Inelastic Financial Markets and Foreign Exchange Interventions*

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November 9, 2023
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Abstract

Are foreign exchange interventions effective at moving exchange rates? In this paper, we leverage the rebalancings of the a local-currency government bonds index for emerging countries as a quasi-natural experiment and identify the required size of foreign exchange interventions to stabilize exchange rates. We show that the rebalancings create large currency demand shocks that are orthogonal to the macroeconomic fundamentals. Our results provide empirical support for models of inelastic financial markets where foreign exchange intervention serves as an additional policy tool to effectively stabilize exchange rates. Under inelastic financial markets, a fixed exchange rate does not have to compromise monetary policy independence even with free capital mobility, relaxing the classical Trilemma constraint. Our results show that to achieve a 1% exchange rate appreciation, the average required intervention is about 0.4% of annual GDP. We also show that free-floats are more than three-fold more effective at stabilizing exchange rates than managed-floats (or peggers). This is because the volatile exchange rates for the free-floats lead to more inelastic financial markets and generate further departure from the Trilemma.

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Chang He is indebted to her doctoral committee members Oleg Itskhoki (advisor), Andy Atkeson, Tyler Muir, and Pierre-Olivier Weill for their continuous support. We are grateful to Patrick Adams, David Baqaee, Ariel Burstein, Saki Bigio, Marcos Chamon, Mikhail Chernov, Wenxin Du, Andres Fernandez, Miguel Faria-e-Castro, Joao Guerreiro, Valentin Haddad, Bernard Herskovic, Sun Yong Kim (discussant), Annie Lee, Fernando Martin, Chris Neely, Dimitry Mukhin, Lee Ohanian, Stavros Panageas, Avanidhar Subra, Anand Systla, and Tomas Williams for insightful discussions at different stages of this paper. We thank the research team at the EPFR, JP Morgan Markets and IMF for the help with data and special thanks to Tomas Williams for guiding us through the data. We also benefited from the useful conversations with numerous participants in various seminars and conferences.

1 Introduction

Are foreign exchange interventions effective at moving exchange rates? And if they do, how large should the size of interventions be to stabilize exchange rates? Policymakers frequently resort to large-scale foreign exchange interventions. For example, during the post "taper-tantrum" episode[1], the inflation-targeting Latin American countries engaged in massive sales of foreign reserves to defend the value of their home currencies. In this episode, Mexico (managed float) sold foreign reserves worth more than 30 billion USD (3% of GDP) and Peru (crawling peg) sold about 10 billion foreign reserves (5% of GDP) (IMF, 2019).

Assessing the effectiveness of the foreign exchange intervention is empirically challenging as exchange rates, the prevailing macroeconomic conditions, and the intervention itself are jointly endogenous. Several papers have provided empirical evidence on the effects of foreign exchange interventions by resorting to confidential and high-frequency data on intervention episodes (Adler et al., 2019; Fratzscher et al., 2019). Yet, a valid identification calls for a natural experiment that exogenously changes the currency composition of the government bonds in an economy.

In this paper, we overcome the identification challenge addressed above and estimate the required size of interventions to stabilize exchange rates through a quasi-natural experiment. We leverage our exogenous currency demand shock from the mechanical rebalancings of the Government Bond Index Emerging Market (GBI-EM) Global Diversified index. Our empirical results provide evidence for models of inelastic financial markets where foreign exchange intervention serves as an effective policy tool to stabilize exchange rates. Through the lens of the model, we identify the required size of foreign exchange interventions to stabilize exchange rates for countries with different exchange rate regimes.

The exogenous currency demand shock created by the mechanical rebalancings of the GBI-EM Global Diversified index is crucial for our identification. The index is the most widely tracked benchmark indices by mutual funds that invest in local-currency government bonds in emerging markets with an estimated asset under management

[1]Taper-tantrum refers to the episode with falling capital inflows in emerging countries following the 2013 Fed announcement of tapering down Quantitative Easings (QE). The announcement set off a market reaction – the taper tantrum – affecting the U.S. and nations abroad.

over 200 billion USD in 2019. The monthly rebalancings cap the benchmark weight of each country in the index at 10% and any excess weight above the cap is redistributed to smaller countries so that all the weights add up to 1. At the rebalancing dates, countries *not* at the cap experience positive weight increase not due to an improvement in their economic conditions, but purely as a result of the bigger countries hitting the cap. The rebalancing feature thus gives rise to large cross-border capital flows orthogonal to the macroeconomic condition for countries not at the weight cap.

We construct our exogenous currency demand shock as the percentage change in the country weights before and after a rebalancing event. Intuitively, the shock captures the change in quantity (face amount) of local-currency sovereign bonds in the index purely implied by the mechanical rebalalancings, independent of the market prices and macroeconomic conditions. For clean identification, we only use currency demand shocks from countries not at the 10% weight cap at the rebalancing dates. A one standard deviation of the shock equals 21% market value (or on average of 2.5 billion USD) of a country's government bonds in the GBI-EM Global Diversified index.

We show that exchange rates respond significantly to the currency demand shock and the effects are persistent up to at least three months. On average, a one standard deviation of the currency demand shock appreciates local currencies by 1%, in the days following one rebalancing event. Despite the significant response of exchange rates, we show that central bank monetary policy rates do *not* respond to the currency demand shock. This implies that the macroeconomic conditions are smooth around the index rebalancing events, consistent with the exogeneity assumptions.

The fact that exchange rates respond significantly is consistent with models of inelastic financial markets (Itskhoki and Mukhin, 2021; Gabaix and Maggiori, 2015). Under inelastic financial markets, a currency demand shock changes arbitrageurs' holdings and gives rise to endogenous deviations in uncovered interest parity (UIP) condition. By comparison, standard macroeconomic models (Mundell, 1962; Gali and Monacelli, 2005; Farhi and Werning, 2012) assume perfectly elastic financial markets or UIP holds. If financial markets were truly elastic, a currency demand shock would have no impact on the path of exchange rates as well as the UIP condition.

Inelastic financial markets have important implications for the effectiveness of foreign exchange interventions at stabilizing exchange rates. Under models of inelastic financial markets, foreign exchange interventions shift arbitrageurs' risk-bearing capacity in a similar way as the currency demand shock, leading to endogenous deviations in uncovered interest parity condition. Therefore, foreign exchange interventions serves an additional policy tool to effectively stabilize exchange rates while the monetary policies can be entirely inward-focused on domestic inflation and output gap. Even under free capital flows, an economy can simultaneously have an independent monetary policy and a managed exchange rate through foreign exchange interventions. We refer to this condition as the "relaxed Trilemma" (Itskhoki and Mukhin, 2022).

We show that the more inelastic the financial markets, the more effective the foreign exchange interventions. This would imply that the interventions are more effective for floaters. Through the lens of our model, the higher exchange rates volatility for floaters makes the financial markets more inelastic and generates further departure from the the Trilemma constraint. On the other extreme where exchange rates are fully pegged, we are back to the elastic financial markets model under the Trilemma constraint where foreign exchange interventions are ineffective.

Our estimates suggest that foreign exchange interventions are more than three-fold more effective for free-floaters than for managed-floaters/peggers. The can be seen from the larger exchange rates response to the currency demand shock for free-floats. We convert the estimates of exchange rates response to the USD flows by computing the mutual funds flows implied from the rebalancings of the index. Through the lens of our model, the counterfactual size of interventions required to stabilize exchange rates would have to exactly offset the impact from the currency demand shock. Our findings suggest that the required size of interventions (as a share of GDP) is more than three-times smaller for free-floaters compared to managed-floaters/peggers, meaning that the interventions work more effectively for the former.

We find that to achieve 1 percent exchange rates appreciation, the average required foreign reserves that the central bank needs to sell in foreign exchange interventions is about 0.4% of GDP (or about 2.5 billion USD on average) for the emerging countries in our sample. Our results are largely consistent with the early literature on estimating the size of foreign exchange interventions using event studies (Adler et al., 2019), and the asset pricing literature that identifies demand elasticities for currencies (e.g., Hau, Massa, and Peress., 2009 and Evans and Lyons., 2002).

Related Literature. Our results contribute to various strands of literature in both macroeconomics and finance and are informative to central bank policymakers. First, we contribute to the large empirical literature on the effects of foreign exchange interventions, including Fatum and Hutchison (2003), Blanchard et al. (2015), Fratzscher et al. (2019) and Adler, Lisack and Mano (2019), and the foreign exchange policy framework in Itskhoki and Mukhin (2022), Jeanne (2012), Amador, Bianchi, Bocola, and Perri (2019), Cavallino (2019), Fanelli and Straub (2021). This paper adds to the literature foreign exchange interventions by finding a plausible exogenous currency demand shock by leveraging the rebalancings of a local currency government bond index as a natural experiment.

Moreover, our paper connects with the broad finance literature on asset demand estimation and evidence for inelastic financial market. Empirical studies using index rebalancing (for example, the rebalancings of S&P 500) to estimate asset demand curves dates back to Shleifer (1986), followed by a series of studies by Lynch and Mendenhall (1997), Kaul, Mehrotra and Morck (2000), and Chang, Hong and Liskovich (2014) with more refined and cleaner identification strategies. Recent work such as Pandolfi and Williams (2019), Koijen and Yogo (2019, 2020) and Camanho, Hau and Rey (2021) estimate the (global) asset pricing demand system and Gabaix and Koijen (2022) discusses policy implications for inelastic financial markets. Our paper applies the empirical strategy of index rebalancing traditionally used to estimate asset demand in a new context: the foreign exchange interventions.

In addition, our paper speaks to the macro-finance literature on exchange rates dynamics in segmented markets with frictional financial markets. The segmented financial market model we use in this paper builds on Alvarez, Atkeson and Kehoe (2009), Gabaix and Maggiori (2015), Gourinchas, Ray and Vayanos (2019), Greenwood, Hanson, Stein, and Sunderam (2020) and Itskhoki and Mukhin (2021). Another recent work by Jiang, Krishnamurthy and Lustig (2022) produces similar exchange dynamics but features incomplete rather than segmented financial markets.

Finally, our works is related to the large literature on exchange rates prediction. The related work includes but not limited to Fama (1984), Evans and Lyons (2002), Tornell and Gourinchas (2004), Lustig and Verdelhan (2007), Engel (2016), and Jiang, Krishnamurthy and Lustig (2022). While these work mostly leverage taste shocks or expectation errors in forecasting exchange rates, our currency demand shocks for predicting exchange rates relies on a quantity demand shock from the mechanical index rebalancing.

Outline. The rest of the paper is structured as follows. In the first part of the paper, we introduce the exogenous currency demand shock and illustrates its relation to the dynamics of exchange rates and interest rates. To interpret these stylized empirical facts, the second part of the paper presents an inelastic financial market model where a currency demand shock leads to endogenous deviations in uncovered interest parity condition. In the third and last part of the paper, we introduce foreign exchange interventions into the inelastic financial market model and estimate the required size of interventions to stabilize exchange rates.

2 Introducing the Currency Demand Shock

We leverage the mechanical rebalancing features of a local-currency government bond index for emerging countries to construct an exogenous currency demand shock. We document in detail below the rebalancing rules of the index and introduce our measure for the currency demand shock as well as the implied flows from the shock.

2.1 Mechanical Rebalancings of the GBI-EM Global Diversified Index

Our empirical strategy relies on the mechanical rebalancings of the Government Bond Index Emerging Market (GBI-EM) Global Diversified published by JP Morgan. The GBI-EM Global Diversified is the largest local currency government bonds index for emerging countries. An estimated asset under management of more than 200 billion USD of of mutual funds are tracking the index in 2020[2]. There are currently 19 emerging countries in the index with each country weight equals to the share of its market value of the local-currency sovereign bonds in the index. A larger country like Brazil has a larger weight in the index than smaller countries like Peru or Chile.

The mechanical rebalancings by GBI-EM Global Diversified index on the country weight cap are crucial for the identification in this paper. The country weight fluctuates

[2]The 200 billion USD is a large number for the emerging market sovereign bonds market as the total new issuance of the emerging market sovereign bonds is merely 160 billion USD in 2019 (Refinitive data).

at the daily frequency as the market price of the sovereign bonds moves up or down. At the rebalancing date (the end of the business day of each month), however, the index mechanically caps the country-weight at 10% for all countries to limit concentration risk. Any excess weight above the cap is redistributed to smaller countries that are below the cap proportionally so that all country weights add up to 100%. The rebalancings can go on recursively for multiple rounds until all the country weights are either at or below the 10% cap.[3]

We argue that for countries *not* at the 10% country-weight cap, their change in weights in the GBI-EM Global Diversified index creates currency demand shocks that are uninformative to the macroeconomic fundamentals of the sovereign. For example, if Brazil's country weight is rebalanced down from 15% to 10% and leads to an increase in the Peru's country weight, those benchmarked mutual funds have to sell local-currency sovereign bonds of Brazil and buy Peruvian Sol in order to purchase local-currency sovereign bonds of Peru. In this rebalancing example, a smaller country like Peru experienced a positive currency demand shock on their local-currency bonds *independent* of their own macroeconomic conditions and purely as a result of Brazil hitting the 10% cap.

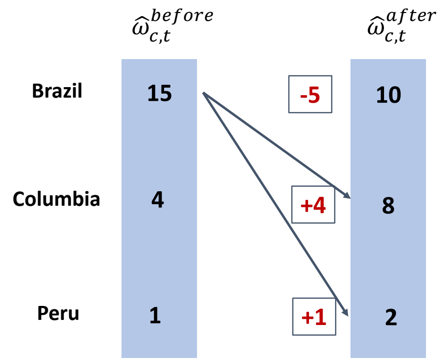
2.2 Measuring the Currency Demand Shock

We introduce $\mu_{c,t}$ to capture the currency demand shock from the mechanical rebalancings of the GBI-EM Global Diversified Index, for country c at the rebalancing date t. As shown in equation (1), we define $\omega_{c,t}^{\text{before}}$ and $\omega_{c,t}^{\text{after}}$ as the country weight before and after the rebalancing event, at the rebalancing date. Since J.P. Morgan has no direct control on the market price ($P_{c,t}$), they can only adjust the country weights (from $\omega_{c,t}^{\text{before}}$ to $\omega_{c,t}^{\text{after}}$) through changing the face amount ($\hat{Q}_{c,t}$) of the country included in the index:

$$\mu_{c,t} = \frac{\omega_{c,t}^{\text{after}} - \omega_{c,t}^{\text{before}}}{\omega_{c,t}^{\text{after}}} \tag{1}$$

[3] The rebalancings are done in three layers in order and the country-weight rebalancing is the last layer following face-amount inclusion and bond maturity threshold. Appendix A discusses the first two layers of rebalancings and how the countries are chosen to enter/exit the index.

Table 2.1: A rebalancing example at 10% weight cap



Note: This table presents a simplified rebalancing example that caps the country weight at 10%. For simplicity, assume there're 11 countries in the index and 8 of them are already at 10%. The rebalancings therefore only apply to to Brazil (with weight 15%) above the cap and Peru (with weight 1%) and Columbia (with weight 4%) below the cap. Each round of rebalancing takes the excess weight of the country and redistribute to smaller countries below the cap proportionally to the weight of the country. The rebalancings continue recursively until all country weights are either at or below the 10% cap. In this example, the currency demand shock $\mu_{c,t}$ for both Colombia and Peru are 1/2.

where $\omega_{c,t}^{\text{before}} = \frac{P_{c,t}\hat{Q}_{c,t-1}}{\sum_c' P_{c',t}\hat{Q}_{c',t}}$ and $\omega_{c,t}^{\text{after}} = \frac{P_{c,t}\hat{Q}_{c,t}}{\sum_c' P_{c',t}\hat{Q}_{c',t}}$; $P_{c,t}$ is the aggregate market price of the local-currency sovereign bonds for country c at rebalancing date; $\hat{Q}_{c,t-1}$ and $\hat{Q}_{c,t}$ are the face amount of the local-currency sovereigns bonds included in the index from the last rebalancing and the current rebalancing, respectively.[4] Intuitively, $\mu_{c,t}$ captures purely the quantity (face amount) change in sovereign bonds implied by the mechanical rebalalancings[5]. We construct $\mu_{c,t}$ as the change in weights as a share of country's own weight since countries have different "depth" (reflected in the size of the market value of and therefore the weight of the country) in the sovereign bonds market. Table 2.1 gives a simplified rebalancing example.

We focus only on currency demand shocks from countries that do *not* meet the 10% cap at the rebalancing dates. These countries have to change their weights as a result of the bigger countries meeting the cap and therefore their weights change are independent of their macro-fundamentals, which are smooth around the rebalancing date. In the example in Table 2.1, we would only use weights change from Peru and Columbia for the

[4]It's important to distinguish the face amount of sovereign bonds included into the index ($\hat{Q}_{c,t}$) from the face amount of the actual issuance ($Q_{c,t}$) by the sovereign.

[5]If you write out the expression for country weights $\omega_{c,t}^{\text{before}}$ and $\omega_{c,t}^{\text{after}}$, the market price $P_{c,t}$ will be cancelled out and leave $\mu_{c,t}$ with the quantity effects only. See appendix A.2.1 for derivation.

