

Exchange Rates and Asset Prices in a Global Demand System

Ralph S.J. Koijen^a Motohiro Yogo^b

^aUniversity of Chicago, NBER, and CEPR

^bPrinceton 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
 - ▶ 25.2 for short-term debt.
 - ▶ 3.1 for long-term debt.
 - ▶ 1.2 for equity.
2. Portfolio flows and macro variables explain
 - ▶ 17% of variation in exchange rates.
 - ▶ 99% of variation in long-term yields.
 - ▶ 39% of variation in market-to-book equity.
3. Convenience yield on US long-term debt: 0.76%.

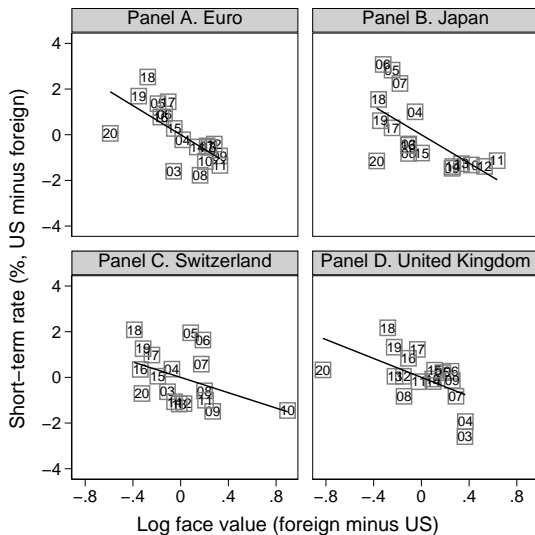
Data structure

- ▶ 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.

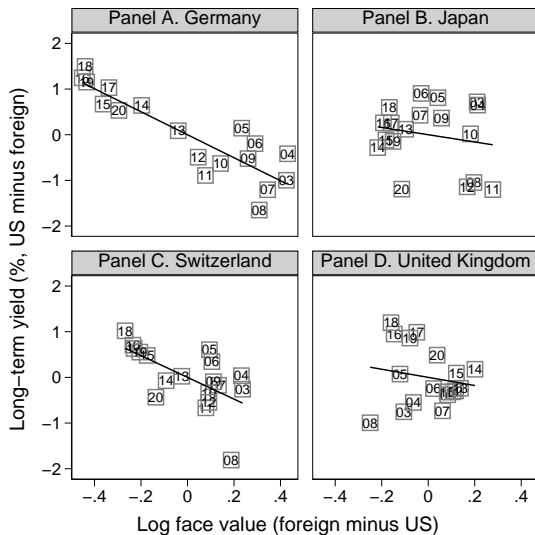
Top 10 investors by asset class

Short-term debt		Long-term debt		Equity	
Investor	Billion US\$	Investor	Billion US\$	Investor	Billion US\$
United States	5,423	United States	38,283	United States	56,324
Japan	1,444	China	17,331	Japan	12,424
Reserves	1,025	Japan	16,206	China	11,952
France	827	United Kingdom	5,752	France	10,376
United Kingdom	496	Germany	5,513	Canada	7,361
Canada	471	France	5,490	United Kingdom	6,800
China	440	Reserves	4,952	Netherlands	5,971
Brazil	395	Italy	3,721	Germany	3,393
India	325	Canada	2,979	Switzerland	3,390
South Korea	301	South Korea	2,350	Hong Kong	3,240

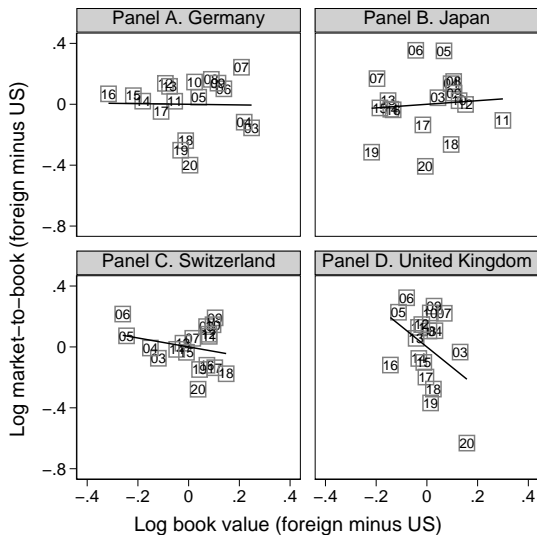
Relative short-term debt prices versus quantities



