Understanding the Strength of the Dollar*

Zhengyang Jiang†

Robert J. Richmond‡

Tony Zhang§

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Abstract

We explain variation in the strength of the U.S. dollar with capital flows driven by primitive economic factors. Prior to the global financial crisis, global savings and demand shifts depreciated the dollar, whereas they appreciated it after. Interest rates impacted the dollar's value over short horizons, but declined in significance over longer horizons as rates converged. Our estimates imply that the dollar's value is stable even when one foreign country unilaterally sells its U.S. assets. However, a weakening global demand for U.S. assets of the same magnitude as the early 2000s could significantly depreciate the dollar.

Keywords: Dollar, Exchange Rates, Capital Flows, Asset Demand System

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†**Northwestern University, Kellogg School of Management, and NBER**; 2211 Campus Drive, Evanston, IL 60208. E-mail: zhengyang.jiang@kellogg.northwestern.edu.

‡**New York University, Stern School of Business, and NBER**; E-mail: rrichmon@stern.nyu.edu.

§**Federal Reserve Board**; E-mail: tony.zhang@frb.gov.

The strength of the dollar has far-reaching consequences for global trade, asset prices, and economic and financial conditions. Since the break-down of the Bretton Woods system in the early 1970s, the dollar has experienced several episodes of appreciation and depreciation, sometimes sharp and other times sustained. The top panel of Figure 1 plots the trade-weighted index of the dollar relative to advanced foreign economies (dollar AFE index) from 2002 to 2021, the period studied in this paper.[1] Fluctuations of the dollar exchange rate are often accompanied by narratives of their underlying economic sources. For example, the dollar's sustained depreciation in early 2000s has been attributed to large capital outflows from the U.S. to emerging markets, driven by the desire to take part in the rapid growth of these markets. When the 2008 global financial crisis hit, this trend reversed and the dollar appreciated sharply as global investors sought the safety of U.S. assets. After the panic subsided, the dollar weakened and again reached its lowest pre-crisis level. Finally, starting in 2012, the dollar experienced a decade-long appreciation, which has been partly attributed to the divergence of monetary policies between the U.S. and the rest of the world.

While these are useful narratives about the economic drivers of the dollar, they are rarely justified with data. A proper understanding of the drivers of the dollar involves answering several important economic questions. First, do these drivers affect the dollar's strength in systematic ways across business cycles? Second, do different drivers reinforce or offset one another? Third, do their relative contributions vary over time? For example, while risk appetite was high both in the early 2000s and in the mid-to-late 2010s, the dollar depreciated in the first period and appreciated in the second. We answer these questions using a portfolio-based approach which connects the variation in the dollar's exchange rate to the variation in the supply of and the demand for financial assets driven by primitive economic factors. Using this approach, we also study the implications of hypothetical large-scale demand shifts on the value of the dollar.

[1] The dollar AFE index contains currencies of seven countries/regions (average weights over this period in parentheses): Europe (36%), Canada (30%), Japan (14%), United Kingdom (11%), Switzerland (4%), Australia (3%), and Sweden (1%).

We employ the demand system approach to asset pricing (Koijen and Yogo 2019a,b; Koijen, Richmond, and Yogo 2019; Koijen, Koulischer, Nguyen, and Yogo 2021) by adopting the model of Jiang, Richmond, and Zhang (2022). In the presence of downward-sloping asset demand curves, our approach traces out how the dollar exchange rate responds to variations in asset supply and demand. For example, an increase in foreign demand for U.S. assets leads to a capital inflow to the U.S. and a dollar appreciation, whereas a decrease in the U.S. short-term interest rate leads to capital outflows and a dollar depreciation. We estimate our model using a comprehensive dataset of bilateral equity and debt portfolio positions between 2002 and 2021. Then, by linking changes in exchange rates and asset prices with the changes in portfolio positions and capital flows, we are able to provide an account of the economic drivers of dollar exchange rates over time.

We divide our model's primitive demand and supply factors into three categories: (i) investor savings and asset issuances, (ii) central banks' monetary policies, including interest rates and reserve holdings, and (iii) changes in investor demand. These demand and supply factors, which we treat as exogenous, jointly explain the endogenous variables in our model, including exchange rates, asset prices, and portfolio allocations. From one year to the next, had all of the exogenous variables remained unchanged, the endogenous variables would have remained constant as well. We attribute exchange rate variation to these primitive factors by using our model to compute how changes in the exogenous variables impact equilibrium exchange rates.

We report our main results in the bottom panel of Figure 1. Each factor is depicted by a different color bar in the four bars representing different sub-periods. In the pre-crisis period, 2002–2007, the dollar's depreciation was mainly driven by shifts in investor's demand, specifically from U.S. assets to foreign assets. This demand factor alone generated a 25% depreciation of the dollar index. Additionally, investor savings and asset issuances depreciated the dollar by another 11%. This depreciation was largely due to savings from foreign regions, such as Europe, being directed toward their domestic assets as a result of home bias. This increase in savings flows to foreign countries appreciated their currencies relative to the dollar. Finally, the U.S. interest rate was on the rise relative to foreign interest rates, which strengthened the dollar and offset the dollar's depreciation by 5%.

In 2008, the dollar appreciated 10% against the basket of AFE currencies, which was partially driven by investor savings and asset issuances and partially driven by investor demand which shifted back to the U.S. assets in a flight to safety. As the panic from the financial crisis subsided in 2009, the demand shift towards U.S. safe assets reversed and led to a dollar depreciation. Changes in central bank reserves led to further depreciation. As the Fed engaged in quantitative easing, the dollar depreciated further, which is consistent with the recent theoretical works that show that quantitative easing can lead to a currency depreciation by lowering the bond and currency risk premia (Gourinchas, Ray, and Vayanos 2020; Greenwood, Hanson, Stein, and Sunderam 2020; Jiang, Krishnamurthy, Lustig, and Sun 2021b).

In the post-crisis period, 2010–2021, investor savings and demand shifts both contributed to the decade-long appreciation of the dollar. Investor savings in this period appreciated the dollar by 14%, and demand shifts towards U.S. assets appreciated the dollar by another 11%. In particular, we find two notable patterns about these demand shifts. First, foreign investors' demand for U.S. assets increased. This shift in demand towards U.S. financial assets, particularly towards U.S. equity, was also instrumental in explaining the returns on U.S. financial assets in the post-crisis period and the disappearance of U.S. exorbitant privilege (Atkeson, Heathcote, and Perri 2021; Jiang, Richmond, and Zhang 2022). Second, U.S. investors' demand for foreign assets declined over the last decade, putting downward pressure on foreign currencies relative to the dollar. Moreover, the strong appreciation of the dollar was partially offset by the Fed's quantitative easing, which depreciated the dollar by 5% in this period.

Perhaps surprisingly, interest rate policies are not revealed as a primary contributor to long-term variation in the dollar value in our sub-samples. The reason is that, within each of the sub-samples we study, interest rates mostly converged across the countries in the dollar index. That said, the interest rate differential of the U.S. versus foreign countries did drive the dollar's exchange rate movements from one year to the next. Notably, our estimates imply that a 1% interest rate increase in the U.S. appreciates the dollar by 3.3%, which is consistent with research using high-frequency identification strategies (Curcuru et al. 2017).

We learn a number of important economic lessons from our decomposition of the dollar during these four periods. First, our results highlight how the specialness of the U.S. financial assets interacts with changes in the supply of U.S. assets through net issuances. This specialness of U.S. assets manifests itself as investors having a measurably stronger preference for U.S. assets. When the supply of U.S. financial assets increases, foreign investors within our model are disproportionately willing to shift their portfolios towards holding U.S. financial assets given their specialness. As a result, net issuances of U.S. financial assets tend to drive dollar appreciation over our sample. Absent this U.S. specialness, however, increases in the net supply of U.S. financial assets would have faced weaker global investor demand and would have had a less clear impact on the dollar exchange rate.

Second, the U.S. interest rate has a strong impact on the dollar's exchange rate over the horizon of 1–2 years, which is consistent with the literature on the global financial cycle (Rey 2015; Miranda-Agrippino and Rey 2020). However, the U.S. and foreign interest rates tend to converge over longer horizons, which closes the interest rate gap and stabilizes the dollar's exchange rate. As such, while it is beyond our model, the adjustment in the foreign interest rates could be viewed as a response to the U.S. interest rate.

Third, our results on investor demand point to an important regime shift: During the "risk-on" period in the early 2000s, demand for foreign risky assets, including those in emerging markets increased; however, in the "risk-on" period in the 2010s, investors instead found the U.S. assets much more desirable. As a result, the demand for risky assets led to a dollar depreciation in the early 2000s, while it led to a dollar appreciation in the 2010s, fundamentally shifting the dollar's cyclicality in this period.

Finally, motivated by the importance of the unique demand for dollar assets, in the last part of the paper we study the consequences of hypothetical large-scale sales of U.S. financial assets on the value of the dollar. We find that even if a large economy, such as China, *unilaterally* sells all of its holdings of U.S. assets, the impact on the dollar's value is surprisingly modest. The reason is that, assuming U.S. fundamentals remain stable, sales of U.S. financial assets by any single country are met by purchases by the other countries, as foreign investors are willing to substitute toward U.S. assets with only slight discounts. This result highlights the stability of the dollar as a global currency, conditional on the U.S. maintaining strong fundamentals, and supports the literature on the dollar's hegemony and coordination on reserve currencies.

In another hypothetical scenario, we assume that the demand shift away from the U.S. in the pre-crisis period happened again at the end of our sample in 2021. While we do not take a stance on the driver of this demand shift, it could be driven by a change in investors' risk appetite or a change in the relative attractiveness of U.S. assets. We find that this demand shift, which could be driven by a change in the asset fundamentals, could lead to a much more significant depreciation of the dollar.

Overall, we develop a portfolio-based approach to trace the fluctuations in the dollar's exchange rate to primitive economic factors driving asset supply and demand. In doing so, our approach sheds light on how the drivers of the dollar's strength evolved over time, thereby providing a view that is complementary to the standard risk-based view that focuses on the dollar's cyclical properties (Lustig, Roussanov, and Verdelhan 2011, 2014; Verdelhan 2018).

Literature. We provide a new perspective on the exchange rate variation of the U.S. dollar, which plays a critical role in trade and the international financial system (Maggiori 2017; Maggiori, Neiman, and Schreger 2020; Jiang, Krishnamurthy, and Lustig 2020; Gopinath and Stein 2021; Gourinchas, Rey, and Sauzet 2019). One literature views the dollar's strength as a barometer of global risks, driving the global financial cycle (Rey 2015; Avdjiev, Du, Koch, and Shin 2019; Miranda-Agrippino and Rey 2020). As a result, the dollar is a priced risk factor in the currency market (Lustig, Roussanov, and Verdelhan 2014; Verdelhan 2018). Complementary to this risk-based view, another literature relates the dollar's value to the demand for safe assets (Du and Schreger 2021; Jiang, Krishnamurthy, and Lustig 2021a; Jiang 2021). Our approach relates the dollar's strength to demand and supply factors in the international financial markets.

Our paper builds on works that connect exchange rates to international capital flows (Kouri 1977; Kouri et al. 1978). Gabaix and Maggiori (2015) presents a model for how exchange rates and capital flows are related in segmented financial markets. Lilley, Maggiori, Neiman, and Schreger (2022) document that after the global financial crisis, the dollar's value is closely tied to measures of global risk appetite and to U.S. foreign bond purchases. Hau and Rey (2006) present an equilibrium model of exchange rates and capital flows and show that changes in exchange rates are correlated with capital flows. Camanho, Hau, and Rey (2018) study mutual fund rebalancing and exchange rates. Our paper contributes to this literature by quantifying how factors that drive capital flows can jointly explain the dynamics of the dollar. Evans and Lyons (2002); Froot and Ramadorai (2005) provide empirical evidence on the relation between exchange rates and flows. Gabaix and Koijen (2021) provide evidence of inelastic financial markets and show how flows can have a substantial impact on asset prices.

Finally, our paper contributes to the literature on reserve currencies and the dollar. Maggiori (2017) studies the emergence of and properties of a reserve currency in a model with countries with varying degrees of financial development. Farhi and Maggiori (2017); He, Krishnamurthy, and Milbradt (2019) study models of the international financial system and the implications of supply and demand for reserve assets. Our study highlights the stability of the dollar regime based on the asset substitution patterns of different investors.

1 A Portfolio Approach to Dollar Valuation

Our model follows Jiang, Richmond, and Zhang (2022), which builds on Koijen and Yogo (2019b). There are three key ingredients: (1) investors' asset demand curves, (2) investors' wealth dynamics, and (3) market clearing. These ingredients constitute an asset demand system that relates exchange rates and asset prices to the demand and supply of financial assets.

Importantly, the characteristics based demand curve used in the model can be microfounded as the outcome of an optimal portfolio choice problem in the presence of a factor structure in returns (Koijen and Yogo 2019a) or cash flows (Koijen, Richmond, and Yogo 2019).

1.1 International Asset Demand System

Time is discrete. There are I investor countries that each contain a representative investor who allocates wealth across the asset space. There are N countries that issue assets. These sets of countries can be overlapping. Issuer countries supply assets in asset classes indexed by ℓ: short-term debt ($\ell = 1$), long-term debt ($\ell = 2$), and equity ($\ell = 3$). Each asset class contains $N + 1$ assets — one for each issuer country plus an "outside" asset indexed $n = 0$. This outside asset contains holdings in small countries that are not in our main sample due to data limitations.

We denote investor country i's portfolio weight on issuer country n in asset class ℓ by $w_{i,t}(n, \ell)$, which can be decomposed as:

$$w_{i,t}(n, \ell) = w_{i,t}(n|\ell) \cdot w_{i,t}(\ell), \tag{1}$$

where $w_{i,t}(n|\ell)$ is investor country i's portfolio weight on issuer country n within asset class ℓ, and $w_{i,t}(\ell)$ is investor country i's total portfolio weight on asset class ℓ. For concreteness, consider the U.S. representative investor deciding on their portfolio allocation to long-term debt and within long-term debt to Germany as an issuer country. Thus, i is the U.S., n is Germany, and $\ell = 2$ represents long-term debt. As a result, $w_{i,t}(2)$ will be the overall U.S. portfolio weight on long-term debt and $w_{i,t}(n|2)$ will be the allocation to German long-term debt, conditional on the overall share invested in long-term debt.

Demand within Asset Class. Within an asset class ℓ, the portfolio weight for investor i at time t in country n is a logistic function[2]:

$$w_{i,t}(n|\ell) = \frac{\delta_{i,t}(n,\ell)}{1 + \sum_{k=1}^{N} \delta_{i,t}(k,\ell)}, \tag{2}$$

where $\delta_{i,t}(n,\ell)$ captures the relative desirability of a country's asset in this asset class:

$$\delta_{i,t}(n,\ell) = \exp(\beta_\ell \mu_{i,t}(n,\ell) + \boldsymbol{\theta}_\ell' \mathbf{x}_{i,t}(n) + \kappa_{i,t}(n,\ell)). \tag{3}$$

This desirability has three components. First, $\mu_{i,t}(n,\ell)$ denotes the expected return at time t for country i's investor in country n's asset of class ℓ. Second, $\mathbf{x}_{i,t}(n)$ denotes a set of observable asset characteristics that can be country-specific or bilateral in nature. The loadings, $\boldsymbol{\theta}_\ell$, capture the weight investors place on the characteristics within each asset class. By assumption, the importance of asset characteristics to the portfolio allocation is the same across investors within an asset class. Third, $\kappa_{i,t}(n,\ell)$, denotes latent demand and describes additional variation in the portfolio weights that is not captured by the expected return or observable asset characteristics.[3]

Again considering the U.S. representative investor deciding on their portfolio weight on German long-term debt. The variable $\mu_{i,t}(n,\ell)$ captures the local currency (U.S. Dollar) return the U.S. investor expects to earn on German long-term debt. The vector $\mathbf{x}_{i,t}(n)$ captures characteristics such as the size (GDP) of Germany and the geographic distance

[2] By construction, the total weight in each asset class equals 1, $\sum_{n=0}^{N} w_{i,t}(n|\ell) = 1$. The portfolio weight in the outside asset in asset class ℓ is therefore $w_{i,t}(0|\ell) = 1/(1 + \sum_{n=1}^{N} \delta_{i,t}(n,\ell))$.

