

# Exchange Rates and Asset Prices in a Global Demand System

Ralph S.J. Koijen<sup>a</sup>   Motohiro Yogo<sup>b</sup>

<sup>a</sup>University of Chicago, NBER, and CEPR

<sup>b</sup>Princeton University and NBER

# Determinants of exchange rates and asset prices

- ▶ Global investors.
  - ▶ Hold financial assets across countries and asset classes (short-term debt, long-term debt, and equity).
  - ▶ Demand depends on exchange rates, asset prices, and macro variables.
- ▶ Policy.
  - ▶ Debt quantities through fiscal and monetary policy.
  - ▶ Foreign exchange reserves: Central banks hold foreign assets.

# This paper

- ▶ Data on global financial markets for 2003–2020.
  - ▶ Exchange rates, asset prices, and macro variables across 37 countries.
  - ▶ Cross-country holdings from IMF's Coordinated Portfolio Investment Survey.
- ▶ Asset pricing = Portfolio choice + Market clearing
  - ▶ Match cross-country holdings together with asset prices.
- ▶ A demand system approach to
  - ▶ Decompose variation in exchange rates and asset prices.
  - ▶ Interpret events such as the European sovereign debt crisis.
  - ▶ Estimate convenience yield on US assets.

# Summary

1. Inelastic demand. Elasticity of
  - ▶ 21.1 for short-term debt.
  - ▶ 2.2 for long-term debt.
  - ▶ 0.8 for equity.
2. Observed variables explain
  - ▶ 36% of variation in exchange rates.
  - ▶ 43% of variation in long-term yields.
  - ▶ 74% of variation in market-to-book equity.
3. Convenience yield on US long-term debt: 1.05%.

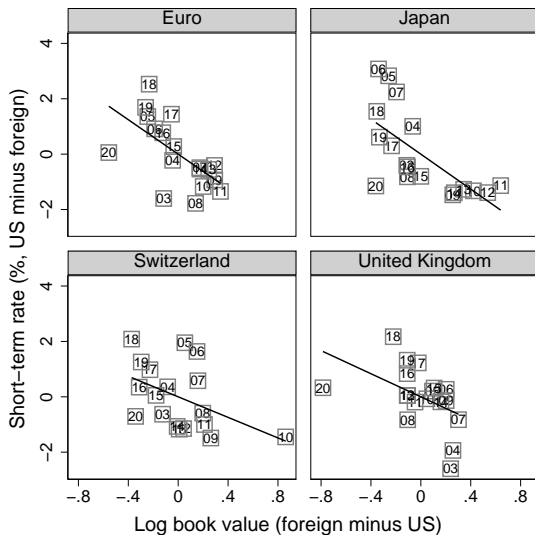
## Data structure

- ▶ Annual data for 2003–2020 across 3 asset classes.
  1. Short-term debt.
  2. Long-term debt
  3. Equity.
- ▶ 37 **issuer countries** with complete data on asset prices and characteristics.
  - ▶ All 22 countries in the MSCI World Index.
  - ▶ 15 of 21 countries in the MSCI Emerging Markets Index.
  - ▶ Other countries aggregated as “outside asset” for each asset class.
- ▶ **Investors**: 37 countries, other countries, and
  - ▶ Foreign exchange reserves: Central bank holdings of foreign assets.

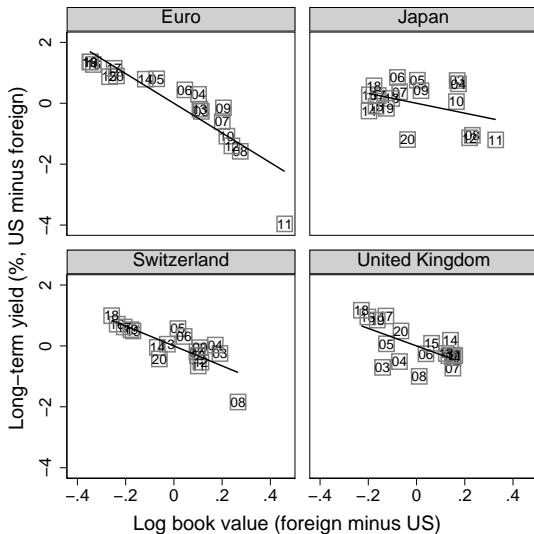
## Top 10 investors by asset class

Short-term debt		Long-term debt		Equity	
Investor	Billion US\$	Investor	Billion US\$	Investor	Billion US\$
United States	5,452	United States	38,885	United States	109,102
China	2,456	Japan	16,389	Japan	15,327
Japan	1,456	China	11,138	France	14,329
Reserves	1,025	United Kingdom	6,617	China	12,054
France	857	France	5,684	United Kingdom	9,970
United Kingdom	596	Germany	5,612	Canada	9,653
Canada	480	Reserves	4,952	Germany	9,026
Brazil	396	Italy	3,783	Netherlands	7,337
South Korea	301	Canada	3,303	Switzerland	5,270
Germany	277	Spain	2,401	Italy	4,885