Relative long-term debt prices versus quantities



Relative equity prices versus quantities



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

- ▶ 10 countries in the euro area.
- ▶ 2 currency pegs.
 - ▶ HK\$ pegged to US\$.
 - ▶ Danish krone pegged to euro.
- ▶ 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.
- ▶ 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.

Model of short-term rates

- ▶ Linearized Euler equation:

$$r_{t+1}(n) = -\log(\beta) + \mathbb{E}_{n,t}[\Delta b_{n,t+1}] + \gamma \mathbb{E}_{n,t}[\Delta c_{n,t+1}] - \frac{\text{Var}_{n,t}(\gamma \Delta c_{n,t+1} + \Delta b_{n,t+1})}{2}$$

- ▶ Since $r_{t+1}(n) = -p_t(n)$, rewrite as

$$p_t(n) = \mathbf{\Pi}' \mathbf{z}_t(n) + \zeta_t(n)$$

Portfolio choice

- ▶ Mean-variance portfolio: $\mathbf{w}_i = \boldsymbol{\Sigma}_i^{-1} \boldsymbol{\mu}_i$
 - ▶ 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.

$$\log \left(\frac{w_i(n)}{w_i(0)} \right) = \lambda p(n) + \boldsymbol{\Lambda}' \mathbf{x}(n) + \epsilon_i(n)$$

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 local currency.
 - ▶ Estimate a predictive regression for each asset class.

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

- ▶ Expected excess returns in investor i 's local currency:

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

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

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

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

Allocation across asset classes

- ▶ Portfolio weight in asset class l .

$$w_{i,t}(l) = \frac{\left(1 + \sum_{m=0}^N \delta_{i,t}(m, l)\right)^{\rho_l} \exp(\alpha_l + \xi_{i,t}(l))}{\sum_{k \in \{S, L, E\}} \left(1 + \sum_{m=0}^N \delta_{i,t}(m, k)\right)^{\rho_k} \exp(\alpha_k + \xi_{i,t}(k))}$$

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

Estimating equations

- ▶ Substitution within asset class.

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

- ▶ Substitution across asset classes.

$$\log \left(\frac{w_{i,t}(l)}{w_{i,t}(E)} \right) = -\rho_l \log(w_{i,t}(0|l)) + \rho_E \log(w_{i,t}(0|E)) + \alpha_l + \xi_{i,t}(l)$$

Estimation methodology

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

Instrumental variables

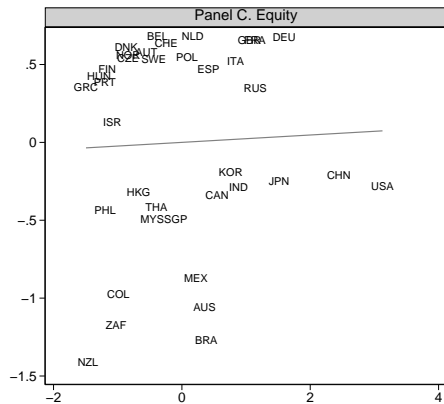
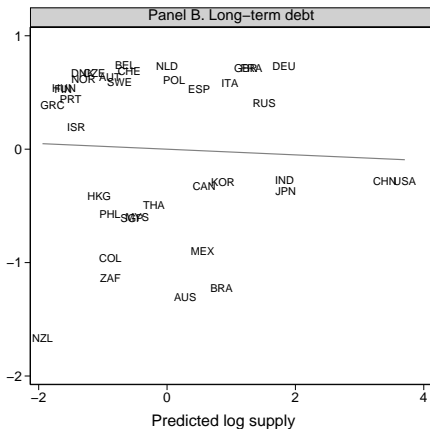
- Write market clearing as

$$P_t(n, l) \frac{E_t(n)}{V_t(n)} = \left(\underbrace{A_{i,t} w_{i,t}(n, l)}_{i\text{'s demand}} + \underbrace{\sum_{j \neq i} A_{j,t} w_{j,t}(n, l)}_{\text{other investors}} \right) \underbrace{\frac{1}{V_t(n) Q_t(n, l)}}_{\text{supply}}.$$