[3] Koijen and Yogo (2019a) provides a micro-foundation for this functional form of the characteristics-based demand curve as the outcome of a portfolio choice problem.

between the U.S. and Germany. Finally, the loadings $\boldsymbol{\theta}_\ell$ capture how characteristics matter for the long-term bond portfolio allocation.

Expected Returns. Investors care about expected returns in their own currency. We measure expected excess returns in dollars and convert them to each investor's currency. Let $r_{t+1}(n,\ell) = \log(R_{t+1}(n,\ell))$ denote the log return in dollars on asset class ℓ in country n from time t to $t+1$. To measure expected returns, we use a forecasting regression as in Koijen and Yogo (2019b):

$$r_{t+1}(n,\ell) - r_{t+1}(US,1) = \phi_\ell \cdot pb_t(n,\ell) + \psi_\ell \cdot (e_t(n) - z_t(n)) + \chi_{n,\ell} + \nu_{t+1}(n,\ell). \quad (4)$$

This regression projects the excess return at time $t+1$ for a U.S. investor onto its log market-to-book ratio $pb_t(n,\ell)$ at time t and the log real exchange rate $(e_t(n)-z_t(n))$ between country n and the dollars. The book value in the market-to-book ratio is equity book value for equity and par value for debt. The log real exchange rate is the difference between the log nominal exchange rate $e_t(n) = \log E_t(n)$ and the log consumer price index $z_t(n)$. The exchange rate, $E_t(n)$, is in dollars per unit of foreign currency. The regression coefficients ϕ_ℓ and ψ_ℓ are specific to each asset class ℓ. Based on this regression, the expected log excess return on asset n in investor i's currency (converting from U.S. dollars) is

$$\begin{aligned}\mu_{i,t}(n,\ell) &= \mathbb{E}_t[r_{t+1}(n,\ell) - r_{t+1}(i,1)] \\ &= \phi_\ell pb_t(n,\ell) + \psi_\ell(e_t(n) - z_t(n)) + \chi_{n,\ell} - \phi_1 pb_t(i,1) - \psi_1(e_t(i) - z_t(i)) - \chi_{i,1}. \quad (5)\end{aligned}$$

Demand Across Asset Classes. To allow for substitution across asset classes, the asset class portfolio weight is specified as a nested logit. The portfolio weight for investor i at time t in asset class ℓ is

$$w_{i,t}(\ell) = \frac{(1+\sum_{k=1}^N \delta_{i,t}(n,\ell))^{\lambda_\ell} \exp(\alpha_\ell + \xi_{i,t}(\ell))}{\sum_{m=1}^3 (1+\sum_{k=1}^N \delta_{i,t}(k,m))^{\lambda_m} \exp(\alpha_m + \xi_{i,t}(m))}, \quad (6)$$

where α_ℓ captures asset class fixed effects and $\xi_{i,t}(\ell)$ captures asset class latent demand.[4] The terms $(1 + \sum_{k=1}^{N} \delta_{i,t}(n, \ell))$ are referred to as inclusive values for a given asset class ℓ, which capture the relative attractiveness of investing in each asset class. For example, when relative prices of assets within an asset class increase, the asset class becomes less desirable as a whole, and investors may substitute away from the asset class accordingly.

Investor Wealth Dynamics. Investor wealth adjusts according to the returns on the assets the investor holds. The law of motion for the assets under management (AUM) for investor i in dollars is:

$$A_{i,t} = A_{i,t-1} \sum_{\ell=1}^{3} \sum_{n=0}^{N} w_{i,t-1}(\ell) w_{i,t-1}(n|\ell) R_t(n, \ell) + F_{i,t}, \tag{7}$$

where $R_t(n, \ell)$ is the capital gains on asset n in asset class ℓ in time t in dollars, and $F_{i,t}$ is investor i's net financial savings in dollars, including dividend yield.[5]

Central Banks. We differentiate between demand of private investors and central banks through their reserve holdings. We use $B_{i,t}(n, \ell)$ to denote the quantity of country n's assets held by country i's central bank in local currency book value, which we take as exogenous.

Market Clearing. Let $Q_t(n, \ell)$ denote the book quantity supplied by country n in asset class ℓ in its local currency. Specifically, $Q_t(n, \ell)$ is the total book value in local currency for equity, and the par value in local currency for long-term and short-term debt. We assume the quantity of assets outstanding in each period is exogenously determined. Nevertheless, the dollar book value, $E_t(n)Q_t(n, \ell)$, and the dollar market value, $PB_t(n, \ell)E_t(n)Q_t(n, \ell)$, of any asset are endogenous, because exchange rates and market-to-book ratios are endogenously determined.

[4] Jiang, Richmond, and Zhang (2022) show how this nested logit form can also be derived as the outcome of a portfolio choice problem.

[5] The capital gain $R_t(n, \ell)$ is specified in the standard way, as a function of the market-to-book ratio of assets and the exchange rate. We provide details in Appendix A.1.

The market clearing condition for asset (n, ℓ) in dollars is

$$PB_t(n,\ell)E_t(n)Q_t(n,\ell) = \sum_{i=1}^{N} A_{i,t}w_{i,t}(\ell)w_{i,t}(n|\ell) + PB_t(n,\ell)E_t(n)\sum_{i=1}^{N} B_{i,t}(n,\ell). \quad (8)$$

The left-hand side is the total market value, and the right-hand side is the sum of the dollar value of investors' portfolio holdings of the asset plus the sum of the dollar value of central banks' reserve holdings.

Exchange Rate Determination. We assume the short-term interest rate is controlled by each country's monetary authority so its price $PB_t(n, 1)$ is exogenous. When there is a shock to investor demand on the right-hand side of equation (8), the exchange rate $E_t(n)$ adjusts.[6] Intuitively, if demand for country n short-term debt increases in dollar terms, the country n currency appreciates in value to clear the short-term debt market ($E_t(n)$ increases). In this sense, exchange rates are determined by market clearing for short-term debt. Demand for equity and long-term debt also affect exchange rates due to substitution across asset classes.

In sum, there are 3 asset classes with N assets each, which leads to $3N$ market clearing conditions. Taking short-term bond prices as given, there are N long-term bond prices, N equity prices, $N-1$ exchange rates with respect to the dollar, and the U.S. short-term bond supply. This leads to an exactly determined system.

1.2 Data

We employ three types of data: (1) cross-country bilateral portfolio holdings, (2) asset/country characteristics, and (3) asset returns. At each stage of our data construction, we combine the best available data to get an accurate representation of cross-border portfolio holdings and asset returns. We summarize our data here and provide details in Appendix B.1.

Our cross-border holdings data are based upon IMF CPIS and the Treasury TIC databases.

[6]Pegged exchange rates (CHN, HKG, DNK) are cleared by assuming that the country's central bank maintains the peg by adjusting the supply of short-term debt.

Our approach relies on market clearing and therefore requires relatively comprehensive coverage. As a result, we focus on bilateral country-level positions aggregated across currencies and issuing sectors. While disaggregating the data by issuing sector or by currency would potentially uncover interesting heterogeneity, coverage of the currency denomination of the cross-border holdings is limited. Therefore, we use total cross-border holdings and assume all cross-border holdings are denominated in the local currency of the issuer.

We improve the quality of the cross-border holdings and returns data in three ways. First, we use the reallocation matrices from Coppola, Maggiori, Neiman, and Schreger (2020) to account for mis-attributed investments in offshore financial centers. Second, we estimate the U.S. dollar reserve holdings of individual central banks whenever possible to disaggregate the quantities attributed to official asset purchases at the region level. Third, we use detailed estimates of asset returns from the TIC data to construct reliable estimates of capital gains and net savings.

We measure asset characteristics, $\mathbf{x}_{i,t}(n)$, that investors would use to proxy for expected returns and their riskiness. These characteristics include the market-to-book value of equity and the yields on short-term and long-term debt. We use yields on 3-month government debt to capture the yield on short-term debt, and the yield on 10-year government debt for long-term debt. The issuer country characteristics are its log GDP, log population, trade network centrality (Richmond 2016), sovereign default risk, volatility, real exchange rate, and inflation. Bilateral characteristics are import and export exposures and distance.[7] We also include indicator variables for domestic investment, U.S. issuer, investor country, and year fixed effects.

Our sample runs from 2002 to 2021, and consists of 21 investor regions and 29 issuer countries. We pool EMU countries into a single investor region due to the complexity of attributing EMU investments to specific origins (Beck, Coppola, Lewis, Maggiori, Schmitz,

[7] Lustig and Richmond (2020) show how the factor structure in exchange rates is related to measures of distance, which may arise due to their relation with portfolio flows as shown in this paper. Bailey, Gupta, Hillenbrand, Kuchler, Richmond, and Stroebel (2021) show how social distance between countries influences global trade patterns.

and Schreger 2023). Holdings in issuer countries for which we do not observe a complete panel of characteristics and asset price data are aggregated into an "outside" asset.

1.3 Estimation and Identification

We now describe how we estimate investor's demand curves. Equations (2) and (3) imply

$$\log\left(\frac{w_{i,t}(n,\ell)}{w_{i,t}(0,\ell)}\right) = \beta_\ell \mu_{i,t}(n,\ell) + \boldsymbol{\theta}'_\ell \mathbf{x}_{i,t}(n) + \kappa_{i,t}(n,\ell). \tag{9}$$

This equation determines the within-asset-class demand, which we estimate separately for each asset class ℓ. We obtain the estimation equation for across-asset-class demand by dividing equation (6) for short-term ($\ell = 1$) and long-term debt ($\ell = 2$) by the equation for equity ($\ell = 3$):

$$\log\left(\frac{w_{i,t}(\ell)}{w_{i,t}(3)}\right) = \lambda_\ell \log\left(1 + \sum_{n=1}^{N} \delta_{i,t}(n,\ell)\right) - \lambda_3 \log\left(1 + \sum_{n=1}^{N} \delta_{i,t}(n,3)\right) + \alpha_\ell + \xi_{i,t}(\ell). \tag{10}$$

The main challenge to estimating equations (9) and (10) is that expected returns may be endogenous to latent demand. Consider the estimation of the within-asset-class demand curves, equation (9). If investors have high latent demand for a particular issuer's asset, the price of this asset will be higher, which will impact this asset's expected return and bias the estimated demand coefficient β_ℓ due to the correlation between the regressor, $\mu_{i,t}(n,\ell)$, and the residual, $\kappa_{i,t}(n,\ell)$. Similarly, for the across asset demand curves in equation (10) — If a particular asset class has high latent demand, this will increase the price of this asset class and potentially bias the estimation since the inclusive value, $1 + \sum_{n=1}^{N} \delta_{i,t}(n,\ell)$, contains the price. To address these endogeneity concerns we construct instruments for both estimation equations, building on the identification strategy in Koijen and Yogo (2019b).

Our goal is to estimate the cross-sectional demand elasticities in equations (9) and (10). We therefore require instruments that are correlated with cross-sectional differences in country-level expected returns for equation (9) and asset-class level desirabilities for equation (10). We do not necessarily need instruments which vary over time. To construct instruments, we need cross-sectional variation in country-level expected returns that is uncorrelated with the latent demand. Country-level expected returns are related to prices and exchange rates through the return forecasting regression, equation (5). Therefore, we can use exogenous variation in prices and exchange rates as instruments for expected returns. To obtain such variation, we use our model to construct instruments for prices under the assumption that investor portfolios are determined by exogenous characteristics.

Formally, our identifying assumption is that asset characteristics, asset supply, and investment in outside assets (investor wealth) are exogenous to latent demand:

$$\mathbb{E}\left[\begin{array}{c|c} \kappa_{i,t}(n,\ell) & \\ & \mathbf{x}_t, \mathbf{Q}_t, \mathbf{O}_t, \\ \xi_{i,t}(\ell) & \end{array}\right] = \mathbf{0}, \tag{11}$$

where $\mathbf{x}_t$ is a matrix of characteristics for all countries, $\mathbf{Q}_t$ is the vector of asset supplies, and $\mathbf{O}_t$ is the vector of holdings of outside assets.

We begin by constructing exogenous portfolio weights by estimating a simplified version of the within-asset-class demand:

$$\log\left(\frac{w_{i,t}(n,\ell)}{w_{i,t}(0,\ell)}\right) = \boldsymbol{\theta}_\ell' \mathbf{x}_{i,t}(n) + \kappa_{i,t}(n,\ell). \tag{12}$$

In this equation, we omit expected returns and use a set of exogenous characteristics: bilateral distance between countries, issuer country population, an own country dummy, and investor fixed effects. By including investor fixed effects we control for the cross-sectional variation in investor's weights in the outside asset, which uses the assumption that outside asset holdings are exogenous. We use predicted values from (12) to construct predicted desirabilities, $\hat{\delta}_{i,t}(n,\ell)$, which are driven entirely by variation in exogenous characteristics.

The across-asset-class equation determines how investors substitute across asset classes when the relative desirability of all assets in a particular asset class changes. For example, when equities become more desirable relative to long-term debt, investors may substitute toward equity and away from long-term debt. The amount of this substitution is determined by the elasticities λ_ℓ. To estimate this equation we need exogenous variation in the overall desirability of each asset class. With our exogenous asset desirabilities, $\hat{\delta}_{i,t}(n,\ell)$, we are able to compute instruments for the overall asset level desirabilities, or inclusive values, in equation (10):

$$1+\sum_{n=1}^{N}\hat{\delta}_{i,t}(n,\ell).$$

Using this instrument, we are able to identify the parameters in the across-asset-class demand curve, equation (10).

The full estimates for equation (10) are reported in Appendix B.2 and Table B.5. Here we note that all λ_ℓ values are between 0 and 1. This implies that there is some substitution between asset classes when the relative value of an asset class varies. This is in contrast to the case when $\lambda_\ell = 0$, in which the allocations across asset classes are independent of the relative desirabilities of individual assets. When $\lambda_\ell = 1$, the substitution between asset classes only depends on the desirabilities of individual issuer countries' assets, and the demand system collapses to one tier.

