673)	(0.0594)
FFR shock × Intervention							0.667***	0.000991	0.0690	0
							(0.208)	(0.121)	(0.110)	(.)
FFR shock × Intervention × Dollar Debt									0.237**	0.223**
									(0.0993)	(0.0870)
Observations	2578	609	109683	3636	112278	4262	3206	113534	116754	116754
R-squared	0.0895	0.181	0.0339	0.148	0.0335	0.146	0.0856	0.0332	0.0328	0.0862
Dollar Debt	Yes	Yes	No	No	Both	Both	Yes	No	Both	Both
Intervention	No	Yes	No	Yes	No	Yes	Both	Both	Both	Both
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Date FE	No	No	No	No	No	No	No	No	No	No
Clusters	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date	Firm, Date

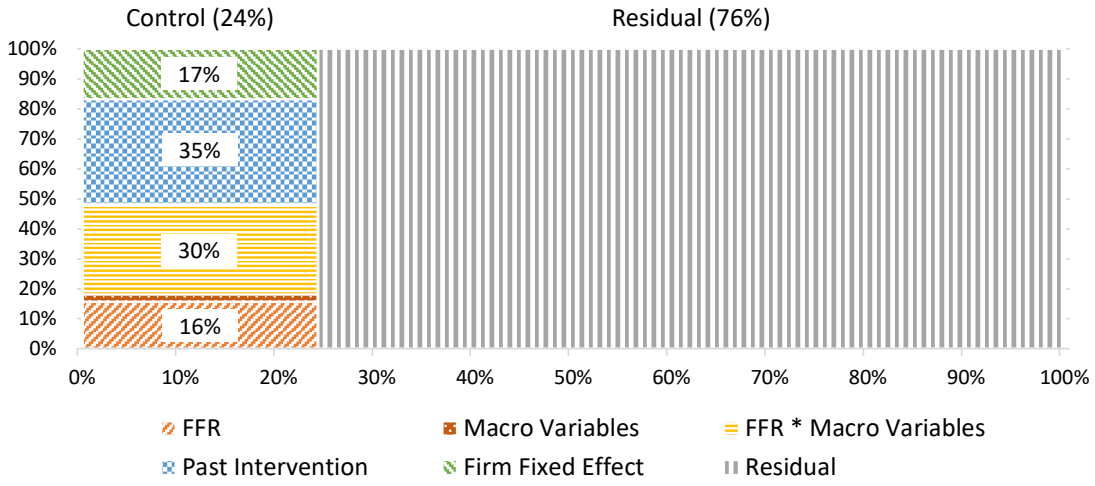
Note: Columns (1)-(4) report the estimated coefficient from Equation (4). Column (1) reports the result for firms with Dollar debt and countries without FX intervention. Column (2) reports the result for firms with Dollar debt and countries with FX intervention. Column (3) reports the result for firms without Dollar debt and countries without FX intervention. Column (4) reports the result for firms without Dollar debt and countries without FX intervention. Columns (5) and (6) report the estimated coefficients from Equation (5) for countries without and with FX intervention, respectively. Columns (7) and (8) report the estimated coefficients from Equation (6) for firms with and without Dollar debt, respectively. Columns (9) and (10) report the estimated coefficients from Equation (7) with and without country-date fixed effect, respectively. The dependent variable is the percentage change in stock price from date $t-1$ to $t+1$, where t is the FOMC announcement date. The stock price is denominated in local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. The counter-intervention is defined as unexpected if the residual from estimating Equation (1) is larger than 75 percentile in absolute value. We controlled for export intensity, import content of production, total asset, liquidity-to-asset ratio, firm age, and their interaction with Fed funds rate shock. Standard errors are in parentheses. Standard errors are double clustered at the firm and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Figure 1: Spot Exchange Rate: US Dollar to Japanese Yen