## Relative price and quantity of short-term debt

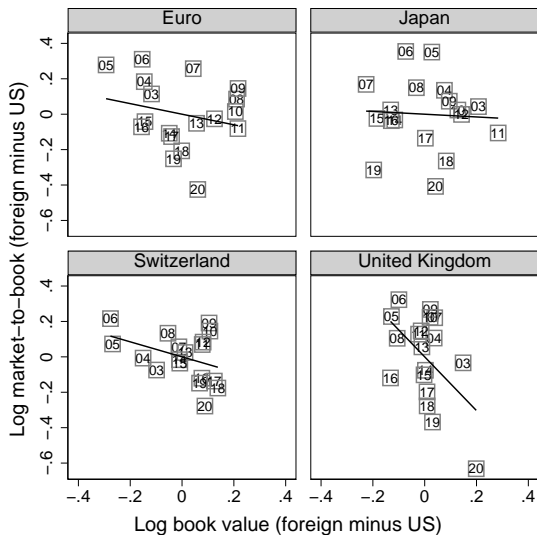


## Relative price and quantity of long-term debt





## Relative price and quantity of equity



## Market clearing

- ▶ Market clearing for each country  $n$  and asset class  $l$ .

$$P_t(n, l)E_t(n)Q_t(n, l) = \sum_{i=1}^I A_{i,t}w_{i,t}(n, l; \mathbf{P}_t, \mathbf{E}_t)$$

- ▶ Supply.
  - ▶  $P_t(n, l)$ : Market-to-book ratio (or price per unit of face value).
  - ▶  $E_t(n)$ : Exchange rate in US\$ per country  $n$ 's currency unit.
  - ▶  $Q_t(n, l)$ : Book (or face) value in country  $n$ 's currency unit.
- ▶ Demand.
  - ▶  $A_{i,t}$ : Investor  $i$ 's wealth.
  - ▶  $w_{i,t}(n, l)$ : Portfolio weight in country  $n$  and asset class  $l$ .

## Demand system asset pricing

- ▶ Market clearing is a system of equations.
  1. Optimal consumption: 26 Euler equations.
  2. Short-term debt: 26 markets.
  3. Long-term debt: 37 countries.
  4. Equity: 37 countries.
  - ▶ Drop one market by Walras's law.
- ▶ Endogenous exchange rates and asset prices.
  1. 25 exchange rates (relative to US\$).
  2. 26 short-term rates
  3. 37 long-term yields.
  4. 37 equity prices.
- ▶ A model of portfolio weights that
  - ▶ Matches cross-country holdings.
  - ▶ Easy to estimate demand elasticities.
  - ▶ Flexible substitution within and across asset classes.

## Portfolio choice

- ▶ Mean-variance portfolio:  $\mathbf{w}_i = \Sigma_i^{-1} \mu_i$ 
  - ▶ Heterogeneous beliefs about returns.
- ▶ **Assumptions:**
  1. Covariance matrix has factor structure.
  2. Expected returns and factor loadings depend on characteristics.
- ▶ Kojien and Yogo (2019) derive a logit model.

$$\log \left( \frac{w_i(n)}{w_i(0)} \right) = \beta p_i(n) + \gamma' \mathbf{x}_i(n) + \epsilon_i(n)$$

## Two extensions

1. Nested logit to allow for imperfect substitution across asset classes.

$$w_{i,t}(n, l) = \underbrace{w_{i,t}(n|l)}_{\text{within}} \underbrace{w_{i,t}(l)}_{\text{across}}$$

2. Portfolio weights depend on expected returns in own currency unit.

- ▶ Estimate a predictive regression for each asset class.

$$r_{t+1}(n, l) - y_t(\text{US}) = \theta_l p_t(n, l) + \Theta_l (e_t(n) - z_t(n)) + \nu_{t+1}(n, l)$$

