Currency Risk Premia, Exchange Rate Dynamics and International Finance

Xiang Fang

The University of Hong Kong

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1. Exchange rates: a brief history

The Mundell-Fleming Paradigm

- Also known as the IS-LM-BP model
  - Fixed exchange rate: the loss of monetary autonomy or capital control
  - Flexible exchange rate: exchange rate to adjust external imbalances
    - The choice of exchange rate regime: Friedman vs. Mundell
    - Extension of the IS-LM framework in Keynesian economics into the open economy
  - Modern version: build on New Keynesian macroeconomics, known as the New Open Economy Macroeconomics (NOEM), started by Obstfeld and Rogoff (1995 JPE)
  - Related modern research
    - The global financial cycle
    - Optimal exchange rate policy under frictional financial market + NK framework
    - External imbalance and the international financial system

Exchange Rates: Real and Nominal Factors

- International real business cycle (IRBC) model
  - Mendoza (1995 IER): IRBC in SOE with multiple goods
  - Cole and Obstfeld (1991 JME): the role of financial market
  - Backus, Kehoe and Kydland (1994 AER): tradables
  - Stockman and Tesar (1995 AER): nontradables
- Building block of international GE models

Exchange Rates: Real and Nominal Factors

- The Neoclassical view: RER determined by the real side; NER determined by RER and inflation; inflation is determined by monetary factors
  - RER tracks NER closely (Mussa, 1986)
  - After exchange rates floated, both NER and RER volatility increased, but not the volatility of other macro variables (Baxter and Stockman, 1989 JME)
- The New Keynesian view: money is non-neutral in the short run due to sticky price, but is neutral in the long run
  - Prediction: RER should mean revert at a similar pace as price adjustment
  - Purchasing power parity puzzle (Rogoff, 1996): the persistence of RER is very high, whose half life longer than price adjustment
  - Not quite able to account for exchange rates volatility and persistence (Chari, Kehoe and McGrattan, 2002 RES)
- Overall, exchange rate was no longer a hot research area for a while, but it has revived in the recent 15 years, especially in finance
- Related modern research: Mussa puzzle redux and exchange rate determination

Exchange Rates as an Asset Price

- Dornbusch (1976 JPE): monetary tightening appreciates the currency more than the long-run equilibrium level (PPP) due to sluggish price adjustment
  - Exchange rate reflects not only current macroeconomic factors (e.g., interest rates), but also expected future macroeconomic factors
  - Cornerstone: the uncovered interest rate parity and its deviation
- Prediction: exchange rates should be related to the current and expected future monetary and real factors (lack solid evidence, Engel and West, 2005 JPE)
- The dynamic relation between interest rate and exchange rate
  - A big macro literature that studies the response to exchange rate to interest rate shock (Evans and Eichenbaum 1995 QJE; Schmitt-Grohe and Uribe, 2022 JIE)
  - A big finance literature that explores the predictive regression of exchange rates
- Related modern research: the whole asset pricing literature on exchange rates

Exchange Rates Disconnect

- Meese and Rogoff (1983 JIE): Empirically, exchange rate correlation between macro variables is weak (out of sample inferior than the random walk)
- Some advancement: Mark (1995 AER), Gourinchas and Rey (2007 JPE), Chen and Rogoff (2003 JIE), Liu and Shaliastovich (2023 JFE), Jiang, Krishnamurthy and Lustig (2021 JF), Liliey et al (2019 REStat), **Engel and Wu (2024)**
- Remain largely challenging for international macro-finance models now
- Related modern research: look for fundamentals correlated with exchange rates

Exchange Rates, Relative Price of Goods, and Balassa-Samuelson Effect

- Exchange rates and the relative price of goods
  - Suppose the price level of two countries are

$$p_t = (1-\alpha)p_t^T + \alpha p_t^N, p_t^* = (1-\beta)p_t^{T*} + \beta p_t^{N*}$$

    Real exchange rates can be decomposed into

$$q_t = \underbrace{(s_t + p_t^{T*} - p_t^T)}_{\text{LOOP deviation for tradable}} + \underbrace{\left[\beta(p_t^{N*} - p_t^{T*}) - \alpha(p_t^N - p_t^T)\right]}_{\text{Relative price of nontradable}}$$

    - Deviation from LOOP for tradable goods
    - Different relative price of nontradable goods (Balassa-Samuelson effect)
- Engel (1999 JPE): The deviation of LOOP for tradable goods
- Burnstein, Neves and Rebelo (2003 JME), tradable + nontraded distribution
- Balassa-Samuelson effect: due to the presence of nontradables, RER of underdeveloped currencies tend to be undervalued
- Building block of modern international macroeconomics research

Exchange Rates: The Asset Pricing Approach

- For financial economists, exchange rate studies mainly focus on the Fama (1984) puzzle, or the failure of the uncovered interest rate parity
  - Asset pricing approach in the 90's (Backus, Gregory and Telmer, 1993 JF; Bekaert, 1996 RFS; Bansal, 1997 RFS; Lewis 1995 Handbook chapter)
- Lustig and Verdelhan (2007 AER), Lustig, Roussanov and Verdelhan (2011 RFS) establish a finance-centric view of exchange rates, i.e., highlighting risk premia
  - What are the sources of risk premia?
  - Structural models of risk premia, especially in general equilibrium with endogenous risk sharing, where SDF are endogenously determined

Exchange Rates, Intermediary Frictions and Portfolio Balancing

- Portfolio balancing is a popular approach in the 1970-80s, summarized in Branson and Henderson (1985 Handbook chapter), but lack micro foundation then
- Revived in its modern form by Gabaix and Maggiori (2015 QJE)
- Main idea: exchange rates determined by portfolio flows - portfolio inflows appreciate the currency of a country
- Related research: Hau and Rey (2008 RFS), Camanho, Hau and Rey (2023 RFS), Koijen and Yogo (2024)
- A core ingredient: international financial market frictions
  - A very active research area following Gabaix and Maggiori (2015 QJE)
  - CIP deviation (Du, Tepper and Verdelhan, 2018 JF) is strikingly convincing evidence that intermediary frictions matter

Exchange Rates in General Equilibrium

- Regardless of how you view exchange rates, they are general equilibrium objects
  - Goods market view
  - Asset market view (highlighting risk premia or not)
  - Portfolio balance view
- Ultimately, understanding international prices and quantities are manifestation of understanding international risk sharing, and macro and asset price data provides different information
  - Lewis (1996 JPE, 2000 JIE), Lewis and Liu (2015 JME, 2017 JIE, 2023)
  - Brandt, Cochrane and Santa Clara (2006 JME)
  - All international GE models have implications on international risk sharing
- A nice survey article by Itskhoki (2023)

2. Exchange rate basics: an asset market view

Notations

- Domestic and foreign SDF (in logs): m_{t+1}, m^*_{t+1}. US be the domestic economy
- Change of log exchange rate Δs_t, where s_t is the price of foreign currency per dollar. A rise of Δs_t indicates a foreign depreciation
- The one-period risk free rate in the two markets: r_t, r^*_t

Euler Equations

$$E_t\left[\exp(m_{t+1}+r_t)\right]=1, E_t\left[\exp(m_{t+1}+r_t^*-\Delta s_{t+1})\right]=1$$
$$E_t\left[\exp(m^*_{t+1}+r_t^*)\right]=1, E_t\left[\exp(m^*_{t+1}+r_t+\Delta s_{t+1})\right]=1$$

- Complete market: these Euler equations not only hold for r_t, r_t^* but for all state contingent claims
- Exchange rate under complete market

$$\Delta s_{t+1}=m_{t+1}-m^*_{t+1}$$

- Incomplete market
  - Lustig and Verdelhan (2019, AER); Maurer and Tran (2021, JFE); Sandulescu, Trojani and Vedolin (2021, JF); Bakshi, Cerrato and Crosby (2018, RFS), Jiang, Krishnamurthy, Lustig and Sun (2024)

Intuition

- With complete markets, investors in both countries have to agree on the price of any state contingent security
- m_{t+1} the LC price, m^*_{t+1} the FC price, exchange rate makes the two equal
- A dollar's value is higher for foreign investors when they are in relative bad times - this cannot happen, dollar must devalue
- An asset pricing formulation of Mundell-Fleming trilemma: If a country adopts fixed exchange rates plus free capital flows (under complete market), the SDFs must be perfectly correlated? Nominal or real? The role of inflation?

Interest Rate, Exchange Rate, and Currency Risk Premia

- Interest rates

$$i_t = -E_t(m_{t+1}) - \frac{1}{2}var_t(m_{t+1}), i_t^* = -E_t(m_{t+1}^*) - \frac{1}{2}var_t(m_{t+1}^*)$$

- Exchange rate

$$\Delta s_{t+1} = m_{t+1} - m_{t+1}^*$$

- Currency risk premia

$$E_t\left[i_t^* - i_t - \Delta s_{t+1}\right] = \frac{1}{2}\left(var_t(m_{t+1}) - var_t(m_{t+1}^*)\right)$$

- Predictable component of m: offset in interest rate and expected exchange rate

Two approaches

- How do exchange rate data discipline SDFs?
  - Aggregate moments: analogous to Hansen-Jaganathan bound
  - Time-series: time-varying price of risk
  - Cross-section: different from equities where cross-sectional differences reflects heterogeneous CF risk loadings, cross-sectional currency heterogeneity indicates heterogeneous SDF risk loadings
- What are the economic variables in the SDF and why?
  - Seeking for macro-finance models
  - Less "macro-finance disconnect" as exchange rates play a central role in the international economy
  - General Equilibrium: two-way macro-exchange-rate determination (discuss later)

The Present Value Approach to Exchange Rates

Define currency excess return

$$rx_{t+1} = s_t - s_{t+1} + r_t^* - r_t$$

Iterate forward

$$s_t = \sum_{\tau=0}^{T} -(r_{t+\tau}^* - r_{t+\tau}) + \sum_{\tau=0}^{T} E_t rx_{t+\tau+1} + \lim_{T\to\infty} s_{T+1}$$

- Suppose the long-run exchange rate is a constant, foreign currency depreciates either because current and future foreign interest rate is low, of the currency and future risk premium is high
- Analogous to the Campbell-Shiller decomposition
- Exact here, because interest rate and exchange rates are multiplicative
- Early studies focus on the interest rate differential term, which includes money growth, output gap, inflation etc (e.g., Frankel, 1979 AER)
- Disppointing evidence in Meese and Rogoff (1983 JIE)

3. Empirical studies of exchange rates and currency risk premia

Engel and West (2005 JPE)

- Despite the disappointing empirical features of exchange rates (random walk, lack of predictability), they can be a natural outcome of present value models
  - Macroeconomic fundamentals are random walks (or close)
  - Discounting is arbitrarily close to 1
- Exchange rates can be used to forecast future macroeconomic variables (idea similar to Campbell-Shiller predictability tests, but different in its implementation)

Decomposition: Froot and Ramadorai (2005 JF)

- VAR System

$$z_t = \Gamma z_{t-1} + u_t$$

  where z_t includes currency return rx_t, interest rate differential d_t and real exchange rate s_t

- With the VAR estimated, we can then compute the interest rate news and risk premia news $\sum_{\tau=0}^{T} -(r^*_{t+\tau} - r_{t+\tau})$ and $\sum_{\tau=0}^{T} E_t rx_{t+\tau+1}$

Table III

Variance Decomposition

This table shows the components of the variance of excess currency returns. These are estimated using the intrinsic value and expected-return decomposition obtained from our vector autoregression (VAR) estimates. The columns present, in order, the total variance of currency excess returns; the variance of the intrinsic value component of excess returns; the variance of the expected-return component of excess returns; the covariance between the two components, expected return, and intrinsic value; the variance of short horizon expected returns (k signifies 30 trading days); the variance of long horizon expected returns (from $k+1$ onward); and the covariance of short and long horizon expected returns. These estimates are presented for the major countries first, followed by the estimates for all countries. Standard errors are presented below coefficients in parentheses, and are estimated using the delete-1 jackknife method.

