Understanding the Strength of the Dollar*

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Abstract

We attribute variation in the strength of the U.S. dollar and its covariance with other major currencies to economic primitives using a demand system for global portfolio holdings. We take global investor savings, asset supply, and monetary policy as exogenous primitives, and show how these variables explain dollar exchange rate behavior. Prior to the global financial crisis, global savings and demand shifts explain dollar depreciation, whereas they explain dollar appreciation afterwards. Interest rates and cross-border bank loans explain short-term fluctuations in the dollar, but decline in significance over longer horizons. When explaining the dollar factor structure, we find that global savings drive common variations across foreign currencies, whereas investor demand shifts explain cross-sectional heterogeneity in dollar betas.

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

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Variation in the value of the U.S. 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 market economies, 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 quantified with data. In this paper, we make progress by providing an economically motivated decomposition of how the strength of the U.S. dollar and its covariance with other currencies are related to a set of primitive economic factors. To do so, we use a model of supply and demand for international financial assets to attribute variation in the dollar's exchange rate to a set primitive economic factors, which we take as exogenous. The model disciplines the equilibrium relation between exchange rates and the primitive economic factors, therefore allowing us to answer a number of key questions. First, do primitive economic factors explain the dollar's strength in systematic ways across business cycles? Second, do different factors reinforce or offset one another? Third, do their relative

[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%).

contributions vary over time? Fourth, which set of economic primitives are most important for explaining systematic variation in the dollar and foreign currencies' exposures to this systematic variation.

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). This approach requires us to make a number of assumptions related to identification, structural forms, and exogeneity of certain variables, but allows us to trace 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. In the model, capital flows are driven by a set of primitive economic factors. We estimate our model using a comprehensive dataset of bilateral equity and debt portfolio positions between 2002 and 2021.

We divide the model's primitive economic 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, which include 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. Then, using this approach, we study three important features of the U.S. dollar: (i) how it's level versus other currencies varies over time, (ii) what explains the variance of the dollar factor, and (iii) which factors explain the covariance of different exchange rates with the dollar factor.

We first provide a decomposition of which factors explain the value of the U.S. dollar

AFE index over time. We report our 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 is mainly explained by shifts in investors' demand, specifically from U.S. assets to foreign assets. Shifts in investor demand alone explain a 25 percentage points (pp) depreciation of the dollar index. Investor savings and asset issuances explain an additional 11 pp dollar depreciation. 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. Increasing investor savings flowing to foreign countries appreciates their currencies relative to the dollar. Finally, increasing U.S. interest rates relative to foreign interest rates counterbalanced the other factors, offsetting the dollar's depreciation by 5 pp.

In 2008, the dollar appreciated 10% against the basket of AFE currencies, which is partially explained by investor savings and asset issuances and partially explained 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 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, our model attributes the decade-long appreciation of the dollar to investor savings behavior and demand shifts. Investor savings in this period explain 14 pp of the dollar's ascent, and demand shifts towards U.S. assets explain another 11 pp. We find two notable patterns about these demand shifts. First, foreign investor 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. Finally, dollar appreciation was partially offset by the Fed's quantitative easing.

Perhaps surprisingly, our model does not attribute long-term variation in the dollar AFE index to changes in interest rate policies. The reason is that, within each of the sub-samples we study, interest rates mostly converged between the U.S. and foreign countries. That said, the interest rate differential between the U.S. and foreign countries does drive the dollar exchange rate from one year to the next, consistent with the literature on the global financial cycle (Rey 2015; Miranda-Agrippino and Rey 2020). Notably, our estimates imply that a 1pp U.S. interest rate increase 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 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, these assets become cheaper and hence more desirable, and foreign investors in our model are disproportionately more 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 explain dollar appreciation over our sample. Absent this U.S. specialness, increases in the net supply of U.S. financial assets would have faced weaker global investor demand and their relationship with the dollar exchange rate would have been less clear.

Second, 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.

Third, we also incorporate cross-border bank lending as additional capital flows into our demand system. Similar to interest rates, we show that the bank lending flows do not have strong influence on the dollar's strength over the longer horizon. The reason is that, despite the fact that the bank flows are quite volatile at the annual frequency, they tend to offset each other over longer horizons.

After presenting our decomposition of the strength of the dollar, we next study the sources of the variance of the dollar factor as well as foreign currencies' loadings on the dollar factor. This analysis is motivated by the asset pricing literature that identifies the dollar exchange rate as a systematic risk factor, which explains a large fraction of the variation in other exchange rates Verdelhan (2018). Using the same decomposition steps, we ask how the model's primitive economic variables contribute to this factor structure.

We find that savings and issuances and investor demand shifts again explain large shares (36% and 55%) of the dollar factor's variance, whereas monetary policy rates and reserve accumulation play a minor role. Therefore, the global investor savings and demand shocks contribute to not only the long-term trend in the dollar exchange rate, but also the short-term fluctuations in the dollar factor.

When studying foreign currencies' loadings on the dollar factor, i.e., their dollar betas, we find that savings and issuances only explain why foreign currencies have a positive loading on the dollar factor, whereas demand shifts explain why certain foreign currencies have a higher loading than others. In particular, when demand shifts drive asset allocation towards the U.S. and appreciate the dollar, Japan tends to be also on the receiving end of international capital flows and has a strong yen, whereas Australia tends to experience negative demand shocks and has a weak Australian dollar. This result further differentiates the roles played by savings and demand shifts in driving the exchange rate dynamics, and could help shed light on the origins of the cross-country variations in currency risk premia.

Finally, motivated by our findings of the importance of demand shifts for explaining the dollar, in the last part of the paper we study the consequences of hypothetical large-scale shifts in demand for U.S. financial assets on the value of the dollar. These results clarify the mechanism through which demand for U.S. assets impacts the dollar exchange rate within the model. 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 within the model. 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. On the other hand, a large correlated demand shock for dollar assets could lead to a much more significant depreciation of the dollar.

Underlying our novel quantification of the economic sources of variation in the dollar exchange rate are a number of assumptions. We highlight these assumptions here and discuss them further in the relevant places throughout the paper. First, our approach requires a key assumption regarding our estimates of investor countries' price elasticity of demand. We estimate this price elasticity in a manner that measures how investors substitute across countries in response to shocks to the cross-section of prices. We assume that this price elasticity also measures how investors will substitute in response to time-series shocks to prices. This is a potentially strong assumption that we hope future work on identification in international finance can improve upon. Second, we assume that our estimated demand curve coefficients are time-invariant. Third, we assume that exchange rates are determined by international portfolio flows (and bank holdings in an extension) and as specified in the model. Finally, we assume that supply of equity and long-term bond assets is exogenous and does not respond to prices. Given the nascent stage of the literature on demand system asset pricing in international finance and on exchange rates, we believe that future research can make substantial progress in relaxing these assumptions.

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 Explaining the Dollar

We now present a model of international asset demand and exchange rates. The model is designed to discipline the joint determination of exchange rates and numerous supply and demand factors, which we take as exogenous. With this structure, we are able to analyze how these forces affect key variation in the dollar exchange rate in equilibrium.

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. 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

[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 $w_{i,t}(0|\ell) = 1/(1 + \sum_{n=1}^{N} \delta_{i,t}(n, \ell))$.

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 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):

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

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

[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.

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:

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

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]

[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.

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. We assume that central bank policy is exogenous and does not respond to the components with the demand system. Endogeneity of central bank reserve policy (for example, through QE) may have important implications for exchange rate dynamics, which we leave for future research.

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. For the purposes of our decompositions of the dollar, we make the assumption that the quantity of assets outstanding in each period is exogenously determined. In some cases, this may be a fairly strong assumption, though we leave fully endogenizing the production side in the presence of heterogeneous asset demand for future work. 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.

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]

[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.

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 and 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. 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. In section Section 2 we also introduce data on cross-border banking assets and liabilities from the BIS International Banking Statistics to understand how they impact the strength of the dollar.

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, 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

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

[7] Lustig and Richmond (2020a) 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.

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 ($\ell = 3$):

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

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). By construction, latent demand is any residual variation in the investor's demand that is unexplained by expected returns and the observable characteristics in $x_{i,t}(n)$. If investors have high latent demand for a particular issuer's asset due to some unobservable asset characteristic, the price of this asset will be higher. This higher price will impact the asset's expected return and bias the estimated coefficient on expected returns, 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.

We address this identification problem in two ways. First, we employ an instrumental variables approach for cross-sectional differences in country-level expected returns for equation (9) and asset-class level desirabilities for equation (10). We construct these instruments for the endogenous components of both estimation equations by building on the identification strategy in Koijen and Yogo (2019b). Second, we conduct sensitivity analysis in Section 2.4 where we vary the elasticities across a range of plausible values from the literature and study how this affects our key findings.

The baseline identifying assumption which we use is that asset characteristics, asset supply, and investment in outside assets (investor wealth) are exogenous to latent demand:

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

In this equation, $\mathbf{x}_t$ 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. The identification approach uses the exogeneity of asset characteristics, supply, and investor wealth to construct instruments for prices. We can use the instruments for prices when estimating the within-asset-class demand curve, because expected returns are a function of prices.