- ▶ Expected returns in investor  $i$ 's currency unit:

$$\mathbb{E}_t[r_{t+1}(n, l) - \Delta e_{t+1}(i) - y_t(i)] = \mu_{i,t}(n, l)$$

## Allocation within asset class

- ▶ Portfolio weight in country  $n$  within asset class  $l$ .

$$w_{i,t}(n|l) = \frac{\delta_{i,t}(n, l)}{1 + \sum_{m=0}^N \delta_{i,t}(m, l)}$$

where

$$\log(\delta_{i,t}(n, l)) = \beta_l \mu_{i,t}(n, l) + \gamma_l' \mathbf{x}_{i,t}(n, l) + \epsilon_{i,t}(n, l)$$

- ▶  $\mathbf{x}_{i,t}(n, l)$ : Observed characteristics.
- ▶  $\epsilon_{i,t}(n, l)$ : Latent demand.

## Allocation across asset classes

- ▶ Portfolio weight in asset class  $l$ .

$$w_{i,t}(l) = \frac{\left(1 + \sum_{m=0}^N \delta_{i,t}(m, l)\right)^{\lambda_l} \exp\{\alpha_l + \xi_{i,t}(l)\}}{\sum_{k=1}^3 \left(1 + \sum_{m=0}^N \delta_{i,t}(m, k)\right)^{\lambda_k} \exp\{\alpha_k + \xi_{i,t}(k)\}}$$

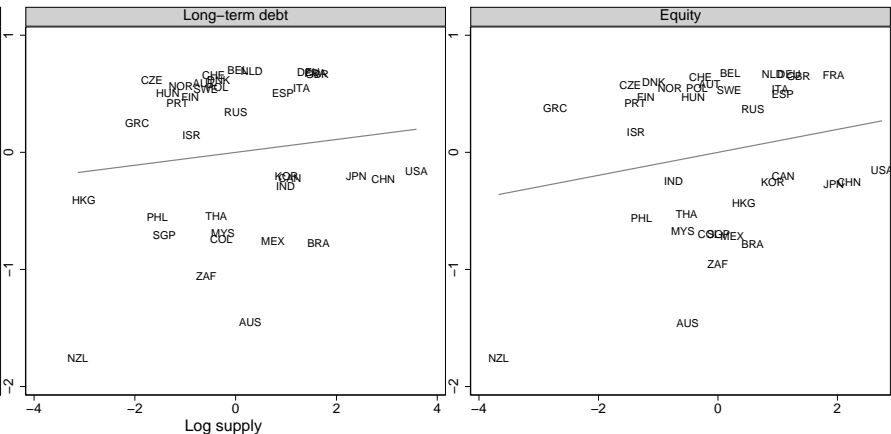
- ▶  $\xi_{i,t}(l)$ : Asset-class latent demand.
- ▶ Special cases:
  - ▶  $\lambda = \mathbf{1}$ : Logit (Kojien and Yogo 2019).
  - ▶  $\lambda = \mathbf{0}$ : No substitution across asset classes.

## Estimation methodology

- ▶ Observed characteristics.
  - ▶ Macro: Log GDP, log GDP per capita, inflation, equity volatility, and sovereign debt rating.
  - ▶ Bilateral: Export/import shares and distance.
  - ▶ Dummies: Own country (“home bias”) and year.
- ▶ Identification.
  - ▶ Asset characteristics and quantities are exogenous (in the spirit of endowment economies).
  - ▶ IV: Project bilateral portfolios on distance.



# Instrumental variables by asset class



## Predictive regressions

Variable	Exchange rate	Long-term debt	Equity
Log market-to-book		-0.58 (0.13)	-0.15 (0.22)
Log real exchange rate	-0.27 (0.07)	-0.46 (0.08)	-0.54 (0.28)
Constant	0.10 (0.02)	-0.12 (0.04)	0.25 (0.20)
$R^2$	0.16	0.33	0.12
Observations	424	640	640