- Instrument for $\mu_{i,t}(n, l)$:

$$\text{IV}_{i,t}(n, l) = \log \left(\underbrace{\sum_{j \neq i} \frac{O_{j,t} \hat{w}_j(n, l)}{1 - \sum_{l \in \{S, L, E\}} \sum_{n=1}^N \hat{w}_j(n, l)}}_{\text{predicted log demand}} \right) - \underbrace{\left(v_t(n) + \hat{q}_t(n, l) \right)}_{\text{predicted log supply}}.$$

Instrumental variables



Predictive regressions

Variable	Exchange rate	Long-term debt	Equity
Log asset price		-0.74 (0.11)	-0.15 (0.22)
Log real exchange rate	-0.27 (0.07)	-0.36 (0.07)	-0.54 (0.28)
Constant		-0.07 (0.02)	0.25 (0.20)
R^2	0.17	0.32	0.12
Observations	424	640	640

Estimated demand within asset class

Variable	Short-term debt	Long-term debt	Equity
Expected return	14.33 (2.32)	4.52 (0.51)	10.33 (0.79)
Log GDP	1.28 (0.02)	1.10 (0.01)	1.32 (0.02)
Log GDP per capita	3.67 (0.35)	2.16 (0.11)	3.68 (0.19)
Inflation	-23.49 (4.22)	-9.22 (1.79)	-16.56 (1.88)
Volatility	-2.83 (0.40)	-0.52 (0.27)	-5.89 (0.36)
Rating	-0.77 (1.26)	10.24 (1.29)	13.96 (1.23)
Distance	-0.08 (0.01)	-0.18 (0.00)	-0.15 (0.01)
Indicator variables:			
Domestic ownership	8.46 (0.18)	6.19 (0.09)	7.69 (0.14)
Reserves	0.01 (0.19)	0.10 (0.10)	-2.83 (0.14)
Other countries	0.78 (0.17)	0.77 (0.06)	-1.86 (0.10)
Constant	-52.35 (3.67)	-34.78 (1.15)	-50.94 (2.14)
<i>F</i> -statistic for weak IV	130	1,297	521
Observations	20,549	23,431	23,779

Estimated demand across asset classes

Variable	Symbol	Estimate
Log outside portfolio weight:		
Short-term debt	ρ_S	0.25 (0.03)
Long-term debt	ρ_L	0.53 (0.05)
Equity	ρ_E	0.49 (0.04)
Indicator variables:		
Short-term debt	α_S	-1.21 (0.19)
Long-term debt	α_L	0.73 (0.18)
F -statistic for weak IV		802
Observations		1,352

Variation in exchange rates and asset prices

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

$$\begin{bmatrix} e_t \\ p_t \end{bmatrix} = m(Q_t, O_t, X_t, \epsilon_t, \xi_t, \zeta_t)$$

- ▶ Decompose annual changes into
 1. Portfolio flows and asset quantities: Q_t .
 2. Macro variables: X_t .
 3. Latent demand: $\epsilon_t, \xi_t, \zeta_t, O_t$.

Variance decomposition of exchange rates and asset prices

Change in	Exchange rate	Short-term rate	Long-term yield	Market-to-book equity
Portfolio flows	0.01 (0.05)		0.58 (0.19)	0.20 (0.07)
Macro variables	0.16 (0.06)	0.14 (0.06)	0.41 (0.09)	0.19 (0.03)
Latent demand	0.83 (0.07)	0.86 (0.06)	0.01 (0.26)	0.61 (0.07)
Reserves	0.10 (0.02)		0.02 (0.03)	-0.01 (0.01)
North America	0.32 (0.09)	0.45 (0.14)	-0.23 (0.20)	0.15 (0.08)
Europe	0.22 (0.04)	0.17 (0.06)	0.16 (0.06)	0.26 (0.04)
Pacific	0.22 (0.06)	0.03 (0.02)	-0.02 (0.02)	0.09 (0.02)
Emerging markets	-0.05 (0.02)	0.21 (0.06)	0.08 (0.07)	0.12 (0.05)
Other countries	0.02 (0.01)		0.00 (0.01)	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 ($\rho = \mathbf{1}$).
 2. First-order approximation.
- ▶ Bilateral regression explains 8% 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.