The instruments we construct are the counterfactual prices, according to our model, under the assumption that investor portfolios are determined solely by the exogenous characteristics and not by expected returns. These instruments are simply non-linear functions of the exogenous variables. The identification strategy draws on a large industrial organization literature that (i) models demand as a linear function of a product's characteristics and then (ii) uses characteristics of competing products as instruments (Reiss and Wolak 2007). More recently, Gandhi and Houde (2019) argue that using characteristics of competing products as instruments in demand estimation provides a class of strong instruments as long as the characteristics provide an exogenous degree of product differentiation. We also note that, since the instruments which we construct are non-linear functions of the conditioning variables in Equation (11), they will not be correlated with latent demand itself. This is because latent demand is any residual variation in demand after controlling the observable characteristics.

Details of the Estimation Procedure. We now turn to the details of the estimation procedure. First, we construct a set of exogenous asset desirabilities which are linear combinations of exogenous characteristics. Second, we aggregate the exogenous asset desirabilities to the asset-class level, which generates instruments for estimating the cross-asset class demand equation. Third, after estimating the cross-asset class demand equation, we construct a set of hypothetical portfolio weights under the assumption that investor countries' portfolio weights are entirely functions of the exogenous characteristics. Finally, we construct instruments for exchange rates and prices using market clearing with the exogenous component of portfolio weights. We then use these instruments to estimate the within-asset-class demand curves.

We begin by constructing exogenous portfolio weights by estimating a version of the within-asset-class demand which omits the endogenous expected returns:

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

For simplicity, we use the following characteristics: bilateral distance between countries, issuer country population, an own country dummy, and investor fixed effects.[8] 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 linear combinations of the exogenous characteristics.

Next, we estimate the across-asset-class demand curves. To estimate the parameters governing the elasticity of substitution across asset classes, λ_ℓ, we need exogenous variation in the overall desirability of each asset class. We compute instruments for the overall asset level desirabilities in equation (10) by aggregating the exogenous asset desirabilities, $\hat{\delta}_{i,t}(n,\ell)$:

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

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

[8] While distance and population are clearly exogenous in this setting, it is possible that a characteristic like GDP, which is included in the final demand curve estimate, is endogenous to asset prices. To alleviate this concern, Jiang, Richmond, and Zhang (2022) show that endogenizing GDP does not substantially impact the demand elasticity estimates.

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 constructed weights are exogenous to latent demand and are calculated using Equations (1), (2), (3), and (6) 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. We also note that the characteristics of all countries enter into these model implied portfolio weights, which is the result of the term $1+\sum_{k=1}^{N}\hat{\delta}_{i,t}(k,\ell)$ summing over all of the exogenous desirabilities. As a result, our instruments are a non-linear function of all issuer country's characteristics, based upon the structure of our model. These instruments are in the spirit of a large literature in industrial organization that uses characteristics of competing products to instrument for a given product price (Reiss and Wolak 2007; Gandhi and Houde 2019). Therefore, our instruments still remain valid, despite the fact that we control for each issuer country's characteristics in the estimation of investor countries' demand curves.

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:

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

There are two things to note about this equation. First, we label values which are considered to be exogenously determined with hats. In our instrument construction, we assume that supply and the distribution of assets are exogenous.[9] Second, we omit price-to-book ratios in this specific market clearing equation as we are taking short-term interest rates as determined by countries' monetary policy — for example by following a Taylor rule.

We use the instrument for exchange rates and market clearing in long-term bonds and equities to derive our instruments for prices of equity and long-term debt:

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

This procedure identifies differences in prices and, therefore, 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-

[9] A substantial portion of the variation in both supply and assets is a function of country-level populations, which are likely to have been determined long before asset prices. It is possible to obtain exogenous cross-sectional variation in both supply and assets under management using country-level population (see Jiang, Richmond, and Zhang (2022)). Using this exogenous variation in the instrument construction does not significantly alter estimated cross-sectional elasticities.

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.[10] 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.

Discussion of assumptions and identification. To estimate the demand system and to use it to study the dollar, we need to make a number of assumptions. First, the above identification procedure imposed time fixed effects and used cross-sectional variation to identify the price elasticity of demand. As a result, the identified elasticities measure how investors substitute across countries in response to cross-sectional shocks to asset prices. We make the assumption that these price elasticities also measure substitution in response to time-series shocks to prices. One important example that is absorbed by the time-fixed effects in our estimation would be an aggregate global savings glut. Our assumption is that demand responses to this type of shock will be governed by the elasticities which we identify cross-sectionally. In equities, there is an emerging literature which is making progress on the measurement prices elasticities with respect to aggregate equity market shocks (Gabaix and Koijen 2021). Given this emerging literature, we hope that future work can make further progress on the identification and measurement of elasticities in international financial

[10] 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%.

markets and in particular for exchange rates.

Second, we assume in our decompositions that asset supply is exogenous and does not respond to prices. For example, the savings glut mentioned above has been used in narratives to explain the large issuance of MBS issuance prior to the global financial crisis. An important direction for future research is to fully endogenize model elements like asset supply, monetary policy, and reserves policy in order to jointly study asset demand and the production side of the global economy.

2 A Decomposition of Dollar Exchange Rates

In this section, we use our estimated demand system to provide a model-based decomposition of key moments of U.S. dollar based exchange rates. We take savings, asset supply, and monetary policy as exogenous primitives, and trace out how these forces explain the dollar's dynamics through market clearing in global asset markets. Specifically, we use the model to provide a decomposition from 2002 to 2021 of the dollar's level versus other currencies, the variance of the dollar factor, and its covariance with other major currencies. We describe our decomposition methodology in Section 2.1, and then present the main results in Section 2.2 and Section 2.3. We present robustness in Section 2.4 where we study how our results vary with the underlying demand elasticities in the model.

2.1 Decomposition Overview

We decompose changes in the exchange rates between year $t-1$ and t by first setting all primitive exogenous variables in our model 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, including exchange rates, in the baseline step are simply the $t-1$ values. We then sequentially restore each primitive variable to its year-t value, and recompute exchange rates at each step using market clearing.[11] At each step j we denote the equilibrium dollar exchange rate for country n by $E_t^j(n)$. 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. By construction, our model attributes 100% of the variation in exchange rates to the primitive exogenous variables, so any predictability of these variables implies predictability of exchange rates in the demand system. We use this decomposition of dollar-based exchange rates to study the level of the dollar AFE index, variance of the dollar factor, and covariance of exchange rates with the dollar factor in the following section.

Before providing the actual decompositions, we describe the sequence of steps we use. Our labeling of the primitive variables is motivated by various literatures that study the drivers of exchange rate movements and international capital flows. Broadly, 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, we are able to study the effects of the excess savings that are not satiated by local investment opportunities (i.e. savings gluts, Bernanke 2005).

When we restore changes in investor savings from year to year, these additional assets under management are allocated according to the investors' existing demand curves. Thus, the savings and issuances component also informs us about how much of variation in the dollar is explained by the more permanent, unconditional country characteristics.

[11] Appendix B.3 provides computational details.

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 changes in variables that shift investors' asset demand curves year by year. These variables include country characteristics $\mathbf{x}_{i,t}(n)$, within-asset-class latent demand $\kappa_{i,t}(n, \ell)$, and across-asset-class latent demand $\xi_{i,t}(\ell)$. This step accounts for changes in the relative desirability of assets that arise from changes in country 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).

Cross-border Bank Loans and Deposits. After presenting our main decomposition of the impact of portfolio flows on the dollar AFE index, we augment our analysis with cross-border bank balance sheet data and study the impact of cross-border bank flows. We do not include the analysis of the banking flows in the main analysis, because the bank balance sheet data is limited to a shorter sample. We provide details of how we account for bank holdings data at the end of Section 2.2.

2.2 Decomposition of the Strength of the Dollar

We begin by studying the model based decomposition of the level of dollar exchange rate over the last two decades. We report cumulative log changes in the dollar advanced foreign economy (AFE) index, denoted by $\Delta \overline{e}_t$, at each step of the decomposition. The dollar AFE index weights are obtained from the Federal Reserve Board (FRB) and our weighting scheme follows that of the FRB. Our main results focus on the dollar advanced foreign economy

(AFE) index; we provide a decomposition of the dollar emerging economy (EME) index in Appendix Section B.5.

Let $\Delta\overline{e}_t^j$ denote the difference in the log of the implied dollar index between the $(j-1)$-th step and the j-th step:

$$\Delta\overline{e}_t^j = \overline{e}_t^j - \overline{e}_t^{j-1}. \tag{14}$$

The sum of $\Delta\overline{e}_t^j$ across all J steps is equal to the actual log change in the dollar in period t: $\sum_{j=1}^{J} \Delta\overline{e}_t^j = \Delta\overline{e}_t$. We aggregate each step's incremental contribution over various sub-periods:

$$\overline{e}^j = \sum_{t=1}^{T} \Delta\overline{e}_t^j, \tag{15}$$

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

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 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 each set of variables contributed to the dollar's exchange rate movement over time.