	σ^2_{fx}	σ^2_{iv}	σ^2_{er}	$\sigma_{er,iv}$	$\sigma^2_{er(1,k)}$	$\sigma^2_{er(k+1,\infty)}$	$\sigma_{er(1,k),er(k+1,\infty)}$
Majors	2,804.94	537.27	2,022.12	−122.79	4.33	2,079.72	−30.96
	(88.29)	(109.28)	(1,647.53)	(768.75)	(11.86)	(1,698.51)	(177.75)
All	6,704.69	1,047.3	4,514.48	−571.47	277.51	6,289.72	−1,026.41
	(500.30)	(418.19)	(1,879.72)	(756.26)	(640.22)	(3,185.19)	(1,843.65)

Engel and Wu (2024): Exchange Rate Models are Better Than You Think

$$\Delta s_t = \alpha + \beta \Delta r_t + \beta_2 \Delta r_t^* + \beta_3 \pi_t + \beta_4 \pi_t^* + \beta_5 \Delta RISK_t + \beta_6 q_{t-1} + \beta_7 \frac{TB}{GDP}_t + \beta_8 \eta_t + u_t$$

- 1999-2023: significance and good fit
- It did not work in the 70s to 90s
- Why it does not work in the old days?
  - Monetary policy credibility
  - Learning literature: Lewis (1989 AER), Gourinchas and Tornell (2004 JIE), etc

Regression Results

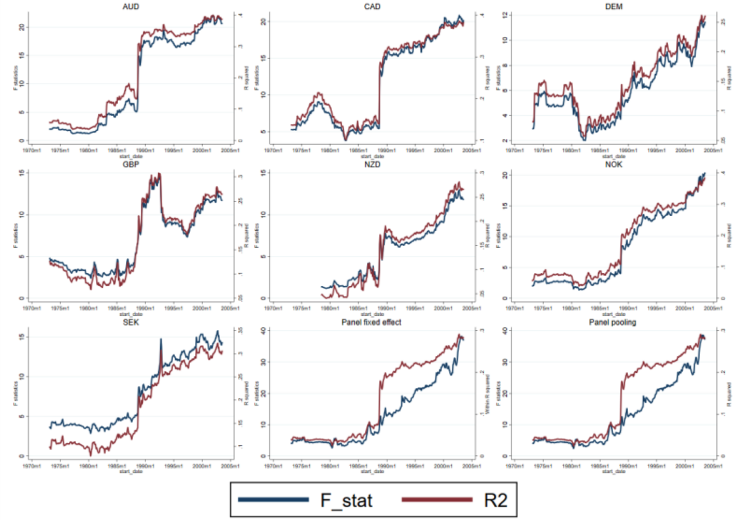
Table 1: Baseline regression with inflation level, and convenience yield

	AUD	CAD	EUR	GBP	NZD	NOK	SEK	Panel fixed effect	Panel pooled
Δr_t	-1.12***	-1.66***	-2.34***	-1.37***	-0.92***	-1.85***	-1.94***	-1.48***	-1.47***
	(0.292)	(0.261)	(0.289)	(0.258)	(0.325)	(0.291)	(0.296)	(0.201)	(0.201)
Δr_t^*	1.12***	1.16***	2.21***	1.80***	1.06***	0.23	0.80**	0.92***	0.94***
	(0.279)	(0.269)	(0.395)	(0.371)	(0.356)	(0.198)	(0.333)	(0.163)	(0.164)
π_t	-0.25**	-0.21*	-0.69***	-0.33***	-0.45***	-0.21*	-0.58***	-0.34***	-0.33***
	(0.104)	(0.126)	(0.141)	(0.116)	(0.129)	(0.111)	(0.125)	(0.078)	(0.077)
π_t^*	0.03	0.14	0.53***	0.14	0.24*	-0.19	0.24**	0.15**	0.18***
	(0.126)	(0.154)	(0.131)	(0.107)	(0.136)	(0.129)	(0.095)	(0.068)	(0.064)
$\Delta RISK_t$	-0.03***	-0.02***	-0.01***	-0.01***	-0.02***	-0.02***	-0.02***	-0.02***	-0.02***
	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
q_{t-1}	-0.01	-0.01	-0.02**	-0.03***	-0.01	-0.03***	-0.01	-0.01**	-0.00
	(0.007)	(0.007)	(0.009)	(0.012)	(0.008)	(0.009)	(0.010)	(0.006)	(0.000)
$\frac{TB}{GDP_t}$	-0.48***	-0.45***	-0.63***	-0.73***	-0.37*	-0.66***	-0.80***	-0.54***	-0.48***
	(0.172)	(0.122)	(0.163)	(0.210)	(0.195)	(0.209)	(0.201)	(0.127)	(0.125)
$\Delta \eta_t$	-1.92**	-2.33***	-0.86	-1.52*	-1.56**	-1.20*	-1.04	-1.38**	-1.45**
	(0.918)	(0.798)	(0.941)	(0.861)	(0.742)	(0.680)	(0.674)	(0.618)	(0.621)
N	296	296	295	296	296	296	296	2071	2071
F	21.80	21.45	13.30	11.56	11.33	16.80	13.12	22.65	21.50
R2	0.38	0.37	0.27	0.24	0.24	0.32	0.27		0.25
R2_adj	0.36	0.36	0.25	0.22	0.22	0.30	0.25		
R2_within								0.25	

Note: Standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01. Sample period is from Jan 1999 to Aug 2023. The explanatory variable in all regression is the change of U.S. exchange rate with the currency in the column head. For the panel regressions, standard errors are Driscoll Kraay 1998 standard errors. r_t and r_t^* are the change of home and foreign real interest rate, π_t and π_t^* are the home and foreign CPI inflation rate, $RISK_t$ is the first principal component of five risk variables. q_{t-1} is the real exchange rate in the previous period. TB/GDP_t is the trade balance to GDP of the U.S. η_t is the measure of the U.S. convenience yield relative to the foreign country, using 1-year government bond rates, as in Engel and Wu (2023).

Goodness of Fit

Figure 3: *F*-statistic of 20-year rolling window regressions of equation (1)



Note: The figure reports the F-statistics and R squared in equation (1) with a 20-year rolling window regression. X-axis corresponds to the start date of the rolling window regression. The first regression is Mar 1973-Feb 1993. The last regression is Sep 2003-Aug 2023.

Other Correlates: Liu and Shaliastovich (2021 JFE)

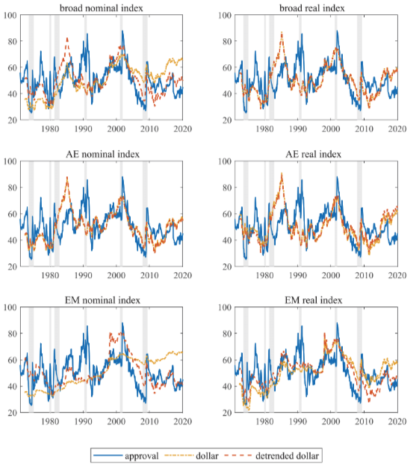


Fig. 6. Approval rate and the dollar index value. The figure shows the time series of US presidential approval rate and the dollar index. The dollar index is computed as an equal-weighted average value of the US dollar against a broad group of currencies (broad), against advanced economy currencies (AE), and against emerging market currencies (EM). The panels show the raw and detrended index after removing a linear trend. All series are normalized to have zero mean and unit variance. Data are monthly from 1971:1 to 2019:12.

Predictor: Liu and Shaliastovich (2021 JFE)

Table 4
Approval rate and exchange rate predictability: univariate evidence.

	Nominal				Real				Excess return			
h	Coef	$t(H)$	$t(NW)$	$\bar{R}^2$	Coef	$t(H)$	$t(NW)$	$\bar{R}^2$	Coef	$t(H)$	$t(NW)$	$\bar{R}^2$
					Broad dollar index							
1	-0.12	-1.34	-1.34	0.00	-0.13	-1.52	-1.51	0.00	-0.18	-1.96	-1.97	0.01
3	-0.18	-2.10	-1.89	0.02	-0.19	-2.26	-2.10	0.02	-0.23	-2.72	-2.47	0.03
12	-0.20	-2.65	-2.67	0.07	-0.20	-2.70	-2.80	0.08	-0.25	-3.33	-3.46	0.11
24	-0.19	-2.73	-3.04	0.12	-0.18	-2.55	-2.80	0.11	-0.24	-3.35	-3.60	0.17
36	-0.15	-2.26	-2.29	0.10	-0.12	-1.83	-1.86	0.07	-0.18	-2.71	-2.60	0.13
60	-0.11	-2.20	-2.19	0.11	-0.09	-1.85	-2.02	0.09	-0.14	-2.61	-2.53	0.14
					AE dollar index							
1	-0.18	-1.71	-1.71	0.00	-0.19	-1.84	-1.83	0.01	-0.21	-2.01	-2.01	0.01
3	-0.24	-2.41	-2.26	0.02	-0.25	-2.50	-2.41	0.03	-0.27	-2.70	-2.55	0.03
12	-0.27	-2.94	-3.06	0.10	-0.26	-2.92	-3.06	0.10	-0.29	-3.24	-3.32	0.11
24	-0.24	-2.84	-3.04	0.15	-0.22	-2.61	-2.78	0.13	-0.27	-3.13	-3.22	0.16
36	-0.17	-2.18	-2.20	0.11	-0.14	-1.77	-1.85	0.08	-0.19	-2.38	-2.35	0.11
60	-0.14	-2.15	-2.36	0.13	-0.11	-1.73	-2.18	0.09	-0.15	-2.29	-2.59	0.12
					EM dollar index							
1	0.01	0.09	0.09	0.00	-0.01	-0.14	-0.14	0.00	-0.07	-0.92	-0.92	0.00
3	-0.03	-0.39	-0.34	0.00	-0.05	-0.67	-0.63	0.00	-0.10	-1.43	-1.29	0.01
12	-0.05	-0.82	-0.78	0.00	-0.07	-1.17	-1.25	0.01	-0.14	-2.07	-2.18	0.04
24	-0.09	-1.42	-1.62	0.03	-0.11	-1.78	-2.21	0.06	-0.16	-2.57	-2.81	0.10
36	-0.08	-1.47	-1.56	0.04	-0.08	-1.56	-1.78	0.06	-0.13	-2.42	-2.12	0.11
60	-0.07	-1.60	-1.32	0.04	-0.08	-1.94	-1.95	0.11	-0.11	-2.64	-1.79	0.11

The table presents the univariate regression evidence of the predictability of future dollar index values by US presidential approval rate: $1/h\sum_{j=1}^{h} y_{t+j} = const + \beta_h^{App} App_t + e_{t:t+h}^{FX}$. The dependent variables y are the average log changes in nominal and real dollar index values and average dollar excess returns. The table shows the OLS coefficient ("Coef") on the approval rate β_h^{App}, the associated Newey-West and Hodrick t-statistics, and the adjusted R^2. The dollar index is computed as an equal-weighted average value of the US dollar against a broad group of currencies (broad), against advanced economy currencies (AE), and against emerging market currencies (EM), in real and nominal terms. Data are monthly from 1971:1 to 2019:12.

Predictor: Gourinchas and Rey (2007 JPE)

- Intertemporal budget constraint of a country

$$NA_{t+1} = R_{t+1}(NA_t + NX_t)$$

  - A country borrows from the RoW either because it will repay by trade surplus or because it has valuation gain
  - Part of the valuation gain comes from exchange rates
  - For a long time, the valuation gain was not studied much because most models do not include risk and risk premia
    - Explain the global imbalance: From World Banker to World Venture Capitalist (Gounrinchas and Rey, 2007a); Exorbitant privilege and exorbitant duty (Gourinchas, Rey and Govillot, 2017), Maggiori (2017 AER)
  - Part of the valuation effect comes from exchange rates - exchange rate predictability

Quantifying Real and Financial Adjustment

TABLE 2
FORECASTING QUARTERLY RETURNS
A. RETURNS

z_t	Total Real Return (r_{t+1}) (1)	r_t (2)	$(d_t/p_t) - (d_t^*/p_t^*)$ (3)	xm_t (4)	Real Equity Differential (Δr_{t+1}^e) (5)	Δr_t^e (6)	$(d_t/p_t) - (d_t^*/p_t^*)$ (7)	xm_t (8)
$\hat{\beta}$	**−.36**	**−.33**	**−.46**	**−.37**	**−.13**	**−.14**	**−.17**	−.07
	(.07)	(.07)	(.08)	(.16)	(.03)	(.03)	(.03)	(−.06)
$\hat{\delta}$		.09	−1.43	.01		−.07	−.63	−.09
		(.07)	(1.60)	(.19)		(.07)	(.61)	(.07)
$\bar{R}^2$	.10	.10	.15	.10	.07	.07	.12	.07
Observations	208	207	136	208	208	207	136	208

B. DEPRECIATION RATES

z_t	FDI-Weighted (Δe_{t+1}) (1)	Δe_t (2)	xm_t (3)	$i_t - i_t^*$ (4)	Trade-Weighted (Δe_{t+1}^T) (5)	Δe_t^T (6)	xm_{t-1} (7)	$i_t - i_t^*$ (8)
$\hat{\beta}$	**−.08**	**−.09**	**−.10**	**−.09**	**−.09**	**−.09**	**−.08**	**−.08**
	(.02)	(.02)	(.04)	(.02)	(.02)	(.02)	(.03)	(.02)
$\hat{\delta}$		−.04	.02	.32		.02	−.01	−.67
		(.07)	(.05)	(.32)		(.07)	(.05)	(.34)
$\bar{R}^2$	.09	.08	.08	.08	.11	.10	.10	.13
Observations	125	124	125	125	124	123	124	124

NOTE.—Regressions of the form $y_{t+1} = \alpha + \beta nxa_t + \delta z_t + \epsilon_{t+1}$, where y_{t+1} is the total real return (r_{t+1}), the equity return differential ($\Delta r_{t+1}^e = r_{t+1}^{ae} - r_{t+1}^{le}$) (panel A), the FDI-weighted depreciation rate (Δe_{t+1}), or the trade-weighted depreciation rate (Δe_{t+1}^T) (panel B). $(d_t/p_t) - (d_t^*/p_t^*)$ is the relative dividend-price ratio (available since 1970:1); $i_t - i_t^*$ is the short-term interest rate differential; xm_t is the stationary component from the trade balance, defined as $\epsilon_t^x - \epsilon_t^m$. The sample is 1952:1–2004:1 for total returns and 1973:1–2004:1 for depreciation rates. Robust standard errors are in parentheses. Boldface entries are significant at the 5 percent level.