The next step is to estimate the within-asset-class demand curves, as given by equation (9). To do so, we use the estimated cross-asset demand parameters, the exogenous desirabilities, and market clearing to construct instruments for prices and exchange rates. Given exogenous asset desirabilities $\hat{\delta}_{i,t}(n,\ell)$, and estimated cross-asset demand parameters, $\hat{\lambda}_\ell$ and $\hat{\alpha}_\ell$, we compute the model-implied portfolio weights:

$$\hat{w}_{i,t}(n,\ell)=\frac{\hat{\delta}_{i,t}(n,\ell)}{1+\sum_{n=1}^{N}\hat{\delta}_{i,t}(n,\ell)}\frac{\left(1+\sum_{n=1}^{N}\hat{\delta}_{i,t}(n,\ell)\right)^{\hat{\lambda}_\ell}\exp\left(\hat{\alpha_\ell}\right)}{\sum_{m=1}^{3}\left(\left(1+\sum_{n=1}^{N}\hat{\delta}_{i,t}(n,m)\right)^{\hat{\lambda}_m}\exp\left(\hat{\alpha_m}\right)\right)}. \tag{13}$$

These exogenous weights are calculated using Equations (1), (2), (3), and (6), but using the exogenous asset desirabilities. These weights can be thought of as counterfactual portfolio weights for issuer country n's asset in class ℓ if portfolios were determined by the distance between countries, issuer country population, and home bias.

Given these exogenous portfolio weights, we use the market clearing equation (8) to calculate implied asset prices and exchange rates, which we then use as instruments to estimate the within-asset-class demand curve. Specifically, we set each investor country's total assets under management as

$$\hat{A}_{i,t} = \frac{O_{i,t}}{1 - \sum_{k=1}^{3} \sum_{m=1}^{N} \hat{w}_{i,t}(m,k)},$$

where $O_{i,t}$ is investor i's total investment into outside assets. Market clearing in the short-term debt market yields our instruments for exchange rates:

$$\hat{E}_t(n) = \frac{1}{Q_t(n,1)} \sum_{i=1}^{N} \hat{A}_{i,t} \hat{w}_{i,t}(n,\ell),$$

and market clearing in long-term bonds and equities yields our instruments for prices:

$$\hat{PB}_t(n,\ell) = \frac{1}{\hat{E}_t(n) Q_t(n,\ell)} \sum_{i=1}^{N} \hat{A}_{i,t} \hat{w}_{i,t}(n,\ell).$$

Intuitively, the above procedure identifies differences in expected returns that arise due to the fact that asset prices are higher in countries that are geographically closer to large investor countries, and countries that tend to issue fewer assets. In this way, we obtain instruments for exchange rates and asset prices, which we use to identify the within-asset-class demand curve, equation (9). For short-term debt, we instrument expected returns with $\hat{E}_t(n)$. For long-term debt and equity we instrument expected returns with $\hat{E}_t(n)$ and $\hat{P}_t(n,\ell)$ for $\ell = 2, 3$.

The full estimates for within-asset-class demand curves are presented in Appendix Table

B.6, here we discuss the key implications of these estimates. First, our estimates imply average demand elasticities of 313 for short-term debt, 4.3 for long-term debt, and 2.7 for equities.[8] Second, conditional on price and other characteristics, investor countries have a large home bias. Third, investors have a higher preference for debt issued by the U.S. and for countries with higher GDPs, like the U.S. This tilt of investor demand towards U.S. assets has significant implications for variation in the U.S. dollar, which we detail in the next section.

To ensure the robustness of our findings to the estimation and identification procedure, in Section 2.3 we present results where we vary the estimated elasticities across a range of values and recompute our main decomposition.

2 Explaining the Dollar Exchange Rate

In this section, we attribute the dollar exchange rate's movements from 2002 to 2021 to the primitive variables in our model. We first describe our decomposition methodology in Section 2.1, we present the main results in Section 2.2, and we provide robustness tests in Section 2.3. Our main results focus on the dollar advanced foreign economy (AFE) index; we provide a decomposition of the dollar emerging economy (EME) index in Section 2.4.

2.1 Decomposition Methodology

To decompose changes in exchange rates between year $t-1$ and t, we begin by setting all primitive exogenous variables in our model back to their values in year $t-1$. We refer to this equilibrium as the *baseline* step and index it with $j = 1$. By construction, the exogenous and endogenous variables in the baseline step are simply the $t-1$ values. We then sequentially

[8] Appendix B.4 discusses the details of this conversion. These numbers are comparable to those found in Koijen and Yogo (2019b) and Jiang, Richmond, and Zhang (2022), which also presents a number of variants on this estimation methodology and finds similar estimates. For short-term debt with a maturity of 3 months, this elasticity implies that a 1% increase in annualized yield increases demand for short-term debt by 78%. For long-term debt with a maturity of 10-years this demand elasticity implies that a 1% increase in annualized yield increases demand for long-term debt by 43%.

restore each primitive variable to its year-t value, and recompute equilibrium exchange rates, asset prices, and portfolio holdings at each step using market clearing. Appendix B.3 provides computational details. After restoring all primitive variables, we arrive at the actual observed year-t values for the variables in the system, which we refer to as the *observed* step ($j = J$). In this manner, we attribute variation in exchange rates to the observed changes in the primitive variables.

Our focus is on understanding what drove changes in the dollar exchange rate. To do so, we report cumulative log changes in the Dollar advanced foreign economy (AFE) index, denoted by USD, at each step of the decomposition. Dollar AFE index weights are obtained from the Federal Reserve Board (FRB) and our weighting scheme follows that of the FRB. Let $\Delta_{j,t}$ denote the difference in the log of the implied dollar index between the $(j-1)$-th step and the j-th step:

$$\Delta_{j,t} = \log\left(USD_t^j / USD_t^{j-1}\right). \tag{14}$$

The sum of $\Delta_{j,t}$ across all J steps is equal to the actual log change in the dollar in period t: $\sum_j \Delta_{j,t} = \log(USD_t/USD_{t-1})$.

We also aggregate each step's incremental contribution over various sub-periods:

$$\overline{\Delta}_j = \sum_{t\in\mathcal{T}(s)} \Delta_{j,t}, \tag{15}$$

where $\mathcal{T}(s)$ is a set of years. The sum of $\overline{\Delta}_j$ is equal to the actual cumulative change in the dollar for a given set of years (e.g. 2002–2007 or 2010–2022). We also present results for individual countries' exchange rates vis-à-vis the dollar using the same methodology.

Having specified our decomposition methodology, we next describe the sequence of steps we use in our decomposition. Our labeling of the primitive variables is motivated by various literatures that study the drivers of exchange rate movements and international capital flows. In particular, these variables measure (1) investor savings and asset issuances, (2) monetary policies, and (3) shifts in investor demand and asset characteristics.

Savings and Issuances. We start by measuring the contribution of investors' net savings, $F_{i,t}$, and asset issuances, $Q_t(n, \ell)$, in various geographic regions. In each step, we restore investors' savings and issuances simultaneously for a given geographic region. In doing so, our exercise allows us to evaluate the effects of the excess savings that are not satiated by local investment opportunities (i.e. savings gluts, Bernanke 2005). Furthermore, by first restoring savings and issuances we isolate the impact of new excess savings, holding investor demand curves constant.

Monetary Policies. Next, we account for two forms of central bank monetary policies: (i) reserve accumulation and (ii) changes in nominal short-term interest rates. Reserve accumulation includes both official reserve holdings, which are each country's central bank holdings of foreign assets, and U.S. quantitative easing, which is the U.S. central bank's holdings of its domestic assets. We split these two forms of monetary policies into two separate blocks.

Demand Shifts. Finally, we restore the drivers of the investors' asset demand curves, which include changes in country characteristics $\mathbf{x}_{i,t}(n)$, within-asset-class latent demand $\kappa_{i,t}(n, \ell)$, and across-asset-class latent demand $\xi_{i,t}(\ell)$. These steps account for changes in the relative desirability of assets that arise from changes in asset fundamentals (such as economic growth), as well as changes in the taste for assets and asset classes that are not captured by observed characteristics (latent demand).

2.2 Decomposition of the Strength of the Dollar

We present our decomposition in Figure 1. We split our 2002–2021 sample into 4 sub-periods: the pre-crisis period (2002–2007), the Global Financial Crisis part 1 (2008) and part 2 (2009), and the post-crisis period (2010–2021). The dollar AFE index depreciated by 31.7% in the pre-crisis period, appreciated by 9.3% in 2008, depreciated by 7.4% in 2009, and appreciated by 19.3% in the post-crisis period.

The bottom panel of Figure 1 attributes the dollar exchange rate movement to four blocks of the primitive variables: Investor savings and asset issuances, reserve accumulation, monetary policy rates, and shifts in investor demand. We also report these results numerically in Table 1, along with additional breakdowns within each block. Based on these results, we describe how they contributed to the dollar's exchange rate movement differently and how their contributions varied over time.

Savings and Issuances. Starting with the block capturing investor savings and asset issuances, we find that savings and issuances jointly depreciated the dollar before the financial crisis, while these factors appreciated the dollar during and after the crisis. To understand this difference, we plot the contributions of the savings and issuances of individual regions in Figure 2.

Over the full sample period, the U.S. consistently issued more financial assets than it saved. This increasing asset supply decreased the prices of the U.S. assets. The cheaper prices attracted foreign investors to allocate their wealth towards the U.S. assets, and this force was particularly strong given the U.S. assets' unique characteristics that foreign investors found attractive. This capital flow toward U.S. assets led to U.S. dollar appreciation over all four periods. In this way, U.S. savings and issuances consistently appreciated the dollar while lowering U.S. asset prices.

In constrast, foreign countries' savings and issuances demonstrated different behaviors before and after the crisis, with Europe demonstrating a particularly stark shift. The change in the contribution of European savings and issuances largely explains the time variation in the aggregate contribution of the savings and issuances block to the dollar exchange rate. Specifically, prior to the crisis, Europe had high savings relative to their issuances. This relatively high savings increased demand for euro-denominated short-term debt due to home bias, resulting in a depreciation of the dollar relative to the euro. After the crisis, the European sovereign debt crisis had a substantial and volatile impact on European savings and issuances, which, on average, led to little impact on the dollar/euro exchange rate. Consistent with this observation, Figure 2 shows that European savings and issuances contributed to dollar depreciation before the crisis, but had little impact on the dollar after the crisis.

In Table 1, we also split investor savings and asset issuances into those coming from developed markets (DM) and emerging markets (EM) and find that the developed markets have always been the main driving force. In comparison, emerging markets only became relevant in the post-crisis sample, in which they contributed almost 50% of the total effect of savings and issuances in this sub-period. Consistent with this observation, Figure 2 shows that Chinese savings and issuances started to have an impact on the appreciation of the dollar AFE index after the crisis.

Central Bank Reserves. Next, central banks' reserve accumulation further depreciated the dollar during and after the financial crisis, but had a minor role before the crisis. The reserves component of the post-crisis dollar depreciation was predominantly driven by the Federal Reserve's quantitative easing (QE), which increased the price of U.S. long-term debt assets. As a result, private investors substitute away from U.S. assets, leading to a depreciation of the dollar. In this way, quantitative easing behaved like a negative issuance shock to the U.S. assets and the dollar exchange rate. This result is consistent with recent exchange rate theories, which show that the quantitative easing can lower the local bond yield and depreciate the local currency by making the local bond less attractive (Gourinchas, Ray, and Vayanos 2020; Greenwood, Hanson, Stein, and Sunderam 2020; Jiang, Krishnamurthy, Lustig, and Sun 2021b).

Monetary Policy Rates. Third, monetary policy rates appreciated the dollar before the crisis, but they played a minor role during and after the crisis. This is because the U.S. policy rate increased more than foreign policy rates before the crisis, whereas the U.S. and foreign rates tended to converge during and after the crisis.

However, this does not mean that U.S. policy rates had no effect on the dollar exchange from one year to the next. The top-right panel of Figure 3 plots the change in the U.S. monetary policy rate in each year against the model-implied dollar exchange rate movement due to the rate change alone. Increases in U.S. monetary policy rates relative foreign policy rates appreciate the dollar, because higher U.S. interest rates make U.S. assets more attractive to foreign investors and attract inflows to the U.S. The model implies an almost perfect relationship, suggesting that a 1% rate hike leads to an approximately 3.3% dollar exchange rate movement. Notably, our model-implied dollar response is consistent with research using a high-frequency identification strategy which also shows that the dollar appreciates around 3% against the basket of trade-weighted AFE currencies in response to a 1% U.S. monetary policy shock (Curcuru et al. 2017).

As a result, changes in the U.S. policy rate appreciated the dollar from 2010 to 2018 and depreciated the dollar from 2018 to 2021, which is consistent with the U.S. rate rising faster in the early part of the post-crisis period and being caught by the foreign rates in the later part of the post-crisis period. To present this pattern more clearly, we report the year-by-year decomposition in Appendix Figure B.4.

Demand Shifts. Shifts in investor demand have the most dynamic pattern. They depreciated the dollar before the crisis, appreciated the dollar in 2008, depreciated the dollar in 2009, and appreciated the dollar after the crisis. Most of the demand shifts were driven by the developed market (DM) investors, as we would expect given their large shares in the global distribution of financial wealth.

Specifically, the dollar depreciation before the crisis was driven by a strong demand for foreign assets in this "risk-on" period, which is consistent with large capital flows into riskier assets in foreign countries (Miranda-Agrippino and Rey 2022). This trend reversed when the global financial crisis hit in 2008, when the strong flight-to-safety appreciated the dollar. However, this strong demand for safety was relatively short-lived. As the panic subsided in 2009, the dollar's exchange rate reverted. In these three sub-periods, demand shifts played a major role in the dollar's exchange rate movement, and the direction of their contribution was consistent with that of the overall movement in the dollar index.

Finally, the dollar appreciated after the crisis, even though this period was characterized by relatively high asset prices and risk appetites. This pattern, which is very different from the demand shifts in the pre-crisis period, is driven by an increase in demand for U.S. risky assets (Atkeson, Heathcote, and Perri 2021; Jiang, Richmond, and Zhang 2022). Specifically, as U.S. risky assets became more attractive to foreign investors, the U.S. experienced capital inflows which appreciated the dollar in good times. This pattern is very different from the traditional view of the dollar as the safe haven currency. In other words, the preference for U.S. assets instead of foreign assets dominated the preference for risky currencies instead of safe currencies in this period, which is characterized by high asset prices and high risk appetites.

As in the discussion of the U.S. policy rates, we further examine the exchange rate movement from one year to the next to show that both U.S. and foreign investors' demand shifts played a major role in shaping the dollar's exchange rate dynamics. In the top-right panel of Figure 3, we plot shifts in the U.S. investors' demand for advanced foreign economies' assets against the model-implied dollar exchange rate movements. In the bottom-left panel, we plot the shifts in the advanced foreign economies' demand for U.S. assets against the implied dollar exchange rate movements. As expected, weaker U.S. demand for foreign assets leads a depreciation of foreign currencies and therefore an appreciation of the dollar, whereas stronger foreign demand for U.S. assets leads to a dollar appreciation. Notably, in the post-crisis period, the U.S. demand shifted away from foreign assets while the foreign demand shifted towards U.S. assets. Both demand shifts contributed to the dollar appreciation in this period.

2.3 Robustness to Variation in Demand Elasticities

A potential concern is that our decomposition may be sensitive to the estimation and identification procedure we detail in Section 1.3. To demonstrate that our findings are robust to reasonable variations in our estimated demand elasticities, we scale the estimated coefficients on expected returns and recompute our decomposition of the dollar AFE index. For each scaled coefficient on expected returns, we re-estimate the remaining demand curve parameters.