Savings and Issuances. Starting with the block capturing investor savings and asset issuances, we find that savings and issuances explain notable dollar depreciation before the financial crisis, but these factors explain dollar appreciation during and after the crisis. Recall, changes in investor savings are allocated towards different countries based on the time $t-1$ estimate of the demand curve. Shifts in the contribution of savings and issuances to the dollar AFE index often capture changes in the savings rates of different countries. Thus, to understand the shift in the explanatory power of savings and issuances, 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 generates a decline in the prices of U.S. financial assets, which attracted foreign investors to allocate their wealth towards U.S. issued assets. Global investor demand for U.S. assets is particularly strong given the unique immutable characteristics U.S. financial assets (e.g., that they are often safer and more liquid than assets issued elsewhere). These capital flows toward U.S. assets led to U.S. dollar appreciation over all four periods. In this way, our model consistently attributes dollar appreciation to the observed changes in U.S. savings and issuances.

By contrast, foreign countries' savings and issuances explain different dollar AFE index behaviors before and after the crisis, with Europe demonstrating a particularly stark shift. This change in the role of European savings and issuances largely accounts for the time variation in the aggregate contribution of the savings and issuances block to the dollar exchange rate. Prior to the crisis, Europe had high savings relative to their issuance. Given that investors exhibit home bias in their demand curve, high European savings rates generated high demand for euro-denominated short-term debt. This high demand for euro-denominated financial assets accounts for dollar depreciation against the euro. After the Global Financial 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 savings and issuances of developed market economies always explain more of the variation in the dollar exchange rate when compared to emerging market economies. 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. Figure 1 shows central banks' reserve accumulation account for moderate dollar depreciation during and after the financial crisis, but only 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 within our model substituted away from holding U.S. financial assets, leading to a depreciation of the U.S. dollar. In this way, quantitative easing behaves like a negative issuance shock to the U.S. assets. 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. Monetary policy rates explain dollar appreciation 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 attributed to the policy 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 pp 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 pp U.S. monetary policy shock (Curcuru et al. 2017).

Thus, changes in the U.S. policy rate account for dollar appreciation from 2010 to 2018 and dollar depreciation 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.3.

Demand Shifts. The role of investor demand shifts has the most dynamic pattern according to our model. Changes in demand curves explain dollar depreciation before the crisis, dollar appreciation in 2008, dollar depreciation in 2009, and finally dollar appreciation after the crisis. Most of these demand shifts were driven by developed market (DM) investors, as we would expect given their large shares in the global distribution of financial wealth.

Specifically, our decomposition attributes the dollar depreciation before the crisis to 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 a strong flight-to-safety motive led to dollar appreciation. 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 explained 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 even 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.

Figure 3 presents model-implied exchange rate movement attributed to shifts in U.S. and foreign investor demand from one year to further clarify how changes in demand explain the dollar exchange rate. 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 explains a depreciation of foreign currencies and therefore an appreciation of the dollar, whereas stronger foreign demand for U.S. assets explains 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.

Cross-border Bank Loans and Deposits. For some countries, the cross-border loans and deposits in banking sector can account for a large share of their external positions. Similar to the cross-border portfolio flows we study above, they can also be an important determinant of exchange rates. Unfortunately, the data on cross-border bank loans are not as complete as the data on portfolio flows, as data coverage is sparse before 2010. Thus, in this section, we evaluate the role of bank lending in explaining the long-run trend in dollar appreciation from 2010 to 2021.

We obtain cross-border bank assets and liabilities denominated in various currencies for as many countries as possible from the BIS International Banking Statistics. For the most part, these bank loan data are provided at face value, and we therefore treat the data as measurements of the quantities of loans supplied and demanded rather than market values. We classify the asset classes of the loans based on their destination sectors: we assume that the loans to banks are short-term debt and are cleared with other short-term debt assets, and we assume that the loans to non-banks are long-term debt and are cleared with other long-term debt assets.

We allocate assets and liabilities to destination countries based on the loans' currency of denomination. 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 country's banking sector to the market clearing condition (8):

$$\begin{aligned} PB_t(n,\ell)E_t(n)Q_t(n,\ell) = \sum_{i=1}^{N} A_{i,t}w_{i,t}(\ell)w_{i,t}(n|\ell) + PB_t(n,\ell)E_t(n)\sum_{i=1}^{N} B_{i,t}(n,\ell) \\ + PB_t(n,\ell)E_t(n)\sum_{i=0}^{N} \widetilde{B}_{i,t}(n,\ell), \end{aligned} \tag{16}$$

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 further add an "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 Eq. (16) to hold in equilibrium.

In our counterfactual analysis, we treat the banking sector's 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 net external position to evaluate its impact on the dollar AFE index.

Figure 4 shows the contribution of changes in the net positions of countries' banking sectors on the dollar AFE index from 2010 to 2021. Strikingly, the aggregate impact of the changes in banking sector positions are relatively small. For example, changes in the net external positions of the German banking sector only explain around 2.5 percent appreciation of the dollar AFE index over the 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 long-term explanatory power of banking sector flows on the dollar is because the banking sector's positions tend to mean-revert. Figure 5 shows the contribution of individual countries' banking positions to the dollar AFE index year by year. For any given country, changes in bank external positions tend to explain dollar appreciation in one year and dollar depreciation 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.

To conclude, these results do not imply 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.

2.3 Decomposition of the Dollar's Variance and Factor Loadings

Up until this point, we used our model to study changes in the level of the dollar, which was motivated by its historic rise in the decade following the Global Financial Crisis. In this section, we study features of the U.S. dollar that relate to its importance in international asset pricing.

The dollar is particularly important in the foreign exchange markets because its systematic variation explains a substantial portion of the variation in other currencies Verdelhan (2018). Given this, we study two key questions: First, what drives systematic fluctuations in the dollar? Second, what explains the heterogeneous exposures that different foreign currencies have on this systematic variation in the dollar? To study these questions, we follow Lustig, Roussanov, and Verdelhan (2011) and Verdelhan (2018) and define the dollar factor $\Delta\overline{e}_t$ as the *equal-weighted* average of the dollar exchange rate movements against the currencies of both advanced foreign economies (AFE) and emerging market economies (EME).

Dollar Variance. We begin by asking which primitive variables in our model explain the variance of the dollar factor. Here, $\Delta\overline{e}_t^j$ denotes the log change in the equal-weighted dollar factor from step $j-1$ to step j: $\Delta\overline{e}_t^j = \overline{e}_t^j - \overline{e}_t^{j-1}$, and the sum of $\Delta\overline{e}_t^j$ across all J steps is equal to the actual dollar factor in period t: $\sum_j \Delta\overline{e}_t^j = \Delta\overline{e}_t$. We therefore decompose the dollar factor's variance as

$$var(\Delta\overline{e}_t) = cov(\Delta\overline{e}_t, \sum_j \Delta\overline{e}_t^j) = \sum_j cov(\Delta\overline{e}_t, \Delta\overline{e}_t^j).$$

We attribute the dollar factor's variance to the J steps explained by different primitive variables:

$$1 = \sum_j \frac{cov(\Delta\overline{e}_t, \Delta\overline{e}_t^j)}{var(\Delta\overline{e}_t)}.$$

By construction, the contributions of all steps sum to one. If a given step j has a large contribution, then, this step generates dollar exchange rate movements that are aligned with the actual dollar factor.

Table 2 reports the results of this decomposition. The salient feature of this decomposition is that savings and issuances (from developed markets in particular) and investor demand account for the largest share of the dollar factor's variance over time. Monetary policy rates and reserve accumulation play a minor role. Therefore, global investor's savings and demand shocks contribute to not only the long-term trend in the dollar exchange rate, but also the short-term fluctuations in the dollar factor.

Dollar Betas. Next, we study which primitive variables account for foreign currencies' exposures to the dollar factor, as well as to the dispersion in these exposures. In Panel A of Table 3, we regress log foreign currency changes on the dollar factor and report the slope coefficient and the R-squared.[12] As Verdelhan (2018) shows, there is substantial heterogeneity in the loadings and R-squared values, even across developed markets. Furthermore, Lustig and Richmond (2020b) show that variation in these dollar factor loadings are closely related measures of physical and cultural distance between countries. For example, while Japan has a dollar beta of 0.18, Australia has a dollar beta of 1.97. As a result, when the dollar factor strengthens, the Japanese yen also tends to appreciate against the Australian dollar. In this sense, the dollar factor also explains bilateral exchange rate movements between two foreign currencies.

We use our model's decomposition to shed light on the origins of this heterogeneity in dollar betas, which is defined as the slope coefficient in the regression of each foreign currency's log exchange rate movement against the dollar $\Delta e_t(n) = \Delta \log E_t(n)$ on the dollar factor $\Delta \overline{e}_t$. We use $\Delta e_t^j(n) = e_t^j(n) - e_t^{j-1}(n)$ to denote the bilateral exchange rate movement in the j-th step of our decomposition. Then, we decompose the factor loading as

$$\beta(n) = \frac{cov(\Delta \overline{e}_t, \Delta e_t(n))}{var(\Delta \overline{e}_t)} = \frac{cov(\Delta \overline{e}_t, \sum_j \Delta e_t^j(n))}{var(\Delta \overline{e}_t)} = \sum_j \frac{cov(\Delta \overline{e}_t, \Delta e_t^j(n))}{var(\Delta \overline{e}_t)}.$$

Panel B of Table 3 reports the contribution to the factor loading at each step, i.e., $\frac{cov(\Delta \overline{e}_t, \Delta e_t^j(n))}{var(\Delta \overline{e}_t)}$ where the first column represents the average contribution to the seven major foreign currencies we consider. This column shows that savings and issuances explains a

[12] When studying the exposure of a given country's exchange rate to the dollar factor, we always omit that currency in the construction of the dollar factor itself, including in the following decompositions.

loading of 0.53 on the dollar factor on average, reserve accumulation explains an increase in the loading to 0.03, monetary policy rates give rise to 0.18, and demand shifts give rise to 0.50. Similar to what we learned about the dollar's strength and the dollar factor's variance, savings and issuances and demand shifts most closely relate to the average loadings on the dollar factor.