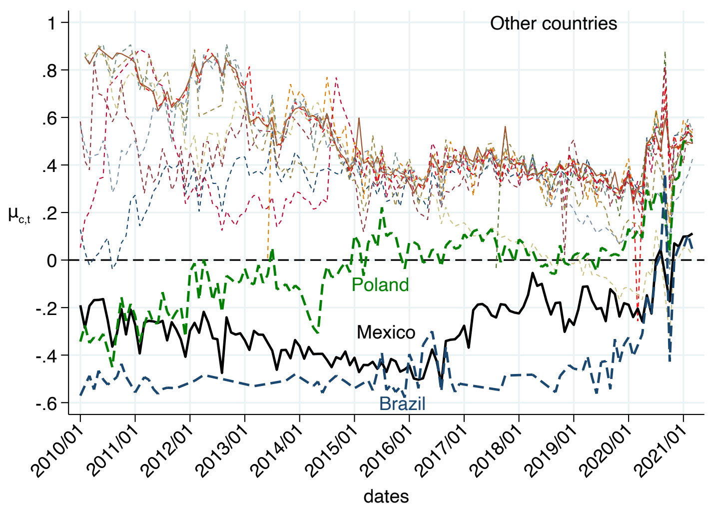
Table 2.2: Summary Statistics of the Currency Demand Shock ($\mu_{c,t}$)

$\mu_{c,t}$, *including* observations at 10% cap

Obs	Mean	Std.	Min	Max	Median	90%	10%
2,044	0.292	0.315	-0.58	0.91	0.36	0.65	-0.21

$\mu_{c,t}$, *excluding* observations at 10% cap

Obs	Mean	Std.	Min	Max	Median	90%	10%
1,436	0.405	0.211	-0.43	0.91	0.39	0.70	0.13



Note: This Table (top) reports the summary statistics on the currency demand shock ($\mu_{c,t}$) implied by monthly rebalancings of the GBI-EM Global Diversified index. The Figure (bottom) plots the of $\mu_{c,t}$ across time for each country. $\mu_{c,t}$ for Brazil, Poland and Mexico are labeled and bolded. A negative $\mu_{c,t}$ (< 0) implies that the country is rebalanced downwards while hitting the 10% cap. In the empirical analysis below, we drop the countries at the 10% cap for cleaner identification. Chile and Argentina are excluded in the figure due to their short time series.

identification. Table 2.2 gives the summary statistics and the time series of the currency demand shocks for the countries in our sample. While most countries experience positive currency demand shocks ($\mu_{c,t} > 0$), a few bigger countries namely Brazil, Mexico and Poland have mostly negative shocks ($\mu_{c,t} < 0$) throughout the sample as a result of being rebalanced downwards when their weights exceed the 10% cap.

2.3 Flows Implied by the Currency Demand Shock

The mechanical rebalancings of the GBI-EM Global Diversified index create large demand shocks on the local-currency government bonds. We show that the mutual funds tracking the index passively and with large asset positions are in compliance with the rebalancing rules, as seen by their high performance R-squared against the returns of the GBI-EM Global Diversified index. We select all emerging market bond funds from the EPFR dataset whose benchmark indices are the GBI-EM Global Diversified index[6] and regress the monthly returns of each fund on the returns the index[7]. This gives us a large median R-squared of 0.92 (Table B.3a in appendix). We also construct the weighted average return (by asset under management) of these mutual funds and regress the weighted return on the index returns, which results in an even higher R-squared of 0.97 (Table B.3b).

To convert the currency demand shocks to USD flows, we estimate the total asset under management of the mutual funds that tracks the GBI-EM Global Diversified index globally. Figure B.2 panel (a) plots the asset under management of funds tracking the GBI-EM Global Diversified index in the EPFR data from 2016 to 2022. Figure B.2 panel (b) shows the representation of EPFR data in the total mutual funds population as estimated by the Investment Company Institutes (ICI) Global. The figures shows that EPFR data represents about 60% of the world-wide mutual funds population in 2019.

2.4 Data Sources

The main data source is the Index Composition and Statistics reports from J.P. Morgan. These reports include monthly information on benchmark weights and rebalancing for their sovereign bonds benchmarks, including GBI-EM Global Diversified index. Our

[6] See appendix on details in how to select mutual funds into the data.

[7] We follow Amihud and Goyenko (2013) and Pandolfi and Williams (2019) and use return regression to test the performance of mutual funds. The method regresses the fund-level monthly returns on the monthly returns of GBI-EM Global Diversified as below:

$$r_{i,t} = \alpha + \beta r_{B,t}$$

where $r_{i,t}$ is the monthly return from fund i at time t and $r_{B,t}$ is the monthly return from the benchmark – in this case, the JP Morgan GBI-EM Global Diversified index. We then collect the fitted R-squared from each return regression. A higher fitted R-squared indicates the fund tracks the benchmark index more closely.

sample includes a panel of 17 countries from 2010 to 2021: Argentina, Brazil, Chile, Cezh Republic, Colombia, Hungary, Indonesia, Malaysia, Mexico, Peru, Philippines, Poland, Romania, Russia, South Africa, Thailand, and Turkey.[8] These J.P. Morgan Markets reports allow us to construct our currency demand shock as introduced above.

The second main data source we use is the Emerging Portfolio Fund Research (EPFR) data on the asset positions of the emerging market bond funds. We show that the currency demand shock is correlated with the changes in asset positions of the mutual funds that track the GBI-EM Global Diversified index in the EPFR data. Moreover, we use the EPFR data to compute the flows in USD implied by the rebalancings by our currency demand shock.

Finally, we combine J.P. Morgan reports and EPFR fund flows data with daily data of exchange rates and central bank policy rates data from the Bank for International Settlements. We complement these data with sovereign bonds yields for various maturities for each country from Du and Schruger (2016) with the dataset updated to 2021.

3 Currency Demand Shock and Exchange Rates Dynamics

In this section, we present four novel stylized facts on how the currency demand shocks affect exchange rates and interest rates.

Stylized Fact 1. *The currency demand shock moves exchange rates in the short run. Specifically, a one standard deviation increase of the shock appreciates exchange rates by an average of 1%.*

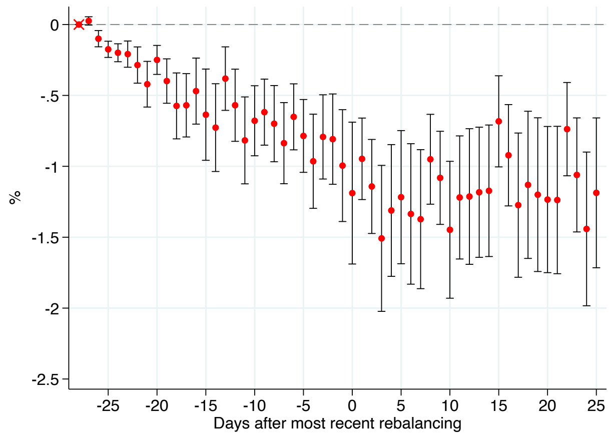
Figure 1 reports the estimated coefficients of cumulative exchange rate changes on our currency demand shock as measured by $\mu_{c,t}$ in equation (1). The regression takes the following form:

$$\Delta e_{t,t+d} = \alpha_c + \alpha_{\text{month}} + \alpha_{\text{year}} + \beta_\mu \, \mu_{c,t} + \epsilon_{c,t}$$

where α_c, α_{month} and α_{year} are country, month, and year fixed effects and we cluster standard errors at the country level; $\mu_{c,t}$ is the currency demand shock defined in equation

[8] We exclude China for current analysis due to limited time series in data as China just entered the GBI-EM Global Diversified index in 2020; we exclude Nigeria from the analysis due to limited data on exchange rates.

Figure 1:
Fact 1: Currency demand shock moves exchange rates in the short run



Note: This figure presents the estimated regression coefficient of exchange rates change on the currency demand shock measured by $\mu_{c,t}$ in equation (1). $\mu_{c,t}$ is standardized by its mean and standard deviation in the regression. Exchange rates change (local currencies per USD) is measured as the cumulative change starting from 28 days before the recent rebalancing at day 0. The regression is performed in a pooled OLS using time- and country-fixed effects with standard errors clustered at the country level. The results are reported in point estimates (red) with 90% confidence interval (black).

(1). Exchange rates are measured in local currencies per USD and the exchange rate change $\Delta e_{t,t+d}$ is the cumulative change starting from the 28 days before the rebalancing date 0 until d days after rebalancing ($d < 0$ for days before the rebalancing date 0; if $d > 0$, vice versa). As discussed, we drop all country-month observations that exceeds the 10% threshold in the regression to ensure our currency demand shock is truly information-free and independent of the macro-fundamentals.

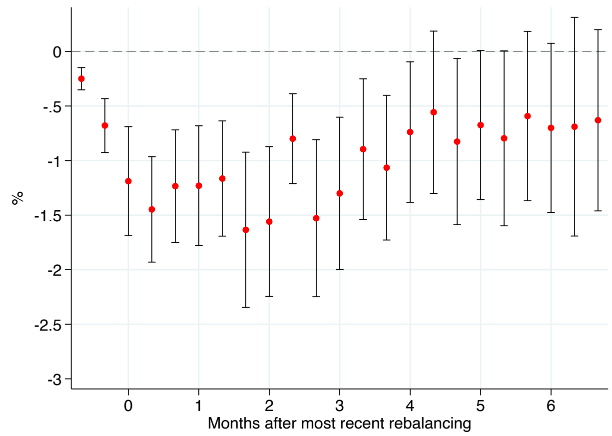
The pooled-OLS regression shows that one standard deviation increase of $\mu_{c,t}$ (21% increase in the market value of the country in the index, or an average of 2.5 billion USD flows) appreciates local currency exchange rates by 1% significantly after one rebalancing event.[9] Our estimates are consistent with literature on currency demand elasticities. A detailed discussion on this will follow in Section 6.2 of the paper.

Stylized Fact 2. *The currency demand shock has persistent impact on exchange rates, with the effect lasts for at least three months after one rebalancing event.*

Figure 2 makes clear that the rebalancings effects on exchange rates do not disappear and

[9]See appendix A.2.1 for backing out the flows implied the currency demand shock $\mu_{c,t}$.

Figure 2:
Fact 2 : Currency demand shock has persistent effects on exchange rates



Note: This figure plots the estimated coefficients of cumulative exchange rates change on the currency demand shock measured by $\mu_{c,t}$ in the horizon of 6 months after rebalancing. $\mu_{c,t}$ is standardized by its mean and standard deviation in the regression. The dependent variable is cumulative exchange rate change starting from 28 days prior to the first rebalancing. All regressions are performed in a pooled OLS using using time- and country-fixed effects with standard errors clustered at the country level. The results are reported in point estimates (red) with 90% confidence interval (black).

remain significant for at least three months after one rebalancing event. Compared to the level of exchange rate before the first rebalancing, cumulative exchange rates on average appreciate about 1.5% in response to one standard deviation increase in $\mu_{c,t}$. There's reversion-to-mean starting at four months after the first rebalancing with the effects then gradually lose significance. The regression results are with time- and country-fixed-effects with standard errors clustered at the country level.[10]

Remark 1. *Why do exchange rates start to move before the rebalancing date 0?*

As shown in Figure 1 and 2, exchange rates respond significantly to the currency demand shock $\mu_{c,t}$ before the rebalancing date at 0 arrives. We state that these dynamics are expected and strongly support the "efficient market hypothesis" (Fama, 1970). Information about the change in country weights is revealed before the rebalancing dates

[10]We do not control for macro-fundamentals as variables like GDP and net foreign asset positions are much more slow-moving compared to exchange rates and including them do not alter the baseline results. We also show in Table B.4 that the macro fundamentals (GDP and net foreign asset positions) are immune to the currency demand shock.

as the J.P. Morgan Markets announces its mid-month projections[11]. The mutual funds tracking the index would buy or sell government bonds almost immediately as new information about the next rebalancing feeds in and exchange rates would move before the rebalancing happens, exactly as what the "efficient market hypothesis" predicts. The fact that exchange rates start to move before the rebalancing date is also consistent with the movements of stock prices in other work on index rebalancings (Duffie, 2010; Kaul, Mehrotra and Morck, 2000).

Remark 2. *Why does the currency demand shock have persistent effects on exchange rates?*

As shown in Figure 2, exchange rates have significant and persistent response to the currency demand shock for at least three months. The fact that it takes time before exchange rates reversal is consistent with the "slow-moving capital" argument (Duffie, 2010) that the price reversal happens gradually over time as additional capital becomes available following the initial currency shock. Another reason that the effects are long-lasting is due to the persistence of the shock – as reported in Table B.10 in the appendix – the average currency demand shock $\mu_{c,t}$ follows an AR(1) process with persistence 0.66.[12] Finally, one should note that our regression captures a *level* shift in exchange rates (since -28 before rebalancing) and there are no gains of excess returns for arbitrageurs in the financial market.

Remark 3. *Can other local-currency emerging market sovereign bonds index also contribute to the observed exchange rate movements?*

One concern on identification is that other local-currency emerging market sovereign bonds index (apart from the JP Morgan GBI-EM Global Diversified) would also contribute to the variation in exchange rates. We examine carefully the rebalancing mechanisms of all leading local currency government bonds indices for emerging countries. We find that most of them have different rebalancing schemes and timing compared to GBI-EM Global Diversified index with the exception of Russell FTSE Emerging Markets Government Bond Index (EMGBI-Capped)[13]. However, a simple aggregation exercise

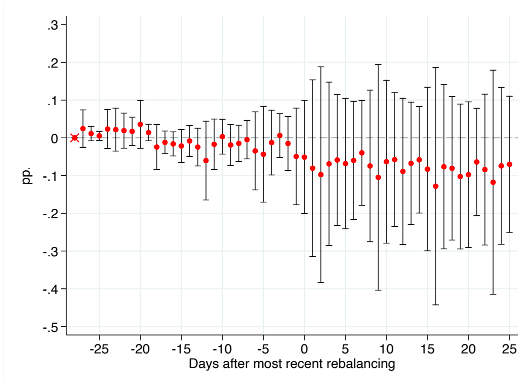
[11]Nevertheless, those projections are imprecise, especially for smaller countries that won't meet the 10% cap as J.P. Morgan cannot directly control the movements of market prices.

[12]Table B.11 and B.12 in the appendix gives the summary statistics of $\Delta\mu_{c,t} \equiv \mu_{c,t} - \mu_{c,t-1}$ and reproduce Fact 1 using the using $\Delta\mu_{c,t}$ instead. Using the alternative definition $\Delta\mu_{c,t}$ does not change our main results.

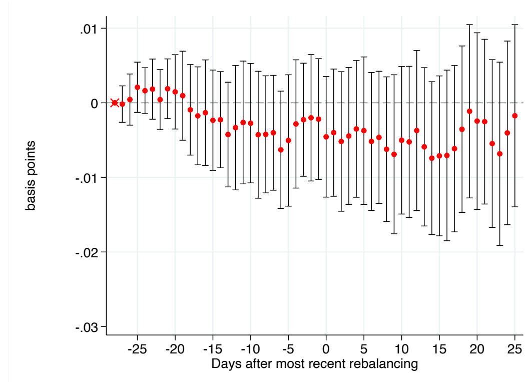
[13]FTSE fixed income EMGBI by Russell was introduced in 2018 as a "rebranding" of older Citi Group WGBI index. It's an emerging market local-currency government bonds index and has an end-of-month country weight cap at 10%.

Figure 3:
Fact 3: Policy rates and Yields do *not* respond to the currency demand shock

(a) Policy Rates



(b) One-Year Yields Relative to USD



Note: Pooled regression coefficients of change in monetary policy rates (in percentage point, left panel) and change in one-year local-currency government bonds yields relative to synthetic USD yields ($i_{c,t} - i^*_{c,t}$) in basis points, not annualized, right panel) with 90% confidence interval. Monetary policy rates and one-month government bonds yields are provided at the daily frequency are defined as the cumulative change from 28 days before the rebalancing date.

shows that the total asset positions of the funds tracking the EMGBI-Capped is not even 10% of the positions of GBI-EM Global Diversified index in our EPFR dataset. Therefore, we consider the variation in exchange rates created by these indices negligible compared to the rebalancings of the GBI-EM Global Diversified.

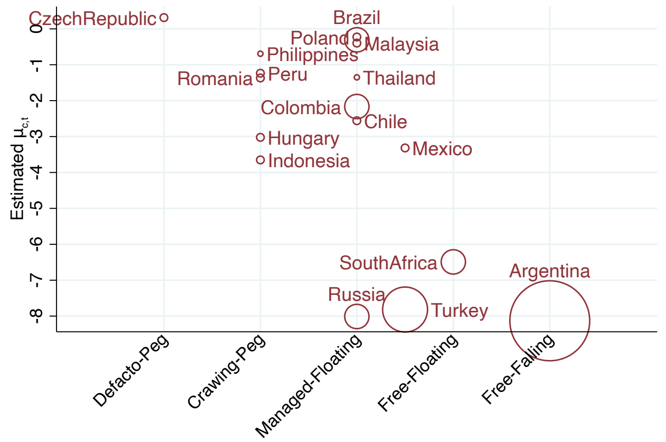
Stylized Fact 3. *Policy rates and yields do **not** respond to the currency demand shock.*

Another concern for identification is that central bank policy rates might respond to the rebalancings of GBI-EM Global Diversified index. If the policy rates were to move, the macro-fundamentals in the economy will also respond, violating the exogenous nature of the currency demand. We show that this is it *not* the case.

Central bank policy rates and yields are immune to the exogenous currency demand shock.[14] The OLS regression using changes in central bank policy rates (starting from -28 days before rebalancing) on the currency demand shock gives insignificant coeffi-

[14] Pandolfi and Williams (2019) find that a one standard deviation in the flows-implied-by-rebalancings of the GBI-EM Global Diversified index leads to sovereign debt prices of 8 basis in the window -5 to +5 of the rebalancing date zero. Note that 1). our regressor is the change in local-currency yields relative to synthetic USD yields. 2). similar as their findings, our movements in yields are also tiny.

Figure 4:
Fact 4: Floats respond more to the currency demand shock than peggers



Note: This figure presents the relation between country-specific exchange rates response to the currency demand shock (measured by $\mu_{c,t}$) and the exchange rates regimes classified by Ilzetzki, Reinhart and Rogoff (2021). The y-axis is the estimated exchange rates response to $\mu_{c,t}$ at the horizon 0-10 days after rebalancing, with time fixed effects (except Brazil and Mexico are with year fixed effects due to limited observations); the x-axis is the exchange rate regimes ranging from "de facto peg" (left) to "free falling" (right). All regression estimates are significant at 1% level except for Czech Republic, Brazil, Malaysia and Poland. The circle size represents exchange rates volatility of the currency. The larger the circle, the larger the volatility.

cients for all countries in our sample, as shown both in Figure 3 and Table B.5 for the country-by-country regression. The results make clear that the central banks are *not* using monetary policy rates to offset the exchange rates moves due to the rebalancings of the index. In addition, Figure 3 shows that changes in local-currency government bond yields relative synthetic USD yields ($i_{c,t} - i^*_{c,t}$) also have insignificant response to the currency demand shock. Table B.6 gives the country-specific regressions.