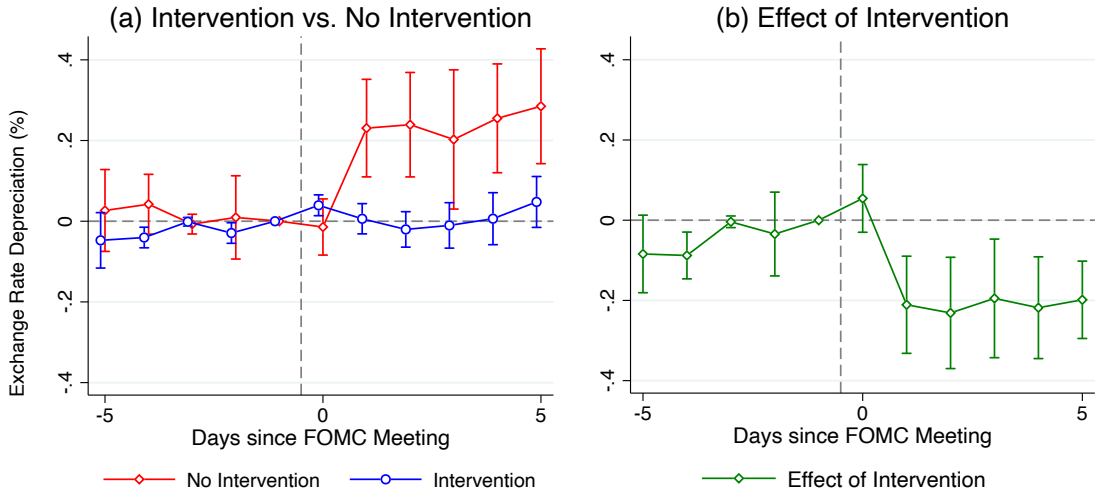
Note: The figure reports the minute-by-minute US Dollar to Japanese yen spot exchange rate on September 22, 2022. The exchange rate is defined as the value of one US Dollar in terms of yen and higher value implies the appreciation of Dollar or depreciation of Japanese yen. Source: Datastream.

Figure 2: Variance Decomposition for Counter-Intervention



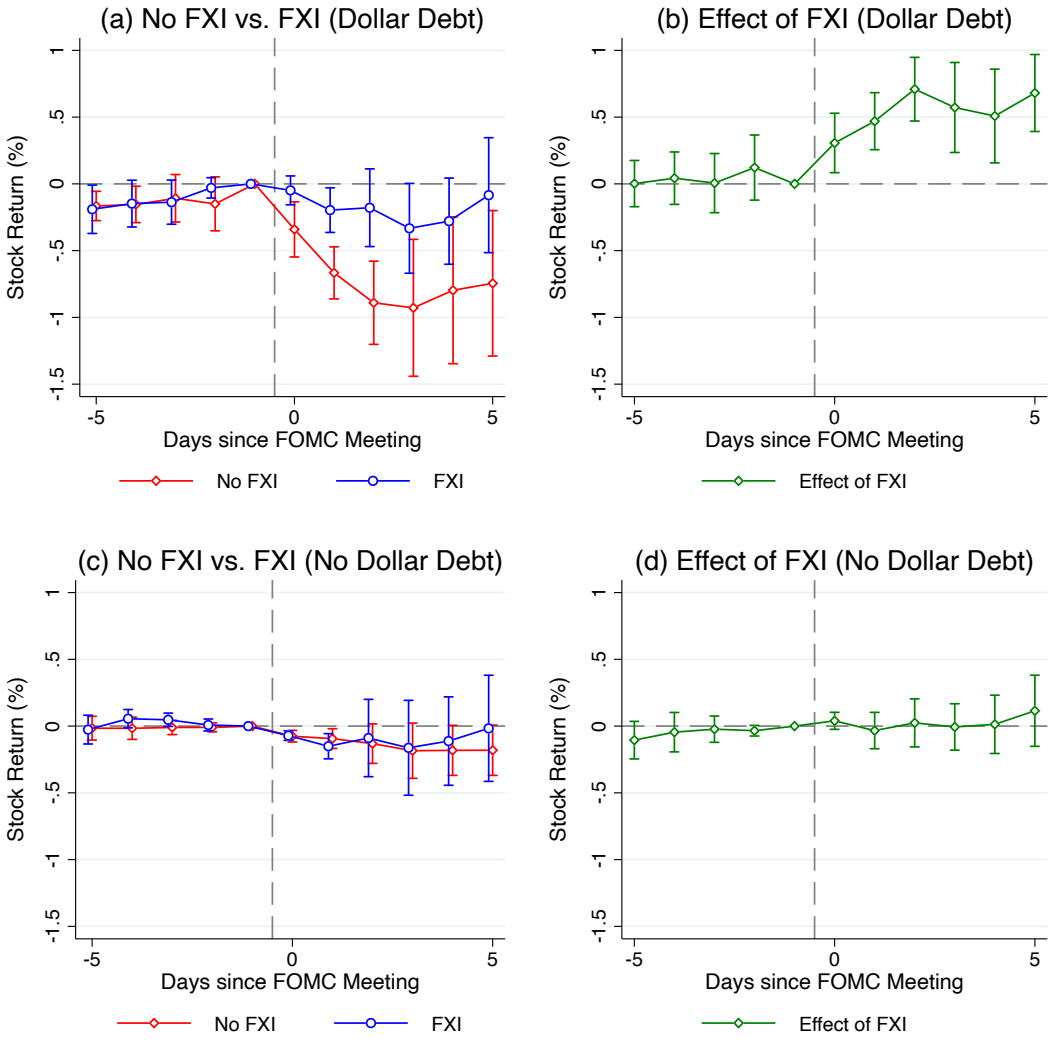
Note: The table shows the results for variance decomposition for Equation (1). We control Fed funds rate shock, macroeconomic variables, including the policy rate, GDP, CPI inflation rate, trade balance over GDP ratio, unemployment rate, and their interaction with Fed funds rate shock, FX intervention before FOMC event dates. We include country fixed effect.