When we focus on accounting for the cross-sectional dispersion in foreign currencies' exposures to the dollar factor, the demand shifts stand out. The demand shifts increase the Australian dollar's exposure to the dollar factor by 1.12, but they decrease the Japanese yen's exposure to the dollar factor by -0.30. Intuitively, the demand for U.S. assets tends to increase during global recessions, which tend to coincide with capital outflows from Australia and capital retrenchment into Japan. As a result, when the dollar factor strengthens, the Australian dollar tends to depreciate against the dollar, whereas the Japanese yen tends to stay flat against the dollar.

Our results help to clarify potential origins of the factor structure in exchange rates. This factor structure has been studied under different theoretical frameworks such as size (Hassan 2013), export composition (Ready et al. 2017), trade centrality (Richmond 2016), and fiscal condition (Jiang 2021). Using a more reduced-form approach, Hassan and Mano (2019) also shows the special role played by the dollar in understanding the currency factor structure. Our decomposition differentiates between how long-term differences versus year-to-year changes in characteristics explain currency covariances, especially with respect to the dollar factor.

Specifically, the savings and issuances step takes the demand curve as given, and measures how the exchange rate varies as investors' saving behavior varies over the business cycle. Our decomposition shows that this step largely explains the U.S. dollar moves against the average foreign currency. On the other hand, shifts in demand curves are largely responsible for the heterogeneity in different foreign countries' loadings on the dollar factor. In this way, Table 3 shows how the static and the time-varying features of the asset demand curve contribute to the level and the cross-country heterogeneity of the dollar beta. We believe this methodology provides a starting point for future research to clarify how asset demand curves can explain different features of currency risk.

2.4 Decompositions with Varying Demand Elasticities

In this section, we study how our findings vary as we scale the underlying demand elasticities in the model. These results provide further insight into the mechanism through which our model decompositions operate and help to alleviate potential concerns about estimation and identification procedure we detail in Section 1.3. To study how variation in the underlying demand elasticities impact our results, we perturb the coefficient on expected returns systematically up and down, and then we recompute each of our decompositions of the dollar AFE index. For each perturbed coefficient on expected returns, we re-estimate the remaining demand curve parameters.

The top panel of Figure 6 presents the decomposition of the dollar exchange rate movement under different demand elasticities, while the bottom panel presents corresponding coefficients on expected returns in the demand curves (top 3 figures) along with the implied demand elasticities (bottom 3 figures).[13] 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 speaking, the qualitative features of the results are similar to our baseline estimates.

As we increase the elasticity of demand, our decomposition tends to attribute more of the changes in the dollar AFE index to changes in demand (yellow bars) and less to changes in savings (purple bars). An increase in the demand elasticity means small changes in prices explain larger changes in portfolio weights. When global investors have more elastic demand

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

curves, only small prices movements are needed to clear financial markets after changes in savings in issuances. As a result, savings and issuances tend to explain a small share of the changes in the dollar exchange rate. However, the change in the amount of variation explained by savings and issuances between the most elastic and least elastic demand curves is small over the whole sample period, and we conclude that changes in savings and issuances across countries continues to play an important role in determining the value of the dollar.

Figure 7 presents the results for our variance decomposition of the dollar factor where e scale the elasticity of demand and show how the share of the variance in the dollar factor explained by each set of variables changes. Similar to the exercise decomposing the dollar AFE index, Figure 7 shows the share of variation explained by savings and issuances decreases in magnitude as demand becomes more elastic. The share of variation explained by shifts in the demand curve increases. Nevertheless, the factors that explain the largest share of variation in the dollar factor continue to be savings and issuances and shifts in demand.

Finally, Figure 8 shows how different factors explain the average loading of the seven major currencies we consider in Table 3. Similar to the other exercises, the contribution of savings and issuances declines as we systematically increase the elasticity of demand and the role of demand shifts increases. Nevertheless, global investor savings and changes in demand curves continue to explain the bulk of the average covariance between the exchange rates of the seven major currencies in our sample and the dollar factor.

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

Our results so far suggest that investors' demand shifts play an important role in the dollar's exchange rate dynamics, even after we account for investor savings, asset issuances, and monetary policy stances. While our approach does not allow us to trace out the origins of these demand shifts, we can further shed light on how counterfactual changes in demand for U.S. assets impacts the dollar exchange rate within the context of our stylized model. We conduct two counterfactual exercises in this section. Studying these hypothetical demand shifts from the lens of our model provides a benchmark for understanding the magnitude of demand shifts needed to potentially influence the dollar.

The first hypothetical scenario we consider is one in which a large country, such as China, unilaterally sells all its U.S. assets because it finds the U.S. assets unappealing relative to other assets. Starting with our end-of-sample data from $t = 2021$, we compute equilibrium portfolio holdings and exchange rates assuming one country's investors and central bank reallocate their entire U.S. asset holdings to other countries' assets. 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 further 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 9 shows the change in the value of the AFE dollar index according to our model 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%.[14] If Japan, Canada, or Switzerland disposes of its U.S. assets, the dollar will depreciate by less than 1%.

These impacts on the dollar AFE exchange rate are surprisingly small, which highlights an important feature of our model: Under existing estimates of demand curves, the demand for U.S. dollars from international investors is strong enough to absorb large unilateral sales of U.S. assets. For example, if the European Monetary Union offloads its entire portfolio holdings of U.S. assets, other countries within the model will increase their positions in U.S. assets by 10 to 30 percent.

While it is appealing to draw policy conclusions from this result, we caution that understanding the underlying driver of the demand shift is the key. For example, China's decision

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

to sell its U.S. assets could be driven by underlying economic or political factors that could also impact the saving patterns, the monetary policy stances, and the demand shifts for countries all over the world. In reality, China's sell off might not happen in isolation, but could be accompanied or followed by actions from other countries. What we report here in this exercise is the impact of this unilateral sale in isolation, which, in our opinion, is more about shedding light on the nature of the investors' substitution patterns than about providing a realistic policy scenario.

In order for our model to generate a large dollar depreciation, we need to induce correlated sales of U.S. assets. Our results in Section 2.2 show that demand shifts away from U.S. assets in the pre-crisis period explain a 25% depreciation of the U.S. dollar from 2002 to 2007. A natural question is what would happen to the current dollar's value if it experiences demand shifts similar to those in the pre-crisis period. In our second counterfactual exercise, 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. These correlated shifts in demand away from U.S. assets across many countries results in a depreciation of the U.S. dollar of more than 25 percent.

The results of these two counterfactuals show that our model maintains a relatively stable value of the U.S. dollar under idiosyncratic shifts in demand while allowing for larger exchange rate fluctuations when shifts in demand are correlated across countries. From a broader theoretical perspective, the ability for global investors to absorb U.S. assets under idiosyncratic demand shifts is precisely what is required to maintain a stable reserve currency (e.g., Farhi and Maggiori (2017); He, Krishnamurthy, and Milbradt (2019)).

4 Conclusion

In this paper, we use a portfolio-based demand system to relate key moments of dollar exchange rates to primitive economic factors. Our estimates uncover significant structural changes in the nature of the investors' excess savings and demand shifts before and after the financial 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. Importantly, 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.

While our results confirm some of the existing narratives about the dollar's strength and specialness, they also highlight the importance of further studying investors' portfolio decisions and their underlying drivers in different economic environments. Furthermore, our results rely on a assumptions regarding exogenous asset supply and monetary policy, as well as assumptions about how investors substitute in response to cross-sectional and time-series shocks to prices. We hope that future work can relax these assumptions in order to shine additional light on the drivers of the dollar exchange rate.