We present the results in Figure 4. The top half of the figure presents the decomposition of the dollar exchange rate movement, while the bottom half presents the coefficients on expected returns in the demand curves (top 3 figures) along with the implied demand elasticities (bottom 3 figures).[9] Each bar corresponds to estimates from our baseline model, along with 6 alternative elasticities that are consistent with the ranges found in the literature on asset demand (Koijen and Yogo 2019b; Gabaix and Koijen 2021; Jiang, Richmond, and Zhang 2022). The top 4 panels (one for each time period) show how our decomposition varies as we increase and decrease the demand elasticities. Broadly, as we vary the elasticity we see that the decomposition tends to attribute more or less to demand versus savings. While this shift varies across periods, this figure demonstrates that the key conclusions we draw from our decomposition remain robust to varying the demand elasticities.

2.4 EME Breakdown

Up to this point, we have limited our discussion to advanced foreign economies. In this section, we repeat our main exercise but focus on the dollar index with respect emerging market economy (EME) currencies. We report our results for emerging markets currencies in Figure 5, which shows changes in the dollar relative to a trade weighted basket of China, India, Malaysia, Mexico, Singapore, South Korea, and Thailand, which covers the majority

[9] Appendix B.4 discusses the details of this conversion.

of the Federal Reserves EME dollar index.[10]

Overall, the results are qualitatively similar to the baseline results using the AFE dollar index: savings and issuances depreciated the dollar before the crisis and appreciated the dollar during and after the crisis; reserve accumulation depreciated the dollar during and after the crisis; monetary policy rates appreciated the dollar before the crisis and played a minor role afterwards; finally, demand shifts depreciated the dollar before the crisis and in 2009, and appreciated the dollar in 2008 and after the crisis. Quantitatively, the most notable difference is that the demand shifts depreciated the dollar EME index to a less extent in the pre-crisis sample, because the demand shifts were most pronounced towards the foreign developed markets as opposed to emerging markets.

2.5 Cross-border Bank Loans and Deposits

For some countries, banking sector cross-border loans and deposits account for a large share of their external positions and can therefore also be an important determinant of exchange rates. In this section, we briefly discuss the impact of cross-border loans and deposits on the longer-term trends in the dollar AFE index. We relegate a more detailed discussion of the data that we use and the methodology behind our extended analysis to Appendix B.5.

Overall, our extended analysis shows that the aggregate impact of changes in the banking sector position of individual countries on the dollar AFE index are relatively small over the post-crisis period (2010 to 2021). For example, changes in the net external positions of the German banking sector contributed around 2.5 percent appreciation of the dollar AFE index over the post-crisis period. The contribution of most countries' banking sectors is less than 1 percent. The main reason for this result is that changes in countries' net external banking sector positions tend to contribute positively to dollar appreciation in one year and negatively in the following year. Unlike the portfolio data, changes in banking sector external positions in the data fluctuate around longer-run averages rather than reveal longer-term sustained

[10] Our sample of emerging economies is limited by the data covered by our holdings panel.

trends in capital flows. Thus, when we aggregate these contributions up for a single country's banking sector over the full sample period, the overall effects tend to be small.

3 What Happens to the Dollar If the Demand for U.S. Assets Changes?

Motivated by the findings in the previous section on the importance of demand shifts on the value of the dollar, we next study the impact of two potential changes in demand for U.S. assets on the value of the dollar. In the first scenario, we assume that one foreign country sells all its U.S. assets. In the second scenario, we assume that the demand shifts in the pre-crisis period, which depreciated the dollar, happen again at the end of our sample.

3.1 Counterfactual 1: One Country Selling All Its U.S. Assets

We would like to understand how the dollar's value responds to one country unilaterally selling all its U.S. assets. This counterfactual scenario also sheds light on which countries' holdings matter the most for the dollar's value.

We use our end-of-sample data and estimates from $t = 2021$, and compute the equilibrium portfolio holdings and exchange rates assuming one country's investors and central bank reallocate their U.S. asset holdings to other assets according to their demand curve. To do so, we set country i's latent demand for all U.S. assets, $\kappa_{i,t}(US, \ell)$, to a large negative number. We also assume that the country's central bank liquidates its reserve holdings of U.S. assets and distributes the wealth to its domestic investors, who will reallocate this wealth towards non-U.S. assets. As a result, this country's private and official sectors will sell all its U.S. assets, which are absorbed by the investors in other countries.

The top panel of Figure 6 shows the change in the value of the AFE dollar index as each country liquidates their dollar asset holdings. China and the European Monetary Union (EMU) stand out. If either China or the EMU disposes of its U.S. assets, the dollar will depreciate by around 2.5%.[11] If Japan, Canada, or Switzerland disposes of its U.S. assets, the dollar will depreciate by less than 1%.

These impacts on the dollar are perhaps surprisingly small, which highlights the stable global demand for U.S. assets. Assuming no change in the U.S. fundamentals, when one country unilaterally sells U.S. assets, other countries are willing to absorb the excess supply of dollar assets at a minor price discount. This is true even when the region we are considering is as large as the EMU. In this scenario, as the EMU sells their U.S. assets, we find that other countries increase their positions in the U.S. assets by 10% to 30%.

This result demonstrates a source of the stability in dollar's valuation. Our demand curve estimates suggest that investors in many countries stand ready to buy U.S. assets when other countries sell, due to the size of the U.S. as a desirable feature and the explicit special demand for its assets. From a theoretical perspective, this willingness to hold U.S. assets is precisely what is required to coordinate on the dollar as a reserve currency (Farhi and Maggiori 2017; He, Krishnamurthy, and Milbradt 2019), and could support the U.S. assets' valuation above their fundamental value (Jiang, Lustig, Van Nieuwerburgh, and Xiaolan 2019).

3.2 Counterfactual 2: Demand Shifts in Early 2000s

Our findings reveal that demand shifts away from the U.S. assets in the pre-crisis period depreciated the dollar by 25% from 2002 to 2007. Since then, the dollar has recovered significantly thanks to both investor savings and favorable demand shifts. A natural question is what happens to the current dollar's value if it experiences demand shifts similar to those in the pre-crisis period. To study this question, we adjust the investors' demand curves as of $t = 2021$ by subtracting the changes in demand (both characteristics and latent demand) from the pre-crisis period. While the previous counterfactual scenario studies one foreign country's unilateral action, this counterfactual scenario studies a correlated change in the relative desirabilities of the U.S. assets across investor countries.

[11] In this counterfactual exercise, we assume that China unpegs from the U.S. dollar.

The bottom panel of Figure 6 reports the change in the value of the AFE dollar for various scalings of the demand shifts. When the U.S. assets experience a decline in foreign demand equivalent to that which occurred between 2002 and 2007 (a scaling of 1), the dollar would depreciate by more than 25%. This result highlights that the U.S.'s fundamental characteristics and the specialness of demand for its assets play first-order roles in determining the dollar's value. Furthermore, it shows specifically how correlated demand shocks can have substantial impact on the dollar's strength.

4 Conclusion

In this paper, we use a portfolio-based demand system to trace the fluctuations in the dollar's exchange rate to primitive economic factors. Our estimates uncover significant structural changes in the nature of the investors' excess savings and demand shifts before and after crisis. As a result, the decade-long appreciation of the dollar after the crisis is driven by different factors than the standard safety features that made the dollar a safe currency during the crisis. Instead, the dollar's strength in the recent past hinges on investors' willingness to save in financial markets as well as their willingness to invest in risky U.S. assets.

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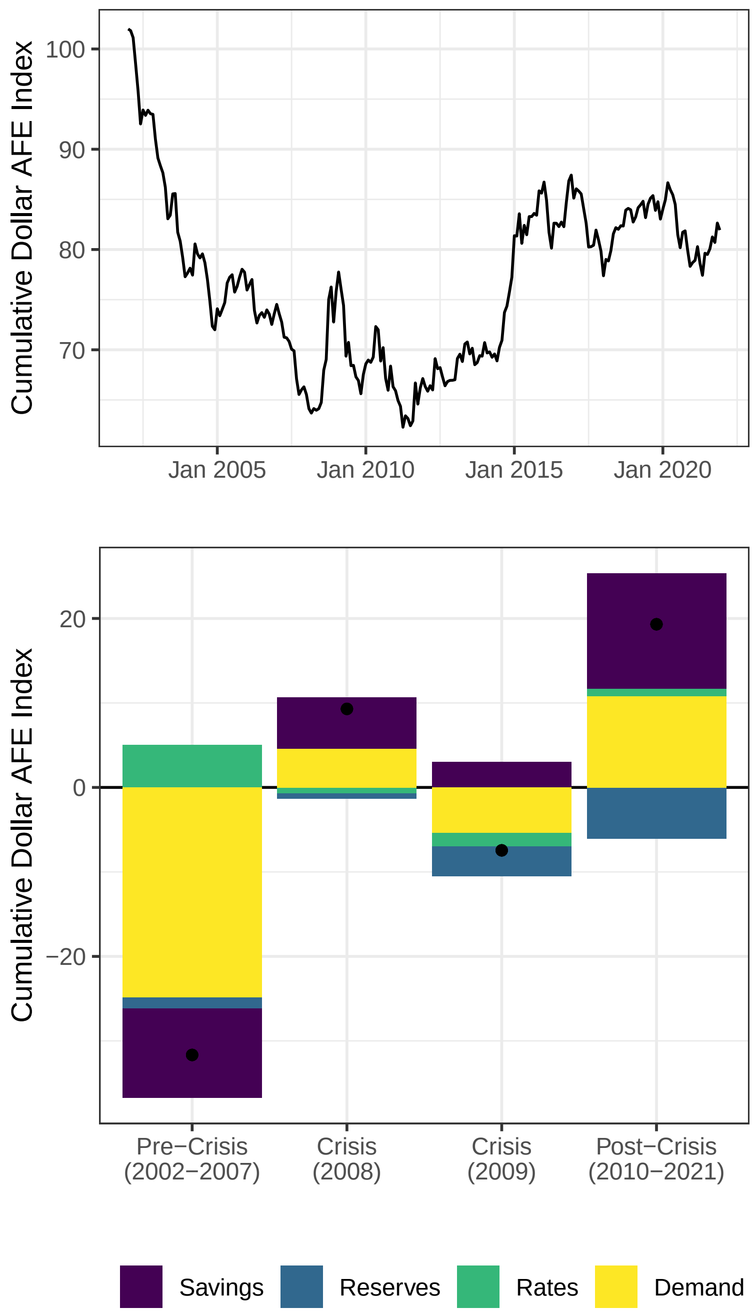
Tables and Figures

Figure 1
Trend Decomposition of Dollar AFE Index



Notes: The top panel presents the nominal level of the dollar AFE index with December 2001 indexed to 100. The dollar AFE index is a trade-weighted basket comprising the euro, the Canadian dollar, the Japanese yen, the British pound, the Swiss franc and the Swedish kroner. The bottom panel presents the contribution of each block of economic primitives to the percent change in the dollar AFE index over the four sub-periods of our analysis. The total change within a sub-period is marked by a black dot.

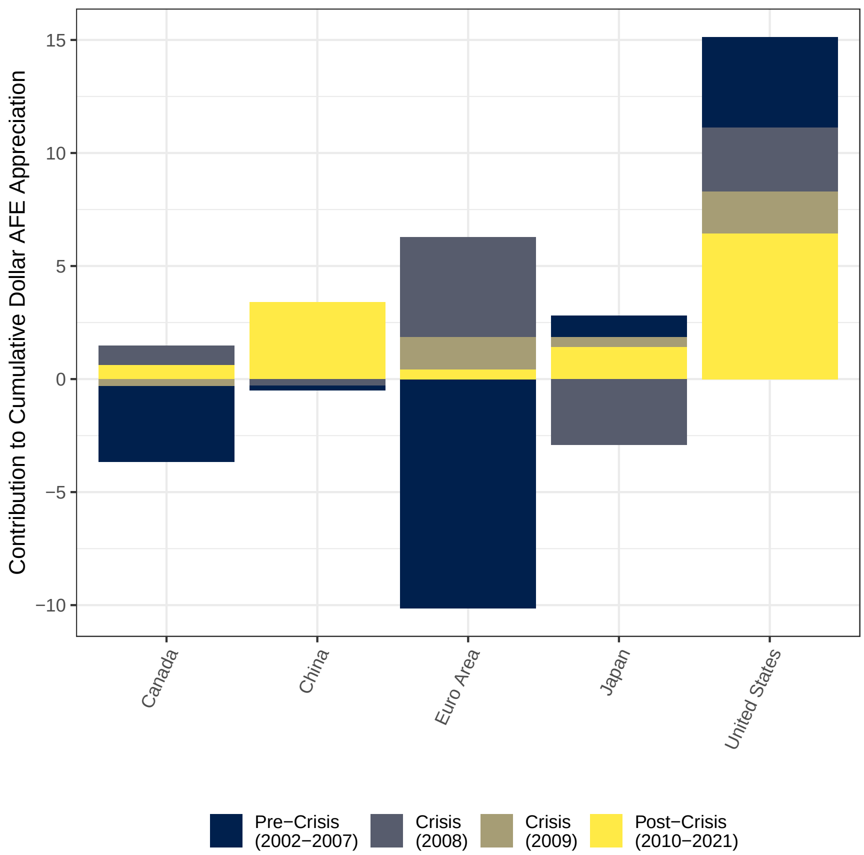
Table 1
Decomposition of Dollar AFE Index

	Pre-Crisis	Crisis		Post-Crisis
	2002-2007	2008	2009	2010-2021
Savings and Issuances				
DM Savings	-9.9	5.8	3.4	7.7
EM Savings	-0.7	0.2	-0.3	6.0
Total Savings	-10.6	6.1	3.0	13.7
Monetary Policies (Reserves)				
US Reserves	0.1	0.1	-3.1	-4.7
DM Reserves	0.1	-0.0	0.0	0.0
EM Reserves	-1.6	-0.7	-0.4	-1.3
Total Reserves	-1.3	-0.7	-3.5	-6.1
Monetary Policies (Rates)				
US Rates	10.8	-5.4	-9.6	-1.4
EM/DM Rates	-5.7	4.8	7.9	2.3
Total Rates	5.1	-0.7	-1.6	0.9
Demand Shifts				
DM Demand	-24.6	3.9	-5.9	9.3
EM Demand	-0.2	0.7	0.6	1.5
Total Demand	-24.8	4.6	-5.4	10.8
Total	**-31.7**	**9.3**	**-7.4**	**19.3**

Notes: This table presents a detailed decomposition of the dollar AFE index over the four sub-periods of our analysis. All numbers represent the dollar's exchange rate movement in percentage units. We group the economic factors explaining dollar appreciation into four blocks — the last row within each block presents the contribution of all variables within that block. The last row of the table presents the aggregate dollar appreciation (i.e., the dollar appreciated 19.3 percent against the trade-weighted basked of AFE currencies between 2010 and 2021). "DM" refers to the developed market economies and "EM" refers to the emerging market economies.