Quantifying Real and Financial Adjustment

TABLE 3
LONG-HORIZON REGRESSIONS

	Forecast Horizon (Quarters)							
	1	2	3	4	8	12	16	24
	A. Real Total Net Portfolio Return $r_{t,k}$							
nxa	**−.36**	**−.35**	**−.35**	**−.33**	**−.22**	**−.14**	**−.09**	**−.04**
	(.07)	(.05)	(.04)	(.04)	(.03)	(.03)	(.02)	(.02)
$\bar{R}^2(1)$	[.11]	[.18]	[.24]	[.26]	[.21]	[.13]	[.09]	[.02]
$\bar{R}^2(2)$	[.14]	[.25]	[.34]	[.38]	[.35]	[.24]	[.19]	[.16]
	B. Real Total Excess Equity Return $r^{ae}_{t,k} - r^{le}_{t,k}$							
nxa	**−.14**	**−.13**	**−.12**	**−.11**	**−.06**	**−.03**	−.02	.01
	(.03)	(.02)	(.02)	(.02)	(.01)	(.01)	(.01)	(.01)
$\bar{R}^2(1)$	[.07]	[.13]	[.17]	[.18]	[.10]	[.03]	[.01]	[.00]
$\bar{R}^2(2)$	[.11]	[.20]	[.28]	[.31]	[.26]	[.15]	[.10]	[.17]
	C. Net Export Growth $\Delta nx_{t,k}$							
nxa	**−.08**	**−.08**	**−.07**	**−.07**	**−.07**	**−.06**	**−.06**	**−.04**
	(.02)	(.02)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
$\bar{R}^2(1)$	[.05]	[.10]	[.13]	[.17]	[.31]	[.44]	[.53]	[.58]
$\bar{R}^2(2)$	[.04]	[.08]	[.12]	[.17]	[.38]	[.55]	[.66]	[.79]
	D. FDI-Weighted Effective Nominal Rate of Depreciation $\Delta e_{t,k}$							
nxa	**−.08**	**−.08**	**−.08**	**−.08**	**−.07**	**−.06**	**−.04**	**−.02**
	(.02)	(.02)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
$\bar{R}^2(1)$	[.09]	[.16]	[.28]	[.31]	[.41]	[.41]	[.33]	[.12]
$\bar{R}^2(2)$	[.10]	[.21]	[.35]	[.40]	[.52]	[.55]	[.55]	[.38]

NOTE.—Regressions of the form $y_{t,k} = \alpha + \beta nxa_t + \epsilon_{t+k}$, where $y_{t,k}$ is the k-period real total net portfolio return ($r_{t,k}$), total excess equity return ($r^{ae}_{t,k} - r^{le}_{t,k}$), net export growth ($\Delta nx_{t,k}$), or the FDI-weighted depreciation rate ($\Delta e_{t,k}$). Newey-West robust standard errors are in parentheses with a $k-1$ Bartlett window. Adjusted R^2's are in brackets. $\bar{R}(1)$ reports the adjusted R^2 of the regression on nxa_t; $\bar{R}(2)$ reports the adjusted R^2 of the regression on $\epsilon^x_t, \epsilon^m_t, \epsilon^a_t$, and ϵ^l_t. The sample is 1952:1–2004:1 (1973:1–2004:1 for the exchange rate). Boldface entries are significant at the 5 percent level.

The Fama Puzzle (1984 JME) and the Failure of the UIP

- Uncovered interest rate parity (UIP)

$$i_t^* - i_t - E_t \Delta s_{t+1} = 0$$

- The Fama regression

$$\Delta s_{t+1} = a + b(i_t^* - i_t) + e_{t+1}$$

  Under the UIP, $b = 1$. In the data, $b < 1$ and sometimes negative

- Alternatively, we may run the following predictive regression

$$r_{t+1} \equiv i_t^* - i_t - \Delta s_{t+1} = \alpha + \beta(i_t^* - i_t) + e_{t+1}$$

  Under the UIP, $\beta = 0$. In the data, $\beta > 0$ and sometimes greater than 1

The Term Structure of UIP: Engel (2016 AER)

$$\rho_{t+j+1} = i^*_{t+j} - i_{t+j} + s_{t+j+1} - s_{t+j}$$

- Fama puzzle: $corr(E_t \rho_{t+1}, i^*_t - i_t) > 0$
- This paper: $corr(E_t \sum_{j=0}^{\infty} \rho_{t+j+1}, i^*_t - i_t) < 0$
  - Measure $E_t \sum_{j=0}^{\infty} \rho_{t+j+1}$ using different methods
  - In the long run, higher-interest-rate currencies tend to have lower risk premium
  - There must be $cov(E_t \rho_{t+j}, i^*_t - i_t) < 0$ for some j
  - Real exchange rate appreciates instantaneously and future risk premium declines
- Delayed overshooting in Evans and Eichenbaum (1995 QJE), Schmitt-Grohe and Uribe (2021, JIE) distinguish permanent and transitory monetary factors

Evidence

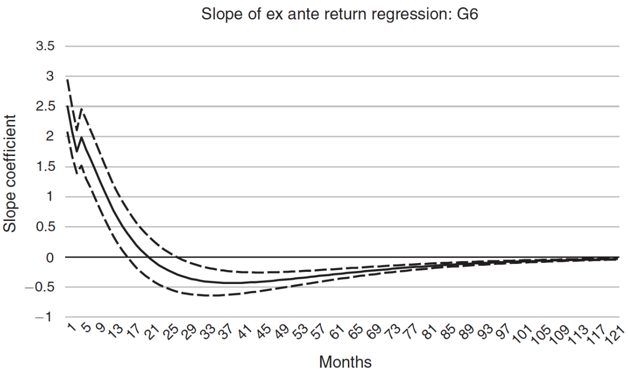


FIGURE 2. SLOPE COEFFICIENTS AND 90 PERCENT CONFIDENCE INTERVAL OF THE REGRESSION: $\hat{E}_t(\rho_{t+j}) = \zeta_j + \beta_j(i_t^* - i_t) + u_t^j$

Notes: Monthly data, 1979:6–2009:10. Confidence intervals calculated from Newey-West standard errors.

Challenge to Existing Models

- Macro model: Typically under UIP
  - Interest rate differential rises, foreign currency appreciates and depreciates afterwards
- Macro-finance models of currency risk premia
  - Interest rate differential rises, foreign currency depreciates and is expected to appreciate
- Data: Interest rate differential rises, foreign currency appreciates and is expected to appreciate further, then depreciate in the long run
- How to address this puzzle?
  - Engel (2016) proposes a liquidity premium based explanation
  - Dahlquist and Penasse (2022, JFE): multiple shocks with different persistence

Currency Risk Premia in the Cross-Section: Lustig Roussanov Verdelhan (2011 RFS)

Table 1
Currency portfolios—U.S. investor

Portfolio	1	2	3	4	5	6	1	2	3	4	5
	Panel I: All Countries						Panel II: Developed Countries				
	Spot change: Δs^j						Δs^j				
Mean	−0.64	−0.92	−0.95	−2.57	−0.60	2.82	−1.81	−1.87	−3.28	−1.57	−0.82
Std	8.15	7.37	7.63	7.50	8.49	9.72	10.17	9.95	9.80	9.54	10.26
	Forward Discount: $f^j - s^j$						$f^j - s^j$				
Mean	−2.97	−1.23	−0.09	1.00	2.67	9.01	−2.95	−0.94	0.11	1.18	3.92
Std	0.54	0.48	0.47	0.52	0.64	1.89	0.77	0.62	0.63	0.66	0.74
	Excess Return: rx^j (without b–a)						rx^j (without b–a)				
Mean	−2.33	−0.31	0.86	3.57	3.27	6.20	−1.14	0.93	3.39	2.74	4.74
Std	8.23	7.44	7.66	7.59	8.56	9.73	10.24	9.98	9.89	9.62	10.33
SR	−0.28	−0.04	0.11	0.47	0.38	0.64	−0.11	0.09	0.34	0.29	0.46
	Net Excess Return: rx^j_{net} (with b–a)						rx^j_{net} (with b–a)				
Mean	−1.17	−1.27	−0.39	2.26	1.74	3.38	−0.02	−0.11	2.02	1.49	3.07
Std	8.24	7.44	7.63	7.55	8.58	9.72	10.24	9.98	9.87	9.63	10.32
SR	−0.14	−0.17	−0.05	0.30	0.20	0.35	−0.00	−0.01	0.21	0.15	0.30
	High-minus-Low: $rx^j - rx^1$ (without b–a)						$rx^j - rx^1$ (without b–a)				
Mean		2.02	3.19	5.90	5.60	8.53		2.07	4.53	3.88	5.88
Std		5.37	5.30	6.16	6.70	9.02		7.18	7.11	8.02	9.64
SR		0.38	0.60	0.96	0.84	0.95		0.29	0.64	0.48	0.61
	High-minus-Low: $rx^j_{net} - rx^1_{net}$ (with b–a)						$rx^j_{net} - rx^1_{net}$ (with b–a)				
Mean		−0.10	0.78	3.42	2.91	4.54		−0.09	2.04	1.51	3.09
		[0.30]	[0.30]	[0.35]	[0.38]	[0.51]		[0.41]	[0.40]	[0.45]	[0.54]
Std		5.40	5.32	6.15	6.75	9.05		7.20	7.11	8.04	9.66
SR		−0.02	0.15	0.56	0.43	0.50		−0.01	0.29	0.19	0.32

(*continued*)

The Common Factor Structure

Table 4
Continued

Panel II: Factor Betas

	All Countries						Developed Countries					
Portfolio	α_0^j	$\beta_{HML_{FX}}^j$	β_{RX}^j	R^2	$\chi^2(\alpha)$	*p–value*	α_0^j	$\beta_{HML_{FX}}^j$	β_{RX}^j	R^2	$\chi^2(\alpha)$	*p–value*
1	−0.10	−0.39	1.05	91.64			0.36	−0.51	0.99	94.31		
	[0.50]	[0.02]	[0.03]				[0.53]	[0.03]	[0.02]			
2	−1.55	−0.11	0.94	77.74			−1.17	−0.09	1.01	80.69		
	[0.73]	[0.03]	[0.04]				[0.85]	[0.04]	[0.04]			
3	−0.54	−0.14	0.96	76.72			0.62	−0.00	1.04	86.50		
	[0.74]	[0.03]	[0.04]				[0.79]	[0.03]	[0.03]			
4	1.51	−0.01	0.95	75.36			−0.17	0.12	0.97	82.84		
	[0.77]	[0.03]	[0.05]				[0.85]	[0.03]	[0.04]			
5	0.78	0.04	1.06	76.41			0.36	0.49	0.99	94.32		
	[0.82]	[0.03]	[0.05]				[0.53]	[0.03]	[0.02]			
6	−0.10	0.61	1.05	93.84								
	[0.50]	[0.02]	[0.03]									
All					6.79	34.05%					2.63	75.64%

The panel on the left reports results for all countries. The panel on the right reports results for developed countries. Panel I reports results from GMM and Fama–McBeth asset pricing procedures. Market prices of risk λ, the adjusted R^2, the square root of mean-squared errors $RMSE$, and the p-values of χ^2 tests on pricing errors are reported in percentage points. b denotes the vector of factor loadings. Excess returns used as test assets and risk factors take into account bid-ask spreads. All excess returns are multiplied by 12 (annualized). Shanken (1992)-corrected standard errors are reported in parentheses. We do not include a constant in the second step of the FMB procedure. Panel II reports OLS estimates of the factor betas. R^2s and p-values are reported in percentage points. The standard errors in brackets are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The χ^2 test statistic $\alpha' V_\alpha^{-1} \alpha$ tests the null that all intercepts are jointly zero. This statistic is constructed from the Newey–West variance-covariance matrix (1 lag) for the system of equations (see Cochrane 2005, p. 234). Data are monthly, from Barclays and Reuters in Datastream. The sample period is 11/1983–12/2009. The alphas are annualized and in percentage points.