Stylized Fact 4. *Country-specific exchange rates response to the currency demand shocks differs by exchange rate regime, with floaters being much more responsive than the peggers.*

We find heterogenous responses of exchange rates to the currency demand shock across countries. We repeat the exercise in Figure 1 for each country and collect the estimated coefficients at the horizon 0-10 days after rebalancing[15]. Most countries respond to $\mu_{c,t}$ with 1% significance and all countries (except Czech Republic) predict the right

[15] We choose the window right after rebalancing date as Fact 1 and 2 made clear that the lion share of exchange rates movements occur before rebalancing date at time 0.

sign[16] – a positive local-currency demand shock (an increase in $\mu_{c,t}$) appreciates local currency exchange rates and decreases the price of USD in units of local currency. Czech Republic, Brazil, Malaysia and Poland do not have significant coefficients. Table B.8 and B.9 in the Appendix gives the country-specific exchange rates response.

There is a clear relation between the country-specific exchange rates response and the exchange rates regimes, as given by the downward trend in Figure 4. The y-axis is the country-specific estimated exchange rates response to the currency demand shock ($\mu_{c,t}$); the x-axis is the coarse exchange rate regimes ranging from "de facto peg" to "free falling" as classified by Ilzetzki, Reinhart and Rogoff (2021). The figure makes clear that free-floaters (e.g., Argentina, South Africa and Turkey) are much more responsive to $\mu_{c,t}$ than peggers (e.g., Czech Republic, Romania and Peru). In addition, the floaters have much larger exchange rate volatility, as seen in their larger circle size.

4 Currency Demand Shocks in Inelastic Financial Markets

In this section, we review major classes of models in international finance where uncovered interest parity condition does not hold. We show that models with endogenous deviations in uncovered interest parity condition in inelastic financial markets can explain the observed stylized empirical facts.

4.1 Uncovered Interest Parity (UIP) Condition

We start with the definition on uncovered interest party (UIP) condition. Let $i_{c,t}$ and $i^*_{c,t}$ be the returns of home- and foreign-currency bonds; $e_{c,t}$ is the exchange rate measured in the number of home currencies per USD (foreign); $\mathbb{E}_t \Delta e_{c,t+1}$ is the expected change of exchange rates from t to $t+1$. The UIP condition implies zero excess-return in the currency carry trade on home- and foreign-bonds. In other words, the expected exchange rates change is fully offset by return differentials and thus no arbitrage profits.

Definition 1. *If Uncovered Interest Parity (UIP) holds,*

$$(i_{c,t} - i^*_{c,t}) - \mathbb{E}_t \Delta e_{c,t+1} = 0 \tag{2}$$

[16]The fact that Czech Republic predicts insignificant and the wrong from the regression is expected as it has de facto pegged exchange rate regime. We will discuss this point more clearly in the section 6.2.

Our stylized facts that the currency demand shock moves exchange rates but not interest rates are clear contradictions to the UIP condition in equation (2). For a given interest rate differential, the exchange rates movements cannot exactly offset the interest differential if they are responding to a currency demand shock while the interest rates do not. In this regard, our empirical evidence adds to the massive literature on deviations in uncovered interest parity (UIP) condition that dates back to Fama (1984).

4.2 Exogenous vs. Endogenous UIP Shock Models

We distinguish exogenous and endogenous UIP shocks to equation (2). Examples of *exogenous* UIP shocks are capital control taxes (Mundell 1962) and exogenous risk-premium shocks (Devereux and Engel 2002; Ivan and Werning 2012) that act as lump-sum costs on the differential between home and foreign interest rates. We distinguish these exogenous UIP shock models from the papers (Gabaix and Maggiori 2015; Itskhoki and Mukhin 2021) that model risk-premium *endogenously*. In the latter class of models, an endogenous UIP shock changes the risk-bearing capacity of arbitrageurs who conduct currency carry trade, alters the equilibrium allocation of currencies as well as exchange rates, and give rise to endogenous deviations in UIP.

Definition 2. *A UIP shock is exogenous if it bears lump-sum costs on the differential between home and foreign interest rates; a UIP shock is endogenous if it changes the equilibrium allocation of currencies as well as exchange rates.*

Definition 3. *The modified Uncovered Interest Parity (UIP) condition is given by:*

$$i_{c,t} - i^*_{c,t} - \mathbb{E}_t \Delta e_{c,t+1} = \underbrace{\tau_{c,t} + \psi_{c,t}}_{exogenous} + \underbrace{\Lambda_{c,t}}_{endogenous} \tag{3}$$

where we denote capital control tax[17] *as $\tau_{c,t}$, exogenous risk-premium shock*[18] *as $\psi_{c,t}$, and endogenous risk-premium shock as $\Lambda_{c,t}$. Both $\tau_{c,t}$ and $\psi_{c,t}$ are exogenous UIP shocks and $\Lambda_{c,t}$ is the endogenous UIP shock.*

[17] Strictly speaking, there should be separate capital taxes for both the home and foreign. Without loss of generality, we use "net" capital tax defined as the difference in home capital tax minus the foreign.

[18] An example of risk-premium shock ($\psi_{c,t} > 0$) is a sudden increase in the world interest rate that make investors deem home assets more risky than foreign asset without changing the equilibrium allocation of assets and exchange rates.

We show that a model with only exogenous UIP shocks cannot square with our stylized empirical facts. Intuitively, both capital control taxes and risk-premium for the macroeconomic conditions are slow-moving variables compared to the exogenous currency demand shocks, which arrive at monthly frequency. We provide formal econometrics to attest to this idea by using capital control index data from Fernandez-Klein-Rebucci-Schindler-Uribe (2021) to proxy $\tau_{c,t}$ and variables of macroeconomic fundamentals (eg., inflation, consumption, output, net exports) to proxy $\psi_{c,t}$. As shown in Table B.4 in appendix, both measures for capital taxes τ_t and risk-premium shock $\psi_{c,t}$ are immune to our exogenous currency demand shock $\mu_{c,t}$. Taken together with results on interest rates (Fact 3), the evidence suggests that models with exogenous UIP shocks cannot explain the observed dynamics in exchange rates (Fact 1 and 2).

4.3 Endogenous UIP Deviations in Inelastic Financial Markets

So far, we have showed that an exogenous currency demand shock has no bearing on exchange rates movements in a model where UIP holds or a model with UIP deviations from exogenous shocks only. This is because in these two types of models, the financial markets are modeled as perfectly elastic with horizontal demand curve for currencies. A currency demand shock would thus have no impact on exchange rates and the equilibrium allocation of currencies.

The empirical facts thus point to a model with inelastic financial markets where a currency demand shock can move exchange rates. In this section, we present a simple model featuring the financial sector only where a currency demand shock shifts arbitrageurs holdings and gives rise to endogenous deviations in UIP. There are two types of agents in the model. Arbitrageurs demand home- and foreign-currency bonds and derive profits from the excess returns in currency carry trades; Noise traders have a constant supply schedule of home- and foreign-currency bonds with their positions subject to the currency demand shocks $\mu_{c,t}$. Importantly, shocks to the noise trader positions are orthogonal to macroeconomic fundamentals.

We present the arbitrageurs holdings and market clearing condition with noise trader positions below:

$$i_{c,t} - i^*_{c,t} - \mathbb{E}_t \Delta e_{c,t+1} \; - (\tau_{c,t} \; + \; \psi_{c,t}) \; = \; \lambda_{c,t} \, d_{c,t} \tag{4}$$

$$m_{c,t} \; + \; d_{c,t} = 0 \tag{5}$$

where in (4), we follow Gabaix and Maggiori (2015) and re-write the endogenous component UIP component Λ_t in equation (3) as the arbitrageurs holdings in local-currency bonds ($d_{c,t}$) times the risk-bearing capacity of the arbitrageurs ($\lambda_{c,t}$). The larger the $\lambda_{c,t}$, the lower the risk-bearing capacity of the arbitrageurs, and the steeper their demand curve. In the limit that $\lambda_t \to \infty$, the international bonds market is completely segmented with financial autarky. In the other extreme when $\lambda_{c,t} = 0$, the arbitrageurs are able to take infinite positions and absorb any non-zero excess returns in the currency carry trade. In the case when $\lambda_{c,t} \in (0, \infty)$, the model endogenously generates UIP deviations given by arbitrageurs risk taking.

An exogenous local-currency demand shock[19] (an increase in $\mu_{c,t}$) shifts noise trader positions $m_{c,t}$ and affects arbitrageurs holdings through the market clearing condition (5). In other words, the exogenous currency demand shock traces out the slope of the demand curve and the risk-bearing capacity of arbitrageurs. The steeper the demand curve (a larger $\lambda_{c,t}$), the more inelastic the financial market, the lower the risk-bearing capacity.

4.3.1 Drivers of Risk-Bearing Capacity in Endogenous UIP model

Since our currency demand shock does not move interest rates nor exogenous UIP shocks (capital control taxes and risk-premium shocks), the exchange rates responses can identify the arbitrageurs risk-bearing capacity $\lambda_{c,t}$. The only caveat is that our measure of currency demand shocks $\mu_{c,t}$ are in share of market size while the noise trader positions are in flows of local currencies. We show in appendix A.2.1 and A.2.2 how to convert the currency demand shocks $\mu_{c,t}$ into flows (as in noise trader positions) and the relation between the estimated $\beta_{\mu_{c,t}}$ and the risk-bearing capacity $\lambda_{c,t}$.

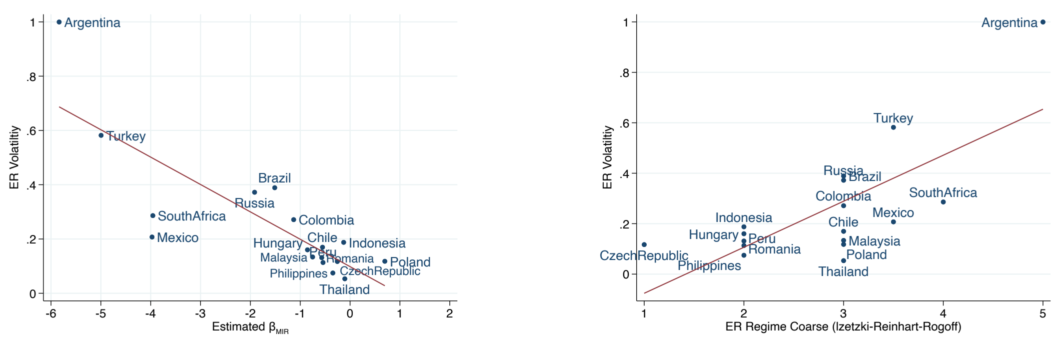
To understand the drivers of risk-bearing capacity across countries, we collect the

[19] As shown below in the model, a currency demand shock shifts noise traders positions and would be seen as shifts in *supply* in the perspective of arbitrageurs. That's why we say the currency demand shock traces out the *demand* curve for arbitrageurs.

estimated exchange rates responses to the currency demand shock ($\beta_{c,t}$) and plot them against different metrics ranging from macroeconomic fundamentals and the depth of the financial markets. We find no correlation between $\beta_{c,t}$ and macro- or financial metrics such as outputs and market size (Table B.7). However, there's one metric shows strong correlation – the exchange rates regime (and the volatility of exchange rates).

As shown in the Stylized Fact 4, the floaters have much larger exchange rates response and much larger exchange volatility than for peggers. This can be seen as the clear downward trend in Figure 4 as well as the relation with exchange rates volatility in Table 4.1. The more floating the exchange rates, the larger the exchange rates volatility, the lower the risk-bearing capacity of arbitrageurs (higher $\lambda_{c,t}$) and the more inelastic the financial market. The next section formally builds a model where the risk-bearing capacity endogenously depends on the volatility of exchange rates.

Table 4.1: Exchange Rates Response Correlates with Exchange Rates Volatility



(a) ER Vol. & country-specific response

(b) ER Vol. & Regime

Note: This figure presents the relation between the country-specific exchange rates response to the currency demand shock (measured by $\mu_{c,t}$) and the exchange rates volatility (panel a), and the relation between exchange rates regime and exchange rates volatility (panel b). The red line is the fitted regression for the x- and y-axis variables.

5 Interventions in Inelastic Foreign Exchange Markets

We have yet been silent about the implications of foreign exchange interventions. In this section, we introduce foreign exchange interventions into our model of inelastic financial markets with endogenous uncovered interest parity (UIP) deviations. We show that under inelastic financial markets, foreign exchange interventions serve as an additional policy tool to stabilize exchange rates without compromising monetary policy independence, regardless of the capital controls.

5.1 Endogenous UIP Model with FX Interventions

Consider a small open economy denoted by c. There're four types of agents in the a partially segmented financial market where both home and foreign households can only hold government bonds of their own currency. Households demand home-currency bond $b_{c,t}$, which is shaped by the macroeconomic fundamentals in the economy. Apart from households, there're three types of agents who can trade both home and foreign currency bonds in the international financial market, Namely, these are noise traders, arbitrageurs and the government, who we assume to all reside in the home country without loss of generality. We describe the problem of these agents below.

Risk-averse arbitrageurs hold zero-capital portfolio for home- and foreign-currency bonds$(d_{c,t}, d^*_{c,t})$ such that $d_{c,t} - i_{c,t} = -(e_{c,t} + d^*_{c,t} - i^*_{c,t})$ with return on one local-currency unit holding of such portfolio given by $\tilde{i}_{c,t+1} = i_{c,t} - i^*_{c,t} - \mathbb{E}_t \Delta e_{c,t+1}$. Arbitrageurs choose $(d_{c,t}, d^*_{c,t})$ to maximize the mean-variance preferences over profits in the currency carry trade:

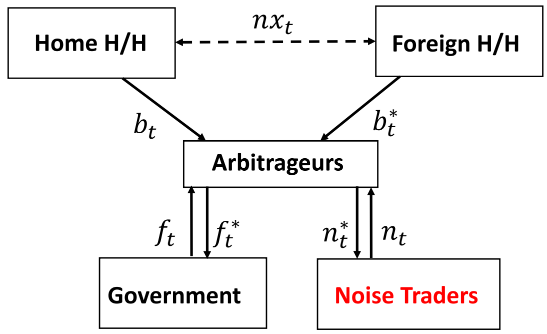
$$d_{c,t} = \frac{1}{\lambda_{c,t}} \big(i_{c,t} - i^*_{c,t} - \mathbb{E}_t \Delta e_{c,t+1} - (\tau_{c,t} + \psi_{c,t}) \big) \tag{6}$$

where $\lambda_{c,t} = \omega \ \sigma^2_{e_{c,t}}$ governs the risk-bearing ability of the arbitrageurs; parameter ω is the risk-aversion coefficient of the arbitrageurs and $\sigma^2_{e_{c,t}}$ the equilibrium volatility of exchange rates. The larger the $\lambda_{c,t}$ (or ω and $\sigma^2_{e_{c,t}}$) , the lower the arbitrageur's risk-bearing capacity. We model the risk-bearing capacity to be endogenously dependent on the the equilibrium volatility of exchange rates as our empirical evidence on risk-bearing capacity strongly correlates with exchange rates volatility (Fact 4).

Noise traders hold zero capital portfolio $(n_{c,t}, n^*_{c,t})$ and are subject to demand shocks so that $n^*_{c,t} - i^*_{c,t} + e_{c,t} + \mu_{c,t} = 0$, where $\mu_{c,t} \equiv n_{c,t} - i_{c,t}$ is the liquidity demand for local-currency bonds of the noise traders. Importantly, $\mu_{c,t}$ is a random variable uncorrelated with the macroeconomic fundamentals. A positive $\mu_{c,t}$ means that noise traders short foreign-currency (USD) bonds and buy local-currency bonds.

The government holds a portfolio of $(f_{c,t}, f^*_{c,t})$ units of home- and foreign-currency bonds, where $f_{c,t}$, and $f^*_{c,t}$ are policy instruments corresponding to open market opera-

Figure 5: Segmented International Bonds Market



Note: This figure presents the four types of agents in a segmented international bonds market, where home and foreign households can only hold government bonds in their own currency. Noise trader positions are subject to exogenous currency demand shocks that's uncorrelated with the macroeconomic fundamentals.

tions in foreign exchange interventions for home- and foreign-currency bonds, respectively. A positive (or negative) $f_{c,t}$ means buying (or selling) local-currency bonds in the foreign exchange interventions.

We also define $b^*_{c,t}$ as the net foreign asset (NFA) position of the home households and government. In our model with only home and foreign countries, $b^*_{c,t}$ equates the foreign households holdings of foreign-currency bonds, as foreign households cannot hold home currency bonds due to segmented financial market. We use a simple diagram to present the four types of agents and their positions a segmented market in Figure 5.

The market clearing condition for home-currency bond states:

$$b_{c,t} + n_{c,t} + d_{c,t} + f_{c,t} = 0 \tag{7}$$

Using the zero-capital position of noise traders and arbitrageurs, one can easily arrive at the following expression for net foreign assets: $b^*_{c,t} = f^*_{c,t} + n^*_{c,t} + d^*_{c,t}$

Combining equation (7) with equation (6) and put exchange rates on the left-hand-side of the equation, we have:

$$\mathbb{E}_t \Delta e_{c,t+1} = i_{c,t} - i^*_{c,t} - (\tau_{c,t} + \psi_{c,t}) \; + \; \lambda_{c,t} \left(b_{c,t} + m_{c,t} + f_{c,t} \right) \tag{8}$$

where $\lambda_{c,t} = \omega \, \sigma^2_{e_{c,t}}$ and we substituted the arbitrageurs holdings using market clearing condition. A currency demand shock $\mu_{c,t}$ on the local-currency bonds moves noise trader holdings $n_{c,t}$ and in turn the position of the arbitrageurs, which then leads to movements in exchange rates and endogenous deviations in UIP. Specifically, a positive local-currency demand shock (an increase in $\mu_{c,t}$) appreciates exchange rates levels tomorrow (a decrease in e_{t+1}) with the size of the appreciation governed by the risk-bearing capacity of the arbitrageurs $\lambda_{c,t} = \omega\ \sigma^2_{e_{c,t}}$.