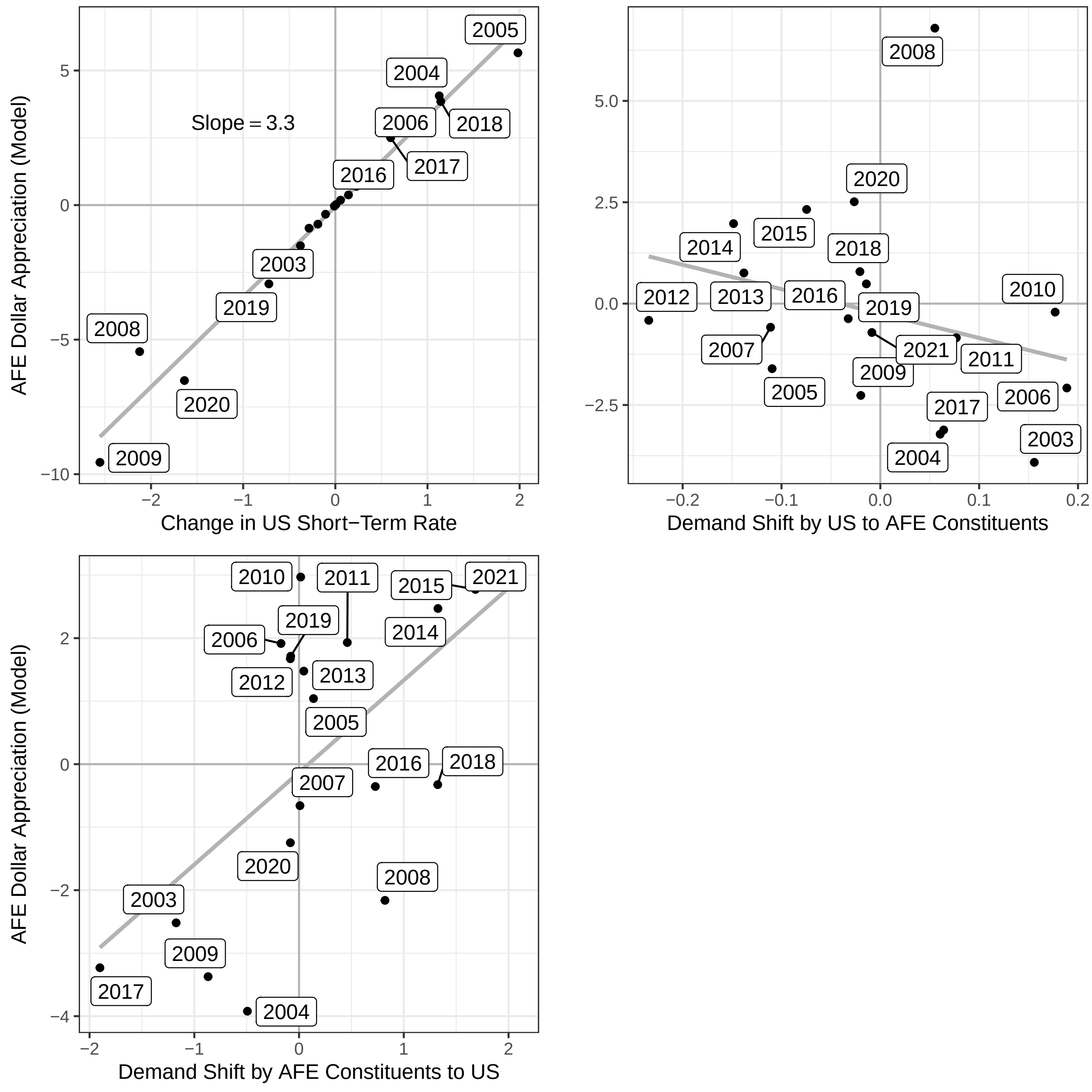
Figure 2

Decomposition of Savings and Issuances Contribution to Dollar AFE Index By Regions



Notes: This figure presents the contribution of the savings and issuances from specific currency regions to the dollar AFE index over the four sub-periods of our analysis.

Figure 3
Dollar AFE Index Appreciation Mechanisms

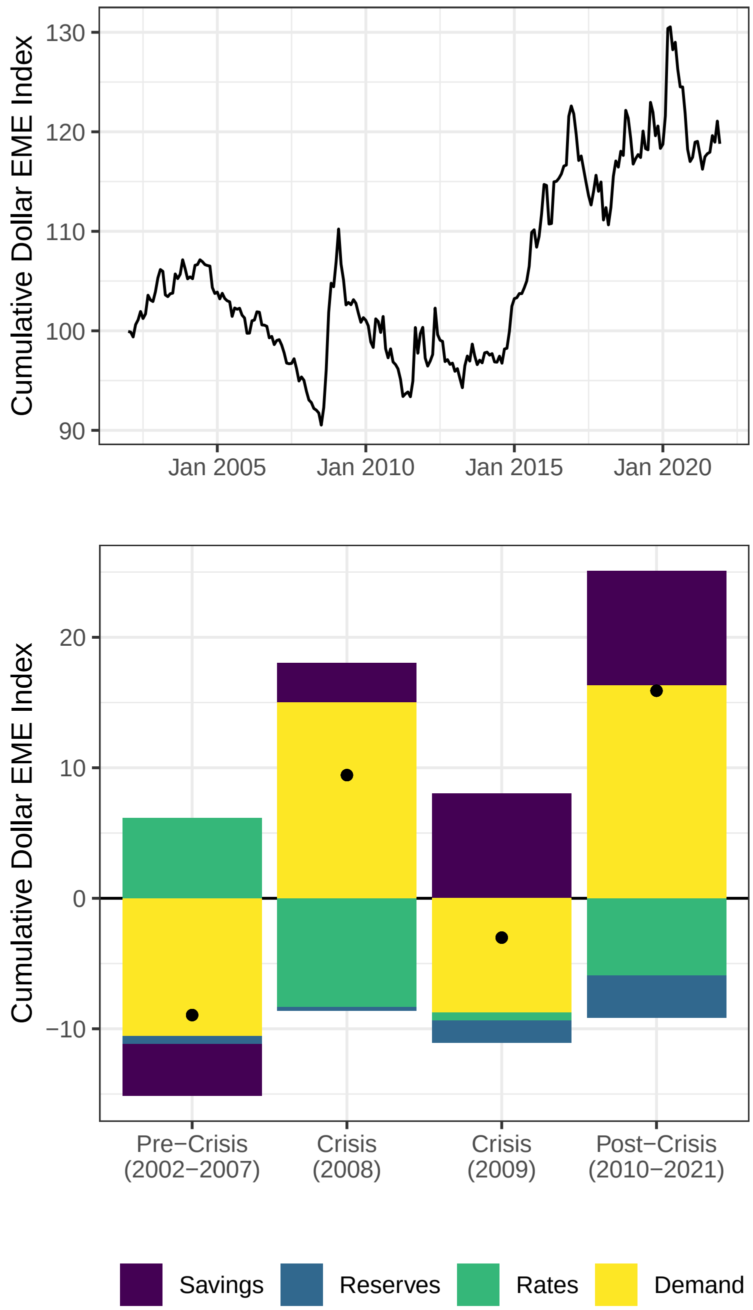


Notes: This figure presents the various mechanisms captured by our framework that jointly explain movements in the dollar AFE index. In each panel, we plot changes in the dollar computed within our model (y-axis) against changes in various data inputs (x-axis). The top-left panel presents dollar appreciation explained by changes in the U.S. short-term interest rate. The top-right panel presents dollar appreciation explained by shifts in U.S. investor demand towards AFE financial assets, and the bottom-left panel presents dollar appreciation explained by shifts in AFE investor demand towards U.S. financial assets. The y-axis is in percentage points.

Figure 4
Trend Decomposition of AFE Index for Different Demand Elasticities

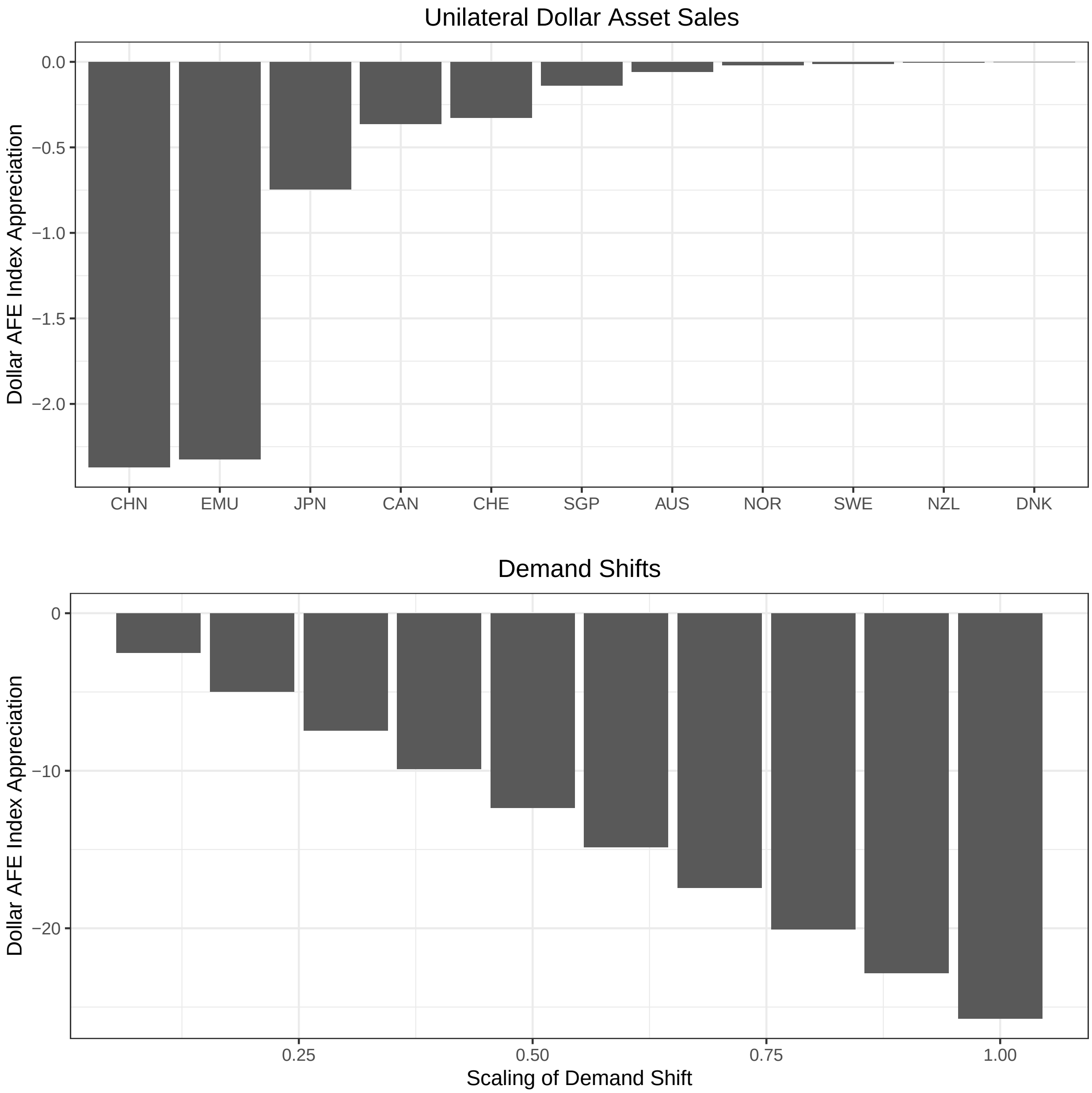
Notes: This figure shows the robustness of our decomposition to variation in estimates of asset demand elasticities. The top panel presents the decomposition of the change in the dollar AFE index in each sub-period across the different parameterizations for demand elasticities. The "Baseline" specification re-iterates the results shown in Figure 1. The six alternative parameterizations scale the demand elasticities in all asset classes up and down as shown in the bottom panel.

Figure 5
Trend Decomposition of Dollar EME Index



Notes: The top panel presents the nominal level of the dollar EME index with December 2001 indexed to 100. The dollar EME index is a trade-weighted basket comprising the Chinese yuan, the Indian rupee, the Malaysian ringgit, the Singapore dollar, the South Korean won and the Thai baht. The bottom panel presents the contribution of each block of economic primitives to the percent change in the dollar AFE index over the four sub-periods of our analysis. The total change within a sub-period is marked by a black dot.

Figure 6
Change in Dollar AFE Index in Counterfactual Scenarios



Notes: This figure presents changes in the value of the dollar AFE index under two counterfactual scenarios using end-of-sample data and estimates from 2021. The top panel presents the changes in the dollar AFE index as each country unilaterally liquidates their dollar asset holdings. The bottom panel presents changes in the dollar AFE index given a shift in global demand curves scaled to what was observed globally from 2002 and 2007.

Appendix

A Theory Appendix

A.1 Capital Gains

The capital gains earned by the investor country is determined by changes in asset prices and changes in exchange rates, $E_t(k)$. Because we assume investors form expectations of asset returns based on market-to-book ratios, we explicitly model realized dollar returns as a function of market-to-book ratios:

$$R_t(k,\ell) = \frac{PB_t(k,\ell)E_t(k)S_t(k,\ell)}{PB_{t-1}(k,\ell)E_{t-1}(k)S_{t-1}(k,\ell)}, \tag{A.1}$$

where $S_t(k,\ell)$ is the conversion factor between book value and share number (i.e. book-per-share) in local currency terms. When mapping our framework to equities data, we translate changes in market-to-book ratios into changes in prices, because the demand curve specification depends on the market-to-book ratio and the dynamics of countries' portfolios depend on capital gains. We compute the multiplicative factor $S_t(k,\ell)/S_{t-1}(k,\ell)$ that achieves this conversion using the return, market-book and exchange rate data.[1] Because $PB_t(k,\ell)$ denotes the market-to-book ratio, $PB_t(k,\ell)S_t(k,\ell)E_t(k,\ell)$ is the dollar price per asset share. For bonds, the book value is the par value, and the conversion factor $S_t(k,\ell)$ is 1.

B Empirical Appendix

B.1 Data Construction

The data we use in this paper largely follows Jiang, Richmond, and Zhang (2022). Our analysis requires three types of data: cross-country portfolio holdings, country/asset characteristics, and realized returns in each asset class. Table B.2 presents the specific set of countries in our sample and their classifications. Table B.3 presents the list of central banks for which we are able to construct bilateral holdings. We discuss our measurement of these data, below. Afterwards, we also discuss how we use these data to impute net financial savings.

B.1.1 Cross-Country Portfolio Holdings

We observe cross-country portfolio holdings data for non-U.S. countries from the Coordinated Portfolio Investment Survey (CPIS) provided by the IMF, and for the U.S. from the Treasury International Capital System (TIC). The TIC data reports U.S. external assets and U.S. external liabilities only. Thus, for U.S. external assets and liabilities, we use all available data from TIC. For all external positions between non-U.S. countries, we use CPIS data. In

[1] Implicitly, the ratio $S_t(k,\ell)/S_{t-1}(k,\ell)$ captures changes in the shares of assets outstanding relative to the book value of assets outstanding.

the end, for each investor country i, we observe year-end holdings of foreign financial assets by asset class and issuer country. The asset classes comprise short-term debt, long-term debt and equity. The asset holders include corporations, and individuals, government entities (such as sovereign wealth funds, but not including the central bank foreign reserve holdings). We use the total value of bilateral positions, and we assume securities are denominated local currency.