Figure 3: Exchange Rate: Difference-in-Difference



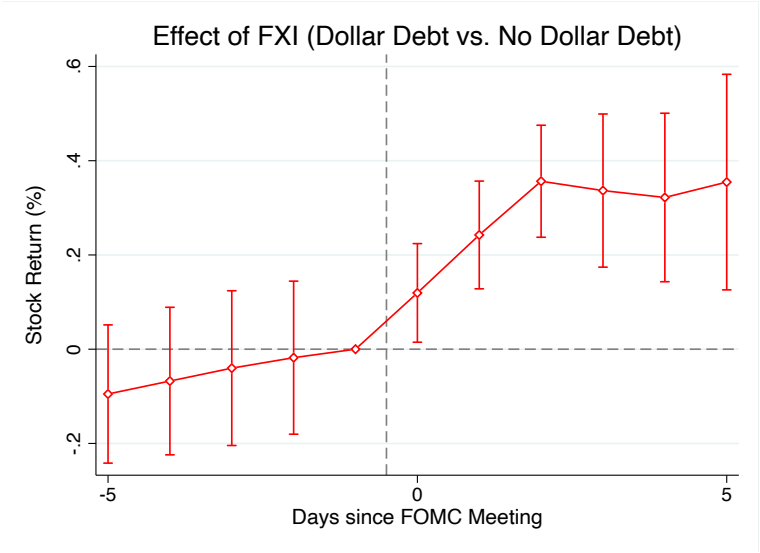
Note: Panel (a) report the estimated coefficient from Equation (2) in countries without and with unexpected counter-intervention, respectively. Panel (b) report the estimated coefficient from Equation (3). The dependent variable is the percentage change in spot exchange rate from date $t-1$ to $t+k$ $(-5 \leq k \leq 5)$, where t is the FOMC announcement date. An increase in e implies the appreciation of US Dollar or depreciation of local currency. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. Standard errors are in parentheses. Standard errors are double clustered at the country and date levels. The symbols *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Figure 4: Stock Price: Difference-in-Difference



Note: Panel (a) reports the estimated coefficient β from Equation (4) for firms with Dollar debt and in countries without and with counter-intervention. Panel (b) reports the estimated coefficient β_3 from Equation (6) for firms with Dollar debt. Panels (c) and (d) report the corresponding coefficients for firms without Dollar debt. The dependent variable is the percentage change in stock price from date $t-1$ to $t+k$, where t is the FOMC announcement date. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. We controlled for export intensity, import content of production, total asset, liquidity-to-asset ratio, firm age, and their interaction with Fed funds rate shock. Standard errors are in parentheses. Standard errors are double clustered at the firm and date levels. The confidence interval is 90%.

Figure 5: Stock Price: Triple Interaction



Note: The figure reports the estimated β_7 coefficient from Equation (7). The dependent variable is the percentage change in stock price from date $t-1$ to $t+k$, where t is the FOMC announcement date. The Fed funds rate shock is the unexpected change in Fed funds futures estimated by Nakamura and Steinsson (2018a). The shock is in basis points and positive shock implies the increase in Fed funds rate. Counter-intervention is defined so that, if the Fed funds rate increases on date t, central banks sell the US Dollar at least once and never buy the US Dollar between dates t and $t+5$, and vice versa when the Fed funds rate decreases. We controlled for export intensity, import content of production, total asset, liquidity-to-asset ratio, firm age, and their interaction with Fed funds rate shock. Standard errors are in parentheses. Standard errors are double clustered at the firm and date levels. The confidence interval is 90%.