5.1.1 Policy Function of FX Interventions

Holding all else constant in equation (8), the foreign exchange interventions $f_{c,t}$ stabilizes exchange rates by exactly offsetting the noise trader shocks, at the same magnitude and persistence. That is, $\partial e_{c,t}/\partial f_{c,t} = \partial e_{c,t}/\partial m_{c,t}$. This condition requires all variables on the right-hand-side of equation (8) to be immune to ethe currency demand shock that moves noise trader positions $m_{c,t}$. We already show that interest rates differentials $(i_{c,t} - i^*_{c,t})$ and exogenous UIP shocks $(\tau_{c,t},\ \psi_{c,t})$ are not responding to $\mu_{c,t}$. In addition, variables indicating macroeconomic-fundamentals $b_{c,t}$ are slow-moving to the currency demand shock and would not contaminate the identification.

Using monthly FX interventions data from Adler-Chang-Mano-Shao (2021), we find no correlation between the spot FX interventions data (as a share of GDP) with our exogenous currency demand shock $\mu_{c,t}$. This suggests the central banks are not actively using FX interventions to offset the noise trader shocks from the exogenous currency demand in equation (8). Thus, it's valid to assume $f_{c,t}$ to be independent of the noise trader positions $m_{c,t}$. In the texts below, we give two examples on how to map the policy function of foreign exchange rate intervention into certain models.

Example 1. *In the Tylor-rule model (Engel and West 2005) with exchange rate target $\bar{e}_c$, where the home- and foreign monetary policy rates follow the form of:*

$$\begin{aligned} i_{c,t} =& \beta_0\ (e_{c,t} - \bar{e}_c) + \beta_1\ y_{c,t} + \beta_2\ \pi_{c,t} + \nu_{c,t} \quad, \beta_0 \in (0,1) \\ i^*_{c,t} =& \beta_1\ y^*_{c,t} + \beta_2\ y^*_{c,t} + \nu^*_{c,t} \end{aligned}$$

The policy function of foreign exchange intervention is given by:

$$\frac{\partial e_{c,t}}{\partial f_{c,t}} = \frac{\partial e_{c,t}}{\partial m_{c,t}} = \frac{1}{(1 + \beta_0 - \rho)} \lambda_{c,t}$$

, where $\lambda_{c,t} = \omega\ \sigma^2_{e_{c,t}}$, under the assumption that (1).$m_{c,t} \sim$ AR(1) with persistence ρ, (2).$m_{c,t} \perp$

$f_{c,t}$, and (3).macro-fundamentals are slow-moving compared to noise trader shocks.

Proof: See Appendix C.

Example 2. *In the general equilibrium model of Itskhoki and Mukhin (2021) that specifies the budget constraint of a country $\beta\, b^*_{c,t} - b^*_{c,t-1} = nx_{c,t} = \gamma\, e_{c,t} + \xi_{c,t}$, where $nx_{c,t}$ is the net exports and $b^*_{c,t}$ the NFA of the home country. The policy function of foreign exchange intervention is given by:*

$$\frac{\partial e_{c,t}}{\partial f_{c,t}} = \frac{\partial e_{c,t}}{\partial m_{c,t}} = \frac{\beta}{(1-\rho\beta)}\lambda_{c,t}$$

, where $\lambda_{c,t} = \omega\, \sigma^2_{e_{c,t}}$, under the assumption that (1).$n_{c,t} \sim AR(1)$ with persistence ρ, (2).$m_{c,t} \perp f_{c,t}$, and (3).macro-fundamentals are slow-moving compared to noise trader shocks.

Proof: See Appendix C.

5.2 Implications for FX Intervention and the Relaxed Trilemma

In this section, we discuss the implications of foreign exchange interventions under inelastic financial markets. We define the "relaxed Trilemma" condition following Itskhoki and Mukhin (2023) for endogenous UIP models with inelastic financial markets. Under inelastic financial markets, foreign exchange intervention serves as an effective policy tool to stabilize exchange rates without compromising monetary policy independence, regardless of the capital controls.

Definition 4. *The "relaxed" Trilemma constraint states that it's **possible** to have all three of the following simultaneously: (1). An independent monetary policy (inward-focused on domestic inflation and output gap); (2). Free capital mobility (absence of capital control taxes); (3). A fixed exchange rate.*

Definition 5. *The "Trilemma Type" models are UIP models that bind under the classical Trilemma constraint; the "Non-Trilemma Type" models are UIP models that hold under the "relaxed" Trilemma constraint.*

Definition 4 contradicts the classical Trilemma constraint (Mundell 1962), which states that you can *not* have all three conditions in Definition 4. Models where UIP condition holds and models with exogenous UIP shocks are subject to the classical Trilemma constraint, which we refer to as the *Trilemma Type* models. If UIP holds, there's free capital mobility by construction and the economy faces the direct Trilemma tradeoff between an independent monetary policy and a fixed exchange rate, as seen in equation (8). If the UIP deviations come from exogenous shocks, monetary policy rates would have to move one-on-one with exchange rates unless capital control taxes ($\tau_{c,t}$) and exogenous risk-premium ($\psi_{c,t}$) can both be used as policy instruments to offset exchange rates. This is clearly not feasible. Thus, under the Trilemma constraint, exchange rates stabilization comes at the cost of compromising monetary policy independence.

By contrast, models with endogenous UIP shocks can have all three conditions in the Trilemma. This is because they have an additional policy instrument to stabilize exchange rates – foreign exchange (FX) interventions. As shown in equation (8), foreign exchange interventions conduct open market operations that shift the arbitrageurs positions, which then lead to endogenous deviations in UIP and move exchange rates. Therefore, the central bank[20] can now stabilize exchange rates through FX interventions while the monetary policy is entirely domestically-focused to close the output gap. In other words, even under perfectly mobile capital flows, the economy no longer has to compromise monetary policy independence to stabilize exchange rates, relaxing the classical Trilemma constraint. We thus refer to the endogenous UIP models as the *Non-Trilemma Type* models.

5.2.1 Empirical Evidence for "Relaxed" Trilemma

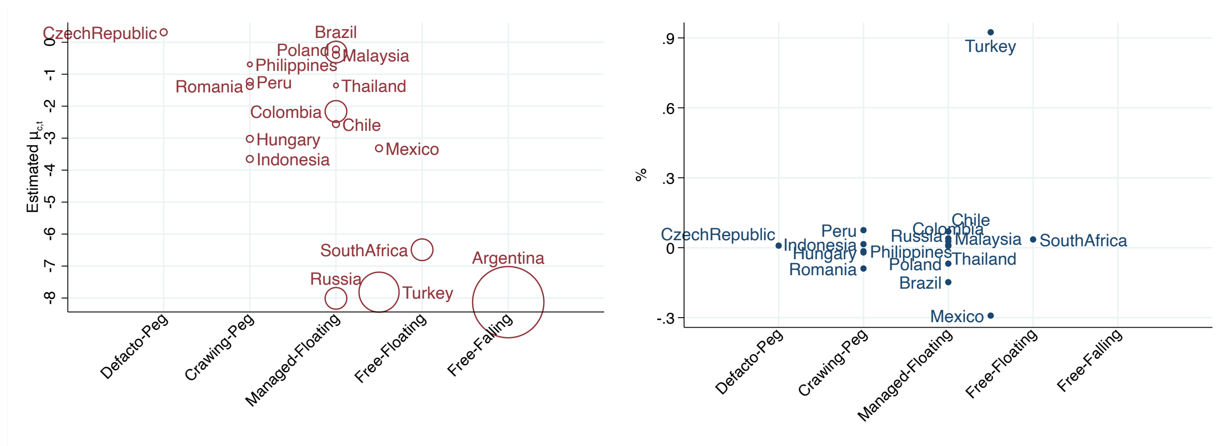
Our stylized fact 3 and 4 show that there're significant exchange rates response for almost all currencies but no response in policy rates to the exogenous currency demand shock. Under Trilemma type models, the movements in exchange rates must be offset one-on-one by monetary policy rates for exchange rates to be fixed, for any given capital control taxes ($\tau_{c,t} \geq 0$ in equation (8)). Our empirical evidence suggests the Non-Trilemma type models and implies that countries under managed exchange rates regimes (namely, de facto peg, crawling peg, and managed floats) must have used instruments other than monetary policies to manage their exchange rates. We view this as the most direct evidence supporting the "relaxed" Trilemma constraint discussed above. Table 5.1 puts both response of exchange rates and policy rates to the currency demand

[20] The central bank's objective is to minimize international risk-sharing wedge and domestic output gap. Please refer to Itskhoki and Mukhin (2022) for details on the central bank objective function.

shock side by side and summarizes this result.

Table 5.1: Empirical Support on Relaxed Trilemma

(a) exchange rates (b) policy rates



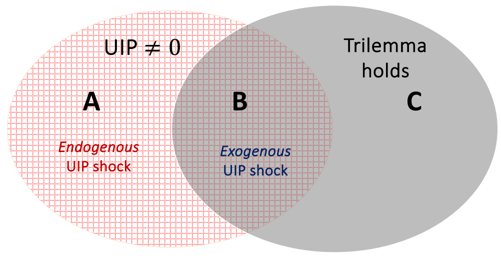
Note: Scatter plot of country-specific exchange rates (left) and policy rates (right) response to the currency demand shock $\mu_{c,t}$ against the exchange rates regime (from strict to relaxed) as classified by llzetzki, Reinhart and Rogoff (2021).

5.2.2 Discussion on (Non)-Trilemma Models and UIP

In this short section, we review the major classes of literature in international finance. We discuss their implications on the Trilemma constraint, the uncovered interest parity (UIP) condition, as well as the (in)elastic financial markets. We start with the Trilemma Type models where UIP either holds or subject to exogenous shocks only, and then compare them with Non-Trilemma Type models with endogenous UIP shocks where FX interventions are effective.

Models where UIP holds or models with exogenous UIP shocks are subject to the classical Trilemma constraint. This is because either models where UIP holds (e.g., Mundell 1962; Obstfeld and Rogoff 1995) or models with exogenous UIP shocks (e.g., Devereux and Engel, 2002; Farhi and Werning, 2012) assume financial markets are perfectly elastic and thus a quantity shock would have no bearing on exchange rates. Even if foreign exchange interventions are implemented, they would be ineffective in these models as they lack the channel where a demand shock endogenously shifts arbitrageurs holdings that in turn leads to deviations in UIP. Therefore, these models are subject to the Trilemma tradeoff between monetary policy rates and exchange rates, as discussed in the previous

Table 5.2: Trilemma Constraint and UIP



Model	Financial market	Papers
endogenous uip shock	inelastic	Gabaix and Maggiori (2016), Itskhoki and Mukhin (2021), Fanelli and Straub (2021), Basu, Boz, Gopinath, Roch and Unsal (2023)
exogenous uip shock	elastic	Devereux and Engel (2002), Farhi and Werning (2012), Jiang, Krishnamurthy and Lustig (2018)
classic Trilemma (uip = 0)	elastic	Mundell (1962), Dornbusch (1976), Obstfeld and Rogoff (1995), Gali and Monacelli (2005)

Note: This diagram presents the relation between models where UIP fails (left circle) and models where Trielamma constraint holds (right circle). Region A refer to models under relaxed Trilemma and UIP fails (endogenous UIP shock); region B refer to models where UIP fails but Trilemma holds (exogenous UIP shock); Region C represents the classic Trilemma models where UIP holds. The table lists the papers in each type of models.

section.

Only in the non-Trilemma type models with endogenous UIP deviations (e.g., Gabaix and Maggiori 2015; Itskhoki and Mukhin 2021) can foreign exchange interventions effectively stabilize exchange rates. In these models, financial markets are inelastic. Foreign exchange interventions serves as an additional policy tool to stabilize exchange rates as demand shocks can have traction on exchange rates under inelastic markets. Thus, foreign exchange interventions and can now work together with independent monetary policy with no capital controls. Table 5.2 presents relation between classical Trilemma models, models with exogenous UIP shocks, and models with endogenous UIP shocks.

6 Identifying the Size of Foreign Exchange Interventions

In this section, we identify the required size of foreign exchange intervention to stabilize exchange rates and discuss the effectiveness of the intervention across different exchange rate regimes. We find that countries with floating exchange rate regimes are more effective in stabilizing exchange rates on average compared to the peggers, with the former requiring less amount of reserves to stabilize exchange rates. The pattern also holds within the group of floaters, with the free floaters more effective at stabilizing exchange rates than the managed floaters.

6.1 Converting the estimates to the size of intervention

We convert the estimates from the currency demand shock into the implied capital flows in USD. We first use the cross-country estimates (Stylized Fact 1) on the average exchange rates in response to the shock and show how to compute the implied flows of mutual funds tracking the GBI-EM Global Diversified index. We report the average counterfactual required size of foreign exchange interventions to stabilize exchange rates and compare with the estimates from the literature.

The caveat in this exercise is that our currency demand shock is measured in shares of market values while the required size of intervention is in flows. Our regressions results show that in a one standard deviation of $\mu_{c,t}$ (21% market value, by Table 2.2) moves exchange rates by 1% (at the 0-10 days horizon after rebalancing) for the pooled-OLS regression with country and time fixed effects. We also know that the average market value of local-currency government bonds in the GBI-EM Global Diversified index is 68 bn.USD in 2019 with the total index value equals to 1221 bn.USD in the same year (Table B.1). In addition, we estimate that the total positions of mutual funds in EPFR that track the Index to be 113.6 bn.USD, while the EPFR dataset represents about 60% of the global mutual funds population from the Investment Company Institutes (ICI) facts book (reported in Table B.2 in the Appendix).

We can therefore write the following equation to back out our estimates into flows required to stabilize exchange rates by 1%:

$$\begin{aligned}&\text{Required flows to move exchange rates by } 1\% = \\ &\frac{1}{\beta_\mu} \times \text{std.}(\mu_{c,t}) \times \frac{\text{avg. country-level market value}}{\text{total market value of the index}} \times \frac{\text{EPFR mutual funds positions}}{\text{Share of EPFR funds in ICI}}\end{aligned}$$

This means that the average required flows to move exchange rates by 1% from our pooled-OLS regression is: $1 \times 0.21 \times \frac{68}{1221} \times \frac{113.6}{0.6} = 2.5$ bn.USD, or about 0.38% of the average annual GDP in 2019 (the average annual nominal GDP in 2019 is 586 bn.USD, reported in Table B.1).

How does our estimates compare with the previous literature? Our results are largely consistent with both the foreign exchange intervention literature using event studies and the asset pricing literature using index rebalancings. Adler et al (2019) focuses on foreign exchange interventions episodes for a group of advanced and emerging market economies and estimate the effects of intervention by replying on an instrumental-variable panel approach. They found that the foreign exchange intervention with the magnitude 1% of GDP results in exchange rates depreciation in the range of [1.7, 2] percent. In other words, the average required size of intervention to move exchange rates by 1% is about 0.5% of GDP, which is very similar to our results.

Our estimates are also aligned with the asset pricing literature on measuring the demand elasticities of currencies. For example, Hau, Massa, and Peress (2009) use the re-weighting of 33 countries in the MSCI's global index as an exogenous shock to estimate currency supply elasticity. Their estimates suggest that an average 2.6 bn. USD are needed for a 1% change in exchange rates in a six-day window around the announcement of the index re-weighting. This is almost exactly the same as our results. By comparison, Evans and Lyons (2002) uses order flows data and estimate that a 1 billion USD daily FX order flows moves exchange rate by 0.5%.[21]

6.2 Size of Interventions for Different Currency Regimes

We estimate the country-specific estimates (Stylized Fact 4) to compute the required size of intervention (USD flows) to stabilize exchange rates. To do so, we repeat the exercise as in section 6.1 but with the country-specific estimates to the currency demand shock, as well as the country-specific market value of the local currency government bonds in the GBI-EM Global Diversified index. The counterfactual required size of intervention to stabilize exchange rates for each country is reported in Table 6.1.

We find that countries with floating exchange rates regimes require much less intervention (and thus are more effective in using FX intervention) to stabilize exchange rates

[21] Camanho, Hau and Rey (2021) is the only paper with much larger estimates. Using quarterly rebalancings from the equity funds, they found that an average capital flow of 5.5 billion USD amounts to move exchange rates by 1%, in a quarterly window. We therefore claim the estimates from Evans and Lyons (2002) and Hau, Massa, and Peress (2009) mentioned above are more comparable to ours due to the similar window of exchange rates movements.

Table 6.1: FXI required to induce 1 % exchange rate change

Country	ER regime (code)	Required FXI	**FXI over GDP (%)**
Peru	crawling peg (2)	0.875	0.380
Hungary	crawling peg (2)	0.435	0.269
Romania	crawling peg (2)	0.582	0.233
Indonesia	crawling peg (2)	1.34	0.108
Philippines	crawling peg (2)	0.124	0.032
Thailand	managed floating (3)	2.397	0.428
Chile	managed floating (3)	0.380	0.145
Colombia	managed floating (3)	0.950	0.295
Russia	managed floating (3)	0.346	0.020
Mexico	managed/free floating (3.5)	1.511	0.116
Turkey	managed floating/free falling (3.5)	0.154	0.021
SouthAfrica	free floating (4)	0.540	0.135
Argentina	free falling (5)	0.026	0.007
Average by group			
crawling peg		0.65	0.21
managed floating		1.02	0.22
free floating/falling		0.56	0.07

Note:

Estimates for Czech Republic (de facto peg, code 1), Brazil, Malaysia and Poland (all managed floating, code 3) are insignificant and we do *not* report them in this table.

This table reports the country-specific required size of FX intervention to stabilize exchange rate by 1% in billions of USD (column 3) and as a share (%) of each country's 2019 nominal GDP (column 4). We sort countries by their coarse exchange rate regimes (column 2, as classified by Iltzetki, Rogoff and Reinhart 2021) from de facto peg to free floating/falling. For countries having multiple exchange rate regime codes during our sample 2010-2021, as with Mexico and Turkey, we take the average regime code across time.