A well-known issue with portfolio holdings data is that flows to and from offshore financial centers can present a highly distorted view of capital allocation. For example, Coppola, Maggiori, Neiman, and Schreger (2020); Beck, Coppola, Lewis, Maggiori, Schmitz, and Schreger (2023) point out that investments by countries in the European Monetary Union are often funneled through Luxembourg. As a result, in the raw CPIS data, Luxembourg is in the top 10 investors for all asset classes. In order to mitigate this issue, after merging the CPIS and TIC data, we apply the reallocation matrices from Coppola, Maggiori, Neiman, and Schreger (2020) to re-attribute portfolio holdings to their investor nationality as much as possible. These reallocation matrices are provided from 2007 to 2017. We extend these matrices forwards and backwards in time to cover the full sample period from 2002 to 2019, by assuming a constant share of funds pass through each offshore center before 2007 and after 2017. Following Coppola, Maggiori, Neiman, and Schreger (2020), we also aggregate all investment holdings by Euro Area countries into a single European Monetary Union (EMU) investor entity, because the vast majority of investment in the euro area is funneled through a small number of tax haven countries. After applying the reallocation matrices there remain some funds held by tax haven countries. We redistribute these remaining holdings proportionally to the countries which have inward investment into the tax havens (Clayton et al. 2023).

We split off central bank and other official holdings, and treat changes in these official holdings as exogenous policy decisions when estimating our structural model. For all non-U.S. countries, we use the IMF Securities Held as Foreign Exchange Reserves (SEFER) survey to estimate the value of each country's assets that are held as reserve assets by central banks.[2] For the United States, official and private holdings of U.S. liabilities are reported together in the TIC data.[3] We parse out the value of foreign official holdings of U.S. liabilities using data describing the currency composition of countries' reserve assets with data capturing the total size of countries' reserve portfolio. The next Appendix Section B.1.2 describes our procedure in detail.

Finally, the cross-country portfolio holdings data do not record domestic holdings of financial assets. Thus, we estimate domestic portfolio holdings by subtracting foreign holdings from total market capitalization data. We observe the country-level stock market capitalization from the World Bank, and we observe the aggregate value of outstanding short-term and long-term debt securities from the BIS. We use total debt market size from the BIS.

[2]The CPIS does not contain reserve holdings of central banks. Thus, the sum of the CPIS and SEFER holdings should capture all holdings held by foreign private and foreign official investors.

[3]For example, the publicly available TIC data only reports that Canadian private and official investors held a total of 1,262 billion dollars of U.S. portfolio liabilities in 2019.

B.1.2 Central Bank Reserve Holdings of U.S. Liabilities

As stated in Appendix B.1.1, the TIC data report both private and official holdings of U.S. liabilities together. Our main challenge is to parse out official holdings from total holdings, because we would like to treat official holdings as an exogenous policy variable in the benchmark analysis of our structural model.

Our procedure involves three steps. First, we estimate the size of each country's official dollar holdings. Then, we attribute each country's official dollar holdings to official holdings into the three asset classes (i.e., short-term debt, long-term debt and equity). Finally, we subtract the estimated official holdings from the TIC holdings data to dis-aggregate the TIC holdings data into private and official holdings.

To estimate the size of each country's official dollar holdings, we multiply the share of each country's reserve portfolio held in dollars (Iancu et al. (2020)) with the total size of each country's reserve portfolio. The total size of each country's reserve portfolio is taken from its "Securities" position from the IMF's International Reserves and Foreign Currency Liquidity Survey. We assume that all countries' dollar reserves are U.S. issued liabilities. While it is true that non-U.S. entities can issue dollar liabilities, we think our assumption is reasonable given that the vast majority of dollar reserves are comprised of U.S. treasury securities.

To attribute total official dollar holdings to separate asset classes, we use the breakdown of the aggregate official holdings of U.S. liabilities from TIC. For each year, TIC reports the aggregate official holdings of U.S. short-term debt, long-term debt, and equity. We divide each country's official U.S. holdings into these three sectors based on the distribution of the aggregate official holdings.

Finally, we subtract out the estimated official holdings by each investor country and in each asset class from the total TIC holdings of U.S. liabilities. Due to potential differences in sample coverage between the TIC data and the IMF data[4], as well as potential measurement errors introduced by our estimation procedure, the total value of official holdings of U.S. liabilities for a given asset class ℓ and investor country n may be larger than the observed TIC holdings. In these instances, we attribute the entirety of the TIC holdings to official holdings and set private holdings for the investor to zero.

Ultimately, our procedure is able to parse out between 21 and 39 percent of the total official holdings for each year in our sample.[5] Finally, we attribute all holdings of U.S. long-term debt by China to Chinese Central Bank reserves.

[4] For example, the IMF data often rely on each country's domestic statistical agency to report reserve assets, whereas the TIC holdings are built off of surveys of custodial bank in the U.S. For a detailed description of various sources of reserves holdings data, see: https://ticdata.treasury.gov/resource-center/data-chart-center/tic/Documents/fohdefs1.904.pdf

[5] As mentioned previously, even though the TIC data do not provide a bilateral breakdown of official and private holdings of U.S. liabilities, the TIC data do report the aggregate value of U.S. liabilities held by foreign official sources. For example, in 2019, foreign official investors held 6.1 trillion dollars of U.S. liabilities. We are able to parse out 1.4 trillion dollars based on our reallocation methodology.

B.1.3 Country Characteristics

We observe country-level market-to-book values of equity, yields on short-term debt, and yields on long-term debt from Datastream. We observe GDP, GDP per capita, and population from the World Bank. We obtain trade network centrality measures from Richmond (2016). We observe S&P sovereign debt ratings and impute sovereign default probabilities using S&P 5-year default rates. Market volatility is annual volatility from each country's MSCI Equity market index in local currency. We obtain dollar exchange rates from Datastream, inflation rates from the IMF, and trade and distance variables from CEPII.

B.1.4 Realized Capital Gains

We want to decompose the changes holdings over time into changes in the valuation of existing assets (*capital gains*), and the net value of additional asset purchases (*capital flows*) between any two periods $t-1$ and t. We therefore need the best possible measurement of realized capital gains and capital flows.

For all investments between two non-U.S. countries, we impute realized capital gains on equity by computing changes in country-level equity price return indexes obtained through Datastream, and we impute realized returns on debt using 3-month and 10-year yields. For short-term debt, the realized return is computed by compounding the four 3-month yields over the course of each year. For long-term debt, the realized return is the annualized 10-year yield from the previous year.

For the U.S. holdings of foreign assets and foreign holdings of U.S. assets, we provide a more accurate view of returns to equity and long-term debt assets by imputing the realized capital gains earned by foreign investors using granular capital flows and positions data from Bertaut and Tryon (2007) and Bertaut and Judson (2014). Tabova and Warnock (2021) show the capital flows data from these two papers are more representative and internally consistent than TIC S capital flows data.

Because the data from Bertaut and Tryon (2007) and Bertaut and Judson (2014) are provided at the monthly frequency, we simply need to aggregate the monthly flows and positions data to the annual frequency. We impute the realized capital gains from investing in country n in asset class ℓ, $R_t(n, \ell)$, from periods $t-1$ and t using the valuation change in the data:

$$R_t(n, \ell) = 1 + \text{VALUATION CHANGE}_t(n, \ell)/\text{POSITION}_{t-1}(n, \ell).$$

Due to data quality concerns, we winsorize the lower bound of $R_t(n, \ell)$ at 1%. We compound the monthly returns into annual returns.

B.1.5 Net Financial Savings

Having obtained data on investor holdings and realized returns in each period, it is straightforward to back out net financial savings $F_{i,t}$ for each investor country using Eq. (7):

$$F_{i,t} = A_{i,t} - A_{i,t-1} \sum_{\ell=1}^{3} \sum_{n=0}^{N} w_{i,t-1}(\ell) w_{i,t-1}(n|\ell) R_t(n, \ell).$$

When restoring the actual net savings $F_{i,t}$, we use a multiplicative growth rate $f_{i,t}$ equal to $F_{i,t}$ divided by time-t value of the portfolio from period $t-1$, and plug in

$$\widetilde{F}_{i,t}^{j} = f_{i,t} \cdot A_{i,t-1} \sum_{\ell=1}^{3} \sum_{n=0}^{N} w_{i,t-1}(\ell) w_{i,t-1}(n|\ell) \widetilde{R}_{t}^{j}(n,\ell)$$

at step j of the counterfactual.

B.2 Identification

In this Appendix we provide additional detail on the various steps of the estimation and identification in Section 1.3.

The results for estimating equation (10) are reported in Table B.5. The first thing to note is that the first-stage F-statistics in the bottom three rows of the table are all greater than 100 (Stock and Yogo 2002). These high first-stage F-statistics imply that the instruments for the inclusive value are all highly correlated with the asset-class level desirabilities, even though they are constructed entirely from exogenous asset characteristics. Next, all λ_ℓ values are between 0 and 1. This implies that there is some substitution between asset classes when the relative value of an asset class varies. This is in contrast to the case when $\lambda_\ell = 0$, in which the allocations across asset classes are independent of the relative desirabilities of individual assets. When $\lambda_\ell = 1$, the substitution between asset classes only depends on the desirabilities of individual issuer countries' assets, and the demand system collapses to one tier. Our estimates are between these two polar cases, implying that there is some segmentation across asset classes.[6]

The first stages for estimating equation (10) are presented in Table B.7. Consistent with the expected return regression (5), expected returns are negatively related to the instruments for prices and exchange rates. Furthermore, the first-stage F-statistic for all three asset classes is high which implies these are strong instruments.

The full estimates for within-asset-class demand curves are presented in Table B.6. The coefficients on expected returns are all positive, which implies that conditional on our set of asset characteristics, assets with higher expected returns are preferred by investors. The coefficients on asset characteristics are all intuitive. Investors prefer assets that provide better hedges against systematic risks, such as the assets of larger countries (higher GDP). Conditional of countries having higher GDP, investors prefer countries with lower population, which implies they tend to prefer countries with higher GDP per capita. Investors also prefer assets from countries that are closer and with whom they have a stronger trade relationship. Finally, the next-to-last row of Table B.6 shows there is strong home bias in all asset classes.

B.3 Solution Methodology

In the following appendix, we apply an approximation of Newton's Method to calculate the equilibrium price in the counterfactual analysis. Our algorithm closely follows Koijen and

[6] See Koijen and Yogo (2019b) for more discussion on the interpretation of these parameters. Our estimates here are consistent with their findings.

Yogo (2019a). For each asset j in sector l at time t, we want to find the zero of the following function:

$$H(\mathcal{P}) = p^l_{j,t} + q_{j,t} - \log\left[\sum_{i=1}^{N} A_{i,t} w^l_{i,t} w^l_{i,j,t}\right],$$

where the vector of parameters:

$$\mathcal{P} = \left[e_{j,t}, q_{j,t}, p^{lt}_{j,t}, p^{eq}_{j,t}\right]$$

comprises nominal exchange rates, short-term debt quantities for issuers in fixed exchange rate regimes, prices of long-term debt, and prices of equity. To re-iterate, the share of investor i assets within asset type l that are allocated to country j at time t is:

$$w^l_{i,j,t} = \frac{\exp\left(\beta^l \mu^l_{i,j,t} + \Theta^l_{i,j,t}\mathbf{x}_{i,j,t} + \kappa_{i,j,t}\right)}{1 + \sum_{n=1}^{N} \exp\left(\beta^l \mu^l_{i,n,t} + \Theta^l_{i,n,t}\mathbf{x}_{i,n,t} + \kappa_{i,n,t}\right)}$$

The share of investor i assets allocated to asset type l is:

$$w^l_{i,t} = \frac{\left(1 + \sum_{n=1}^{N} \exp\left(\beta^l \mu^l_{i,n,t} + \Theta^l_{i,n,t}\mathbf{x}_{i,n,t} + \kappa_{i,n,t}\right)\right)^{\lambda^l} \exp\left(\alpha^l + \xi^l_{i,t}\right)}{\sum_{m=\{st,lt,eq\}}\left[\left(1 + \sum_{n=1}^{N} \exp\left(\beta^m \mu^m_{i,n,t} + \Theta^m_{i,n,t}\mathbf{x}_{i,n,t} + \kappa_{i,n,t}\right)\right)^{\lambda^m} \exp\left(\alpha^m + \xi^m_{i,t}\right)\right]},$$

and the expected return of asset j of type l for investor i at time t is defined:

$$\mu^l_{i,j,t} = \gamma^l_p p^l_{j,t} + \gamma^l_e\left(e_{j,t} - \pi_{j,t}\right) - \left(\gamma^{st}_p p^{st}_{j,t} + \gamma^{st}_e\left(e_{i,t} - \pi_{j,t}\right)\right)$$

Given any initial parameter vector $\mathcal{P}$, Newton's Method would update the price vector with:

$$\mathcal{P}' = \mathcal{P} - \mathcal{J}_H^{-1} H(\mathcal{P})$$

where $\mathcal{J}_H$ represents the Jacobian of the multivariate function H. However, rather than calculate the full Jacobian, we approximate $\mathcal{J}_H$ with its diagonal. Let $H^l_{j,t}$ denote the row of H that corresponds to the market clearing condition for asset j of asset type l in period t.

For an asset j in the short-term debt market with floating exchange rates, the diagonal element of $\mathcal{J}_H$ is:

$$\frac{\partial H^{st}_{j,t}}{\partial e_{j,t}} = -\frac{\sum_{i=1}^{N} A_{i,t}\left(\frac{\partial w^{st}_{i,t}}{\partial e_{j,t}} \times w^{st}_{i,j,t} + \frac{\partial w^{st}_{i,j,t}}{\partial e_{j,t}} \times w^{st}_{i,t}\right)}{\sum_{i=1}^{N}\left(A_{i,t} w^{st}_{i,t} w^{st}_{i,j,t}\right)} \tag{B.2}$$

where

$$\frac{\partial w^{st}_{i,t}}{\partial e_{j,t}} = \begin{cases} \lambda^{st}\beta^{st}\gamma^{st}_e w^{st}_{i,t} w^{st}_{i,j,t} - w^{st}_{i,t}\left(\sum_{m=st,lt,eq} \lambda^m \beta^m \gamma^m_e w^m_{i,t} w^m_{i,j,t}\right) & \text{if } i \neq j \\ -\lambda^{st}\beta^{st}\gamma^{st}_e w^{st}_{i,t}\left(\sum_{k\neq i} w^{st}_{i,k,t}\right) + w^{st}_{i,t}\left(\sum_{m=st,lt,eq} \lambda^m \beta^m \gamma^m_e w^m_{i,t}\left(\sum_{k\neq i} w^m_{i,k,t}\right)\right) & \text{if } i = j \end{cases}$$

and

$$\frac{\partial w_{i,j,t}^{st}}{\partial e_{j,t}} = \begin{cases} \beta^{st}\gamma_e^{st} w_{i,j,t}^{st}\left(1 - w_{i,j,t}^{st}\right), & \text{if } i \neq j \\ -\beta^{st}\gamma_e^{st} w_{i,j,t}^{st}\left(\sum_{k\neq i} w_{i,k,t}^{st}\right), & \text{if } i = j \end{cases} \tag{B.3}$$

For an asset j in the short-term debt market that is part of a currency union, the diagonal element of $\mathcal{J}_H$ is:

$$\frac{\partial H_{j,t}^{st}}{\partial q_{j,t}} = 1, \tag{B.4}$$

where we update the quantity $q_{j,t}$ of short-term debt outstanding.