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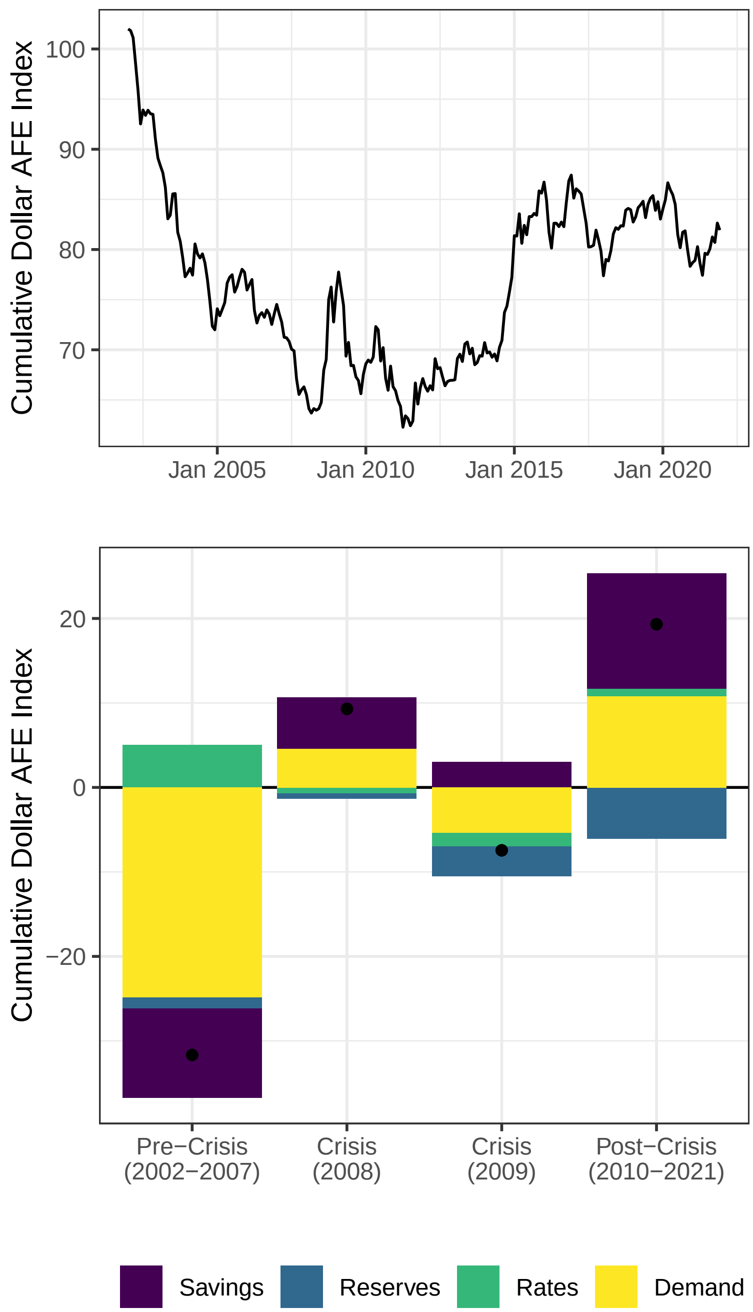
Tables and Figures

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 (e.g., 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.

Table 2
Decomposition of Variance of Dollar Factor

	Share of Variance
Savings and Issuances	
DM Savings	0.40
EM Savings	-0.05
Total Savings	0.36
Monetary Policies (Reserves)	
US Reserves	0.02
DM Reserves	0.00
EM Reserves	0.00
Total Reserves	0.02
Monetary Policies (Rates)	
US Rates	0.06
EM/DM Rates	0.01
Total Rates	0.07
Demand Shifts	
DM Demand	0.42
EM Demand	0.13
Total Demand	0.55

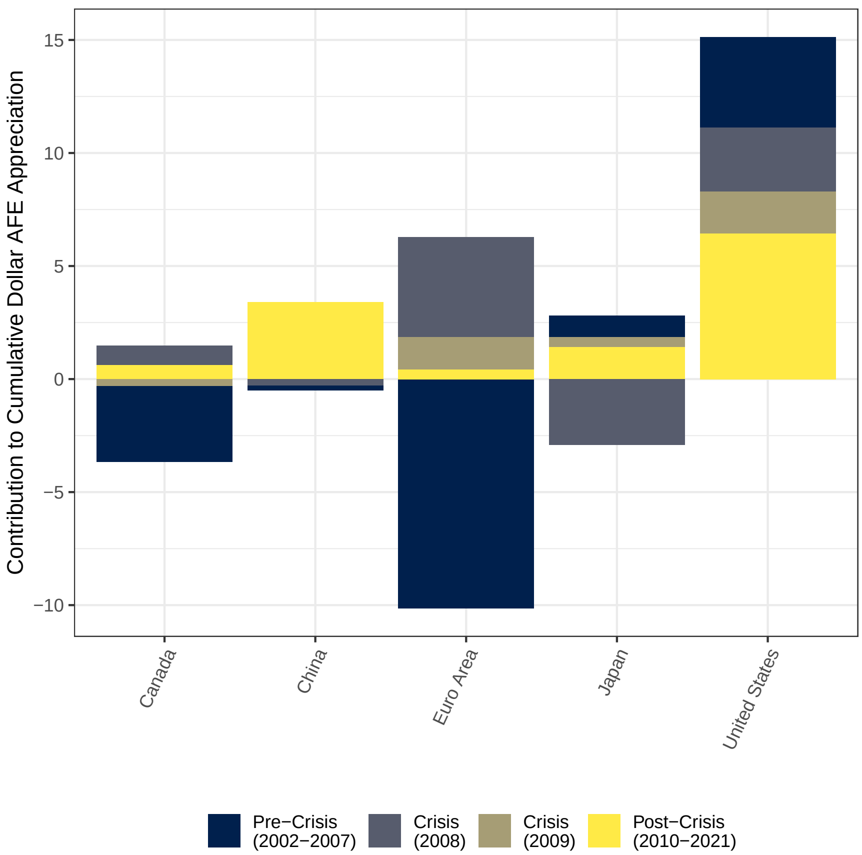
Notes: This table presents a detailed decomposition of the variance of the dollar factor. We follow Verdelhan (2018) to define the dollar factor $\Delta \bar{e}_t$ as the equal-weighted average of the dollar exchange rate movements against the currencies of both advanced foreign economies (AFE) and emerging market economies (EME). All numbers are in percentage units. We group economic factors into four blocks — the last row within each block presents the contribution of all variables within that block. The sum of the last rows of each block equals 100 percent. “DM” refers to the developed market economies and “EM” refers to the emerging market economies.

Table 3
Decomposition of Covariance with Dollar Factor

	Average	AUS	CAN	CHE	DEU	GBR	JPN	SWE
Panel A: Dollar Base Factor Regressions								
Loading	1.24	1.97	1.41	0.68	1.16	1.40	0.18	1.84
R-squared	0.53	0.73	0.64	0.40	0.59	0.56	0.01	0.82
Panel B: Decomposition of Dollar Factor Loadings								
Savings and Issuances								
DM Savings	0.46	0.50	0.52	0.41	0.48	0.50	0.24	0.57
EM Savings	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.06
Total Savings	0.53	0.56	0.58	0.47	0.55	0.57	0.32	0.63
Monetary Policies (Reserves)								
US Reserves	0.03	0.02	0.02	0.03	0.03	0.02	0.04	0.02
DM Reserves	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EM Reserves	0.00	0.00	0.01	-0.01	-0.01	-0.01	0.00	0.01
Total Reserves	0.03	0.02	0.03	0.02	0.02	0.01	0.04	0.04
Monetary Policies (Rates)								
US Rates	0.06	0.05	0.09	0.03	0.04	0.07	0.08	0.05
EM/DM Rates	0.12	0.22	0.05	0.33	-0.07	0.06	0.05	0.22
Total Rates	0.18	0.27	0.15	0.36	-0.02	0.12	0.13	0.27
Demand Shifts								
DM Demand	0.47	1.02	0.63	-0.18	0.60	0.67	-0.30	0.89
EM Demand	0.03	0.10	0.03	0.00	0.02	0.03	-0.01	0.02
Total Demand	0.50	1.12	0.66	-0.18	0.61	0.70	-0.30	0.91