The required size of intervention is computed using the country-specific exchange rate response to the currency demand shock at the 0-10 day horizon after the rebalancing date. All estimates are significant at 1% level. A full table with the country's GDP and market value can be found in Table B.1 in the appendix.

compared to countries with pegged regimes. For example, the required FX intervention over GDP to move exchange rates by 1 percent is about 0.38% of GDP (or 0.875 billion USD) for Peru (crawling peg). By comparison, the group average of crawling peg (Hungary, Peru, Romania, Philippines) and group average of managed floating (Thailand, Chile, Colombia, and Russia) are both about 0.21% of GDP. This is three times bigger than bigger than countries under free-floating exchange rates (Mexico, Turkey, South Africa, and Argentina), which only require interventions in the size of 0.07% of GDP to stabilize exchange rates by 1%.

In addition, it appears that the average required intervention for country-specific estimates in Table B.1 (less than 0.2% GDP) is much smaller than the average required intervention using pooled-OLS as reported in section 6.1 (about 0.4% GDP). We believe the difference comes from a peggers and managed-floaters included in the pooled regression that bias the OLS estimates. When dropping insignificant estimates such as Czech Republic (de facto peg), Brazil, Malaysia and Poland (all managed floating), the required size of intervention become much slower as the sample is weighted more towards the free floaters.

Why are floats more effectiveness at stabilizing exchange rates? The empirical results that the floats are much more effective at stabilizing exchange rates than peggers are consistent with the model mechanism in section 5. The risk-bearing capacity $\lambda_{c,t} \equiv \omega\sigma^2_{e_{c,t}}$ governs the elasticity of exchange rates response to the currency demand shock. A more stable/managed exchange rates would therefore imply a smaller exchange rates volatility ($\sigma^2_{e_{c,t}}$) and therefore more elastic market. In the limit of exchange rates being fully pegged, we are back the elastic financial market model under Trilemma constraint that are immune to a currency demand shocks. In other words, foreign exchange interventions are more effective with floats precisely because they have larger exchange rate volatility (Stylized Fact 4) and more inelastic financial market, and are thus further away from the Trilemma constraint.

Our results on the interventions being more effective for the free-floaters are consistent with the findings by Fratzscher et al (2019). Using confidential FX interventions data from 33 countries, they determine the *success* of foreign exchange interventions – defined as the consistency in the movement of exchange rates during the intervention and the intended direction of the intervention – across different regimes. They found that FX intervention are most effective for free floaters with a success rate of 0.53 through pure purchase/sale of FX reserves. By comparison, the success rate for broad band, narrow band, as well as other exchange rates regimes are significantly lower.[22]

Remark 4. *How does our estimates of currency demand elasticities advance our understanding on FX interventions compared to the early work?*

We believe our estimates on currency demand elasticities from the rebalancings of the GBI-EM Global Diversified index are more suitable to draw inference on the FX interventions for the following reasons: First, we uncover the heterogenous responses across currency regimes between free-floaters and managed-floaters/peggers. A cross-sectional OLS that include the peggers would bias the elasticities downwards. Second, the fact that our currency demand shock (as shown in auto-correlation tests in Table B.10) are rather persistent with an average auto-correlation of 0.66. The persistence matches well with the actual intervention episodes, which typically take place in a repeated fashion and the intervention days are part of a longer intervention period.[23] By comparison, Hau, Massa, and Peress (2009) uses a one-time index re-weighting shock to recover currency demand elasticities.

7 Conclusion

In this paper, we use a well-identified currency demand shock on the noise traders that give rise to endogenous uncovered interest parity (UIP) deviations under an inelastic financial market. Our results show that the exogenous currency demand shock moves exchange rates significantly both in the short- and long-run but not monetary policy rates, providing direct support for models with inelastic financial market and the "relaxed Trilemma" constraint. We assess the effectiveness of foreign exchange intervention for an emerging market central bank to stabilize exchange rates under the inelastic financial market hypothesis. When markets are inelastic, foreign exchange rate intervention works as an additional policy tool to move exchange rates without compromising monetary policy independence, providing evidence relaxing the classical Trilemma constraint.

[22]This is from the results of Table 5 on determinants of effectiveness for foreign exchange intervention by Fratzscher et al (2019). Please check the paper for detailed estimates and definition.

[23]The documented by Fratzscher et al (2019) on detailed characteristics on foreign exchange interventions.

Our results contribute to various strands of literature including the foreign exchange intervention and asset demand estimation and are informative to policymakers at emerging market central banks.

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Appendix

A Data Description and Background

A.1 More on GBI-EM

Published by J.P. Morgan in 2005, the GBI-EM Global Diversified index is the largest local-currency government bonds index for emerging countries. It's also the most popular index among the GBI-EM family of a total of six different indexes. According to the J.P. Morgan Market Survey, the asset under management for the mutual funds tracking the GBI-EM Global Diversified is more than 200 billion US Dollars in 2020 (cite the size of the sovereign market here, [TBA]). There are currently 19 emerging countries in the index. These countries are chosen to enter (and remain in) the index if their Gross National Income per capita are below the J.P. Morgan defined Index Income Ceiling for three consecutive years and the country's long term local currency sovereign credit rating is A-/A3/A- (inclusive) or above for three consecutive years.

The monthly rebalancings of the GBI-EM Global Diversified index have three layers, which are done in order on the last weekday of the month. The first layer uses a diversification methodology that includes only a portion of a country's current face amount outstanding into the index. The included face amount outstanding – called the adjusted face amount – is based on the respective country's relative size in the index and the average size of all countries. The adjusted face amount is then used to compute the market value of each country in the index. The second layer focuses on the bonds maturity threshold that drops bonds with less than 13 months to maturity from the index. As the third and last layer of control, the index rebalancing caps the weight of each country, computed using the adjusted face amount, at 10%.

A.2 More on Currency Demand Shock $\mu_{c,t}$

Two facts worth pointing out on the country-level dynamics: First, while most countries experience persistent positive $\mu_{c,t}$ (for example, Argentina, Chile, Hungary, etc.), some countries (for example, Brazil and Mexico) have negative $\mu_{c,t}$ in most of their episodes. This is because large countries like Brazil and Mexico are more likely to hit the 10% country weight cap during rebalancings. Their excess weights are redistributed to smaller countries that are below the cap such that the weights of all countries in the index sum up to 100%.

Second, data for some countries (for example, Argentina, Nigeria, Uruguay) are available only in a small number of months between 2010 and 2021 for the reason(s) that these countries fail to meet either the income ceiling or the credit rating requirement of the index in those episodes. A big country like Brazil can also be excluded from the GBI-EM Global Diversified index from time to time – as shown by the discontinuous MIR time-series for Brazil from 2010 to 2019. In those months, Brazil was included the GBI-EM Broad (another more inclusive index of the J.P Morgan GBI-EM family) instead possibly due to its intensive capital controls [TBA source].

A.2.1 Converting the currency demand shocks into flows

We can re-write the expression the currency demand shock $\mu_{c,t}$ as the percentage change in market value implied from the rebalancing:

$$\begin{aligned}
\mu_{c,t} &= \frac{\omega_{c,t}^{\text{after}} - \omega_{c,t}^{\text{before}}}{\omega_{c,t}^{\text{after}}} \\
&= \frac{\frac{P_{c,t}\hat{Q}_{c,t}}{\sum_c' P_c\hat{Q}_c} - \frac{P_{c,t}\hat{Q}_{c,t-1}}{\sum_c' P_c\hat{Q}_c}}{\frac{P_{c,t}\hat{Q}_{c,t}}{\sum_c' P_c\hat{Q}_c}} \\
&= \left(\omega_{c,t}^{\text{after}} - \omega_{c,t}^{\text{before}}\right) \times \frac{\sum_c \text{market value}}{\text{market value country c}}
\end{aligned}$$

where $\hat{Q}_{c,t}$ is the face-amount (or quantity) of the local-currency sovereign bonds of country c included in the GBI-EM Global Diversified index at rebalancing date t; $P_{c,t}$ is the aggregate market price of the local-currency sovereign bonds of country c. Once $\hat{Q}_{c,t}$ is chosen at a rebalancing date, it will be fixed for the next month until the end of the business day of the next month when the next rebalancing comes in. The product of face-amount and market price $P_{c,t}\hat{Q}_{c,t}$ is the market value of the sovereign bonds included in the index.

After showing $\mu_{c,t}$ essentially represents the change in market value, we can back out the change in the flows of mutual funds positions implied by rebalancings:

$$\begin{aligned}&\text{Average Implied flows from rebalancings (FIR) } \mu_{c,t} = \\ &\frac{\text{avg. country-level market value}}{\text{total market value of the index}} \times \frac{\text{EPFR mutual funds positions}}{\text{Share of EPFR funds in ICI}}\end{aligned} \tag{9}$$

In the definition above, EPFR mutual funds positions is the asset-under-management (AUM) of the the mutual funds that are passively tracking the GBI-EM Global Diversified Index at time t. However, EPFR doesn't report the universe of mutual funds globally that track GBI-EM Global Diversified Index. We therefore need to scale the positions reported by EPFR by its population share in the mutual funds universe, as reported by the Investment Company Institutes (ICI). We report the estimated AUM of EPFR mutual funds passively tracking the GBI-EM Global Diversified index in panel (a) of Table B.2 and the population share of EPFR data in ICI database in panel (b) of Table B.2.

A.2.2 Converting the currency demand shocks into noise trader shocks

We show below how to connect the flows implied by rebalancings (FIR) with the noise trader positions. As we do not observe the entire variation in the noise trader shocks, we decompose noise trader positions $n_{c,t}$ into two components: the first component is the buy-and-hold portfolio of benchmark invesments who are subject to mechanical rebalancings ($\tilde{n}_{c,t}$); the second component is the part of noise trader positions unexplained by rebalancings ($\tilde{e}_{c,t}$). The two components are *additive* and *orthogonal* to each other.

$$n_{c,t} = \tilde{n}_{c,t} + \tilde{e}_{c,t}, \qquad \text{where} \quad \tilde{n}^*_{c,t} \perp \tilde{e}_{c,t}$$

Holdings of benchmark investments ($\tilde{n}^*_t$) are subject to noise trader shocks ($\tilde{\psi}_t$) when rebalancing happens. Noise traders shocks are orthogonal to macroeconomic fundamentals just as illustrated in the model. The position $\tilde{n}^*_t$ at time t is:

$$\tilde{n}_{c,t} = \begin{cases} \left(\frac{\tilde{n}_{c,t-1}}{R^*_{c,t-1}}\right) R_{c,t} & \text{o.w} \\ \tilde{\psi}_t R_{c,t} & \text{if} \quad t = \text{rebalancing date} \end{cases} \tag{10}$$

At the rebalancing date:

$$\begin{aligned} \tilde{n}_{c,t} = \tilde{\psi}_{c,t} R_{c,t} &= \underbrace{\tilde{\psi}_{c,t} R_{c,t} - \left(\frac{\tilde{n}^*_{c,t-1}}{R_{c,t-1}}\right) R_{c,t}}_{\text{flows implied by rebalancings}} + \underbrace{\left(\frac{\tilde{n}_{c,t-1}}{R_{c,t-1}}\right) R_{c,t}}_{\text{market value buy-and-hold}} \\ &= \quad \text{FIR}_{c,t} \qquad\qquad + \qquad \text{market value}^{BH}_{c,t} \end{aligned}$$

where market $\text{value}^{BH}_{c,t}$ is buy-and-hold market value that equates the faceamount of previous rebalancing $t-1$ times the market price at time t. The flows-implied-by-rebalancings (FIR) can be connected with our currency demand shock as shown in equation (9). We can therefore re-write the noise trader shocks $n_{c,t}$ as:

$$n_{c,t} = \text{FIR}_{c,t} + \quad \text{market value}^{BH}_{c,t} + \quad \tilde{e}^n_{c,t} \tag{11}$$

where $\tilde{e}^n_{c,t} \perp \text{FIR}_{c,t}$, that is, the components of noise trader shocks unexplained by rebalancings are orthogonal to the flows implied by rebalancings of the GBI-EM Global Diversified.

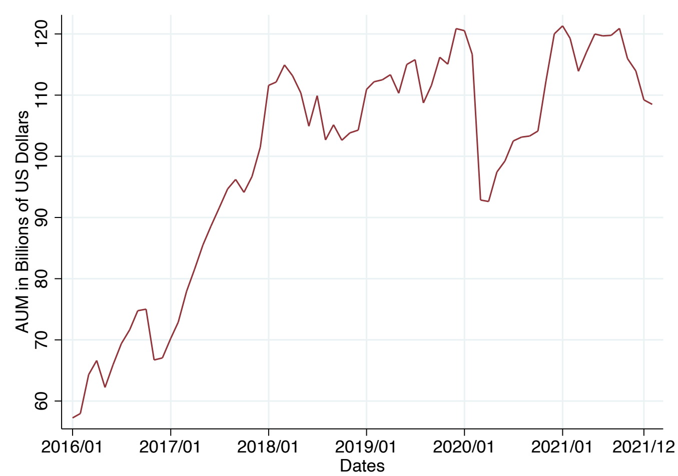
B Additional Figures and Tables

Table B.1: FXI required to induce 1 percent exchange rate change

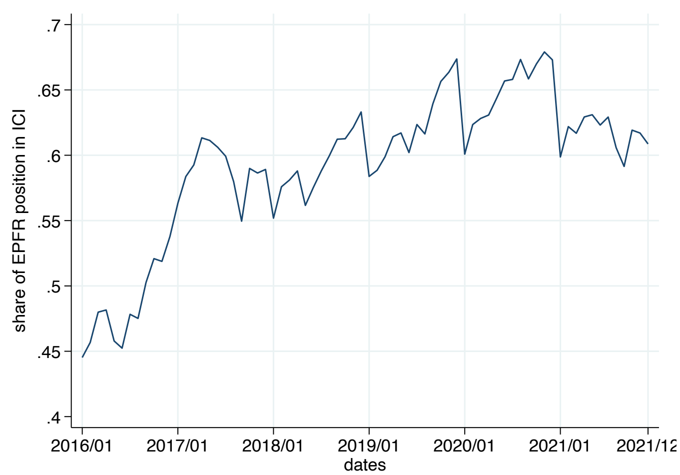
Country	2019 mkt value	2019 GDP
Argentina	6.65	360.57
Brazil	205.72	1833.49
Chile	29.72	262.98
Colombia	62.86	321.81
CzechRepublic	38.09	256.02
Hungary	40.20	161.72
Indonesia	137.43	1138.96
Malaysia	55.98	369.14
Mexico	153.18	1297.19
Peru	33.07	229.93
Philippines	2.63	384.63
Poland	104.24	602.6
Romania	24.33	249.67
Russia	84.76	1764.64
SouthAfrica	107.15	400.25
Thailand	98.98	560.20
Turkey	36.91	725.20
Average	67.95	586.09
Median	48.09	382.91

Note: Column 2 gives the average market value of the local-currency government bonds of each country in the GBI-EM Global Diversified in 2019 (with the except of Argentina that we use the average between 2017-2019 due to limited data). Column 3 gives the annual nominal GDP of 2019. All values are in billions of US Dollars. We used the market value and GDP to compute the required size of foreign exchange interventions in Table 6.1 in the main texts.

Table B.2: AUM of the GBI-EM index in EPFR data and Its Share in ICI Population



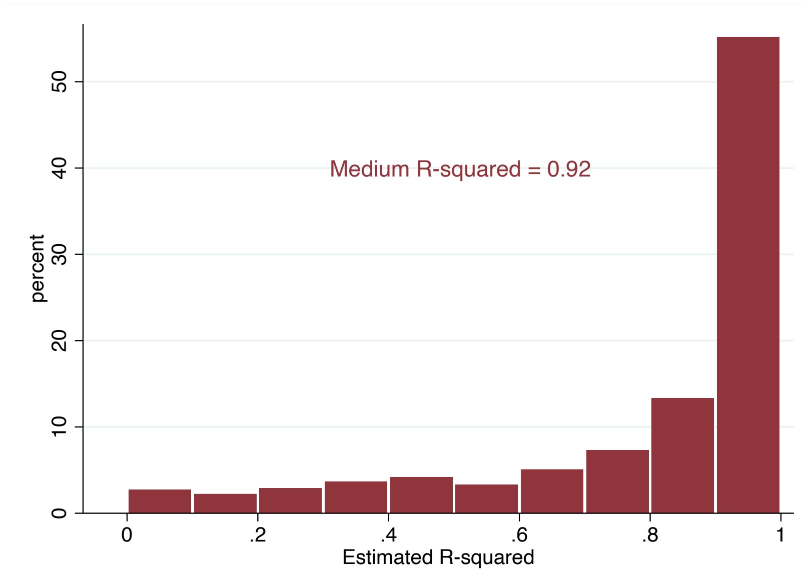
(a) AUM of Funds tracking GBI-EM Global Diversified in EPFR Data



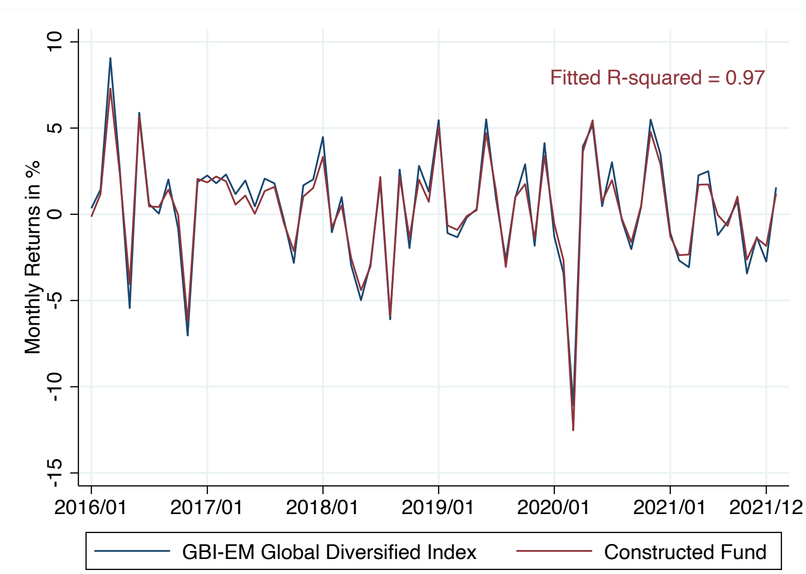
(b) AUM of Funds tracking GBI-EM Global Diversified in EPFR Data

Note: This figure reports the total asset under management of bond funds that track the GBI-EM Global Diversified index in the EPFR dataset (panel a) and the share of total EPFR data representation for the entire mutual funds industry (panel b). The bonds funds aggregated in panel (a) are in Billions of USD and are selected from mutual funds whose benchmark indices track the JP Morgan GBI-EM Global Diversified or their performance R-squared are at least 0.9. Observations are in monthly frequency from January 2016 to December 2021.
For the share of mutual funds representation in panel (b), we aggregate equity, bonds, and money market end-of month assets for both industrialized and emerging markets from the EPFR data and divide that number with investment Company Institute (ICI) Global Facts Sheet. This gives the the population presentation of the EPFR data in the world-wide mutual funds industry.