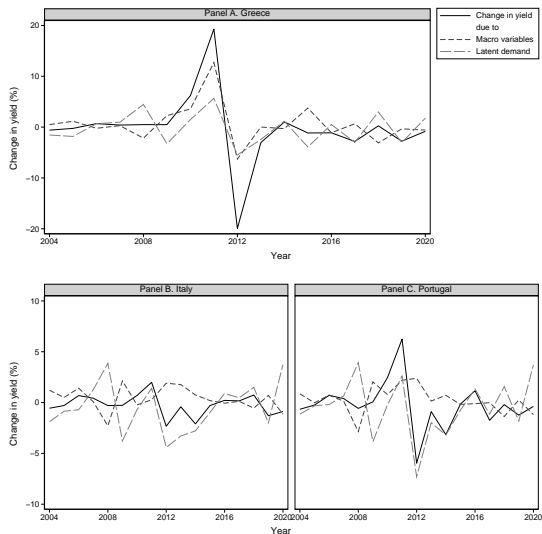
European sovereign debt crisis

- ▶ What caused the long-term yield to sharply increase in 2011 and decrease in 2012?
- ▶ Decompose annual changes into
 1. Portfolio flows and asset quantities.
 2. Macro variables.
 3. Latent demand.

Variance decomposition of long-term yields in the euro area

Change in	Greece	Italy	Portugal
Portfolio flows	0.23 (0.11)	0.15 (0.18)	0.24 (0.05)
Macro variables	0.47 (0.09)	-0.27 (0.17)	0.02 (0.19)
Latent demand	0.31 (0.03)	1.12 (0.31)	0.73 (0.21)
Reserves	0.00 (0.01)	0.02 (0.09)	-0.01 (0.03)
North America	0.01 (0.01)	0.08 (0.07)	0.05 (0.03)
Europe	0.19 (0.01)	0.96 (0.19)	0.64 (0.16)
Pacific	0.02 (0.00)	0.06 (0.02)	0.05 (0.01)
Emerging markets	0.07 (0.02)	0.00 (0.01)	0.00 (0.00)
Other countries	0.02 (0.01)	0.01 (0.00)	0.01 (0.00)
Observations	17	17	17

Change in the long-term yields in the euro area



Convenience yield on US assets

- ▶ US dollar is the global reserve currency.
- ▶ US Treasury debt is the global safe asset.
- ▶ Foreign investors have high mean latent demand of US assets.