## Estimated demand within asset class

Variable	Short-term debt	Long-term debt	Equity
Expected return	21.01 (3.11)	4.55 (0.50)	5.12 (0.28)
Log GDP	1.53 (0.04)	1.19 (0.02)	1.39 (0.02)
Log GDP per capita	3.90 (0.46)	2.06 (0.15)	2.00 (0.08)
Inflation	-32.55 (5.75)	-12.96 (2.37)	-4.82 (1.17)
Volatility	-1.91 (0.43)	-0.51 (0.26)	-4.69 (0.26)
Rating	-0.88 (1.43)	14.03 (1.90)	4.87 (1.02)
Export share	48.13 (4.34)	33.50 (2.32)	50.57 (2.51)
Import share	-22.54 (8.18)	7.95 (2.62)	-1.44 (2.65)
Distance	-0.05 (0.01)	-0.14 (0.00)	-0.08 (0.00)
Indicator variables:			
Own country	9.23 (0.20)	6.62 (0.11)	8.46 (0.12)
Reserves	-1.11 (0.27)	-0.49 (0.10)	0.70 (0.12)
Other countries	-0.34 (0.26)	0.18 (0.07)	1.16 (0.07)
Constant	-53.49 (4.86)	-32.96 (1.67)	-33.70 (0.81)
Test statistic for weak IV	95	798	3,494
Observations	20,549	23,431	23,779

## Estimated demand across asset classes

Variable	Symbol	Estimate
Log outside asset weight:		
Short-term debt	$\lambda_1$	0.08 (0.02)
Long-term debt	$\lambda_2$	0.08 (0.02)
Equity	$\lambda_3$	0.09 (0.02)
Indicator variables:		
Short-term debt	$\alpha_1$	-3.05 (0.09)
Long-term debt	$\alpha_2$	-0.85 (0.09)
Reserves		4.63 (0.13)
Other countries		0.87 (0.08)
Test statistic for weak IV		1,575
Observations		1,352

## Decomposition of exchange rates and asset prices

- ▶ Market clearing defines an implicit function for exchange rates and asset prices.

$$\begin{bmatrix} \mathbf{e}_t \\ \mathbf{p}_t(1) \\ \mathbf{p}_t(2) \\ \mathbf{p}_t(3) \end{bmatrix} = g(\mathbf{x}_t, \mathbf{z}_t, \mathbf{Q}_t, \epsilon_t, \xi_t)$$

- ▶ Decompose annual changes into
  1. Macro variables.
  2. Asset quantities.
  3. Latent demand (including reserves).

## Variance decomposition of exchange rates and asset prices

Variable	Exchange rate	Short-term debt	Long-term debt	Equity
Macro variables	0.43 (0.12)	0.95 (0.06)	-0.06 (0.12)	0.24 (0.08)
Asset quantities	-0.07 (0.14)	0.18 (0.07)	0.49 (0.11)	0.49 (0.08)
Latent demand	0.64 (0.20)	-0.13 (0.07)	0.57 (0.19)	0.26 (0.12)
Reserves	0.13 (0.02)	0.00 (0.00)	0.04 (0.01)	0.00 (0.01)
North America	0.14 (0.03)	-0.06 (0.03)	0.13 (0.09)	0.14 (0.05)
Europe	0.28 (0.13)	-0.04 (0.04)	0.31 (0.09)	0.06 (0.08)
Pacific	0.14 (0.07)	-0.01 (0.01)	0.04 (0.02)	0.07 (0.02)
Emerging markets	-0.07 (0.05)	-0.01 (0.03)	0.04 (0.03)	0.01 (0.02)
Other countries	0.01 (0.00)	0.00 (0.00)	0.01 (0.00)	0.00 (0.00)
Observations	399	416	603	603

## Relation to bilateral regressions

- ▶ Assumptions under which the asset demand system simplifies to a bilateral regression.
  1. Perfect substitution across asset classes ( $\lambda = \mathbf{1}$ ).
  2. First-order approximation.
- ▶ Bilateral regression explains 33% of changes in exchange rates.
- ▶ Issues with the bilateral regression.
  - ▶ Misspecified under the null of the asset demand system.
  - ▶ Unstable coefficients in repeated cross sections.
- ▶ Advantage of the asset demand system.
  - ▶ Decompose residual variation into investor countries.