Table B.3: Return performance of mutual funds in the data



(a) Histogram of fund performance R^2



(b) Weighted (by positions) average returns

Note: This left panel reports the histogram of estimated R-squared of12-month rolling window regressions of monthly fund returns on the returns of GBI-EM Global Diversified index; the median R-squared is 0.92. The right panel plots the returns of GBI-EM Global Diversified index and the returns of weighted (by asset under management) of all mutual funds tracking the index; the performance R-squared here is 0.97.

Table B.4: Capital controls, macro-fundamentals, and FXI are immune to the shock

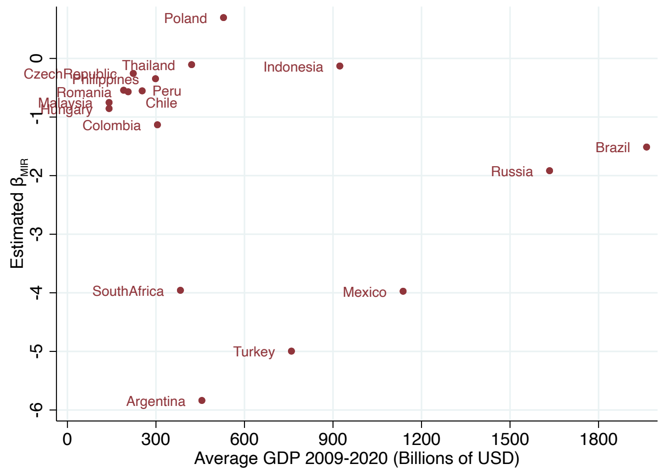
	(1) capital controls	(2) NFA	(3) GDP	(4) FXI over GDP
Currency Demand Shock ($\mu_{c,t}$)	-0.0208	-188.8	-1.783	0.124
	(0.0231)	(160.0)	(1.541)	(0.109)
Constant	0.525***	146.0***	1.332***	0.0447*
	(0.00658)	(44.12)	(0.452)	(0.0314)
Observations	1956	2016	2171	2144
R^2	0.9752	0.9401	0.9297	0.0315
Adjusted R^2	0.975	0.940	0.929	0.024

Standard errors in parentheses

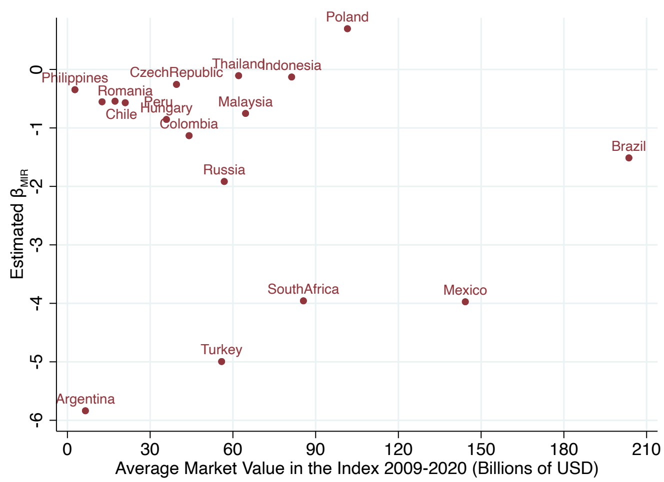
* $p < 0.2$, ** $p < 0.10$, *** $p < 0.05$

Note: This table shows the OLS regression results of the following independent variables on the currency demand shock (MIR): capital control measures (Fernandez-Klein-Rebucci-Schindler-Uribe), net foreign asset positions, nominal GDP, and measured spot FX interventions over GDP. Capital controls, NFA (trillions of local currency) and GDP (billions of local currency) are in annual frequency. FXI data and MIR are both in monthly frequency. All regressions include country fixed effects with standard errors clustered at the country level.

Table B.7: Correlation between Exchange Rates Response with Macro- and Financial Metrics



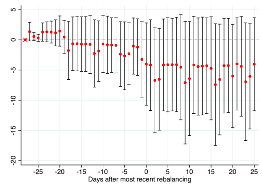
(a) Nominal GDP



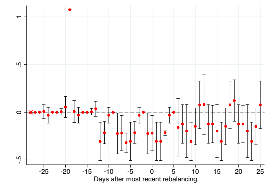
(b) Sovereign bond market size

Note: This Figure presents the relation between the country-specific response to currency demand shock to nominal GDP (c) and sovereign bonds market size in the GBI-EM Global Diversified index.

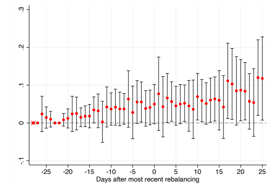
Table B.5: Change in Policy Rates in on $\mu_{c,t}$



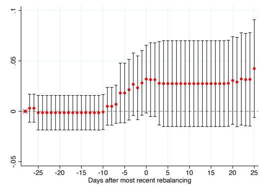
(a) Argentina



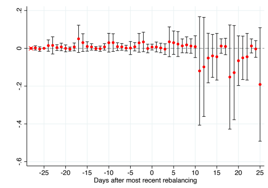
(b) Brazil



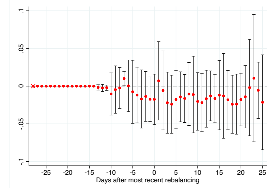
(c) Chile



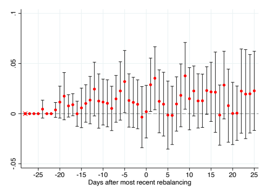
(d) Colombia



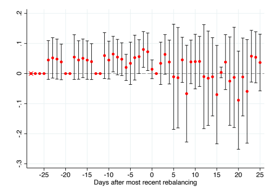
(e) Czech Republic



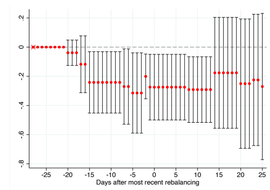
(f) Hungary



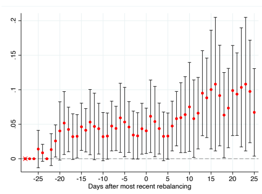
(g) Indonesia



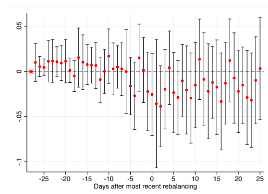
(h) Malaysia



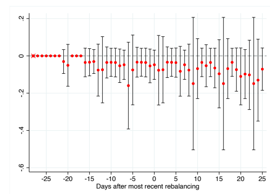
(i) Mexico



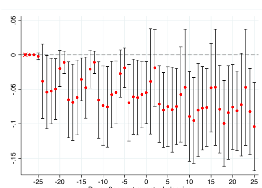
(j) Peru



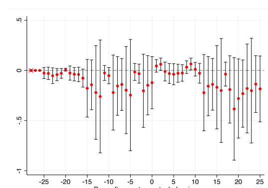
(k) Philippines



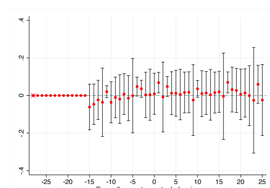
(l) Poland



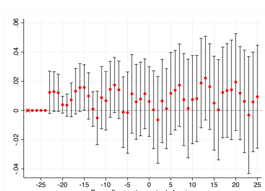
(m) Romania



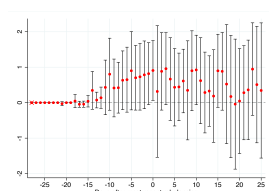
(n) Russia



(o) South Africa



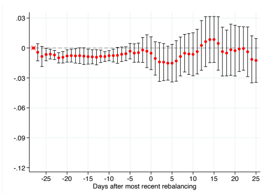
(p) Thailand



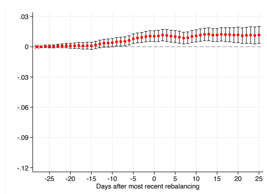
(q) Turkey

Note: This panel of figures provide the regression coefficients of country-specific central bank policy rates (in percentage points) in response to the currency demand shock $\mu_{c,t}$. The change in central bank policy rates are provided by Bank of International Settlements (BIS) and measured as the change since 28 before rebalancing dates.

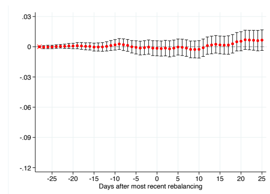
Table B.6: Change in one-year government yields in relative to USD yields on $\mu_{c,t}$



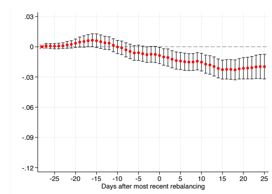
(a) Brazil



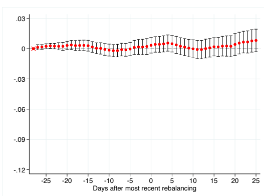
(b) Chile



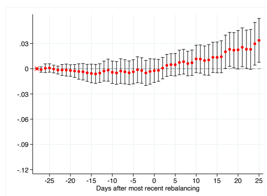
(c) Colombia



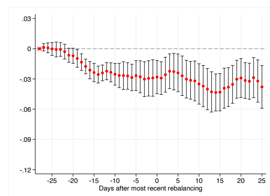
(d) Hungary



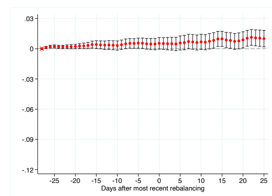
(e) Indonesia



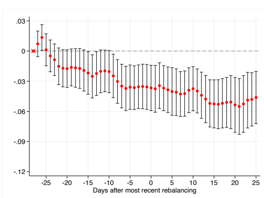
(f) Malaysia



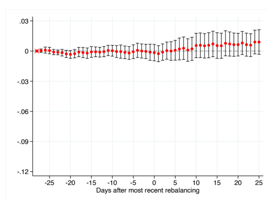
(g) Mexico



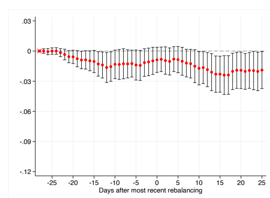
(h) Peru



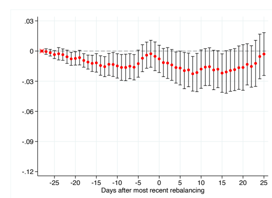
(i) Philippines



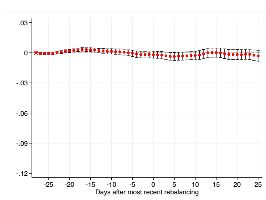
(j) Poland



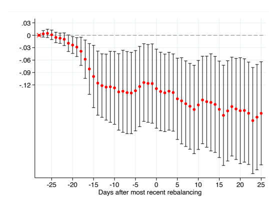
(k) Russia



(l) South Africa



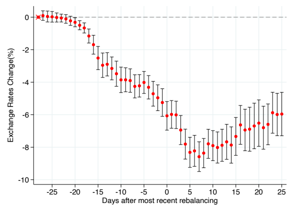
(m) Thailand



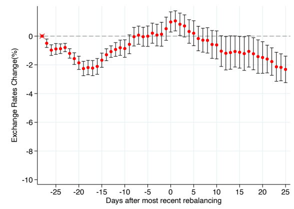
(n) Turkey

Note: This panel of figures provide the regression coefficients of country-specific one-year local-currency government bonds yields relative to synthetic USD yields ($i_{c,t} - i^*_{c,t}$) in response to the currency demand shock $\mu_{c,t}$. The change in yields are measured in basis points and defined as the change since 28 before rebalancing dates.

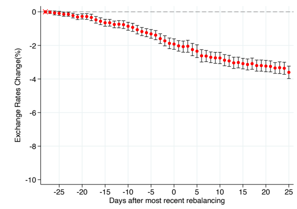
Table B.8: Exchange Rates Change on $\mu_{c,t}$ with year and month fixed effects



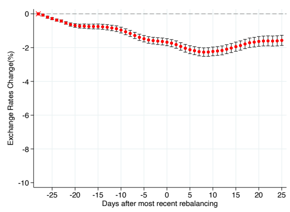
(a) Argentina



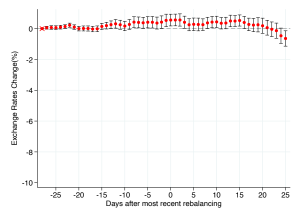
(b) Brazil



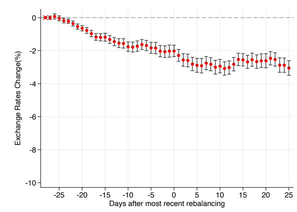
(c) Chile



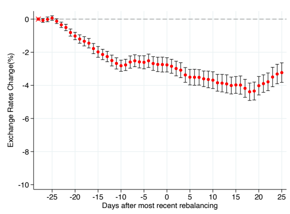
(d) Colombia



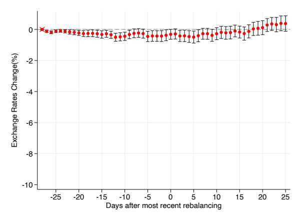
(e) Czech Republic



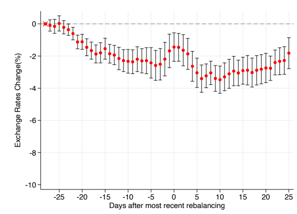
(f) Hungary



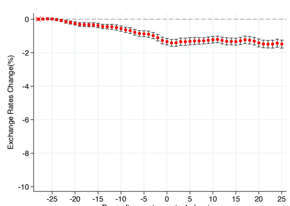
(g) Indonesia



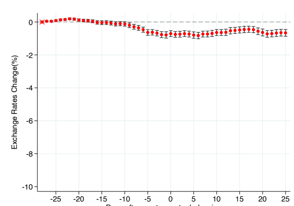
(h) Malaysia



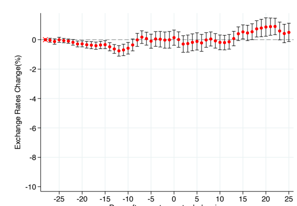
(i) Mexico



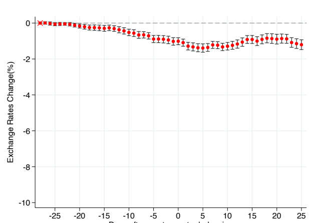
(j) Peru



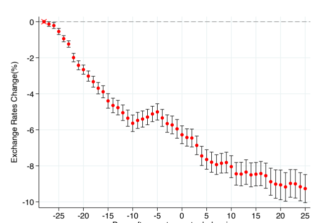
(k) Philippines



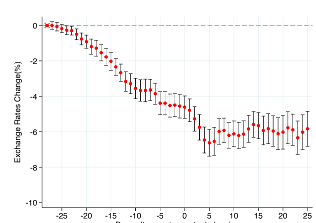
(l) Poland



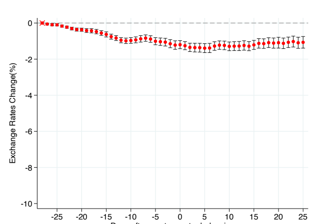
(m) Romania



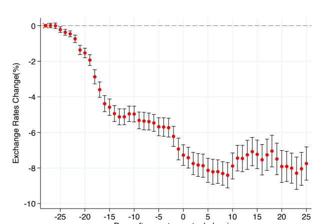
(n) Russia



(o) South Africa



(p) Thailand



(q) Turkey

Note: This panel of figures reports the regression coefficient of country-level cumulative exchange rates change (in % or $100 \times \Delta \log(.)$) in response to $\mu_{c,t}$. Exchange rates change are defined as the change since 28 days before the current rebalancing. Black lines indicate confidence interval of 90%. Regressions of Mexico and Brazil have year fixed effects due to limited observations.