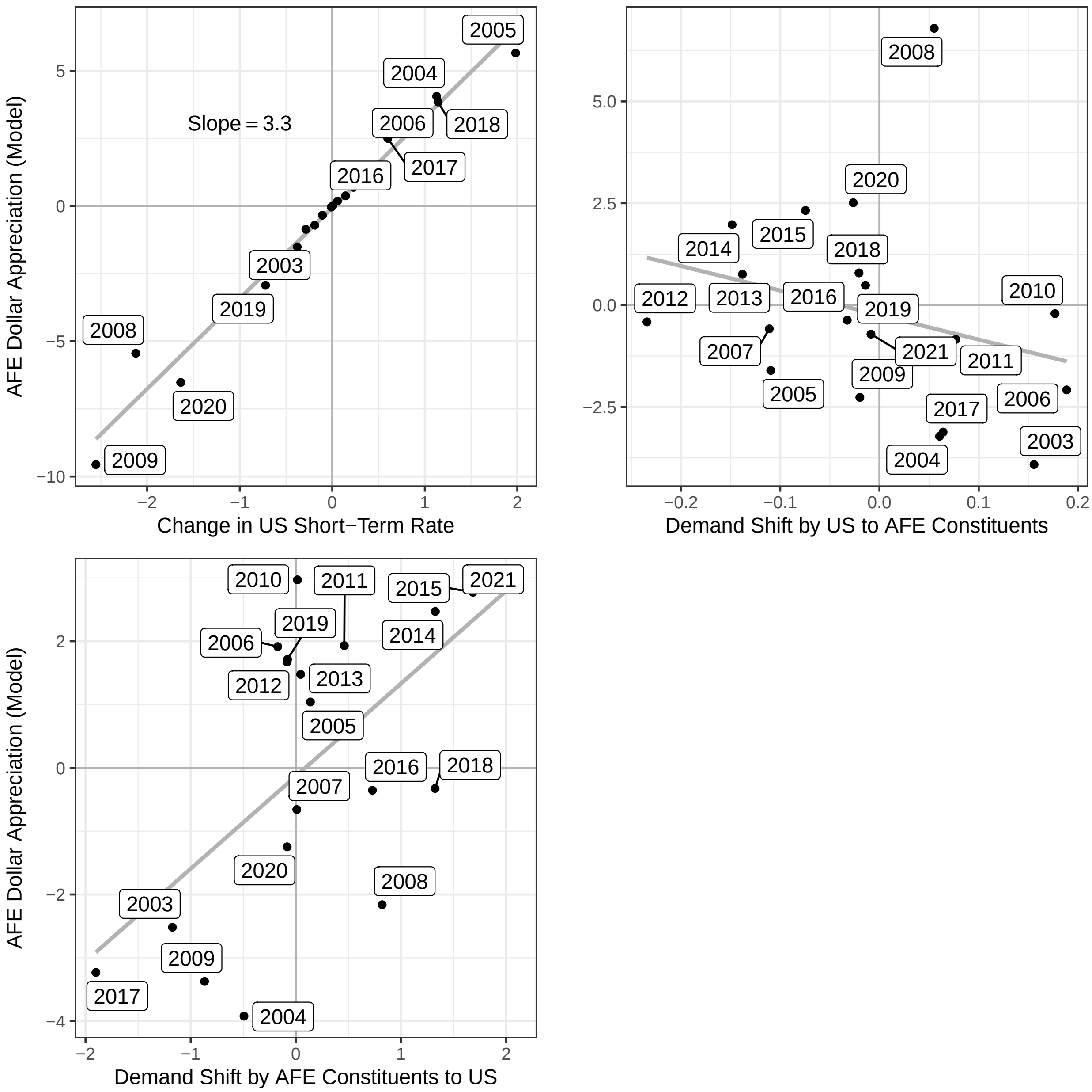
Notes: Panel A presents the loading of each currency on the dollar factor along with the share of variation in the currency explained by the dollar factor. Panel B presents a detailed decomposition of the factor loadings. The first column presents the average loading of the seven major currencies in our sample on the dollar factor and the decomposition into the economic primitives. The remaining columns show the decomposition of the individual currencies. We group economic factors into four blocks — the last row within each block presents the contribution of all variables within that block. The sum of the last rows of each block equals the factor loading from Panel A. "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.

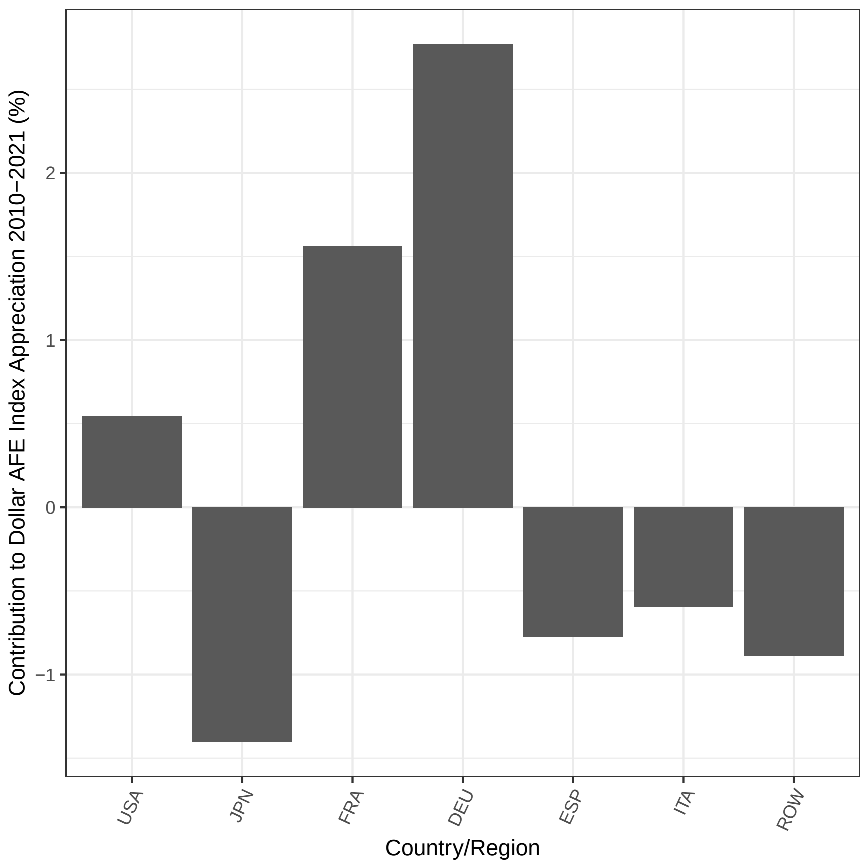
Figure 3
Dollar AFE Index Appreciation Mechanisms



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.

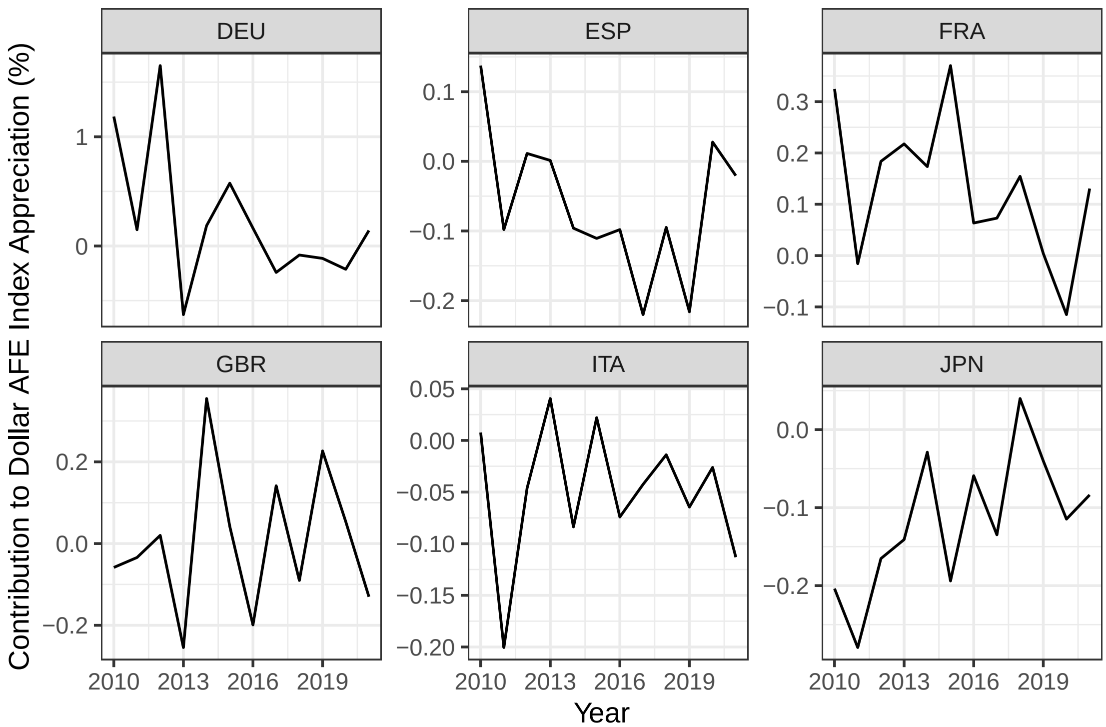
Figure 4

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 from 2010 to 2021. The y-axis values are in percentage points. Each bar represents the contribution of changes to a given country's net external loan position to 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 5
Contribution of Bank Loans to Dollar AFE Index By Year



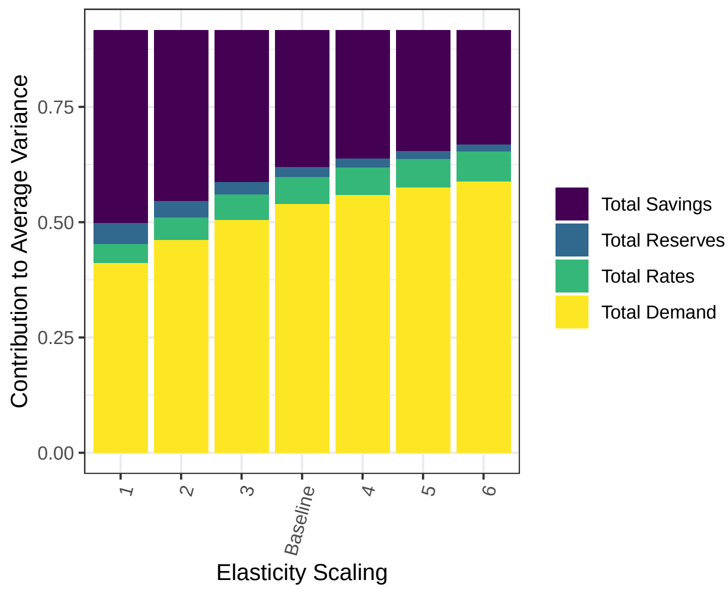
Notes: This figure presents the contribution of individual countries' bank flows to changes in the dollar AFE index year-by-year over the period 2010 to 2021. The y-axis values are in percent.