Price of Risk Estimate

Table 4
Asset pricing—U.S. investor

Panel I: Risk Prices

	All Countries							Developed Countries						
	$\lambda_{HML_{FX}}$	λ_{RX}	$b_{HML_{FX}}$	b_{RX}	R^2	RMSE	χ^2	$\lambda_{HML_{FX}}$	λ_{RX}	$b_{HML_{FX}}$	b_{RX}	R^2	RMSE	χ^2
GMM_1	5.50	1.34	0.56	0.20	70.11	0.96		3.29	1.90	0.29	0.20	64.78	0.64	
	[2.25]	[1.85]	[0.23]	[0.32]			14.39%	[2.59]	[2.20]	[0.23]	[0.23]			45.96%
GMM_2	5.51	0.40	0.57	0.04	41.25	1.34		3.91	3.07	0.35	0.32	−55.65	1.34	
	[2.14]	[1.77]	[0.22]	[0.31]			16.10%	[2.52]	[2.05]	[0.22]	[0.22]			52.22%
FMB	5.50	1.34	0.56	0.20	70.11	0.96		3.29	1.90	0.29	0.20	64.78	0.64	
	[1.79]	[1.35]	[0.19]	[0.24]			9.19%	[1.91]	[1.73]	[0.17]	[0.18]			43.64%
	(1.79)	(1.35)	(0.19)	(0.24)			10.20%	(1.91)	(1.73)	(0.17)	(0.18)			44.25%
Mean	**5.08**	**1.33**					**3.14**	**1.90**						

(continued)

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Economic Sources of Risk

- Stock return vol: average volatility of stock returns in local currency across all currencies

Table 13
Asset pricing–equity volatility risk factor (innovations)

Panel I: Factor Betas

	All Countries			Developed Countries		
Portfolio	$\beta^j_{Vol_{Equity}}$	β^j_{RX}	R^2	$\beta^j_{Vol_{Equity}}$	β^j_{RX}	R^2
1	0.37	1.04	74.78	0.58	0.99	72.55
	[0.12]	[0.05]		[0.25]	[0.06]	
2	0.22	0.94	76.21	0.16	1.01	80.01
	[0.10]	[0.04]		[0.14]	[0.04]	
3	0.19	0.95	74.34	0.20	1.04	86.67
	[0.10]	[0.04]		[0.13]	[0.03]	
4	0.13	0.95	75.44	–0.35	0.97	82.02
	[0.08]	[0.05]		[0.18]	[0.04]	
5	–0.10	1.06	76.30	–0.59	0.99	74.50
	[0.13]	[0.05]		[0.16]	[0.05]	
6	–0.81	1.07	63.84			
	[0.16]	[0.06]				

Panel II: Risk Prices

	All Countries			Developed Countries		
	$\lambda_{Vol_{Equity}}$	λ_{RX}	R^2	$\lambda_{Vol_{Equity}}$	λ_{RX}	R^2
FMB	–4.20	1.33	66.10	–2.31	1.91	48.12
	[1.41]	[1.35]		[1.46]	[1.73]	
	(1.65)	(1.35)		(1.53)	(1.73)	

The panel on the left reports empirical results using actual data for all countries. The panel on the right reports results for the simulated data from the calibrated model. Panel I reports OLS estimates of the factor betas. Panel II reports risk prices from the Fama–MacBeth cross-sectional regression. Market prices of risk λ and adjusted R^2s are reported in percentage points. Excess returns used as test assets and risk factors take into account bid-ask spreads. All excess returns are multiplied by 12 (annualized). To build our volatility factor, we first compute the standard deviation over one month of daily MSCI price index changes for each country in our sample. We then compute the cross-sectional mean of these volatility series. Our risk factor corresponds to volatility innovations, obtained as log differences of our global volatility series. We do not include a constant in the second step of the FMB procedure. The sample period is 11/1983–12/2009. The standard errors in brackets are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). Shanken (1992)-corrected standard errors are reported in parentheses.

FX Volatility as Risk Factor: Menkhoff et al (2012 JF)

- FX volatility measure

$$\sigma_t^{FX} = \frac{1}{T_t} \sum_{\tau \in T_t} \left[\sum_{k \in K_\tau} \left(\frac{|r_\tau^k|}{K_\tau} \right) \right]$$

  K_τ is the number of currencies available

- Carry trade portfolios
- Risk factors: dollar factor + FX vol factor

Results

Table II

Cross-sectional Asset Pricing Results: Volatility Risk

The table reports cross-sectional pricing results for the linear factor model based on the dollar risk factor (DOL) and global FX volatility innovations (VOL). The test assets are excess returns to five carry trade portfolios based on currencies from all countries (left panel) or developed countries (right panel). Panel A shows coefficient estimates of SDF parameters b and factor risk prices λ obtained by GMM and FMB cross-sectional regression. We use first-stage GMM and do not use a constant in the second-stage FMB regressions. Standard errors (s.e.) of coefficient estimates are reported in parentheses and are obtained by the Newey and West (1987) procedure with optimal lag selection according to Andrews (1991). We also report the cross-sectional R^2 and the HJ distance (HJ dist) along with the (simulation-based) p-value for the test of whether the HJ distance is equal to zero. The reported FMB standard errors and χ^2 test statistics (with p-values in parentheses) are based on both the Shanken (1992) adjustment (Sh) or the Newey–West approach with optimal lag selection (NW). Panel B reports results for time-series regressions of excess returns on a constant (α), the dollar risk factor (DOL), and global FX volatility innovations (VOL). HAC standard errors (Newey–West with optimal lag selection) are reported in parentheses. The sample period is December 1983 to August 2009 and we use monthly transaction cost adjusted returns.

Panel A: Factor Prices

All Countries (with b-a)					Developed Countries (with b-a)				
GMM	DOL	VOL	R^2	HJ dist	GMM	DOL	VOL	R^2	HJ dist
b	0.00	−7.15	0.97	0.08	b	0.02	−4.38	0.94	0.06
s.e.	(0.05)	(2.96)		(0.79)	s.e.	(0.03)	(2.73)		(0.89)
λ	0.21	−0.07			λ	0.22	−0.06		
s.e.	(0.25)	(0.03)			s.e.	(0.22)	(0.04)		
FMB	DOL	VOL	χ^2_{SH}	χ^2_{NW}	FMB	DOL	VOL	χ^2_{SH}	χ^2_{NW}
λ	0.21	−0.07	1.35	0.94	λ	0.22	−0.06	0.95	0.83
(Sh)	(0.15)	(0.02)	(0.72)	(0.82)	(Sh)	(0.16)	(0.02)	(0.81)	(0.84)
(NW)	(0.13)	(0.03)			(NW)	(0.15)	(0.03)		

Panel B: Factor Betas

All Countries (with b-a)					Developed Countries (with b-a)				
PF	α	DOL	VOL	R^2	PF	α	DOL	VOL	R^2
1	−0.29	1.01	4.34	0.76	1	−0.23	0.94	4.52	0.71
	(0.08)	(0.04)	(0.70)			(0.09)	(0.05)	(1.42)	
2	−0.15	0.84	1.00	0.74	2	−0.05	1.05	0.43	0.82
	(0.06)	(0.04)	(0.59)			(0.07)	(0.04)	(0.89)	
3	0.05	0.97	−0.30	0.79	3	−0.02	1.01	0.01	0.88
	(0.06)	(0.04)	(0.63)			(0.05)	(0.03)	(0.64)	
4	0.09	1.02	−1.06	0.83	4	0.07	0.96	−1.94	0.82
	(0.06)	(0.04)	(0.71)			(0.07)	(0.03)	(0.97)	
5	0.30	1.15	−3.98	0.67	5	0.24	1.04	−3.02	0.73
	(0.11)	(0.06)	(1.20)			(0.10)	(0.05)	(1.09)	

A Dollar-based UIP Trade: Lustig Roussanov and Verdelhan (2014 JFE)

- Dollar carry
  - Long USD and short others when US interest rate is higher than average
  - Short USD and long others when US interest rate is lower than average

Performance

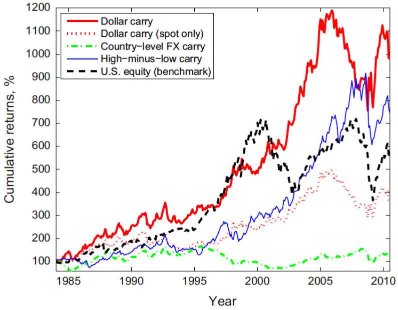

Fig. 2. Carry trade excess return indexes. This figure plots the total return index for four investment strategies, starting at $100 on November 30, 1983. The dollar carry trade goes long all one-month forward contracts in a basket of developed country currencies when the average one-month forward discount for the basket is positive, and short the same contracts otherwise. This strategy is labeled *Dollar carry*. The component of this strategy that is due to the spot exchange rate changes, i.e., excluding the interest rate differential, is *dollar carry* (*spot only*). The individual country-level carry trade is an equal-weighted average of long-short positions in individual currency one-month forward contracts that depend on the sign of the bilateral forward discounts; this strategy is labeled *Country-level FX carry*. The third strategy corresponds to dollar-neutral high-minus-low currency carry trades in one-month forward contracts (*High-minus-low carry*). The fourth strategy, *U.S. equity* (*benchmark*), is simply long the excess return on the CRSP value-weighted U.S. stock market portfolio. All strategies are levered to match the volatility of the stock market.

Countercyclical Currency Risk Premium

Table 10

Forecasting excess returns and exchange rates with industrial production and the average forward discount. This table reports results of forecasting regressions for average excess returns and average exchange rate changes for baskets of currencies at horizons of one, two, three, six, and 12 months. For each basket we report the R^2, and the slope coefficients in the time-series regression of the log currency excess return on the 12-month change in the U.S. Industrial Production Index (ψ_{IP}) and on the average log forward discount (ψ_f), and similarly the slope coefficients ζ_{IP}, ζ_f, and the R^2 for the regressions of average exchange rate changes. The *t*-statistics for the slope coefficients in brackets are computed using the following methods. *HH* denotes Hansen and Hodrick (1980) standard errors computed with the number of lags equal to the length of overlap plus one lag. The *VAR*-based statistics are adjusted for the small-sample bias using the stationary bootstrap distributions of slope coefficients under the null hypothesis of no predictability, estimated by drawing random blocks of residuals of a VAR with the number of lags equal to the length of overlap plus one lag. Data are monthly, from Barclays and Reuters (available via Datastream). We also report the Wald tests (*W*) of the hypothesis that both slope coefficients are jointly equal to zero; the percentage *p*-values in brackets are for the χ^2-distribution under the parametric cases (*HH*) and for the bootstrap distribution of the *F*-statistic under *VAR*. Data are monthly, from Barclays and Reuters (available via Datastream). The returns do not take into account bid–ask spreads. The sample period is 11/1983–6/2010.

	Developed countries								Emerging countries								All countries							
	Excess returns				Exchange rates				Excess returns				Exchange rates				Excess returns				Exchange rates			
Horizon	ψ_{IP}	ψ_f	W	R^2	ζ_{IP}	ζ_f	W	R^2	ψ_{IP}	ψ_f	W	R^2	ζ_{IP}	ζ_f	W	R^2	ψ_{IP}	ψ_f	W	R^2	ζ_{IP}	ζ_f	W	R^2
1	−0.54	2.14	7.00	3.40	−0.54	1.14	3.16	1.53	−1.15	−0.20	3.78	2.74	−1.15	−1.20	6.73	4.93	−0.65	1.68	5.00	2.72	−0.65	0.68	2.49	1.41
HH	[−0.96]	[2.06]	[1.24]		[−0.96]	[1.10]	[29.79]		[−1.95]	[−0.27]	[28.75]		[−1.95]	[−1.57]	[7.64]		[−1.23]	[1.50]	[10.49]		[−1.23]	[0.61]	[49.35]	
VAR	[−1.02]	[2.32]	[0.00]		[−0.97]	[1.26]	[0.00]		[−2.39]	[−0.47]	[0.00]		[−2.32]	[−2.26]	[0.00]		[−1.31]	[1.66]	[0.00]		[−1.41]	[0.70]	[0.10]	
2	−0.65	2.09	10.35	6.25	−0.65	1.09	6.71	3.14	−1.17	−0.64	7.10	6.54	−1.17	−1.64	6.64	11.66	−0.74	1.64	7.53	5.24	−0.74	0.64	4.97	3.06
HH	[−1.34]	[2.02]	[0.63]		[−1.34]	[1.05]	[17.97]		[−2.38]	[−0.80]	[9.83]		[−2.38]	[−2.05]	[2.40]		[−1.65]	[1.52]	[3.43]		[−1.65]	[0.60]	[25.98]	
VAR	[−1.24]	[1.90]	[0.00]		[−1.21]	[1.02]	[0.00]		[−2.35]	[−1.14]	[0.00]		[−2.32]	[−2.78]	[0.00]		[−1.41]	[1.52]	[0.00]		[−1.60]	[0.55]	[0.10]	
3	−0.72	1.99	23.67	8.68	−0.72	0.99	19.77	4.65	−1.28	−0.54	8.01	9.81	−1.28	−1.54	7.59	15.74	−0.82	1.52	10.17	7.57	−0.82	0.52	9.45	4.77
HH	[−1.66]	[1.97]	[0.43]		[−1.66]	[0.98]	[12.21]		[−2.71]	[−0.68]	[3.00]		[−2.71]	[−1.94]	[1.33]		[−2.08]	[1.53]	[1.72]		[−2.08]	[0.53]	[13.49]	
VAR	[−1.28]	[1.69]	[0.00]		[−1.49]	[0.96]	[0.00]		[−2.64]	[−0.92]	[0.00]		[−2.67]	[−2.36]	[0.00]		[−1.76]	[1.23]	[0.00]		[−1.76]	[0.41]	[0.00]	
6	−0.87	1.84	38.02	15.58	−0.87	0.84	32.04	9.57	−1.48	−0.25	6.37	18.21	−1.48	−1.25	6.88	24.14	−0.96	1.59	11.94	15.92	−0.96	0.59	10.58	11.21
HH	[−2.60]	[2.03]	[0.00]		[−2.60]	[0.93]	[0.53]		[−3.06]	[−0.35]	[0.27]		[−3.06]	[−1.74]	[0.50]		[−3.15]	[2.06]	[0.01]		[−3.15]	[0.76]	[0.22]	
VAR	[−1.71]	[1.78]	[0.00]		[−1.85]	[0.84]	[0.00]		[−3.46]	[−0.46]	[0.00]		[−3.24]	[−1.87]	[0.00]		[−2.16]	[1.37]	[0.00]		[−2.36]	[0.51]	[0.00]	
12	−0.91	1.37	16.75	23.20	−0.91	0.37	13.05	15.16	−1.53	−0.07	7.37	28.40	−1.53	−1.07	7.35	34.51	−1.00	1.14	12.55	24.36	−1.00	0.14	10.25	18.49
HH	[−3.39]	[1.50]	[0.00]		[−3.39]	[0.41]	[0.00]		[−3.06]	[−0.08]	[0.24]		[−3.06]	[−1.24]	[0.60]		[−3.64]	[1.71]	[0.00]		[−3.64]	[0.21]	[0.01]	
VAR	[−2.15]	[1.35]	[0.00]		[−2.23]	[0.40]	[0.10]		[−5.27]	[−0.17]	[0.00]		[−5.00]	[−1.77]	[0.00]		[−2.89]	[1.18]	[0.00]		[−2.93]	[0.13]	[0.00]	