Table B.9: Exchange Rates Change on $\mu_{c,t}$ with year and month fixed effects

	(1) Argentina	(2) Brazil	(3) Chile	(4) Colombia	(5) CzechRepublic	(6) Hungary	(7) Indonesia	(8) Malaysia	(9) Mexico
$\mu_{c,t}$	-8.130***	-0.306	-2.559***	-2.164***	0.313	-3.022***	-3.651***	-0.397	-3.317***
	(0.676)	(0.690)	(0.265)	(0.183)	(0.281)	(0.305)	(0.355)	(0.286)	(0.652)
Constant	0.668	-0.451	1.292***	0.0458	-0.469***	1.951***	-0.673***	0.139	-8.295***
	(0.437)	(1.381)	(0.182)	(0.103)	(1.338)	(0.191)	(0.119)	(0.111)	(0.121)
Obs.	228	61	627	1386	313	932	574	468	75
R^2	0.6608	0.0033	0.3201	0.2162	0.3819	0.2581	0.4808	0.2683	0.5426
Adj. R^2	0.638	-0.014	0.296	0.203	0.351	0.239	0.460	0.239	0.523

	(1) Peru	(2) Philippines	(3) Poland	(4) Romania	(5) Russia	(6) South Africa	(7) Thailand	(8) Turkey
$\mu_{c,t}$	-1.237***	-0.693***	-0.227	-1.368***	-8.011***	-6.490***	-1.351***	-7.817***
	(0.152)	(0.134)	(0.398)	(0.164)	(0.430)	(0.543)	(0.179)	(0.518)
Constant	0.800***	0.340***	-0.431	0.356***	1.865***	-9.672***	0.196***	0.449**
	(0.0928)	(0.0724)	(0.611)	(0.0722)	(0.169)	(0.845)	(0.0583)	(0.199)
Obs.	841	886	301	665	724	435	845	549
R^2	0.3242	0.1886	0.3533	0.3078	0.4849	0.4401	0.2268	0.3769
Adj. R^2	0.305	0.168	0.319	0.287	0.469	0.417	0.207	0.353

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: This panel of figures reports the regression coefficient of country-level cumulative exchange rates change (in % or $100 \times \Delta \log(.)$) in response to $\mu_{c,t}$. Exchange rates change are defined as the change since 28 days before the current rebalancing to the horizon 0-10 days after rebalancing. Regressions of Mexico and Brazil have year fixed effects due to limited observations.

Table B.10: Autocorrelation Tests for country-specific time-series of $\mu_{c,t}$

	(1) Argentina	(2) Chile	(3) Colombia	(4) Czech Republic	(5) Hungary	(6) Indonesia	(7) Malaysia
Auto-corr. Coef.	0.009	0.66	0.71	0.58	0.27	0.76	0.91
Portmanteau test							
test-statistics	.003	37.6	47.4	43.7	2.40	77.26	108
p-value	0.96	0.0	0.0	0.0	0.12	0.0	0.0

	(1) Peru	(2) Philippines	(3) Romania	(4) Russia	(5) South Africa	(6) Thailand	(7) Turkey
Auto-corr. Coef.	0.70	0.81	0.37	0.83	0.82	0.74	0.48
Portmanteau test							
test-statistics	67.1	89.5	5.13	90.8	85.3	74.6	22.5
p-value	0.0	0.0	0.02	0.0	0.0	0.0	0.01

Note: This panel of figures the autocorrelation tests for the currency demand shocks ($\mu_{c,t}$) of countries not at the weight cap of 10% in the monthly rebalancing events of the GBI-EM Global Diversified index (tests for Brazil, Mexico and Poland are therefore not reported). We report the estimated auto-correlation for the fitting country-specific $\mu_{c,t}$ with AR(1) and the Portmanteau white noise test on the residuals after fitting. The null hypothesis of the Portmanteau test is that the error terms are white noise.

All Portmanteau white noise tests give significant coefficient except for Argentina. The average auto-correlation coefficient of all countries with significant coefficients is 0.66.

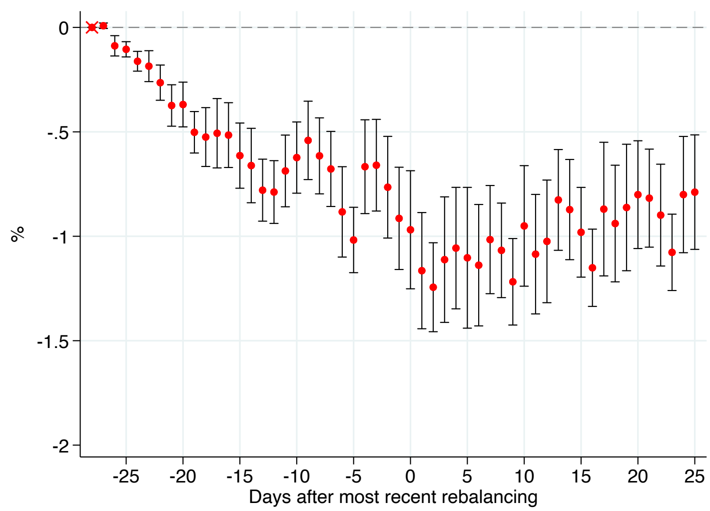
Table B.11: Summary Statistics of the $\Delta\mu_{c,t}$

$\Delta\mu_{c,t}$, *excluding* observations at 10% cap

Obs	Mean	Std.	Min	Max	Median	90%	10%
1,416	-.0002	.113	-.790	1.210	-.006	.098	-.093

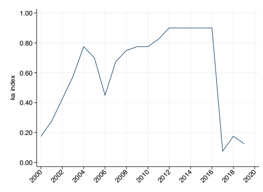
Note: Summary statistics of $\Delta\mu_{c,t}$, defined as $\Delta\mu_{c,t} \equiv \mu_{c,t} - \mu_{c,t-1}$. We exclude observations that hit 10% weight cap at the rebalancing dates in this table.

Table B.12: Exchange rate change on $\Delta\mu_{c,t}$

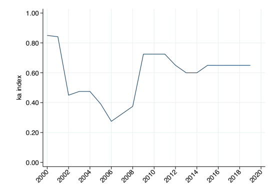


Note: This figure presents the estimated regression coefficient of exchange rates change on the *change* in currency demand shock measured by $\Delta\mu_{c,t}$, which is standardized by its mean and standard deviation in the regression. Exchange rates change (local currencies per USD) is measured as the cumulative change starting from 28 days before the recent rebalancing at day 0. The regression is performed in a pooled OLS using time- and country-fixed effects with standard errors clustered at the country level. The results are reported in point estimates (red) with 90% confidence interval (black).

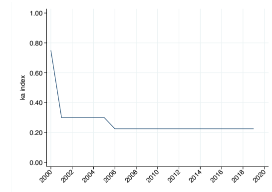
Table B.13: Capital Controls Overall Restriction Index



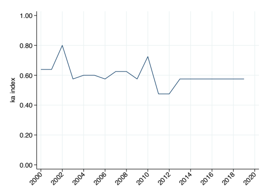
(a) Argentina



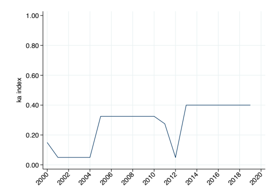
(b) Brazil



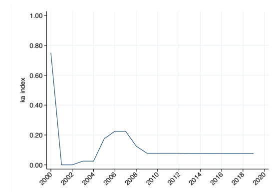
(c) Chile



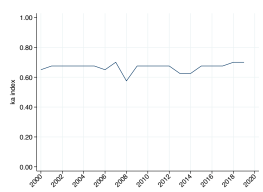
(d) Colombia



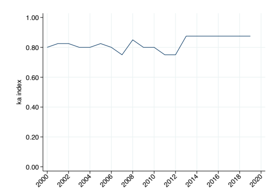
(e) Czech Republic



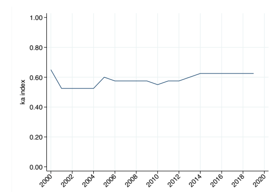
(f) Hungary



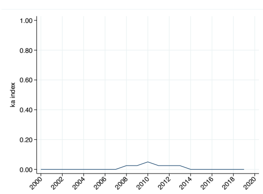
(g) Indonesia



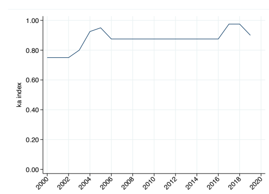
(h) Malaysia



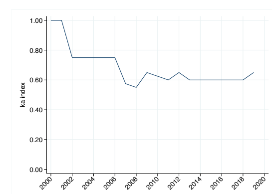
(i) Mexico



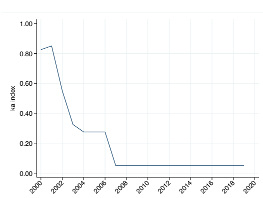
(j) Peru



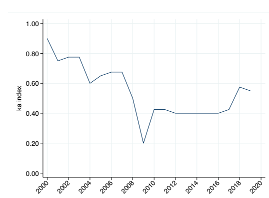
(k) Philippines



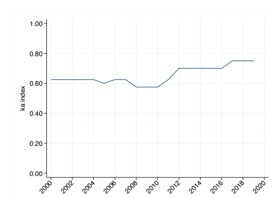
(l) Poland



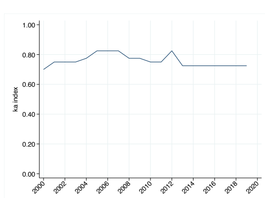
(m) Romania



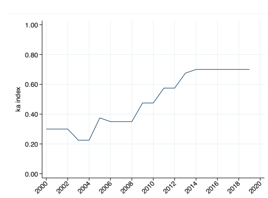
(n) Russia



(o) South Africa



(p) Thailand



(q) Turkey

Note: This panel of figures presents the overall capital restriction index (the average of capital inflow and outflow restriction) for each country provided by Fernandez-Klein-Rebucci-Schindler-Uribe dataset. The measure is in annual frequency.

Table B.14: Summary Statistics of Control Restriction Index

Obs	Mean	Std.	Min	Max	median	90%	10%
340	0.513	0.28	0	1	0.6	0.85	0.05

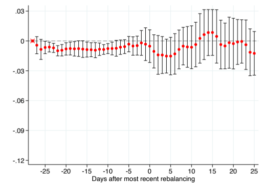
Note: This table presents the summary of statistics on the overall capital restriction index provided by Fernandez-Klein-Rebucci-Schindler-Uribe dataset. Data are in annual frequency.

Table B.15: Summary Statistics of Spot FXI over GDP

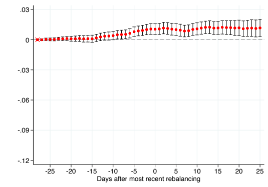
	Mean	Std.	Min	Max	median	90%	10%	Obs.
Argentina	.013	.51	-3.08	1.49	.01	-.49	.58	276
Brazil	.065	.29	-1.06	1.53	.01	-.21	.41	276
Chile	-.0006	.42	-2.11	2.75	.005	-.35	.34	276
Colombia	.048	.238	-1.29	1.13	.04	-.15	.29	276
Czech Republic	.248	1.584	-4.53	10.82	.125	-1.14	1.66	276
Hungary	.04	1.47	-4.96	8.46	-.06	-1.35	1.89	275
Indonesia	.041	.42	-1.64	2.78	.01	-.38	.42	276
Malaysia	.117	1.138	-6.38	5.64	.06	-.79	1.33	276
Mexico	.048	.215	-1.47	1.05	.04	-.17	.27	276
Peru	.106	.71	-2.81	3.48	.04	-.61	.94	276
Philippines	.134	.49	-1.82	3.17	.08	-.36	.71	276
Poland	.074	.842	-2.94	3.99	.03	-.73	1.02	276
Romania	.091	1.02	-6.12	5.29	.09	-.66	.87	273
Russia	.257	.808	-3.86	3.77	.215	-.42	1.11	276
South Africa	.036	.182	-1.26	.99	.02	-.11	.21	276
Thailand	.19	.707	-2.02	3.38	.18	-.58	1.03	275
Turkey	-.022	.481	-1.89	1.36	-.01	-.62	.52	276

Note: This table reports the summary statistics of spot FXI over (3 year average) GDP for the countries in our sample for the year 2000 to 2021. FXI data are at monthly frequency and from Adler-Chang-Mano-Shao (2021).

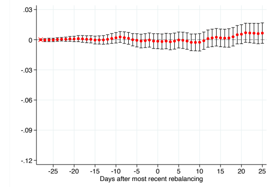
Table B.16: Double-difference Interest rates (one-year) on MIR



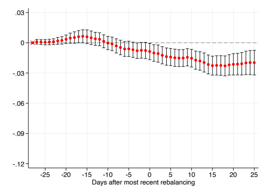
(a) Brazil



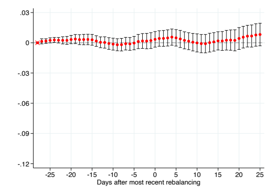
(b) Chile



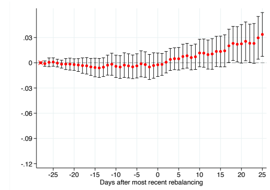
(c) Colombia



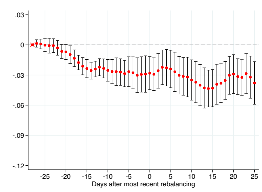
(d) Hungary



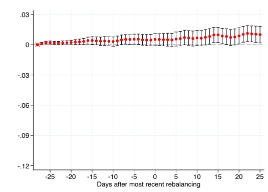
(e) Indonesia



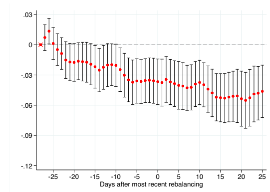
(f) Malaysia



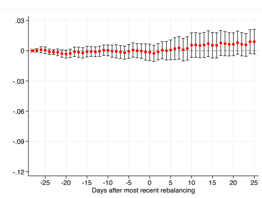
(g) Mexico



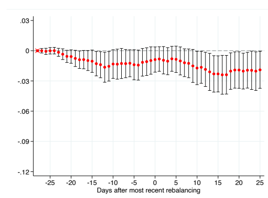
(h) Peru



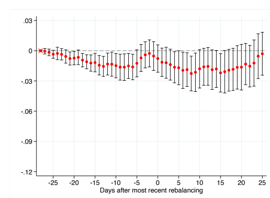
(i) Philippines



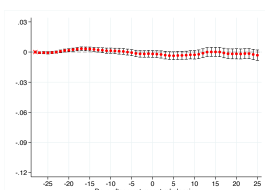
(j) Poland



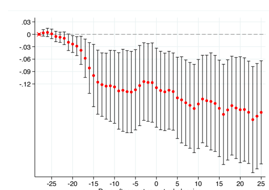
(k) Russia



(l) South Africa



(m) Thailand



(n) Turkey

Note: This panel of figures reports the regression coefficient of "double-interest-rates-differentials" of one-year tenor (in basis points, not annualized) on our instrument MIR. The black line indicates 95% confidence interval. We define "double-interest-rates-differentials" as change in the yield differentials on home and foreign (USD) government bonds since -28 before rebalancing. All countries have the same scale for vertical axis except for Turkey.

C Derivation and Proofs

C.1 Proof for Example 1 and 2

The UIP deviation can be written as:

$$\mathbb{E}_t \Delta z_{t+1} \equiv i_t - i_t^* - \mathbb{E}_t \Delta e_{t+1} = \tau_t + \rho_t - \bar{\omega}\sigma_e^2(\iota b_t^* - n_t^* - f_t^*) \tag{12}$$

We can re-write equation (12) above as:

$$\mathbb{E}_t \Delta e_{t+1} = \underbrace{-\tau_t^a + (i_t - i_t^*)}_{\equiv -x_t} \quad + \quad \underbrace{\bar{\omega}\sigma_e^2(\iota b_t^* - n_t^* - f_t^*)}_{\equiv -u_t} \tag{13}$$

where x_t is the component of exchange rate e_t when the trilemma condition holds; term u_t is the additional component for models of exchange rates when trilemma doesn't hold. Specifically, under trilemma models, the effective risk-aversion of the arbitrageurs $\bar{\omega} = 0$ or exchange rates are fixed (so that $\sigma_e = 0$), arbitrageurs have infinite capacity absorb exchange rates risk an UIP deviation disappears in the limit. The term u_t therefore vanishes under trilemma models where the UIP condition holds.

Iterating (13) forward, we have:

$$e_t = \mathbb{E}_t \, e_\infty + \mathbb{E}_t \sum_{j=0}^{\infty} x_{t+j} + \mathbb{E}_t \sum_{j=0}^{\infty} u_{t+j} \tag{14}$$

and $e_\infty = 0$ if exchange rate e_t follows a stationary process. Below, we introduce both partial equilibrium models (Engel and West 2005) and general equilibrium models (Itskhoki and Mukhin 2021) to solve for the process of exchange rates.

Engel West (2005) Taylor Rule model

Let $\pi_t = p_t - p_{t-1}$ be the inflation rate and y_t the output gap. The home country (in our setting the emerging country) follows a Taylor rule of the form:

$$i_t = \beta_0(e_t - \bar{e}_t) + \beta_1 y_t + \beta_2 \pi_t + v_t \tag{15}$$

where exchange rate target $\bar{e}_t$ ensures PPP so that $\bar{e}_t = p_t - p_t^*$ and $\beta_0 \in (0, 1)$.

The foreign country (US) follows the Tylor rule of the form:

$$i_t^* = \beta_1 y_t^* + \beta_2 \pi_t^* + v_t^* \tag{16}$$

Interest rate difference $i_t - i_t^*$ can thus be written as:

$$i_t - i_t^* = \beta_0(e_t - \bar{e}_t) + \beta_1(y_t - y_t^*) + \beta_2(\pi_t - \pi_t^*) + (v_t - v_t^*)$$

Using the UIP condition in equation (13) to substitute out $(i_t - i_t^*)$:

$$\begin{aligned}
\mathbb{E}_t e_{t+1} = {} & e_t - \tau_t^a + \beta_0(e_t - \bar{e}_t) + \beta_1(y_t - y_t^*) + \beta_2(\pi_t - \pi_t^*) + (v_t - v_t^*) - u_t \\
\Rightarrow (1 + \beta_0)e_t = {} & \tau_t^a + \mathbb{E}_t e_{t+1} + \beta_0(p_t - p_t^*) - \beta_1(y_t - y_t^*) - \beta_2(\pi_t - \pi_t^*) - (v_t - v_t^*) + u_t \\
\Rightarrow e_t = {} & \frac{1}{1+\beta_0}\tau_t^a + \frac{\beta_0}{1+\beta_0}(p_t - p_t^*) - \frac{\beta_1}{1+\beta_0}(y_t - y_t^*) - \frac{\beta_2}{1+\beta_0}(\pi_t - \pi_t^*) + \cdots \\
& - \frac{1}{1+\beta_0}(v_t - v_t^*) + \frac{1}{1+\beta_0}u_t + \frac{1}{1+\beta_0}\mathbb{E}_t e_{t+1}
\end{aligned}$$

Therefore, we can write the solution of exchange rate under Taylor rule in the similar manner as equation (13)

$$e_t = X_t + U_t + \frac{1}{1+\beta_0}\mathbb{E}_t e_{t+1} \tag{17}$$

where $\beta_0 \in (0, 1)$, $U_t = \frac{1}{1+\beta_0}u_t = -\frac{1}{1+\beta_0}\sigma_e^2(\iota b_t^* - n_t^* - f_t^*)$ is the component of non-trilemma models and $X_t = \frac{1}{1+\beta_0}\tau_t^a + \frac{\beta_0}{1+\beta_0}(p_t - p_t^*) - \frac{\beta_1}{1+\beta_0}(y_t - y_t^*) - \frac{\beta_2}{1+\beta_0}(\pi_t - \pi_t^*) + \frac{1}{1+\beta_0}(v_t - v_t^*)$ is the component of trilemma models.