Figure 6

Trend Decomposition of AFE Index for Different Demand Elasticities

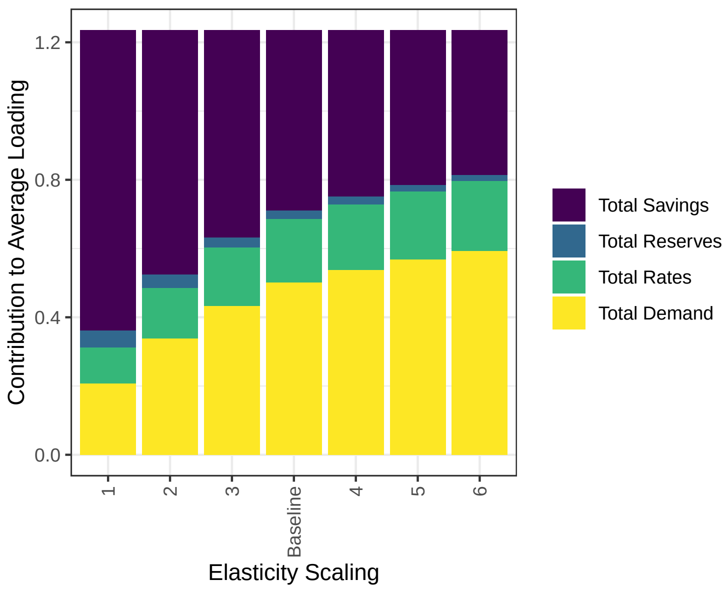
Notes: This figure shows the robustness of our decomposition to variation in estimates of asset demand elasticities. The top panel presents the decomposition of the change in the dollar AFE index in each sub-period across the different parameterizations for demand elasticities. The "Baseline" specification 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 7
Variance Decomposition of the Dollar Factor for Different Demand Elasticities



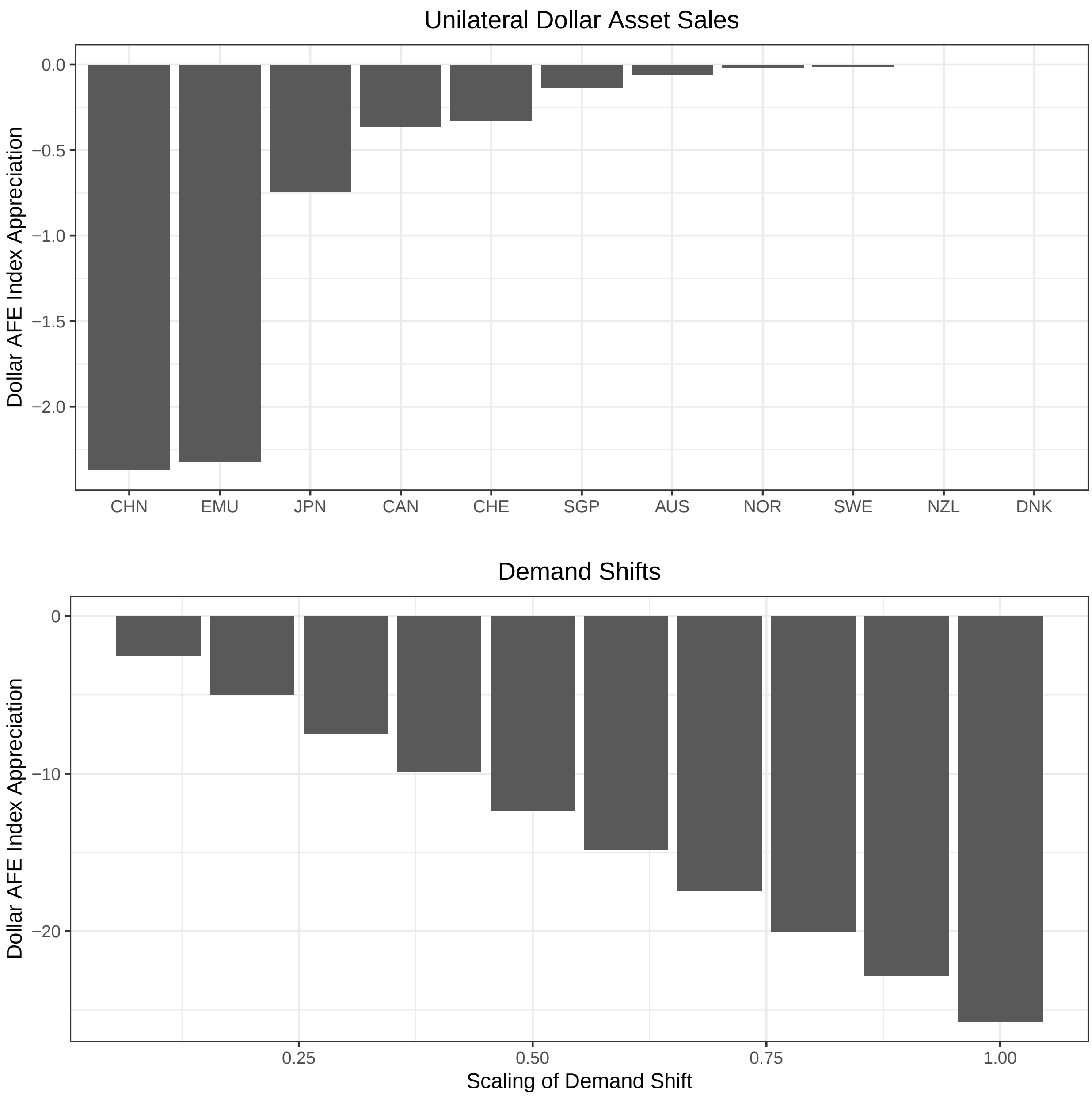
Notes: This figure shows the robustness of our decomposition of the variance of the dollar factor to variation in estimates of asset demand elasticities. Each panel shows how the share of explained variation changes as we systematically increase the demand elasticities. The "Baseline" specification re-iterates the results shown in Table 2. The six alternative parameterizations scale the demand elasticities in all asset classes up and down as shown in the bottom panel.

Figure 8
Decomposition of Covariance with the Dollar Factor for Different Demand Elasticities



Notes: This figure shows the robustness of our decomposition of the average covariance of the seven major currencies in our sample with the dollar factor to variation in estimates of asset demand elasticities. Each panel shows how the share of explained covariance changes as we systematically increase the demand elasticities. The "Baseline" specification re-iterates the results shown in Table 3. The six alternative parameterizations scale the demand elasticities in all asset classes up and down as shown in the bottom panel.

Figure 9
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

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

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:

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

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:

$$\frac{\partial H^{l}_{j,t}}{\partial p^{l}_{j,t}} = 1 - \frac{\sum_{i=1}^{N} A_{i,t}\left(\frac{\partial w^l_{i,t}}{\partial p^l_{j,t}} \times w^l_{i,j,t} + \frac{\partial w^l_{i,j,t}}{\partial p^l_{j,t}} \times w^l_{i,t}\right)}{\sum_{i=1}^{N}\left(A_{i,t} w^l_{i,t} w^l_{i,j,t}\right)} \tag{B.5}$$

where

$$\frac{\partial w^l_{i,t}}{\partial p^l_{j,t}} = \lambda^l \beta^l \gamma^l_p w^l_{i,j,t} w^l_{i,t}\left(1 - w^l_{i,t}\right) \tag{B.6}$$

and

$$\frac{\partial w^l_{i,j,t}}{\partial p^l_{j,t}} = \beta^l \gamma^l_p w^l_{i,j,t}\left(1 - w^l_{i,j,t}\right) \tag{B.7}$$

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:

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

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 EME Breakdown

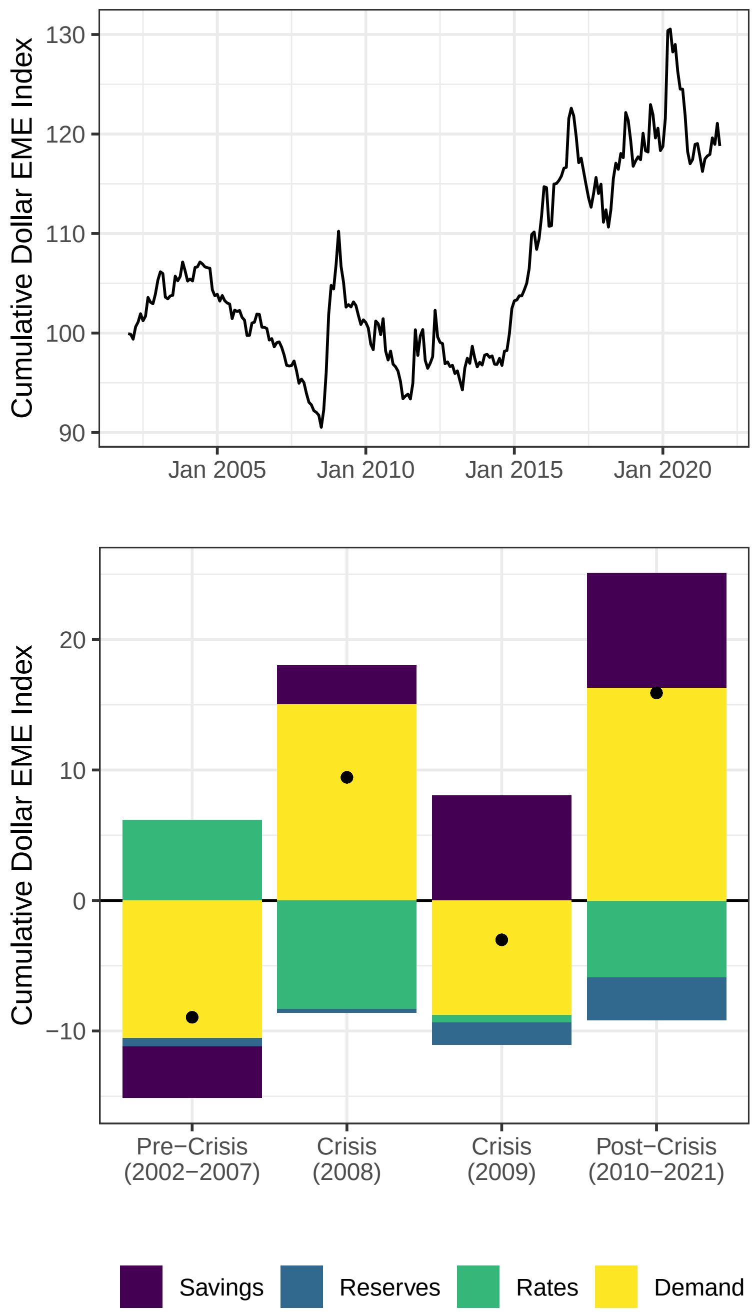
In our decomposition of the level of the dollar in Section 2.2 we focused advanced foreign economies. In this section, we repeat our decomposition of the level of the dollar, but focus on the dollar index with respect emerging market economy (EME) currencies. We report our results for emerging markets currencies in Figure B.1, 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 of the Federal Reserves EME dollar index.[7]

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.

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

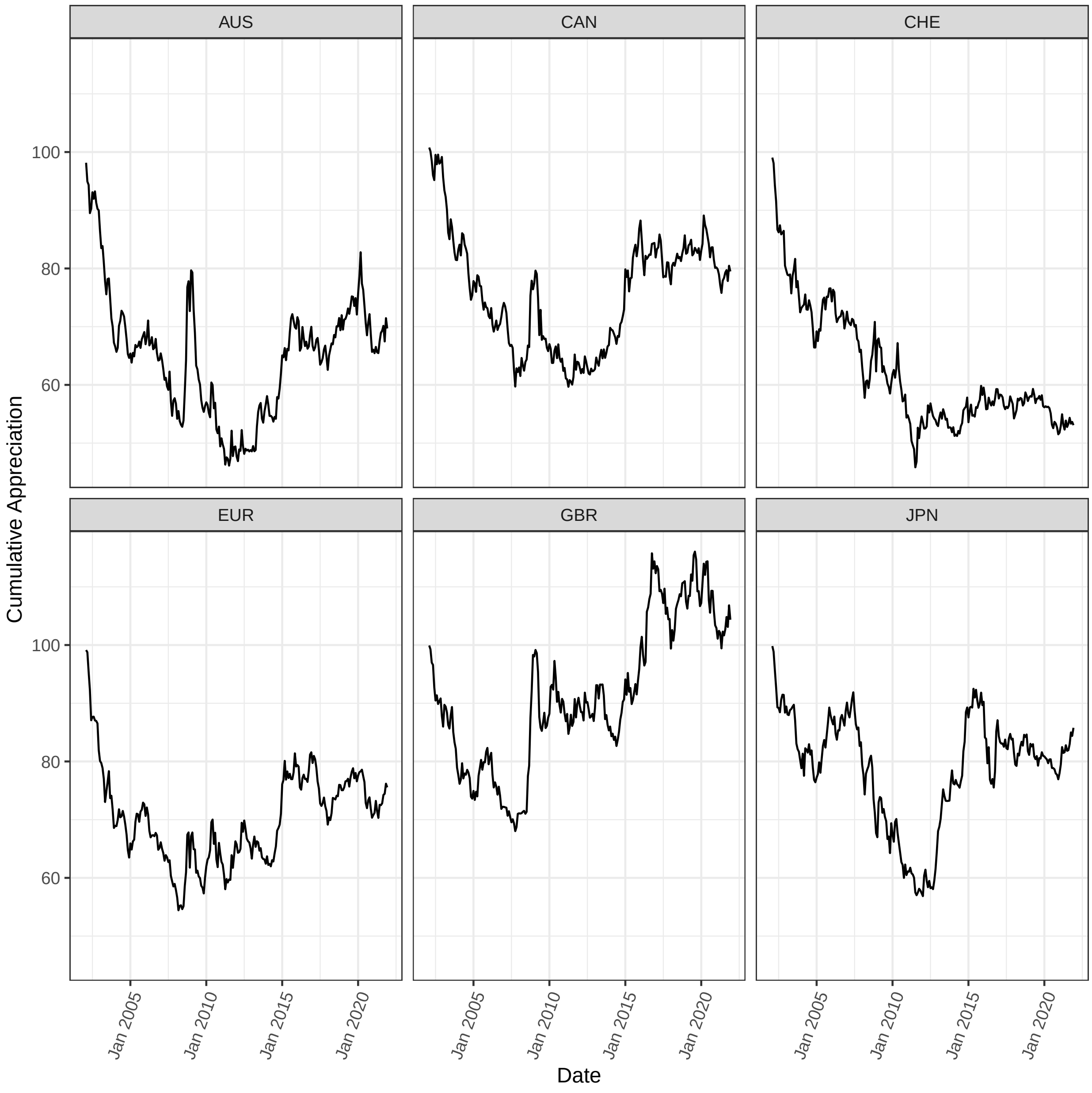
B.6 Additional Tables and Figures

FIGURE B.1
TREND DECOMPOSITION OF DOLLAR EME INDEX



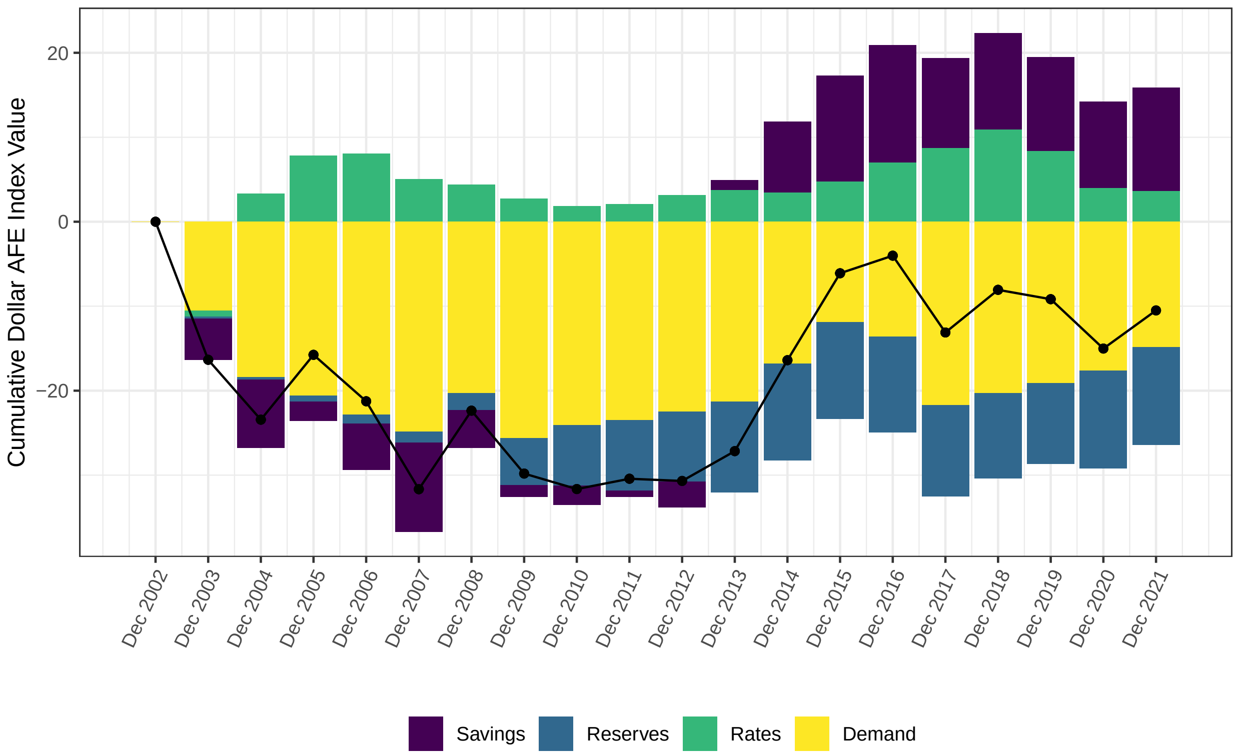
Notes: The top panel presents the nominal level of the dollar EME index with December 2001 indexed to 100. The dollar EME index is a trade-weighted basket comprising the Chinese yuan, the Indian rupee, the Malaysian ringgit, the Singapore dollar, the South Korean won and the Thai baht. The bottom panel 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 B.2
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.3
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 $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$