Interpretation: An Affine Model of SDF

$$-m_{i,t+1} = \alpha_i + \chi_i \sigma_{i,t}^2 + \tau_i \sigma_{w,t}^2 + \gamma_i \sigma_{i,t} u_{i,t+1} + \delta_i \sigma_{w,t} u_{w,t+1} + \kappa_i \sigma_{i,t} u_{g,t+1}$$

- Parameter restrictions: $\chi_i < \frac{1}{2}(\gamma_i^2 + \kappa_i^2)$, $\bar{\delta}_i = \delta$
- As you will see in the solution, these restrictions imply
  - Precautionary saving motive drives interest rates
  - An average dollar portfolio is not exposed to $u_{w,t+1}$ and the carry portfolio is only exposed to $u_{w,t+1}$

Solutions: Interest Rates

- Interest rates (non-US)

$$r_{i,t} = \alpha_i + \left(\chi_i - \frac{1}{2}(\gamma_i^2 + \kappa_i^2)\right) \sigma_{i,t}^2 + \left(\tau_i - \frac{1}{2}\delta_i^2\right) \sigma_{w,t}^2$$

- US interest rate

$$r_t = \alpha + \left(\chi - \frac{1}{2}(\gamma^2 + \kappa^2)\right) \sigma_t^2 + \left(\tau - \frac{1}{2}\delta^2\right) \sigma_{w,t}^2$$

- Average forward discount

$$AFD_t = \bar{\alpha}_i - \alpha + \overline{\left(\chi_i - \frac{1}{2}(\gamma_i^2 + \kappa_i^2)\right) \sigma_{i,t}^2} - \left(\chi - \frac{1}{2}(\gamma^2 + \kappa^2)\right) \sigma_t^2$$
$$+ \left(\bar{\tau}_i - \tau - \frac{1}{2}(\bar{\delta}_i^2 - \delta^2)\right) \sigma_{w,t}^2$$

AFD is driven by the US volatility

Solution: Exchange Rates and Currency Risk Premia

- Exchange rates

$$\Delta s_{i,t+1} = \alpha_i - \alpha + \chi_i \sigma_{i,t}^2 - \chi \sigma_t^2 + (\tau_i - \tau)\sigma_{w,t}^2$$

$$+\gamma_i \sigma_{i,t} u_{t+1}^i - \gamma \sigma_t u_{t+1} + (\delta_i - \delta)\sigma_{w,t} u_{w,t+1} + (\kappa_i \sigma_{i,t} - \kappa \sigma_t) u_{g,t+1}$$

- Currency risk premia

$$rx_{t+1}^i = \frac{1}{2}\left(\gamma^2 \sigma_t^2 - \gamma_i^2 \sigma_{i,t}^2\right) + \frac{1}{2}\left(\delta - \delta_i\right)\sigma_{w,t}^2 + \frac{1}{2}\left(\kappa^2 \sigma_t^2 - \kappa_i^2 \sigma_{i,t}^2\right)$$

Carry Trade

- Different countries have different δ_i
  - Low-interest-rate countries are those with high δ_i
- Carry factor (focusing on δ and $u_{w,t+1}$)

$$Carry_{t+1} = \frac{1}{2}\left(\overline{\delta}^{L2} - \overline{\delta}^{H2}\right)\sigma^2_{w,t} + (\overline{\delta}^{L} - \overline{\delta}^{H})\sigma_{w,t}u_{w,t+1}$$

- Average carry trade return reflects compensation for exposure to $u_{w,t+1}$
- Why it has to be δ heterogeneity? To be consistent with the evidence on heterogeneous loadings

Dollar Carry

- AFD is driven by US volatility, σ_t^2

$$AFD = \overline{\left(\chi_i - \frac{1}{2}(\gamma_i^2 + \kappa_i^2)\right)\sigma_{i,t}^2} - \left(\chi - \frac{1}{2}(\gamma^2 + \kappa^2)\right)\sigma_t^2$$

  When σ_t^2 is high, US interest rate is lower than the world average

- Average risk premia

$$\overline{rx}_{t+1} = \frac{1}{2}\left(\gamma^2 + \kappa^2\right)\sigma_t^2 - \frac{1}{2}\overline{\left(\gamma_i^2 + \kappa_i^2\right)\sigma_{i,t}^2}$$

  $sign(AFD) \times \bar{rx}_{t+1}$ is strongly positive, because the variation in risk premia (sourced from US volatility) is well captured by the conditioning variable of AFD

- Not able to tell $u_{i,t}$ or $u_{g,t}$ through the dollar carry portfolio

What We Know

- Carry factor: heterogeneous loadings on **one** global factor
- US factor: US interest rate captures variations in currency risk premia
- Dollar factor: similar loading for currencies with different interest rates
- Remaining questions (Verdelhan 2018 JF)
  - How much exchange rate variations are due to systematic risk factors?
  - Any evidence showing dollar risk factor is also a priced factor in the SDF?
  - Additional evidence and implications on SDF

Solution: Exchange Rate, Dollar and Carry Risk Factors

- Exchange rate dollar factor

$$Dollar_{t+1} = \overline{\alpha}_i - \alpha + \overline{\chi_i \sigma_{i,t}^2} - \chi \sigma_t^2 - \gamma \sigma_t u_{t+1} + \left(\overline{\kappa_i \sigma_{i,t}} - \kappa \sigma_t\right) u_{g,t+1}$$

- Exchange rate carry factor

$$Carry_{t+1} = \overline{\alpha}_i^H - \overline{\alpha}_i^L + \left(\overline{\tau}_i^H - \overline{\tau}_i^L\right) \sigma_{w,t}^2 + \left(\overline{\delta}_i^H - \overline{\delta}_i^L\right) \sigma_{w,t} u_{w,t+1}$$

Recall bilateral exchange rates

$$\Delta s_{i,t+1} = \alpha_i - \alpha + \chi_i \sigma_{i,t}^2 - \chi \sigma_t^2 + (\tau_i - \tau) \sigma_{w,t}^2$$

$$+ \gamma_i \sigma_{i,t} u_{t+1}^i - \gamma \sigma_t u_{t+1} + (\delta_i - \delta) \sigma_{w,t} u_{w,t+1} + (\kappa_i \sigma_{i,t} - \kappa \sigma_t) u_{g,t+1}$$

How much of exchange rate fluctuations are due to global risks?

Regression Evidence

Table I

Carry and Dollar Factors: Monthly Tests in Developed Countries

This table reports country-level results from the regression

$$\Delta s_{i,t+1} = \alpha_i + \beta_i(r_{i,t} - r_t) + \gamma_i(r_{i,t} - r_t)Carry_{t+1} + \delta_i Carry_{t+1} + \tau_i Dollar_{t+1} + \varepsilon_{i,t+1},$$

where $\Delta s_{i,t+1}$ denotes the bilateral exchange rate in foreign currency per U.S. dollar, $r_{i,t} - r_t$ is the interest rate difference between the foreign country and the United States, $Carry_{t+1}$ denotes the dollar-neutral average change in exchange rates obtained by going long a basket of high interest rate currencies and short a basket of low interest rate currencies, and $Dollar_{t+1}$ corresponds to the average change in exchange rates against the U.S. dollar. The table reports the constant α, the slope coefficients β, γ, δ, and τ, as well as the adjusted R^2 of this regression (in percentage points) and the number of observations N. Standard errors in parentheses are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The standard errors for the R^2s are reported in brackets; they are obtained by bootstrapping. $R^2_{\$}$ denotes the adjusted R^2 of a similar regression with only the *Dollar* factor (i.e., without the conditional and unconditional *Carry* factors). $R^2_{\$}$ denotes the adjusted R^2 of a similar regression without the *Dollar* factor. W denotes the result of a Wald test: the null hypothesis is that the loadings γ and δ on the conditional and unconditional carry factors are jointly zero. *** corresponds to a rejection of the null hypothesis at the 1% confidence level; ** and * correspond to the 5% and 10% confidence levels. Data are monthly, from Barclays and Reuters (Datastream). All variables are in percentage points. The sample period is 11/1983 to 12/2010.

Country	α	β	γ	δ	τ	R^2	$R^2_{\$}$	$R^2_{no\ \$}$	W	N
Australia	0.07	−0.44	0.77	0.16	0.74	25.59	20.05	7.71	***	312
	(0.23)	(0.60)	(0.49)	(0.13)	(0.13)	[5.77]	[5.72]	[4.31]		
Canada	−0.11	−0.02	−0.61	0.21	0.34	19.38	13.11	8.14	***	312
	(0.11)	(0.63)	(0.42)	(0.06)	(0.07)	[6.94]	[4.34]	[4.97]		
Denmark	−0.01	−0.20	0.53	−0.16	1.51	86.08	83.63	3.97	***	312
	(0.07)	(0.38)	(0.13)	(0.03)	(0.04)	[1.67]	[2.03]	[3.99]		
Euro Area	0.07	−0.52	0.10	−0.28	1.62	80.60	76.22	−0.05	***	143
	(0.11)	(0.86)	(0.23)	(0.05)	(0.08)	[3.58]	[3.99]	[4.81]		
France	−0.15	−0.10	0.80	−0.13	1.38	90.97	87.58	12.30	***	181
	(0.07)	(0.34)	(0.14)	(0.03)	(0.04)	[1.48]	[1.93]	[5.90]		
Germany	−0.21	−0.03	0.79	−0.03	1.42	91.00	88.35	22.83	***	181
	(0.09)	(0.34)	(0.17)	(0.04)	(0.04)	[1.36]	[1.75]	[6.20]		
Italy	−0.03	0.26	0.68	−0.07	1.24	68.97	64.59	2.16	***	177
	(0.22)	(0.69)	(0.20)	(0.11)	(0.10)	[5.25]	[6.92]	[6.13]		
Japan	−0.44	−1.13	−0.10	−0.39	0.83	29.52	23.58	5.34	***	325
	(0.24)	(0.86)	(0.45)	(0.11)	(0.12)	[5.51]	[5.45]	[3.47]		
New Zealand	0.10	−0.58	0.76	−0.11	0.95	29.80	26.96	3.43	*	312
	(0.20)	(0.39)	(0.38)	(0.11)	(0.11)	[5.31]	[5.78]	[2.85]		
Norway	−0.07	0.29	0.48	−0.06	1.35	71.23	69.87	3.13	***	312
	(0.12)	(0.37)	(0.11)	(0.05)	(0.08)	[3.99]	[3.98]	[3.36]		
Sweden	0.06	−0.28	0.99	−0.06	1.39	72.42	67.65	5.94	***	312
	(0.10)	(0.35)	(0.16)	(0.04)	(0.06)	[2.90]	[3.41]	[3.46]		
Switzerland	−0.14	−0.19	0.94	−0.11	1.46	74.61	69.03	12.09	***	325
	(0.11)	(0.41)	(0.19)	(0.06)	(0.06)	[2.45]	[2.98]	[3.70]		
United Kingdom	0.06	−0.15	0.63	−0.03	1.06	50.76	49.90	2.13		325
	(0.15)	(0.71)	(0.47)	(0.09)	(0.09)	[5.09]	[5.29]	[3.01]		

Takeaway from the Regression

- A significant share of **bilateral** exchange rate movements are due to global risks, augmented with interest rate differential which captures predictable components
- Significant loading heterogeneity with the dollar factor
  - Not all currencies load similarly on dollar risk, but carry trade portfolios do
  - Next step: extract global factor $u_{g,t+1}$ and examine its pricing

Dollar-Beta Sorted Portfolios

- Estimate each currency's beta on dollar risk factor

$$\beta_{i,dollar} = \frac{\gamma^2\sigma_t^2 + (\kappa_i\sigma_{i,t} - \kappa\sigma_t)(\overline{\kappa_i\sigma_{i,t}} - \kappa\sigma_t)}{\gamma^2\sigma_t^2 + (\overline{\kappa_i\sigma_{i,t}} - \kappa\sigma_t)^2}$$