Iterate (17) forward, we have:

$$e_t = \mathbb{E}_t \sum_{j=1}^{\infty} \frac{1}{(1+\beta_0)^j} X_{t+j} + \mathbb{E}_t \sum_{j=1}^{\infty} \frac{1}{(1+\beta_0)^j} U_{t+j} + \mathbb{E}_t \lim_{j\to\infty} \frac{1}{(1+\beta_0)^j} e_\infty$$

and $\lim_{j\to\infty} \frac{1}{(1+\beta_0)^j} = 0$ in the limit, so the term with e_∞ vanishes.

If we impose the assumption that 1). $(n_t^* + f_t^*)$ inside u_t is an AR(1) process with persistence ρ, that is, $n_{t+1}^* + f_{t+1}^* = \rho(n_t^* + f_t^*) + \epsilon_t$ and 2) financial shock >>macro-fundamental shocks so that $\iota = 0$. We can re-write the solution of e_t as:

$$\begin{aligned} e_t =& \mathbb{E}_t \sum_{j=1}^{\infty} \frac{1}{(1+\beta_0)^j} X_{t+j} + \frac{\bar{\omega}\sigma_e^2}{(1+\beta_0-\rho)}(n_t^* + f_t^*) \\ =& \mathbb{E}_t \sum_{j=1}^{\infty} \frac{1}{(1+\beta_0)^j} X_{t+j} + \frac{\bar{\omega}\sigma_e^2}{(1+\beta_0-\rho)}\, n_t^* \end{aligned}$$

where the second line uses the additional assumption that $f_t^* = -\alpha n_t^*$. Therefore, the impulse response of exchange rate e_t in response to n_t^* is:

$$\frac{\partial e_t}{\partial n_t^*} = \frac{\bar{\omega}\sigma_e^2}{(1+\beta_0-\rho)} > 0$$

Therefore, on impact, a foreign currency demand shock depreciates home currency (so e_t rises). Let $\frac{\partial E_t e_\infty}{\partial n_t^*} = \kappa \frac{\partial e_t}{\partial n_t^*}$. When $\kappa = 1$, this is the fully persistent random walk shock and the level of exchange rates is not identified as the financial market doesn't discipline the levels.

Itskhoki and Mukhin 2021

Apart from equation (13), the budget constraint of a country:

$$\beta b_t^* - b_{t-1}^* = nx_t = \lambda\ e_t + \xi_t \tag{18}$$

where λ (> 0, no particular restriction) is a structural parameter pinned down from the price equations in the goods market, and ξ_t is shock to the net export nx_t orthogonal to e_t. We can therefore combine the UIP condition with the country budget constraint and iterate forward:

$$b_{t-1}^* + \mathbb{E}_t\ \lambda \sum_{j=0}^{\infty} \beta^j e_{t+j} = \lim_{T\to\infty} \beta^T b_{t+T-1} = 0 \tag{19}$$

by No-Ponzi Game Condition (NPGC) of the budget constraint.

From equation (14) and under the assumption that $\iota = 0$, $f_t^* = -\alpha n_t^*$ and that $n_t^* \sim AR(1)$ with persistence ρ, we have:

$$e_t = \mathbb{E}_t\ e_\infty + \mathbb{E}_t \sum_{j=0}^{\infty} x_{t+j} + \bar{\omega}\sigma_e^2 \frac{(1-\alpha)}{(1-\rho)}\ n_t^* \tag{20}$$

Therefore, $\mathbb{E}_t\ e_{t+j} = \mathbb{E}_t\ e_\infty + \mathbb{E}_t\ \sum_{j=0}^{\infty} x_{t+j} + \bar{\omega}\sigma_e^2 \frac{\rho^j(1-\alpha)}{(1-\rho)}\ n_t^*$. Combine with equation (19):

$$\begin{aligned}
& b_{t-1}^* + \lambda \sum_{j=0}^{\infty} \beta^j \left(\mathbb{E}_t\ e_\infty + \mathbb{E}_t \sum_{j=0}^{\infty} x_{t+j} + \bar{\omega}\sigma_e^2 \frac{\rho^j(1-\alpha)}{(1-\rho)}\ n_t^* \right) = 0 \\
\Rightarrow & b_{t-1}^* + \frac{\lambda}{1-\beta} \mathbb{E}_t\ e_\infty + \lambda \mathbb{E}_t \sum \sum_j x_{t+j} + \bar{\omega}\sigma_e^2 \frac{(1-\alpha)}{(1-\rho)} \frac{\lambda}{(1-\rho\beta)} n_t^* = 0 \\
\Rightarrow & b_{t-1}^* + \frac{\lambda}{1-\beta} \underbrace{\left(e_t - \mathbb{E}_t \sum_{j=0}^{\infty} x_{t+j} - \bar{\omega}\sigma_e^2 \frac{(1-\alpha)}{(1-\rho)}\ n_t^* \right)}_{=\mathbb{E}_t\ e_\infty} + \lambda \mathbb{E}_t\ \sum \sum_j x_{t+j} + \bar{\omega}\sigma_e^2 \frac{(1-\alpha)}{(1-\rho)} \frac{\lambda}{(1-\rho\beta)} n_t^* = 0
\end{aligned}$$

where the last line substituted the expression of $\mathbb{E}_t\ e_\infty$ from equation (20).

From above, we have the relation between e_t, b^*_{t-1}, x_t and n^*_t:

$$\frac{\lambda}{1-\beta}e_t + b^*_{t-1} + X_t - \frac{\beta\lambda\bar{\omega}\sigma_e^2(1-\alpha)}{(1-\rho\beta)(1-\beta)}\ n^*_t = 0 \tag{21}$$

where $X_t \equiv -\frac{\lambda}{1-\beta}\sum_j^\infty x_{t+j} + \lambda \sum\sum_j x_{t+j}$ is the non-financial component (or Trilemma component) of exchange rates and do not respond to financial shocks n^*_t.

If we only want to look compute the impact of n^*_t on levels of e_t on impact and treat b^*_t as a constant, then

$$\frac{\partial e_t}{\partial n^*_t} = \frac{\beta(1-\alpha)}{(1-\rho\beta)}\bar{\omega}\sigma_e^2 > 0$$

However, it's important to note that b^*_{t-1} is an endogenous variable that can be potentially correlated with n^*_t tomorrow. We therefore need to solve for the law of motion of b^*_t as a function of n^*_t. We do so by substituting equation (21) into the country budget constraint (18):

$$\begin{aligned}
\beta b^*_t - b^*_{t-1} &= (1-\beta)\Big(\frac{\beta\lambda\bar{\omega}\sigma_e^2(1-\alpha)}{(1-\rho\beta)(1-\beta)}\ n^*_t - b^*_{t-1} - X_t\Big) + \xi_t \\
\Rightarrow \beta(b^*_t - b^*_{t-1}) &= \frac{\beta\lambda\bar{\omega}\sigma_e^2(1-\alpha)}{(1-\rho\beta)}n^*_t - (1-\beta)X_t + \xi_t \\
\Rightarrow \Delta b^*_{t-1} &= \frac{\lambda\bar{\omega}\sigma_e^2(1-\alpha)}{(1-\rho\beta)}n^*_t - \frac{(1-\beta)}{\beta}X_t + \frac{1}{\beta}\xi_t
\end{aligned}$$

To use Δb^*_{t-1} as a function of the shock n^*_t, we re-write equation (21) in difference form:

$$\frac{\lambda}{1-\beta}\mathbf{E}_t\ \Delta e_t + \Delta b^*_{t-1} + \mathbf{E}_t\ \Delta X_t - \frac{\beta\lambda\bar{\omega}\sigma_e^2(1-\alpha)}{(1-\rho\beta)(1-\beta)}\ \mathbf{E}_t\ \Delta n^*_t = 0 \tag{22}$$

Note that $\mathbf{E}_t\ \Delta n^*_t = (\rho - 1)n^*_t$ if $n^*_t \sim$ AR(1) with persistence ρ. Substituting the expression of Δb^*_{t-1}, we can simplify equation (22):

$$\frac{\lambda}{1-\beta}\mathbf{E}_t\,\Delta e_t + \underbrace{\frac{\lambda\bar{\omega}\sigma_e^2(1-\alpha)}{(1-\rho\beta)}n_t^* - \frac{(1-\beta)}{\beta}X_t + \frac{1}{\beta}\xi_t}_{=\Delta b^*_{t-1}} + \mathbf{E}_t\,\Delta X_t - \frac{\beta\lambda\bar{\omega}\sigma_e^2(1-\alpha)}{(1-\rho\beta)(1-\beta)}\,(\rho-1)n_t^* = 0$$

$$\Rightarrow \mathbf{E}_t\,\Delta e_t + \frac{\bar{\omega}\sigma_e^2(1-\alpha)}{(1-\rho\beta)}\big(2-\beta-\rho\big)n_t^* - \frac{(1-\beta)^2}{\beta\lambda}X_t + \frac{1-\beta}{\lambda}\mathbf{E}_t\,\Delta X_t + \frac{1-\beta}{\beta\lambda}\xi_t = 0$$

The impulse response of exchange rate in response to n_t^* is therefore:

$$\frac{\partial \Delta e_t}{\partial n_t^*} = \frac{\bar{\omega}\sigma_e^2(1-\alpha)}{(1-\rho\beta)}\big(\beta+\rho-2\big) < 0$$

Intuitively, a positive demand shock for foreign currency bonds increase the position of n_t^* and depreciate home currency today. This is why $\frac{\partial e_t}{\partial n_t^*} > 0$. But the impulse response for $\frac{\partial \Delta e_t}{\partial n_t^*} < 0$ moving forward and captures the expected component of exchange rate change. The result is consistent with Figure 2 on properties of exchange rate process in Itskhoki-Mukhin 2021.

C.2 Estimating Intervention α_f

We define $\beta_{c,MIR}$ as the country-specific exchange rates response to MIR. We also define open market operations $f_t^* = -\alpha_f n_t^*$, where $\alpha_f \in [0,1]$ and is the share of noise trader shocks offset by open market operations through foreign exchange interventions to stabilize exchange rates. A country with more floating exchange rates regime is expected to have a smaller α_f; vice versa for countries with more stringent (or pegged) regime.

Under these assumptions, the exchange rates solution in equation (**??**) becomes:

$$\Delta e_{c,t+1} = \underbrace{\frac{\beta\omega\sigma_{c,e^2}}{1-\beta\rho}\big(1-\alpha_{c,f}\big)}_{\equiv\beta_{c,f}}\, n^*_{c,t} \tag{23}$$

where β is the impatience parameter of the household; ρ the persistence of the AR (1) process of the noise trade shocks; ω the risk aversion parameter of the arbitrageurs that conduct currency carry trade; σ_{c,e^2} the volatility of exchange rates; and finally $\alpha_{c,f} \in [0,1]$ is the share of noise trade shocks offset by open market operations in foreign exchange interventions.

Parameters ρ, ω and β are homogenous across countries. Exchange rates volatility σ_{c,e^2} and the size of intervention $\alpha_{c,f}$ are the only source of heterogeneity across countries. Given two countries c_1 and c_2, their relative exchange rates response to noise trader shocks $\frac{\beta_{c_1,f}}{\beta_{c_2,f}}$ are determined by the relative exchange rates volatility of two countries $\frac{\sigma_{c_1,e^2}}{\sigma_{c_2,e^2}}$, as well as the relative size of (residual) foreign exchange rate intervention $\frac{(1-\alpha_{c_1,f})}{(1-\alpha_{c_2,f})}$.

We use the estimated country-specific $\beta_{c,MIR}$ to identify $\beta_{c,f} \equiv \frac{\beta\omega\sigma_e^2}{1-\beta\rho}(1-\alpha_f)$. Using equation (9) for converting MIR into flows of noise trader shocks, we arrive at the following relation:

$$\frac{\beta_{c_1,MIR}}{\beta_{c_2,MIR}} = \frac{\kappa_{c_2}}{\kappa_{c_1}} \times \frac{\sigma_{c_1,e^2}(1-\alpha_{c_1})}{\sigma_{c_2,e^2}(1-\alpha_{c_2})} \tag{24}$$

where $\kappa_c = \mathrm{MV}_c \times \frac{\mathrm{AUM}}{\sum_{c'} \mathrm{MV}_{c'}}$; MV_c is the market value of the local currency sovereign bonds in the GBI-EM Global Diversified index; AUM is the asset under management of all the mutual funds closely tracking the index. Equation (24) suggests that countries with larger market size, more volatile exchange rates, and more floating exchange rates regime (less foreign exchange intervention) should expect a larger coefficient of exchange rates in response to MIR.

Parameter α_f measures the share of noise trader shocks offset by central banks through the foreign exchange rate interventions. The exact value of α_f is unobservable in the data. In this section, we seek to identify the value of α_f using the country-specific estimates on exchange rates responses to MIR.

Consider two countries with different exchange rate regimes. Fix country c_2 as the benchmark country with free-floating (or free-falling) exchange rate regime and define $\alpha^* \equiv \alpha_{c_2} = 0$. For any country c that doesn't have a free-floating (or free-falling) exchange rate regime, we can therefore identify its α_c below following equation (24):

$$\alpha_c = 1 - \left(\frac{\beta_{MIR,c} / \sigma^2_{e,c}}{\beta_{MIR,c^*} / \sigma^2_{e,c^*}} \times \frac{\kappa_{c_1}}{\kappa_{c^*}} \right) \tag{25}$$

where $k^* = \text{MV}_{c^*} \times \frac{\text{AUM}}{\sum_{c'} \text{MV}_{c'}}$ for the benchmark country under free-floating (or free-falling) exchange rates regime and the central bank does not intervene with exchange rates at all ($\alpha^* = 0$).

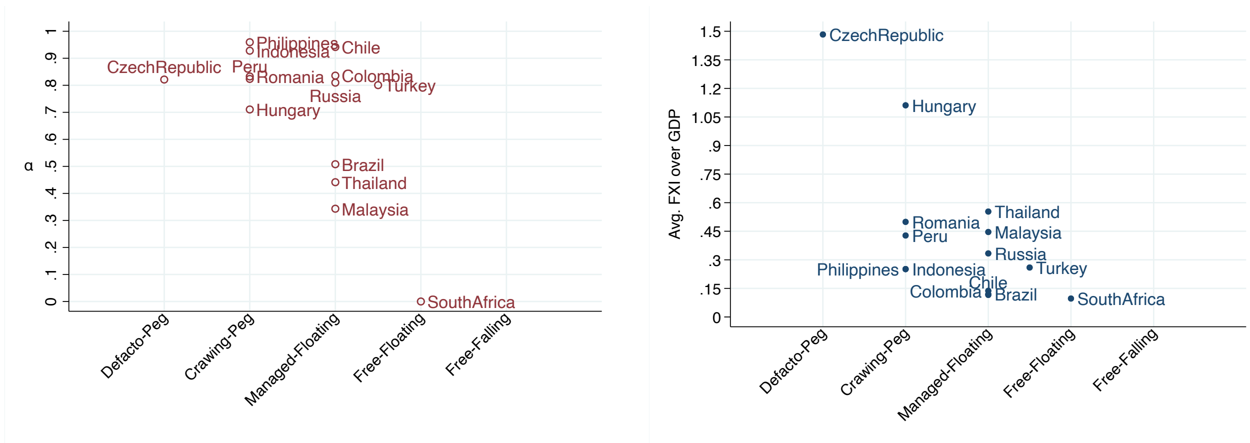
We set South Africa as the benchmark country with $\alpha^* = 0$ in our sample. South Africa is classified as "free-floating" through out some sample years from 2009 to 2021 under the exchange rates regime classification by Ilzetzki, Reinhart and Rogoff (2019, 2021). Moreover, it was included in the GBI-EM Global Diversified index in almost all the sample years with the exception of a few months, as reported in Table **??**.[24]

Using South Africa is the benchmark country, we report the estimated intervention α_f in Table C.1 (left panel). The relation of estimated α_f with exchange rates regimes displayed a clear downward trend: the more floating the exchange rates, the smaller the intervention α_f from the central banks to offset the noise trader shocks. The calibrated intervention α_f reported in Table C.1 are all between 0 and 1, as expected by theory.

The calibrated intervention α_f for each country is largely consistent with the actual historical intervention data, as reported in the right panel of Table C.1. The intervention data is the monthly spot foreign exchange intervention as a percentage share of 3-year moving average annual GDP of the country, as provided by Adler et al (2021). We average the intervention data for each country over 2010 - 2021 for the months the country is included the J.P Morgan GBI-EM Global Diversified index. To measure the magnitude of intervention, we also take the absolute value of the interventions data rather than distinguishing the purchase (positive FXI in the data) or sale (negative) of reserves.

[24] Another country (Argentina, "free-falling") also qualifies as our benchmark country by its exchange rate regime classification. However, Unlike South Africa, Argentina is only included in the GBI-EM Global Diversified index from early 2018 to 2020.

Table C.1: Calibrated Intervention α_f and Actual Intervention



Note: This table (left panel) gives the calibrated intervention α_f and their relation to exchange rates regimes, with South Africa chosen as the benchmark country with $\alpha^* = 0$. The right panel reports the average spot FXI as a share of country's GDP for each country as provided by Adler et al (2021). Estimates for Argentina, Poland and Mexico are not reported.