For long-term debt and equity assets, the diagonal element of $\mathcal{J}_H$ is:

$$\frac{\partial H_{j,t}^{l}}{\partial p_{j,t}^{l}} = 1 - \frac{\sum_{i=1}^{N} A_{i,t}\left(\frac{\partial w_{i,t}^{l}}{\partial p_{j,t}^{l}} \times w_{i,j,t}^{l} + \frac{\partial w_{i,j,t}^{l}}{\partial p_{j,t}^{l}} \times w_{i,t}^{l}\right)}{\sum_{i=1}^{N}\left(A_{i,t} w_{i,t}^{l} w_{i,j,t}^{l}\right)} \tag{B.5}$$

where

$$\frac{\partial w_{i,t}^{l}}{\partial p_{j,t}^{l}} = \lambda^{l}\beta^{l}\gamma_p^{l} w_{i,j,t}^{l} w_{i,t}^{l}\left(1 - w_{i,t}^{l}\right) \tag{B.6}$$

and

$$\frac{\partial w_{i,j,t}^{l}}{\partial p_{j,t}^{l}} = \beta^{l}\gamma_p^{l} w_{i,j,t}^{l}\left(1 - w_{i,j,t}^{l}\right) \tag{B.7}$$

We start with an initial parameter vector $\mathcal{P}$ equal to the observed market prices and quantities, and we update the parameter vector according to:

$$\mathcal{P}' = \mathcal{P} - \left(\operatorname{diag}\left[\mathcal{J}_H\right]\right)^{-1} H\left(\mathcal{P}\right).$$

We continue to iterate until convergence.

B.4 Demand Elasticities and the Price Impact Multiplier

In this section, we derive expressions for demand elasticities with respect to price. We first derive bilateral demand elasticities for each investor-issuer country pair and then we aggregate demand elasticities for each issuer country.

The log demand by country i for country n assets in sector ℓ is given by

$$\hat{q}_{i,t}(n,\ell) = \log\left(A_{i,t} w_{i,t}(\ell) w_{i,t}(n|\ell)\right) - p_t(n,\ell). \tag{B.8}$$

Changes in the log price of assets affect the quantity of assets demanded through its influence on the across-sector weight $w_{i,t}(\ell)$, the within-sector weight $w_{i,t}(n|\ell)$, and the price of the loan itself $p_t(n,\ell)$.

To derive the elasticity of demand for a given investor i to asset n in sector ℓ, we plug equations (2), (3), (6) and (5) into equation (B.8), and differentiate with respect to price:

$$-\frac{\partial \hat{q}_{i,t}(n,\ell)}{\partial p_t(n,\ell)} = 1 - \underbrace{(1-w_{i,t}(\ell))w_{i,t}(n|\ell)\lambda_\ell\beta_\ell\phi_\ell}_{\frac{\partial \log(w_{i,t}(\ell))}{\partial p_t(n,\ell)}} - \underbrace{(1-w_{i,t}(n|\ell))\beta_\ell\phi_\ell}_{\frac{\partial \log(w_{i,t}(n|\ell))}{\partial p_t(n,\ell)}}. \tag{B.9}$$

The aggregate log demand for country n assets in sector ℓ is equal to:

$$\hat{q}_t(n,\ell) = \log\left(\sum_i A_{i,t}w_{i,t}(\ell)w_{i,t}(n|\ell)\right) - p_t(n,\ell).$$

To derive the aggregate demand elasticity for sector ℓ of country n, we take the derivative of the above expression with respect to $p_t(m,\ell)$:

$$-\frac{\partial \hat{q}_t(n,\ell)}{\partial p_t(n,\ell)} = \sum_i \left(\frac{A_{i,t}w_{i,t}(n,\ell)}{\sum_j A_{j,t}w_{j,t}(n,\ell)}\right)\left(-\frac{\partial \hat{q}_{i,t}(n,\ell)}{\partial p_t(n,\ell)}\right) \tag{B.10}$$

Equation (B.10) shows the aggregate demand elasticity for the country n sector ℓ asset is just a weighted sum of the bilateral demand elasticities of each individual investor country.

B.5 Impact of Bank Loans

In this appendix, we evaluate the role of bank lending in driving the long-run trend in dollar appreciation after the Global Financial Crisis. For some countries, banks' cross-border loans and deposits account for a large share of their external positions and can be important determinants of exchange rates. Unfortunately, the data on cross-border bank loans are not as complete and do not cover as long of a sample as the data on portfolio flows, which is why we omit them from the main analysis.

We obtain cross-border bank assets and liabilities denominated in various currencies for as many countries as possible from the BIS International Banking Statistics. We focus on the period from 2010 to 2021 due to data coverage being very sparse before 2010. For the most part, these bank loan data are provided at face value, and we therefore treat the data as measurements of the quantity of loans supplied and demanded (rather than the market value of loans). We use the destination sector of the loan to allocate assets and liabilities into different sectors. We consider loans to banks as part of the short-term debt sector and loans to non-banks as part of the long-term debt sector.

We allocate assets and liabilities to destination countries based on the currency of denomination of the loans. For example, loans that are made in U.S. dollars are cleared with other debt assets issued by the U.S. Although the BIS does provide bilateral banking statistics, the vast majority of loans are made in very few currencies, and we believe this treatment of the data provides a more accurate accounting of the demand for currencies across countries.

In our model, we add the net external position of each countries' banking sector to the market clearing condition (8):

$$PB_t(n,\ell)E_t(n)Q_t(n,\ell) = \sum_{i=1}^{N} A_{i,t}w_{i,t}(\ell)w_{i,t}(n|\ell) + PB_t(n,\ell)E_t(n)\sum_{i=1}^{N} B_{i,t}(n,\ell) + PB_t(n,\ell)E_t(n)\sum_{i=0}^{N} \widetilde{B}_{i,t}(n,\ell), \tag{B.11}$$

where $\widetilde{B}_{i,t}(n,\ell)$ represents the net external position of the banking sector of country i denominated in the currency of country n. We allocate euro denominated positions to Germany, but this assumption is irrelevant because the euro exchange rate is cleared across all countries in the European Monetary Union at once. We furthermore add an additional "outside" country represented by $B_{0,t}(n,\ell)$ that nets out the aggregate external positions of all banks in the BIS data in order for Equation B.11 to hold in equilibrium.

In our counterfactual analysis, we treat banking sector net external positions like we treat central bank reserve positions. We simply reset all banking sectors' net positions from their time t values to their time $t-1$ values, and iteratively restore changes in each country's banking sector's net external position to evaluate its impact on the dollar AFE index.

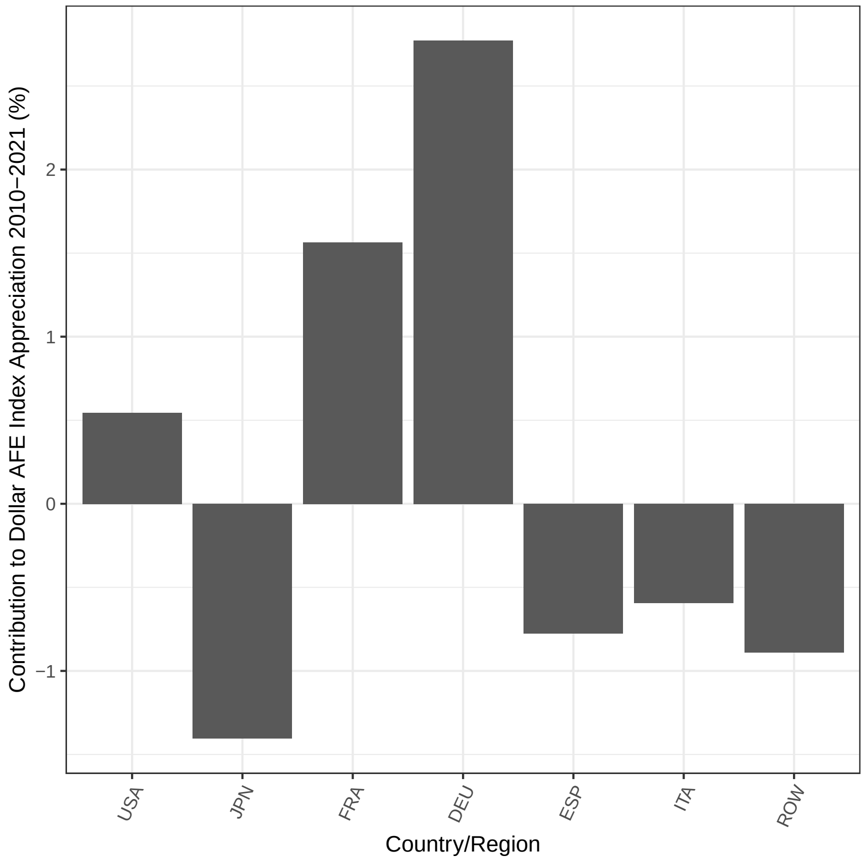
Figure B.1 shows the contribution of changes in the net positions of countries' banking sectors on the dollar AFE position from 2010 to 2021. Overall, the striking result is that the aggregate impact of changes in banking sector positions are relatively small. For example, changes in the net external positions of the German banking sector contributed around 2.5 percent appreciation of the dollar AFE index over the entire sample period. The contribution of most countries' banking sectors is less than 1 percent. These numbers are small relative to the 19.3 percent dollar appreciation relative to the trade-weighted basket of AFE currencies over this period.

The main reason for the lack of contribution of banking sector net external positions to the sustained dollar appreciation is because countries' banking sector positions tend to mean-revert. Figure B.2 shows the contribution of individual countries' banking positions to the dollar AFE index. For any given country, changes in bank external positions tend to contribute positively to dollar appreciation in one year and negatively in the following year, indicating that changes in external positions tend to fluctuate around long-run averages in the data. Thus, when we aggregate these contributions up over the full sample period, the overall effects tend to be small.

Our analysis shows that over the longer run, changes in bank sector external positions do not have a first-order effect on the level of the dollar AFE index. This does not mean that banking sector flows do not impact exchange rates in any single year. Instead, changes in banking sector net external positions seem to revolve around their long-run averages and therefore do not have a large aggregate effect over time.

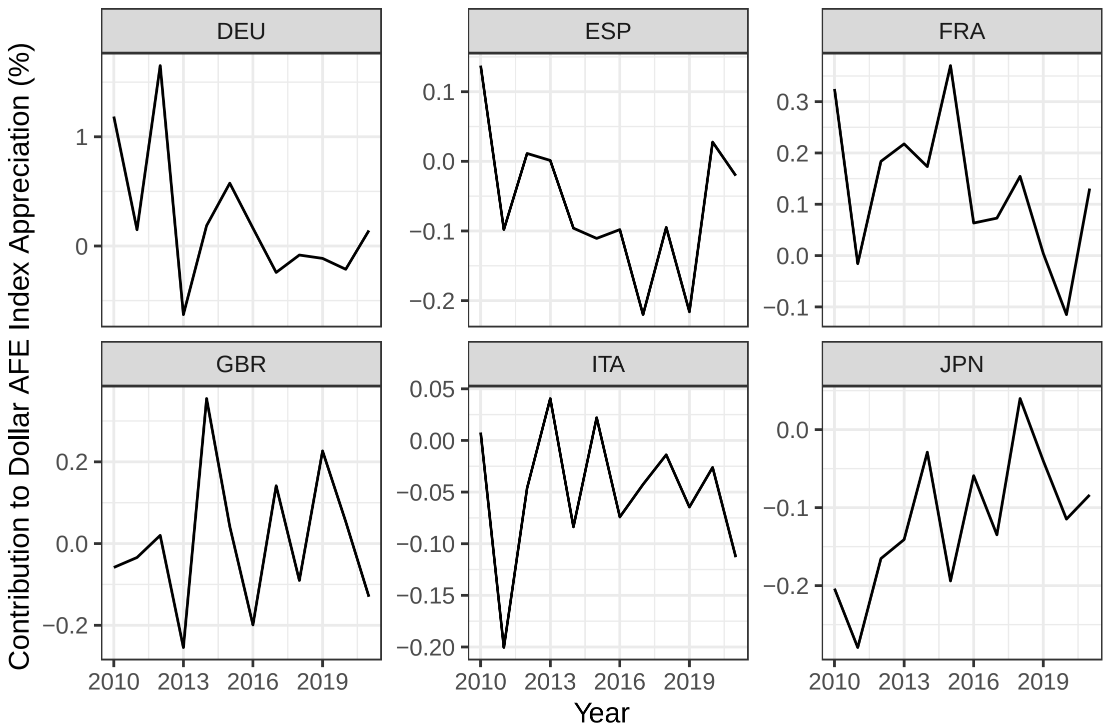
B.6 Additional Tables and Figures

Figure B.1
Contribution of Bank Loans to Dollar AFE Index 2010–2021



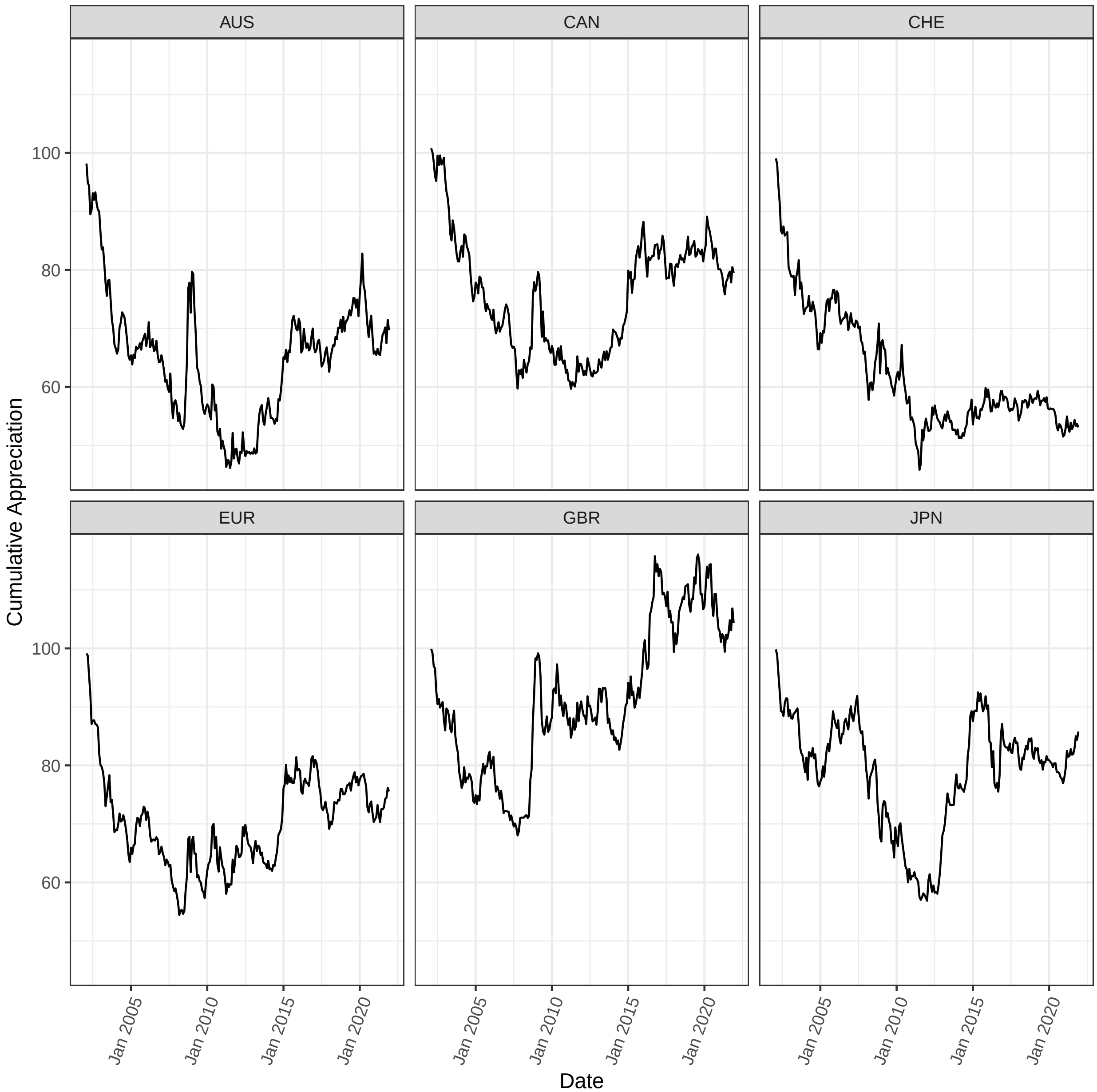
Notes: This figure presents the contribution of individual countries' bank flows to changes in the dollar AFE index over the full period 2010 to 2021. The y-axis values are in percent. Each bar represents the contribution of changes to a given country's net external loan position on the dollar AFE index over the 2010 to 2021 period. The countries explicitly shown are the ones with the largest contributions over the sample period. The "ROW" bar captures the aggregate impact of banking sectors of countries not explicitly shown.