- Recall currency risk premia

$$rx_{t+1}^i = \frac{1}{2}\left(\gamma^2\sigma_t^2 - \gamma_i^2\sigma_{i,t}^2\right) + \frac{1}{2}\left(\delta - \delta_i\right)\sigma_{w,t}^2 + \frac{1}{2}\left(\kappa^2\sigma_t^2 - \kappa_i^2\sigma_{i,t}^2\right)$$

  If a country i has lower $\kappa_i\sigma_{i,t}$, investing in that currency i earns a positive risk premia. However, $\kappa_i\sigma_{i,t}$ is not simply $\beta_{i,dollar}$, but $\beta_{i,dollar} \times sign(\overline{\kappa_i\sigma_{i,t}} - \kappa\sigma_t)$. The latter can be captured by AFD

- Portfolio construction: Long high-dollar-beta and short low-dollar-beta when AFD high, and reverse when AFD low

Portfolio Evidence

Table IV

Portfolios of Countries Sorted By Dollar Exposures

Panel A reports summary statistics for portfolios of currencies sorted on their exposure to the dollar factor. See Section III for details on the construction of these portfolios. Panel B reports results from generalized method of moments (GMM) and Fama-MacBeth (FMB) asset pricing procedures. The market price of risk λ, the adjusted R^2, the square root of mean squared errors (RMSE), and the p-values of χ^2 tests on pricing errors are reported in percentage points. b denotes the vector of factor loadings ($m_{t+1} = 1 - bCond.Dollar_{t+1}$). The last row reports the mean of the risk factor. Excess returns used as test assets and risk factors do not take into account bid-ask spreads. All excess returns are multiplied by 12 (annualized). The second step of the FMB procedure does not include a constant. The last two panels report OLS estimates of the factor betas obtained either with the conditional dollar excess return (Panel C) or with the global component of the dollar factor (built as the difference in exchange rate changes between the last and first dollar beta portfolios). R^2s and p-values are reported in percentage points. The standard errors in brackets are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The alphas are annualized and in percentage points. Data are monthly, from Barclays and Reuters (Datastream). The sample period is 12/1988 to 12/2010.

Panel A: Summary Statistics

Portfolio	1	2	3	4	5	6
Spot change: Δs						
Mean	− 0.97	− 2.12	− 2.88	− 3.66	− 2.99	− 5.07
Std	3.29	5.31	6.70	7.72	10.19	10.68
Forward Discount: $r_t^f - r^f$						
Mean	0.34	0.74	0.99	1.47	2.00	2.07
Std	0.54	1.11	1.24	1.44	0.70	0.55
Excess Return: rx						
Mean	1.31	2.86	3.87	5.13	4.99	7.14
	[0.70]	[1.17]	[1.41]	[1.61]	[2.16]	[2.18]
Excess Return: rx (with bid-ask spreads)						
Mean	0.58	1.43	2.11	3.73	3.73	5.84
	[0.72]	[1.11]	[1.40]	[1.61]	[2.05]	[2.37]
Sharpe Ratio	0.18	0.27	0.32	0.49	0.36	0.55

Panel B: Risk Prices

	$\lambda_{Cond.Dollar}$	$b_{Cond.Dollar}$	R^2	RMSE	χ^2
GMM_1	4.73	0.94	83.06	0.80	
	[1.54]	[0.31]			66.57
GMM_2	4.51	0.90	[81.74]	0.83	
	[1.50]	[0.30]			[66.91]
FMB	4.73	0.94	[85.22]	0.80	
	[1.41]	[0.28]			[50.40]
Mean	4.61				

Panel C: Conditional Dollar Betas

Portfolio	1	2	3	4	5	6
α	0.81	0.87	0.64	0.76	− 1.17	0.44
	[0.90]	[1.00]	[1.06]	[0.91]	[0.99]	[0.90]
β	0.11	0.44	0.71	0.99	1.40	1.52
	[0.03]	[0.06]	[0.06]	[0.06]	[0.06]	[0.05]
R^2	4.40	[28.98]	[48.00]	[71.64]	[78.97]	[86.39]

Share of International Capital Flow Comovement

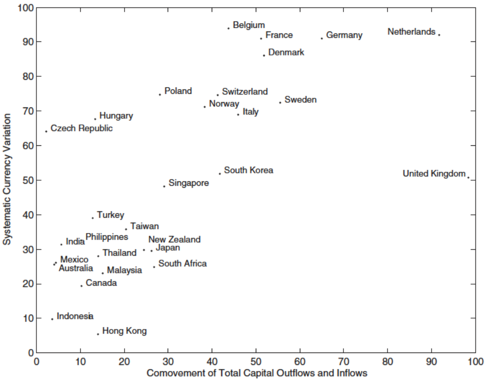

Figure 2. Systematic currency variation and international capital flows comovement. The figure plots the share of systematic variation in the exchange rate of each country (on the vertical axis) as a function of the comovement of that country's capital flows with aggregate capital flows (on the horizontal axis). The shares of systematic variation in the exchange rates correspond to the R^2s of regressions of bilateral exchange rates on the carry and dollar factors, as reported in Tables I and II. Comovement in capital flows for country i is measured as the R^2 of a regression of country i's capital flows on the first three components of all capital flow series (excluding the United States). Measures of capital flows correspond to the average of total inflows and total outflows scaled by GDP. Exchange rate data are monthly, while capital flows are quarterly. The sample period is 11/1983 to 12/2010.

Other Sources of Currency Risk Premia

- Value (Menkhoff, Sarno, Schmeling and Schrimpf 2017 RFS)
- Momentum (Menkhoff, Sarno, Schmeling and Schrimpf 2012 JFE)
- Global imbalance (Della Corte, Riddiough and Sarno 2016 RFS)
- Business cycle (Colacito, Riddiough and Sarno 2020 JFE)
- Sovereign risk (Della Corte, Sarno, Schmeling and Wagner 2021 MS)
- A recent revisit of the "factor zoo" (Nucera, Sarno and Zinna 2023, RFS)
- ...

Predicting Carry: Bakshi and Panayotov (2013 JFE)

- Commodity index, currency volatility and liquidity

Table 2
In-sample predictability of carry trade payoffs with single predictors.

Reported are results from predictive regressions $\overline{z}_{t+1}^{(K)} = b_0 + b_x\, x_t + \epsilon_{t+1}^{(K)}$, where x_t is a single predictor. For $K = 1, \ldots, 4$, the payoff in month t+1 of the carry trade with K short and long positions is $\overline{z}_{t+1}^{(K)} = \frac{1}{K}\sum_{k=1}^{K} z_{t+1}^{(k)} = \frac{1}{K}\sum_{k=1}^{K} (z_{t+1}^{\text{short}_k} + r_{t+1}^{\text{long}_k})/2$, where $z_{t+1}^{\text{short}_k}$ ($z_{t+1}^{\text{long}_k}$) is the payoff of the short (long) position established at the end of month t in the k-th lowest-yielding (highest-yielding) currency. All payoffs are denominated in US dollars, and we consider the G-10 currencies (except the euro). The individual predictors x_t are defined as

$$\Delta \text{CRB}_t = \frac{1}{3}\log(\text{CRB}_t/\text{CRB}_{t-3}), \quad \Delta\sigma_t^{\text{fx}} = \frac{1}{3}\log(\sigma_t^{\text{avg}}/\sigma_{t-3}^{\text{avg}}), \quad \Delta \text{LIQ}_t = -(\text{LIQ}_t^{\text{avg}} - \frac{1}{3}\sum_{j=1}^{3} \text{LIQ}_{t-j}^{\text{avg}}).$$

CRB_t is the Raw Industrials subindex of the CRB Spot Commodity Index, σ_t^{avg} is the average currency volatility for month t across the G-10 currencies, where currency volatility is computed as the square root of the average squared daily log change over a month of a currency's spot exchange rate against the US dollar, and $\text{LIQ}_t^{\text{avg}}$ is the average TED spread (i.e., three-month Libor minus the three-month Treasury bill rate or its equivalent) for month t across the G-10 currencies in our sample (except for NOK and NZD, for which data could not be obtained for the full sample period). The estimates of the slope coefficients b_x are displayed along with the corresponding two-sided p-values NW[p], H[p], and B[p], respectively, based on (i) the heteroscedasticity and autocorrelation consistent (HAC) covariance matrix estimator from Newey and West (1987) (with automatically selected lag as in Newey and West (1994), and shown as 'NW lag"), (ii) the Hodrick (1992) 1B covariance matrix estimator under the null of no predictability, and (iii) the parametric bootstrap, where the predictors are simulated under an ARMA–GARCH structure, chosen based on the BIC (see Panel B of Table A2). Adjusted R^2s are shown as $\overline{R}^2$. Regression intercepts are not reported to save on space.

Predictor	Carry strategy	b_x	NW[p]	H[p]	B[p]	$\overline{R}^2$ (%)	NW lag
Commodity returns, ΔCRB_t	1	0.24	0.00	0.02	0.02	3.9	1
	2	0.17	0.00	0.01	0.01	3.4	3
	3	0.12	0.01	0.02	0.01	2.4	4
	4	0.10	0.00	0.01	0.01	2.4	5
Currency volatility, $\Delta\sigma_t^{\text{fx}}$	1	−0.05	0.01	0.00	0.01	3.7	3
	2	−0.03	0.01	0.01	0.03	2.6	3
	3	−0.03	0.00	0.00	0.00	3.7	4
	4	−0.03	0.00	0.00	0.00	4.3	4
Liquidity, ΔLIQ_t	1	0.03	0.03	0.09	0.09	3.1	0
	2	0.02	0.02	0.07	0.09	2.6	4
	3	0.02	0.00	0.05	0.05	3.5	4
	4	0.02	0.00	0.04	0.03	2.5	3

Carry Trade: Downside Risk

- Several papers show that carry is especially exposed to downside risk
- Lettau, Maggiori and Weber (2014 JFE), Dobrynskaya (2014 RF)

CAPM in Crisis

Table 11: CAPM in Crisis

Portfolio	α^i_m	β^i_m	$p(\%)$	R^2	α^i_m	β^i_m	$p(\%)$	R^2	α^i_m	β^i_m	$p(\%)$	R^2	α^i_m	β^i_m	$p(\%)$	R^2
Sample	26-May-1998				02-Aug-1995				10-Oct-1999				31-Aug-2007			
1	−1.13	0.02	86.16	0.10	4.24	−1.22	0.09	18.20	−0.16	−0.13	16.91	7.33	0.15	−0.13	1.38	11.85
	[0.62]	[0.14]			[1.57]	[0.37]			[0.57]	[0.09]			[0.38]	[0.05]		
2	−0.64	−0.05	75.70	0.59	3.48	−0.90	8.76	8.52	−0.45	−0.11	5.19	9.30	0.17	0.21	0.04	27.84
	[0.92]	[0.16]			[1.90]	[0.53]			[0.35]	[0.05]			[0.37]	[0.06]		
3	−1.45	0.21	11.09	10.97	3.51	−0.89	7.88	11.97	0.85	−0.05	34.63	1.93	0.74	0.18	0.02	28.38
	[0.71]	[0.13]			[1.80]	[0.50]			[0.34]	[0.05]			[0.27]	[0.05]		
4	−1.43	0.28	2.50	13.55	2.21	−0.48	5.52	11.88	−0.24	−0.23	3.95	29.24	0.31	0.21	0.00	40.08
	[0.59]	[0.12]			[0.83]	[0.25]			[0.22]	[0.11]			[0.25]	[0.03]		
5	−1.81	0.50	0.00	23.41	2.14	−0.55	5.20	10.14	−0.40	0.06	22.28	4.82	0.51	0.25	0.00	45.52
	[0.47]	[0.11]			[0.92]	[0.28]			[0.30]	[0.05]			[0.23]	[0.04]		
6	−3.84	1.14	0.00	23.41	0.42	−0.00	98.46	10.14	0.80	0.25	0.00	4.82	0.44	0.50	0.00	45.52
	[1.53]	[0.27]			[0.43]	[0.14]			[0.48]	[0.05]			[0.43]	[0.10]		
HML_{FX}	−2.71	1.11	0.00	20.15	−3.82	1.22	0.02	11.24	0.96	0.37	0.03	20.87	0.29	0.62	0.00	56.12
	0.60	0.16			1.38	0.33			0.75	0.10			[0.38]	[0.08]		

Notes: This table reports results OLS estimates of the factor betas. The sample period is 129 days (6 months) before and including the mentioned date. The intercept α_0 β, and the R^2 are reported in percentage points. The standard errors in brackets are Newey-West standard errors computed with the optimal number of lags. The p-value is for a t-test on the slope coefficient. The portfolios are constructed by sorting currencies into six groups at time t based on the currency excess return at the end of period $t-1$. The returns are 1-month returns, and take into account bid-ask spreads. Portfolio 1 contains currencies with the lowest previous excess return. Portfolio 6 contains currencies with the highest previous excess return. Data are daily, from Barclays and Reuters in Datastream. We use the value-weighted return on the US stock market (CRSP).