## European sovereign debt crisis

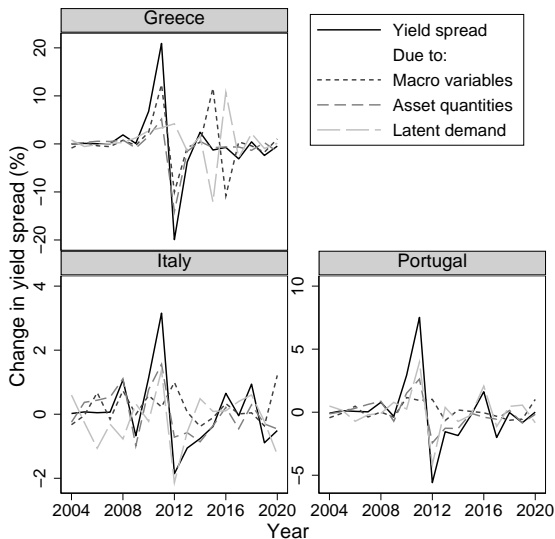
- ▶ What caused the long-term yield to sharply increase in 2011 and decrease in 2012?
- ▶ Decompose annual changes into
  1. Macro variables.
  2. Asset quantities.
  3. Latent demand (including reserves).



## Variance decomposition of long-term yield spreads in the euro area

Variable	Greece	Italy	Portugal
Macro variables	0.52 (0.04)	0.02 (0.10)	0.06 (0.08)
Asset quantities	0.45 (0.13)	0.56 (0.06)	0.40 (0.03)
Latent demand	0.04 (0.12)	0.43 (0.15)	0.54 (0.08)
Reserves	0.00 (0.00)	0.00 (0.01)	0.00 (0.00)
North America	0.01 (0.01)	0.04 (0.01)	0.02 (0.00)
Europe	0.12 (0.04)	0.34 (0.15)	0.48 (0.09)
Pacific	0.00 (0.00)	0.03 (0.01)	0.03 (0.01)
Emerging markets	-0.10 (0.06)	0.01 (0.00)	0.00 (0.00)
Other countries	0.02 (0.01)	0.00 (0.00)	0.01 (0.00)
Observations	17	17	17

## Change in long-term yield spreads in the euro area



## Convenience yield on US long-term debt

- ▶ Special status of the US dollar as reserve currency.
- ▶ Project demand shifters on issuer country fixed effects.

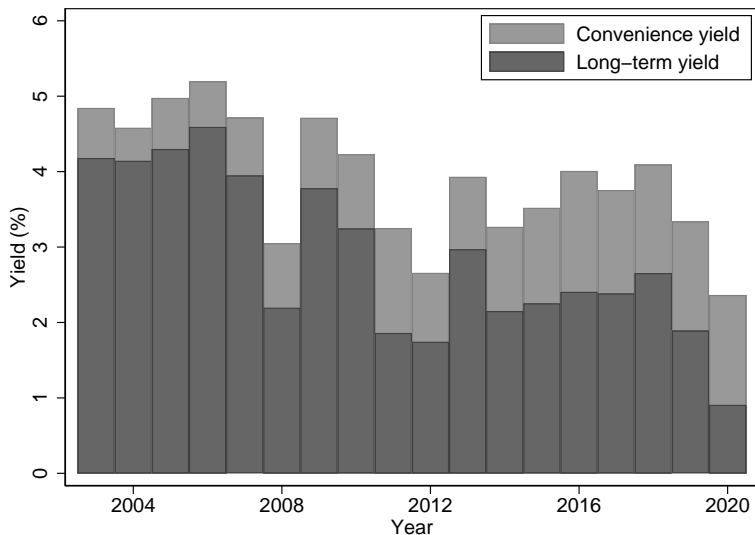
$$\log(\delta_{i,t}(n, l)) = \beta_l \mu_{i,t}(n, l) + \underbrace{\gamma_l' \mathbf{x}_{i,t}(n, l)}_{\text{demand shifter}} + \epsilon_{i,t}(n, l)$$

- ▶ Closest substitute to US by asset class.
  - ▶ Short-term debt: Switzerland.
  - ▶ Long-term debt: Germany.
  - ▶ Equity: United Kingdom.
- ▶ Counterfactual: Shift demand to the closest substitute.