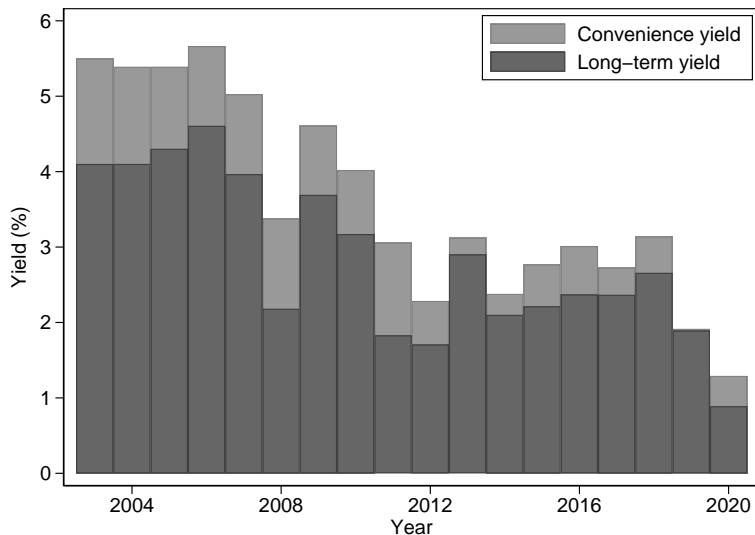
Mean latent demand

Year	United States			Euro area		
	Short-term debt	Long-term debt	Equity	Short-term debt	Long-term debt	Equity
2003	2.6	2.0	2.6	4.5	2.3	4.0
2004	1.5	1.6	1.7	4.3	2.0	3.7
2005	2.1	1.4	2.0	3.9	1.4	2.9
2006	1.3	1.4	1.3	3.3	1.4	3.0
2007	1.1	1.2	1.0	3.0	1.1	3.1
2008	1.8	1.4	1.4	4.4	1.5	3.4
2009	1.3	0.9	0.8	3.5	1.1	2.5
2010	1.5	0.8	0.7	3.0	0.9	1.7
2011	1.2	1.2	0.7	2.5	0.3	1.1
2012	0.4	0.5	-0.1	2.3	0.4	0.9
2013	0.5	0.2	0.2	1.2	0.2	0.6
2014	0.6	0.3	0.3	1.0	0.1	-0.4
2015	0.8	0.5	0.9	0.8	0.3	0.1
2016	1.0	0.6	0.8	0.4	-0.3	-0.6
2017	0.3	0.3	0.3	0.1	-0.1	-0.7
2018	0.8	0.5	1.1	0.3	-0.1	-0.8
2019	0.4	0.0	0.9	-0.3	-0.3	-1.6
2020	0.5	0.4	2.1	0.2	0.1	0.5
Mean	1.1	0.8	1.0	2.0	0.6	1.2

Convenience yields on US assets

Investor	Foreign short-term debt		US long-term debt		US equity	
	Exchange rate	Expected return	Yield	Expected return	Market-to-book	Expected return
Total	5.36 (0.58)	-1.45 (0.16)	0.76 (0.10)	2.81 (0.36)	-3.37 (0.40)	0.50 (0.06)
Reserves	3.49 (0.44)	-0.94 (0.12)	0.28 (0.03)	1.02 (0.13)	-0.07 (0.01)	0.01 (0.00)
North America	0.07 (0.01)	-0.02 (0.00)	0.01 (0.00)	0.05 (0.00)	-0.37 (0.04)	0.05 (0.01)
Europe	0.87 (0.09)	-0.24 (0.03)	0.23 (0.03)	0.85 (0.12)	-1.77 (0.20)	0.26 (0.03)
Pacific	0.53 (0.07)	-0.14 (0.02)	0.21 (0.03)	0.78 (0.11)	-0.88 (0.10)	0.13 (0.02)
Emerging markets	0.14 (0.02)	-0.04 (0.00)	0.01 (0.00)	0.05 (0.01)	-0.16 (0.04)	0.02 (0.01)
Other countries	0.26 (0.03)	-0.07 (0.01)	0.01 (0.00)	0.05 (0.01)	-0.12 (0.02)	0.02 (0.00)

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.

Countries and their data sources

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	OECD
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	WB
Malaysia	2005	BIS	WB
Mexico	2003	OECD	OECD
Philippines	2009	BIS	WB
Poland	2003	OECD	OECD
Russia	2004	BIS	OECD
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	0.22 (1.11)	-0.03 (0.15)	0.18 (0.11)	-0.12 (1.88)
Log GDP per capita	-0.22 (1.15)	0.43 (0.15)	-0.06 (0.13)	-0.05 (2.06)
Inflation	-0.08 (0.95)	0.17 (0.09)	-0.25 (0.08)	-0.29 (0.70)
Volatility	-0.19 (0.11)	-0.14 (0.02)	-0.14 (0.01)	-0.55 (0.16)
Rating	-0.01 (1.31)	-0.08 (0.13)	-0.24 (0.18)	0.03 (1.57)
Relative price index	0.20 (0.41)	-0.02 (0.03)	0.05 (0.03)	0.03 (0.45)
R^2	0.08	0.29	0.15	0.47
Observations	399	416	603	603