Source: Lustig, Roussanov and Verdelhan (2008 WP version)

Macroeconomic Risks in Currencies

- Hard to detect given the disconnect
  - Consumption risk: Lustig and Verdelhan (2007 AER)
- US interest rate risk (Antolin-Diaz et al, 2024)
- Inflation risk
  - Mussa (1986): RER tracks NER closely
  - Hollified and Yaron (2003): inflation risk premium accounts for a negligible part of currency risk premia
  - Fang, Liu and Roussanov (2024): currencies with high interest rates load more negatively on US core inflation risk, both in the time-series and cross-section

The Time-series and Cross-sectional Currency Risk Premia

- When we mention "carry trade", we sometimes refer to cross-sectional trade and sometimes refer to time-series trade, they are distinct
- Theoretically straightforward: time-series focuses on time-varying interest rates and risk premium, cross-section focuses on why different countries have different interest rates and thus risk premium, which can be time-invariant
- Quantifying the time-series and cross-sectional currency risk premia: Hassan and Mano (2019 QJE)

Hassan and Mano (2019 QJE)

- A Decomposition of static, dollar, and dynamic trade

$$\sum_{i,t}\left[\left(rx_{i,t+1}-\overline{rx}\right)\left(fp_{it}-\overline{fp}\right)\right]$$

$$=\underbrace{\sum_{i,t}\left[rx_{i,t+1}\left(\overline{fp}_i^e-\overline{fp}^e\right)\right]}_{\text{Static Trade}}+\underbrace{\sum_{i,t}\left[rx_{i,t+1}\left(fp_{it}-\overline{fp}_t-\left(\overline{fp}_i^e-\overline{fp}^e\right)\right)\right]}_{\text{Dynamic Trade}}+\underbrace{\sum_{i,t}\left[rx_{i,t+1}\left(\overline{fp}_t-\overline{fp}^e\right)\right]}_{\text{Dollar Trade}}$$

$$+\underbrace{\sum_{i,t}\left[\overline{rx}(\overline{fp}^e-\overline{fp})\right]}_{\text{Constant}}, \tag{6}$$

  - Static: long-short based on ex-ante interest rates
  - Dollar: long-short based on average forward premium (relative to dollar)
  - Dynamic: long-short based on deviation from ex ante interest rates

Some Illustration

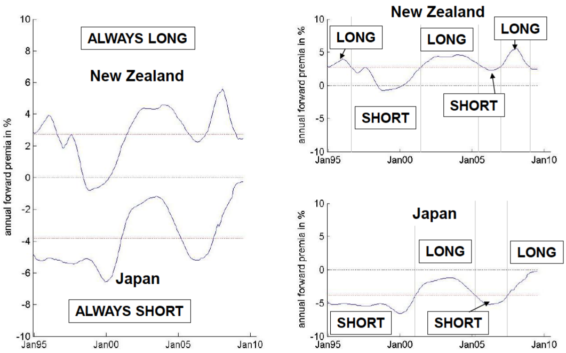

Figure 1: **Carry Trade vs. Forward Premium Trade**
Forward premia of the New Zealand dollar and Japanese yen against the US dollar 1995-2010. Left panel: Carry Trade uses $fp_{it} - \overline{fp}_t$ as portfolio weights, always long the New Zealand dollar, always short the Japanese yen; Right panel: Forward Premium Trade uses $fp_{it} - \overline{fp}_i$ as portfolio weights, goes long when a currency's forward premium exceeds its currency-specific mean. The plot cumulates monthly forward premia to the annual frequency according to $fp_{i,t} = \sum_{m=1}^{12} fp_{i,t+m}$.

Portfolios

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample	**1 Rebalance**				**3 Rebalance**			
Horizon (months)	1	1	6	12	1	1	6	12
Static Trade								
$\sum_{i,t}[rx_{i,t+1}(\overline{fp_i^e} - \overline{fp}^e)]$	3.46	1.36	3.58	3.82	3.09	0.33	2.55	2.53
Sharpe Ratio	0.39	0.15	0.32	0.32	0.37	0.04	0.24	0.22
Dynamic Trade								
$\sum_{i,t}[rx_{i,t+1}(fp_{i,t} - \overline{fp}_t - (\overline{fp_i^e} - \overline{fp}^e))]$	1.50	-0.24	0.33	1.20	1.42	-0.85	-0.12	0.45
Sharpe Ratio	0.24	-0.04	0.05	0.19	0.20	-0.12	-0.02	0.07
Dollar Trade								
$\sum_{i,t}[rx_{i,t+1}(\overline{fp}_t - \overline{fp}^e)]$	2.55	1.24	2.52	3.18	1.90	0.26	2.20	2.36
Sharpe Ratio	0.25	0.12	0.26	0.27	0.15	0.02	0.17	0.18
Carry Trade								
$\sum_{i,t}[rx_{i,t+1}(fp_{i,t} - \overline{fp}_t)]$	4.95	2.81	4.25	5.24	4.50	1.99	2.95	3.35
Sharpe Ratio	0.54	0.31	0.34	0.44	0.54	0.23	0.26	0.29
% Static Trade	**70%**	**121%**	**92%**	**76%**	**69%**	**.**	**105%**	**85%**
Forward Premium Trade								
$\sum_{i,t}[rx_{i,t+1}(fp_{i,t} - \overline{fp_i^e})]$	4.04	1.77	3.03	4.51	3.31	0.28	2.26	2.94
Sharpe Ratio	0.27	0.12	0.20	0.27	0.18	0.02	0.12	0.16
% Dollar Trade	**63%**	**124%**	**88%**	**73%**	**57%**	**.**	**106%**	**84%**

Carry in Other Asset Classes

- Koijen et al (2017 JFE): carry strategy works for many asset classes
- "Carry" predicts returns in both cross-section and time-series
- Not explained by standard return predictors and a generalized version of uncovered interest rate parity is rejected

Koijen et al (2017 JFE)

Table II: **The Returns to Carry Strategies By Asset Class**

Panel A reports, for each asset class, the mean annualized excess return, the annualized standard deviation of return, the skewness of monthly returns, kurtosis of monthly returns, and the annualized Sharpe ratio. These statistics are reported for the long/short carry strategy ("Carry"), a passive equal-weighted exposure in each asset class ("EW"), and a strategy based on the main standard predictor of returns in the existing literature. These statistics are also reported for a diversified portfolio of all carry trades across all asset classes, which we call the "global carry factor," where each asset class is weighted by the inverse of its full-sample standard deviation of returns, and an equal-weighted passive exposure to all asset classes computed similarly. Panel B reports results for carry trades conducted at a coarser level by first grouping securities by region or broader asset class and then generating a carry trade. For equities, fixed income, and currencies we group all index futures into one of five regions: North America, UK, continental Europe, Asia, and New Zealand/Australia and compute the equal-weighted average carry and equal-weighted average returns of these five regions. For commodities we group instruments into three categories: agriculture/livestock, metals, and energy. We then create carry trade portfolios using only these regional/group portfolios. Credit, US Treasuries, and options are excluded from Panel B. In Panel C, we report the results for the long/short carry1-12 strategy ("Carry1-12").

PANEL A: CARRY 1M TRADES BY SECURITY WITHIN AN ASSET CLASS

Asset class	Strategy	Mean	Stdev	Skewness	Kurtosis	Sharpe ratio
Global equities	Carry	9.58	10.48	0.24	5.14	0.91
	EW	5.21	15.73	-0.63	3.86	0.33
	D/P	4.22	11.81	-0.14	5.39	0.36
Fixed income 10Y global (level)	Carry	3.85	7.45	-0.43	6.66	0.52
	EW	5.04	6.85	-0.11	3.70	0.74
	Yield	3.55	7.73	-0.81	10.13	0.46
Fixed income 10Y−2Y global (slope)	Carry	0.68	0.66	0.33	4.92	1.03
	EW	0.01	0.43	-0.28	4.08	0.01
US Treasuries (maturity)	Carry	0.46	0.67	0.47	10.46	0.68
	EW	0.69	1.22	0.58	12.38	0.57
Commodities	Carry	11.22	18.78	-0.40	4.55	0.60
	EW	1.05	13.45	-0.71	6.32	0.08
	Basis	11.22	18.78	-0.40	4.55	0.60
Currencies	Carry	5.29	7.80	-0.68	4.46	0.68
	EW	2.88	8.10	-0.16	3.44	0.36
	Carry	5.29	7.80	-0.68	4.46	0.68
Credit	Carry	0.24	0.52	1.31	18.18	0.47
	EW	0.37	1.09	-0.03	7.10	0.34
	Yield	0.04	0.51	0.43	9.24	0.07
Options calls	Carry	63.55	171.51	-2.82	14.49	0.37
	EW	-73	313	1.15	3.88	-0.23
	Short vol.	5.88	18.00	-7.07	75.58	0.33
Options puts	Carry	178.90	99.30	-1.75	10.12	1.80
	EW	-299	296	1.94	7.11	-1.01
	Short vol.	5.88	18.00	-7.07	75.58	0.33
All asset classes (global carry factor)	Carry	7.18	5.96	-0.03	5.40	1.20
	EW	2.80	6.99	-0.43	9.28	0.40

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Currencies and Long-term Bonds: Lustig, Stathopolous and Verdelhan (2019 AER)

- Implementing carry trade with long-term bonds
  - Using short rate / slope of yield curve as signals
  - Using bonds of different maturities
  - Implementing in both time-series and cross-section
- Implications for SDF

Long-term Bond Carry Trade

- Bond excess return (or maturity k)

$$rx_{t+1}^{(k)} = p_{t+1}^{(k-1)} - p_t^{(k)} - r_t^f$$

- Currency excess return

$$rx_{t+1}^{FX} = r_t^{f*} - r_t^f - \Delta s_{t+1}$$

- Dollar excess return of holding LT bond

$$rx_{t+1}^{(k),\$} = r_{t+1}^{(k)*} - \Delta s_{t+1} - r_t^f$$

$$= rx_{t+1}^{(k)*} + rx_{t+1}^{FX}$$

Short Rate as Predictor

Table 1—Time-Series Predictability Regressions

	Bond dollar return diff. $rx^{(10),\$} - rx^{(10)}$		Currency excess return rx^{FX}		Bond local currency return diff. $rx^{(10),*} - rx^{(10)}$		Slope diff.	Observations
	β	$R^2(\%)$	β	$R^2(\%)$	β	$R^2(\%)$	p-value	
Panel A. Short-term interest rates								
Australia	−0.15	−0.20	1.29	0.56	−1.44	1.51	0.20	492
	(0.91)		(0.55)		(0.52)			
Canada	−1.10	0.11	1.22	0.46	−2.32	3.64	0.02	492
	(0.69)		(0.58)		(0.52)			
Germany	1.52	0.37	2.49	1.71	−0.97	0.48	0.55	492
	(1.18)		(1.05)		(0.40)			
Japan	2.37	1.13	3.11	3.48	−0.74	0.13	0.47	492
	(0.71)		(0.70)		(0.41)			
New Zealand	0.69	−0.03	2.23	3.14	−1.54	1.62	0.20	492
	(1.06)		(0.44)		(0.88)			
Norway	0.72	0.08	1.74	2.26	−1.02	0.97	0.22	492
	(0.57)		(0.55)		(0.34)			
Sweden	−0.64	−0.02	0.89	0.25	−1.53	2.02	0.23	492
	(0.86)		(0.88)		(0.52)			
Switzerland	1.16	0.33	2.45	2.43	−1.29	1.69	0.30	492
	(0.90)		(0.79)		(0.44)			
United Kingdom	1.02	0.04	2.69	2.44	−1.67	1.39	0.32	492
	(1.03)		(1.24)		(0.49)			
Panel	0.65	−0.05	1.98	1.82	−1.34	1.37	0.00	4,428
	(0.50)		(0.49)		(0.33)			
Joint zero p-value	0.19		0.00		0.00		0.32	

(*Continued*)

Yield Curve Slope as Predictor

TABLE 1—TIME-SERIES PREDICTABILITY REGRESSIONS (*Continued*)

	Bond dollar return diff. $rx^{(10),\$} - rx^{(10)}$		Currency excess return rx^{FX}		Bond local currency return diff. $rx^{(10),*} - rx^{(10)}$		Slope diff.	
	β	$R^2(\%)$	β	$R^2(\%)$	β	$R^2(\%)$	p-value	Observations
Panel B. Yield curve slopes								
Australia	3.84	1.54	−1.00	−0.02	4.84	7.65	0.03	492
	(1.69)		(1.16)		(0.96)			
Canada	4.04	2.25	−0.72	−0.07	4.76	9.09	0.00	492
	(1.23)		(0.79)		(0.81)			
Germany	0.50	−0.18	−3.05	1.15	3.55	4.07	0.11	492
	(1.57)		(1.37)		(0.82)			
Japan	−0.32	−0.19	−4.18	2.91	3.85	3.96	0.02	492
	(1.12)		(0.94)		(0.81)			
New Zealand	2.94	1.26	−1.60	0.62	4.55	7.41	0.11	492
	(2.35)		(1.28)		(1.41)			
Norway	0.59	−0.12	−2.03	1.33	2.62	3.35	0.07	492
	(0.98)		(0.97)		(0.52)			
Sweden	3.12	2.12	−0.13	−0.20	3.25	5.29	0.06	492
	(1.21)		(1.02)		(0.82)			
Switzerland	0.97	−0.06	−3.59	1.97	4.55	8.82	0.01	492
	(1.05)		(1.27)		(1.00)			
United Kingdom	1.59	0.17	−3.17	2.11	4.75	7.95	0.03	492
	(1.28)		(1.62)		(0.85)			
Panel	1.94	0.42	−2.02	0.83	3.96	6.08	0.00	4,428
	(0.96)		(0.82)		(0.66)			
Joint zero p-value	0.08		0.01		0.00		0.00	