## Average convenience yield on US assets

Investor	Exchange rate	Short-term debt	Long-term debt	Equity
Total	5.30 (0.37)	0.29 (0.02)	1.05 (0.08)	1.21 (0.11)
Reserves	1.73 (0.14)	0.03 (0.00)	0.21 (0.02)	0.04 (0.01)
North America	0.24 (0.01)	0.02 (0.00)	0.05 (0.01)	0.13 (0.02)
Europe	1.20 (0.07)	0.13 (0.01)	0.39 (0.02)	0.60 (0.05)
Pacific	1.65 (0.12)	0.08 (0.01)	0.32 (0.03)	0.33 (0.03)
Emerging markets	0.39 (0.09)	0.01 (0.00)	0.04 (0.01)	0.06 (0.01)
Other countries	0.11 (0.01)	0.01 (0.00)	0.03 (0.00)	0.04 (0.01)

## Convenience yield on US long-term debt



## Future work

- ▶ Implications for international macro models.
  - ▶ Asset demand shocks unrelated to fundamentals: Blanchard, Giavazzi, and Sa (2005), Gabaix and Maggiori (2015), Itskhoki and Mukhin (2017).
  - ▶ Latent demand can be estimated from cross-country holdings.
  - ▶ Calibration targets: Low demand elasticities and variance of demand shocks.
- ▶ A framework for monetary policy evaluation (both conventional and unconventional) in real time.

## Estimating equations

- ▶ Substitution within asset class.

$$\log \left( \frac{w_{i,t}(n|l)}{w_{i,t}(0|l)} \right) = \beta_l \mu_{i,t}(n, l) + \gamma_l' \mathbf{x}_{i,t}(n, l) + \epsilon_{i,t}(n, l)$$

- ▶ Substitution across asset classes.

$$\log \left( \frac{w_{i,t}(l)}{w_{i,t}(3)} \right) = -\lambda_l \log(w_{i,t}(0|l)) + \lambda_3 \log(w_{i,t}(0|3)) + \alpha_l + \xi_{i,t}(l)$$

# Demand elasticities by country and asset class

Issuer	Short-term debt	Long-term debt	Equity
<i>Developed markets: North America</i>			
Canada	9.1	1.5	0.8
United States	12.9	1.3	0.9
<i>Developed markets: Europe</i>			
Austria		2.7	0.9
Belgium		2.6	0.6
Finland		3.0	1.0
France		2.5	0.8
Germany		2.4	1.2
Italy		1.9	0.9
Netherlands		2.9	0.9
Portugal		2.9	0.6
Spain		2.2	0.7
Euro	19.4		
Denmark		1.9	0.9
Israel	6.7	1.1	0.8
Norway	19.7	2.9	1.0
Sweden	22.8	2.3	0.8
Switzerland	37.3	2.2	1.1
United Kingdom	23.3	1.8	1.2
<i>Developed markets: Pacific</i>			
Australia	15.1	2.7	1.0
Hong Kong		3.6	1.0
Japan	16.2	1.2	1.0
New Zealand	42.2	3.5	1.2
Singapore	65.0	3.5	1.1
<i>Emerging markets</i>			
Brazil	12.8	1.1	1.0
China	10.2	0.9	0.8
Colombia	8.9	1.4	0.6
Czech Republic	27.6	2.1	0.6
Greece		2.7	0.9
Hungary	6.6	1.9	0.4
India	22.7	1.0	1.5
Malaysia	23.0	1.9	0.7
Mexico	11.6	1.4	0.5
Philippines	37.1	2.9	0.4
Poland	4.7	1.7	0.6
Russia	66.0	3.4	0.4
South Africa	7.7	2.3	0.5
South Korea	7.8	1.1	0.9
Thailand	10.9	1.5	0.7
<i>Mean</i>	21.1	2.2	0.8