Figure B.2
Contribution of Bank Loans to Dollar AFE Index By Year



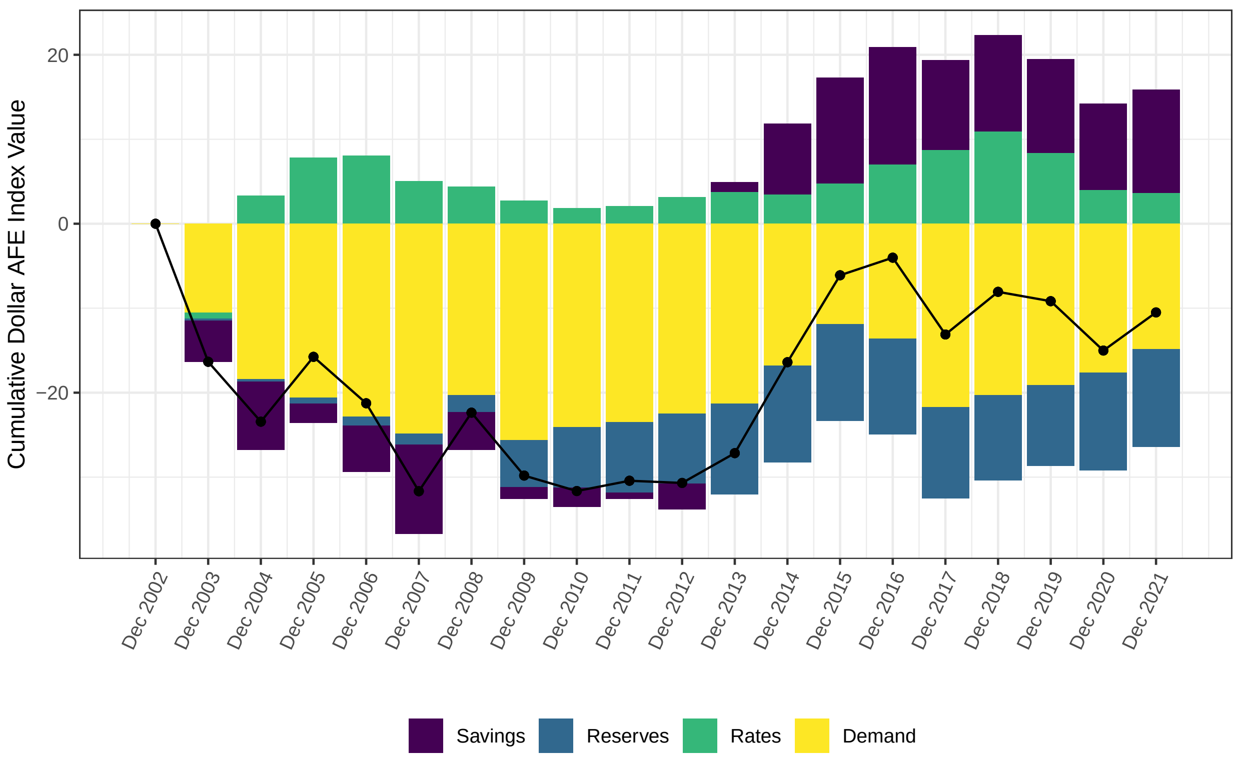
Notes: This figure presents the contribution of individual countries' bank flows to changes in the dollar AFE index year-by-year over the period 2010 to 2021. The y-axis values are in percent.

Figure B.3
Cumulative Appreciation of Dollar AFE Index Constituents



Notes: This figure presents the cumulative appreciation of the dollar against the six largest constituents of the dollar AFE index over our sample period. January 2002 is indexed to 100.

FIGURE B.4
DECOMPOSITION OF DOLLAR AFE INDEX BY YEAR



Notes: This figure presents the contribution of each block of economic primitives to the percent change in the dollar AFE index year-by-year. The total change in each year is marked by a black dot.

Table B.1
Decomposition of Dollar AFE Index By Currency (Crisis)

	AFE	EUR	CAN	JPN	GBR	CHE	AUS	SWE
Index Weight		**36.5**	**30.2**	**13.8**	**11.0**	**4.2**	**2.8**	**1.4**
Savings and Issuances								
DM Savings	5.8	8.0	5.1	3.5	6.9	0.8	2.1	4.1
EM Savings	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2
Total Savings	6.1	8.2	5.3	3.8	7.1	1.1	2.3	4.3
Monetary Policies (Reserves)								
US Reserves	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
DM Reserves	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
EM Reserves	-0.7	-1.0	-0.5	-0.6	-0.7	-0.8	-0.6	-0.5
Total Reserves	-0.7	-0.9	-0.5	-0.6	-0.7	-0.8	-0.6	-0.5
Monetary Policies (Rates)								
US Rates	-5.4	-6.1	-5.6	-1.6	-7.7	-5.7	-4.8	-7.8
EM/DM Rates	4.8	1.4	8.7	-1.0	9.7	9.5	8.4	5.6
Total Rates	-0.7	-4.7	3.1	-2.6	2.0	3.8	3.7	-2.2
Demand Shifts								
DM Demand	3.9	1.5	11.8	-21.7	22.8	-10.4	15.4	17.4
EM Demand	0.7	0.5	0.8	0.3	1.3	0.5	2.3	0.7
Total Demand	4.6	2.0	12.6	-21.4	24.1	-9.9	17.7	18.1
Total (2008)	**9.3**	**4.6**	**20.6**	**-20.8**	**32.5**	**-5.8**	**23.1**	**19.7**
Savings and Issuances								
DM Savings	3.4	5.5	-0.4	7.4	1.8	5.9	-2.6	2.4
EM Savings	-0.3	-0.3	-0.3	-0.4	-0.3	-0.3	-0.3	-0.3
Total Savings	3.0	5.2	-0.6	7.0	1.5	5.6	-2.9	2.1
Monetary Policies (Reserves)								
US Reserves	-3.1	-3.2	-2.8	-4.0	-2.9	-3.1	-2.9	-2.9
DM Reserves	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EM Reserves	-0.4	-0.4	-0.5	-0.5	-0.0	-0.8	-0.1	-0.3
Total Reserves	-3.5	-3.5	-3.2	-4.5	-2.9	-3.9	-3.0	-3.2
Monetary Policies (Rates)								
US Rates	-9.6	-9.6	-10.3	-6.9	-11.0	-9.0	-8.3	-10.5
EM/DM Rates	7.9	13.1	7.7	-6.9	17.5	-7.1	-0.7	8.8
Total Rates	-1.6	3.5	-2.7	-13.8	6.5	-16.1	-8.9	-1.7
Demand Shifts								
DM Demand	-5.9	-8.4	-9.0	12.8	-17.1	10.6	-11.0	-7.4
EM Demand	0.6	0.5	0.5	1.1	0.4	0.5	0.4	0.5
Total Demand	-5.4	-8.0	-8.4	13.8	-16.7	11.1	-10.6	-6.9
Total (2009)	**-7.4**	**-2.8**	**-15.0**	**2.5**	**-11.6**	**-3.2**	**-25.5**	**-9.6**

Notes: This table presents a detailed decomposition of the contribution of each block of economic primitives to the percent change in the dollar AFE index and its constituent currencies in 2008 (top panel) and 2009 (bottom panel). The last row of each panel presents the aggregate dollar appreciation for the year. "DM" refers to the developed market economies and "EM" refers to the emerging market economies.

Table B.2
List of Investor and Issuer Countries

Country	Region	Investor	Issuer
Australia	Asia-Pacific Developed	✓	✓
Austria	Europe Developed		✓
Belgium	Europe Developed		✓
Canada	Other	✓	✓
China	Other	✓	✓
Czechia	Other	✓	✓
Denmark	Europe Developed	✓	✓
European Union	Europe Developed	✓	
Finland	Europe Developed		✓
France	Europe Developed		✓
Germany	Europe Developed		✓
Greece	Europe Developed		✓
Hungary	Other	✓	✓
India	Other	✓	✓
Italy	Europe Developed		✓
Japan	Asia-Pacific Developed	✓	✓
Malaysia	Other	✓	✓
Mexico	Other	✓	✓
New Zealand	Europe Developed	✓	✓
Norway	Europe Developed	✓	✓
Portugal	Europe Developed		✓
Singapore	Asia-Pacific Developed	✓	✓
South Africa	Other	✓	✓
South Korea	Asia-Pacific Developed	✓	✓
Spain	Europe Developed		✓
Sweden	Europe Developed	✓	✓
Switzerland	Europe Developed	✓	✓
Thailand	Other	✓	✓
United Kingdom	Europe Developed	✓	✓
United States	United States	✓	✓

Notes: This table lists the countries in our sample, classifies them by region and marks whether each country enters as an investor or issuer country.

Table B.3
List of Central Banks in Sample

Central Bank	Region
Australia	Developed
Belgium	Developed
Canada	Developed
Chile	Emerging
China	Emerging
Czechia	Emerging
European Central Bank	Developed
Federal Reserve	Developed
Finland	Developed
Germany	Developed
Hong Kong SAR China	Emerging
Iceland	Emerging
Italy	Developed
Latvia	Emerging
New Zealand	Developed
Slovenia	Emerging
South Africa	Emerging
Sweden	Developed
Turkey	Emerging
United Kingdom	Developed

Notes: This table lists the Central Banks in our sample for which we can impute holdings data.

Table B.4
Predicting Expected Excess Returns

	DebtLong (1)	DebtShort (2)	Equity (3)
Log market-to-book	-0.46***	-9.73***	-0.11**
	(0.03)	(1.09)	(0.04)
Log real exchange rate	-0.31***	-0.32***	-0.62***
	(0.04)	(0.03)	(0.11)
Observations	580	580	580
R^2	0.26	0.26	0.11
Country fixed effects	✓	✓	✓

Notes: This table presents results from estimating equation (4). For debt, the log market-to-book ratio is minus the maturity times the yield. All specifications include country fixed effects. Standard errors are clustered by investor country and year. $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Table B.5
Demand Estimation Across Asset Classes

	(1)
λ (Short-Term Debt)	0.42***
	(0.06)
λ (Long-Term Debt)	0.22
	(0.30)
λ (Equity)	0.35***
	(0.07)
α (Long-Term Debt)	1.16
	(1.50)
α (Short-Term Debt)	-2.81***
	(0.27)
Observations	840
F-test (1st stage), λ (Short-Term Debt)	161.6
F-test (1st stage), λ (Long-Term Debt)	8.5
F-test (1st stage), λ (Equity)	67.5

Notes: This table presents results from estimating equation (10). Standard errors are clustered by investor country and year. $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Table B.6
Demand Estimation Within Asset Class

	ST Debt (1)	LT Debt (2)	Equity (3)
E[Excess Return]	48.67**	11.70	23.78***
	(21.17)	(7.75)	(6.75)
Log GDP	2.50***	2.10***	2.96***
	(0.41)	(0.28)	(0.42)
Centrality	-0.01	-0.07	-0.08
	(0.11)	(0.07)	(0.11)
Log Population	-0.59	-0.67**	-1.25**
	(0.34)	(0.26)	(0.44)
Default	-0.05	-0.32	0.13
	(0.15)	(0.20)	(0.13)
Distance	-0.70***	-0.73***	-0.66***
	(0.16)	(0.16)	(0.18)
Import Exposure	0.05	-0.03	-0.16
	(0.19)	(0.13)	(0.15)
Export Exposure	0.28	0.29**	0.59***
	(0.20)	(0.14)	(0.17)
Inflation	-0.43*	0.12	-0.10
	(0.23)	(0.10)	(0.10)
Volatility	0.04	-0.22***	-0.03
	(0.12)	(0.07)	(0.08)
Indicator: Own Country	7.40***	6.46***	5.54***
	(0.82)	(0.80)	(0.89)
Indicator: USA Issuance	1.46*	1.93**	-0.56
	(0.74)	(0.71)	(0.62)
Observations	11,960	12,099	12,180
F-test (1st stage), E[Excess Return]	77.4	122.1	287.7
Investor fixed effects	✓	✓	✓
Year fixed effects	✓	✓	✓
Developed Market fixed effects	✓	✓	✓

Notes: This table presents estimates of equation (9) separately for each asset class when we instrument for expected excess returns. The sample comprises annual data from 2002 to 2021. Default is the 5-year default probability for the sovereign debt category imputed by S&P. All specifications include investor country, year and issuer country MSCI market fixed effects. Standard errors are clustered by investor country and year. $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Table B.7
Demand Estimation Within Asset Class. First Stage.

	ST Debt (1)	LT Debt (2)	Equity (3)
Log NER Instrument	-0.002***	-0.005***	-0.009***
	(0.001)	(0.001)	(0.002)
Log Price Instrument		-0.010***	-0.015***
		(0.003)	(0.004)
Log GDP	-0.020***	-0.013	-0.083***
	(0.006)	(0.008)	(0.017)
Log Population	0.013**	0.001	0.070***
	(0.005)	(0.007)	(0.014)
Centrality	0.004**	0.007***	0.012**
	(0.002)	(0.002)	(0.004)
Default	0.001	0.023***	-0.007*
	(0.002)	(0.007)	(0.004)
Distance	0.002*	0.004**	-0.004**
	(0.001)	(0.001)	(0.002)
Import Exposure	0.000	0.001	0.001
	(0.001)	(0.001)	(0.002)
Export Exposure	0.000	0.000	-0.004
	(0.001)	(0.001)	(0.002)
Inflation	0.010***	0.008***	0.004
	(0.002)	(0.003)	(0.004)
Volatility	-0.003**	0.004	-0.001
	(0.001)	(0.004)	(0.003)
Indicator: Own Country	0.008	0.012	-0.004
	(0.005)	(0.008)	(0.008)
Indicator: USA Issuance	0.017*	-0.021	0.094***
	(0.009)	(0.012)	(0.024)
Observations	11,960	12,099	12,180
F-test (1st stage)	77.4	122.1	287.7
Investor fixed effects	✓	✓	✓
Year fixed effects	✓	✓	✓
Developed Market fixed effects	✓	✓	✓

Notes: This table presents estimates of the first stage regression of the estimation of equation (9). Standard errors are clustered by investor country and year $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$