## Average demand shifters by country and asset class

Short-term debt		Long-term debt		Equity	
United States	0.0	United States	0.0	United States	0.0
Switzerland	-0.3	Germany	-2.2	United Kingdom	-2.4
Germany	-0.7	France	-2.8	Switzerland	-2.6
United Kingdom	-0.8	United Kingdom	-3.1	Netherlands	-2.9
France	-1.3	Netherlands	-3.2	Germany	-3.0
Japan	-1.3	Spain	-3.7	France	-3.2
Netherlands	-1.9	Italy	-3.7	Japan	-3.5
Australia	-2.1	Japan	-3.8	Canada	-3.9
Spain	-2.2	Australia	-3.9	Australia	-4.0
Italy	-2.3	Switzerland	-4.0	Sweden	-4.1
Sweden	-2.4	Canada	-4.1	China	-4.2
Belgium	-2.6	Sweden	-4.3	Spain	-4.6
Canada	-2.8	Belgium	-4.5	Italy	-4.8
Norway	-3.2	Norway	-4.8	Belgium	-4.9
Portugal	-4.3	Austria	-5.0	Hong Kong	-5.2
Hong Kong	-4.3	China	-5.3	Norway	-5.3
Finland	-4.4	Finland	-5.4	Denmark	-5.9
Denmark	-4.6	Denmark	-5.5	Finland	-6.0
China	-4.9	Portugal	-5.8	South Korea	-6.8
Austria	-5.0	Hong Kong	-6.0	Austria	-6.8
Greece	-5.2	South Korea	-6.5	Israel	-7.0
Israel	-5.8	Greece	-7.2	Mexico	-7.0
South Korea	-6.4	Israel	-7.4	Brazil	-7.2
New Zealand	-6.5	Singapore	-7.5	Singapore	-7.2
Singapore	-6.6	New Zealand	-7.7	Portugal	-7.3
Brazil	-8.4	Mexico	-7.7	South Africa	-7.4
Mexico	-8.9	Poland	-7.8	Russia	-8.2
Czech Republic	-9.5	Brazil	-7.9	Greece	-8.5
Russia	-9.6	Russia	-7.9	India	-8.8
South Africa	-10.1	Czech Republic	-8.4	New Zealand	-9.1
Poland	-10.3	South Africa	-8.9	Malaysia	-9.1
Hungary	-11.1	Malaysia	-9.0	Czech Republic	-9.4
Malaysia	-11.2	Hungary	-9.1	Poland	-9.6
Colombia	-11.8	India	-9.8	Thailand	-9.7
Philippines	-12.3	Philippines	-9.9	Hungary	-10.2
India	-12.5	Colombia	-10.2	Philippines	-11.1
Thailand	-12.6	Thailand	-10.5	Colombia	-12.2

# Issuer countries in the sample

Issuer	Sample starts	Data source	
		Debt	Equity
<i>Developed markets: North America</i>			
Canada	2003	OECD	OECD
United States	2003	OECD	OECD
<i>Developed markets: Europe</i>			
Austria	2003	OECD	OECD
Belgium	2003	OECD	OECD
Denmark	2003	OECD	OECD
Finland	2003	OECD	OECD
France	2003	OECD	OECD
Germany	2003	OECD	OECD
Israel	2003	OECD (from 2010)	OECD
		BIS (to 2009)	
Italy	2003	OECD	OECD
Netherlands	2003	OECD	OECD
Norway	2003	OECD	OECD
Portugal	2003	OECD	OECD
Spain	2003	OECD	OECD
Sweden	2003	OECD	OECD
Switzerland	2003	OECD	OECD
United Kingdom	2003	OECD	OECD
<i>Developed markets: Pacific</i>			
Australia	2003	BIS	WB
Hong Kong	2003	BIS	WB
Japan	2003	OECD	OECD
New Zealand	2003	BIS	WB
Singapore	2003	BIS	WB
<i>Emerging markets</i>			
Brazil	2003	OECD (from 2009)	OECD
		BIS (to 2008)	
China	2015	BIS	WB
Colombia	2007	OECD	OECD
Czech Republic	2003	OECD	OECD
Greece	2003	OECD	OECD
Hungary	2003	OECD	OECD
India	2004	BIS	OECD
Malaysia	2005	BIS	WB
Mexico	2003	OECD	OECD
Philippines	2009	BIS	WB
Poland	2003	OECD	OECD
Russia	2004	BIS	WB
South Africa	2003	BIS	WB
South Korea	2003	OECD	OECD
Thailand	2003	BIS	WB

## Regressions of changes in exchange rates and asset prices

Variable	Exchange rate	Short-term debt	Long-term debt	Equity
Log GDP	0.54 (0.10)	0.16 (0.01)	-0.02 (0.00)	-0.10 (0.10)
Log GDP per capita	-0.32 (0.39)	0.30 (0.04)	-0.02 (0.02)	0.02 (0.52)
Inflation	-0.04 (0.87)	0.16 (0.08)	-0.02 (0.03)	-0.18 (0.82)
Volatility	-0.29 (0.08)	-0.13 (0.01)	-0.10 (0.00)	-0.38 (0.15)
Rating	-0.16 (1.77)	-0.13 (0.32)	-0.11 (0.07)	0.03 (0.65)
Relative CPI	0.21 (0.31)	0.05 (0.03)	0.16 (0.01)	-0.05 (0.37)
Asset quantity	0.06 (0.03)	-0.16 (0.01)	0.81 (0.00)	-0.48 (0.09)
$R^2$	0.33	0.32	0.74	0.67
Observations	399	416	603	603