Cross-Sectional Sorting

Table 3—Cross-Sectional Predictability: Bond Portfolios

	Sorted by short-term interest rates				Sorted by yield curve slopes			
Portfolio:	1	2	3	3 − 1	1	2	3	1 − 3
Panel A. Portfolio characteristics								
Inflation rate mean	2.90	3.45	4.81	1.91	4.89	3.41	2.87	2.02
	(0.16)	(0.19)	(0.23)	(0.20)	(0.23)	(0.19)	(0.18)	(0.19)
Inflation rate standard deviation	1.03	1.23	1.48	1.30	1.39	1.16	1.20	1.26
Rating mean	1.45	1.25	1.49	0.04	1.54	1.38	1.28	0.25
	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.02)	(0.03)
Rating (adj. for outlook) mean	1.50	1.37	1.84	0.33	1.84	1.50	1.37	0.47
	(0.03)	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.02)	(0.03)
$y_t^{(10),*} - r_t^{*,f}$ mean	1.52	0.92	−0.44	−1.96	−0.81	0.85	1.96	−2.76
Panel B. Currency excess returns								
$-\Delta s_{t+1}$ mean	−0.44	0.11	−0.60	−0.16	−0.95	0.38	−0.36	−0.58
$r_t^{f,*} - r_t^f$ mean	−0.17	0.54	2.65	2.81	3.35	0.55	−0.88	4.23
rx_{t+1}^{FX} mean	−0.61	0.66	2.04	2.65	2.41	0.92	−1.24	3.65
	(1.35)	(1.44)	(1.36)	(1.14)	(1.48)	(1.38)	(1.40)	(1.18)
rx_{t+1}^{FX} Sharpe ratio	−0.07	0.07	0.23	0.36	0.26	0.11	−0.14	0.49
Panel C. Local currency bond excess returns								
$rx_{t+1}^{(10),*}$ mean	3.53	2.60	−0.25	−3.78	−1.01	2.29	4.61	−5.61
	(0.69)	(0.69)	(0.73)	(0.77)	(0.76)	(0.69)	(0.70)	(0.74)
$rx_{t+1}^{(10),*}$ Sharpe ratio	0.80	0.58	−0.05	−0.77	−0.21	0.53	1.00	−1.18
Panel D. Dollar bond excess returns								
$rx_{t+1}^{(10),\$}$ mean	2.92	3.26	1.80	−1.12	1.40	3.21	3.36	−1.96
	(1.56)	(1.58)	(1.57)	(1.33)	(1.64)	(1.57)	(1.62)	(1.38)
$rx_{t+1}^{(10),\$}$ Sharpe ratio	0.29	0.32	0.18	−0.13	0.14	0.33	0.32	−0.22
$rx_{t+1}^{(10),\$} - rx_{t+1}^{(10)}$ mean	0.14	0.48	−0.98	−1.12	−1.38	0.43	0.59	−1.96
	(1.64)	(1.64)	(1.73)	(1.33)	(1.81)	(1.63)	(1.75)	(1.38)

Notes: The countries are sorted by the level of their short-term interest rates in deviation from the 10-year mean into three portfolios (left section) or the slope of their yield curves (right section). The slope of the yield curve is measured by the difference between the 10-year yield and the one-month interest rate. The standard errors (denoted SE and reported in parentheses) were generated by bootstrapping 10,000 samples of non-overlapping returns. The table reports the average inflation rate, the standard deviation of the inflation rate, the average credit rating, the average credit rating adjusted for outlook, the average slope of the yield curve ($y^{(10),*} - r^{*,f}$), the average change in exchange rates (Δs), the average interest rate difference ($r^{f,*} - r^f$), the average currency excess return (rx^{FX}), the average foreign bond excess return on 10-year government bond indices in foreign currency ($rx^{(10),*}$) and in US dollars ($rx^{(10),\$}$), as well as the difference between the average foreign bond excess return in US dollars and the average US bond excess return ($rx^{(10),\$} - rx^{(10)}$). For the excess returns, the table also reports their Sharpe ratios (denoted SR). The holding period is one month. The log returns are annualized. The balanced panel consists of Australia, Canada, Japan, Germany, Norway, New Zealand, Sweden, Switzerland, and the United Kingdom. The data are monthly and the sample is 1975:1–2015:12.

The Effect of Maturity

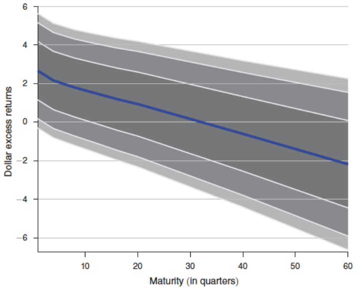


FIGURE 2. LONG-MINUS-SHORT FOREIGN BOND RISK PREMIA IN US DOLLARS

Notes: The figure shows the dollar log excess returns as a function of the bond maturities. Dollar excess returns correspond to the holding period returns expressed in US dollars of investment strategies that go long and short foreign bonds of different countries. The unbalanced panel of countries consists of Australia, Canada, Japan, Germany, Norway, New Zealand, Sweden, Switzerland, and the United Kingdom. At each date t, the countries are sorted by the slope of their yield curves into three portfolios. The first portfolio contains countries with flat yield curves while the last portfolio contains countries with steep yield curves. The slope of the yield curve is measured by the difference between the ten-year yield and the three-month interest rate at date t. The holding period is one quarter. The returns are annualized. The dark shaded area corresponds to one-standard-error bands around the point estimates. The gray and light gray shaded areas correspond to the 90 percent and 95 percent confidence intervals. Standard deviations are obtained by bootstrapping 10,000 samples of non-overlapping returns. Zero-coupon data are monthly, and the sample window is 1985:4–2015:12.

The Key Message

- Term premia and currency risk premia offset each other both in the time-series and cross-section
- There lacks predictive power on the dollar excess return of foreign currency bond
  - Short rate: positive predictiability on rx_{t+1}^{FX}, negative on $rx_{t+1}^{(k)*}$
  - Yield curve slope: negative predictiability on rx_{t+1}^{FX}, positive on $rx_{t+1}^{(k)*}$
- In the cross-section, long-term bond returns in different currencies are similar

Implications for SDFs

- Typical models, such as Lustig, Roussanov and Verdelhan (2011), imply a flat term structure of carry trade risk premia
- A sizeable of short-term carry trade risk premia implies different SDF volatilities (or entropy) across countries
- A similar long-term bond return in different currencies implies similar volatilities (or entropy) of the **permanent** components of SDF across countries

The Concealed Carry: Andrews et al (2023 JFE)

TABLE 1: Traditional Carry

	1 (low)	2	3 (high)	3-1 (high-low)
Whole Sample				
Mean	−1.99	0.34	3.22	5.21***
				[1.92]
Sharpe Ratio	−0.24	0.04	0.32	0.53
Pre-08/2008				
Mean	−3.37	2.01	5.59	8.96***
				[2.47]
Sharpe Ratio	−0.37	0.29	0.76	0.99
Recurrent countries:	Jpn (100%)	Can (77%)	NZ (91%)	
	Swi (100%)	Swe (62%)	Aus (90%)	
	Ger (40%)	UK (34%)	UK (66%)	
Post-08/2008				
Mean	−0.48	−1.47	0.64	1.12
				[1.39]
Sharpe Ratio	−0.06	−0.18	0.05	0.11
Recurrent countries:	Swi (95%)	UK (95%)	NZ (100%)	
	Ger (82%)	Can (59%)	Aus (91%)	
	Jpn (55%)	Swe (47%)	Nor (78%)	

Notes - The table reports the excess returns associated to borrowing at the 3 months interest rate of the US and investing in 3 months bonds of a GDP-weighted portfolio of countries with low (1), medium (2), and high (3) interest rates. The column label "3-1" reports the average return from being long portfolio 3 and short portfolio 1. Portfolios are rebalanced every month. Returns are in gross units. The analysis is conducted over three samples: 1/1995-12/2020 ("Whole sample"), 1/1995-7/2008 ("Pre-08/2008"), and 8/2008-12/2020 ("Post-08/2008"). Numbers in square brackets denote standard errors. Numbers in parentheses refer to the frequency with which a country belongs to a specific portfolio.

The Concealed Carry: Andrews et al (2023 JFE)

TABLE 2: Slope Carry

	1 (flatter)	2	3 (steeper)	3-1 (steep-flat)
Whole Sample				
Mean	4.69	2.22	6.58	1.89
				[2.20]
Sharpe Ratio	0.46	0.22	0.69	0.20
Pre-08/2008				
Mean	6.55	3.95	5.80	−0.75
				[2.20]
Sharpe Ratio	0.66	0.38	0.53	−0.07
Recurrent countries:	UK (83%)	Ger (55%)	Swe (59%)	
	NZ (76%)	Swi (43%)	Jpn (56%)	
	Aus (71%)	Jpn (42%)	Swi (49%)	
Post-08/2008				
Mean	2.67	0.34	7.42	4.75***
				[2.08]
Sharpe Ratio	0.26	0.03	0.88	0.51
Recurrent countries:	Jpn (75%)	Swi (53%)	UK (62%)	
	Aus (67%)	Ger (40%)	Ger (53%)	
	Nor (41%)	Can (40%)	Swe (50%)	

Notes - The table reports the excess returns associated to borrowing at the 3 months interest rate of the US and investing in the 10 year bonds of a GDP-weighted portfolio of countries with flatter (1), medium (2), and steeper (3) yield curves. The column label "3-1" reports the average return from being long portfolio 3 and short portfolio 1. Portfolios are rebalanced every month. Returns are in gross units. The analysis is conducted over three samples: 1/1995-12/2020 ("Whole sample"), 1/1995-7/2008 ("Pre-08/2008"), and 8/2008-12/2020 ("Post-08/2008"). Numbers in square brackets denote standard errors. Numbers in parentheses refer to the frequency with which a country belongs to a specific portfolio.

The Post-Covid Currency Market

- What do different currency strategies look like in recent four years?
- The role of US (and global) monetary policy and, in particular, inflation?
- ...

Chernov and Creal (2023 JF)

- A natural paradigm to study bonds and currencies jointly
  - Estimate SDF using the term structure of interest rates
  - Compute implied FX dynamics
- Conclusion: The bond implied FX dynamics fail to explain the actual data
- Solution in this paper: a factor (to the permanent component) that is not spanned by bonds

Spanning Regression

Table 1: Spanning regressions of currency returns on bond and equity returns

FX	Type of R^2	Bond returns		Bond and equity returns	
		$ returns	FC returns	$ returns	FC returns
Gross returns					
Euro	R^2	22.41	16.74	24.57	17.09
	R^2_{adj}	20.73	14.93	22.75	15.08
British pound	R^2	17.27	17.30	22.36	17.41
	R^2_{adj}	15.47	15.50	20.47	15.41
Australian dollar	R^2	21.44	24.45	25.84	26.53
	R^2_{adj}	19.50	22.59	23.80	24.52
Japanese yen	R^2	35.03	5.85	35.11	15.44
	R^2_{adj}	33.62	3.58	33.54	13.17
Log returns					
Euro	R^2	17.66	16.92	21.10	17.38
	R^2_{adj}	15.87	15.11	19.19	15.38
British pound	R^2	14.52	16.53	22.66	16.71
	R^2_{adj}	12.66	14.71	20.79	14.69
Australian dollar	R^2	23.02	25.25	27.79	26.99
	R^2_{adj}	21.12	23.40	25.81	24.99
Japanese yen	R^2	27.09	5.43	27.38	12.85
	R^2_{adj}	25.50	3.15	25.62	10.50

We report the R^2, regular and adjusted, expressed in percent for spanning regressions. We regress annual currency returns of a given country (obtained by investing in a foreign one-period bond) on annual bond returns of maturities $n = 2, 3, \ldots, 10$ years expressed in the same units (USD, denoted $ returns, or foreign currency, denoted FC returns). We also combine bond returns with MSCI equity index returns in the last two columns.

Lack of spanning of FX by bond and equity returns (unsurprisingly)

A Term Structure Model with Both Bonds and Currencies

$$x_t = \mu_x + \Phi_x x_{t-1} + \Sigma_x \varepsilon_t$$

$$i_t = \delta_0 + \delta_1^{'} x_t$$

$$-m_{t,t+1} = i_t + \frac{1}{2}\lambda_t^{'}\lambda_t + \frac{1}{2}\gamma_t^{'}\gamma_t + \lambda_t^{'}\varepsilon_{t+1} + \gamma_t^{'}\eta_{t+1}$$

$$\lambda_t = \lambda_0 + \lambda_x x_t, \gamma_t = \gamma_0 + \gamma_x x_t$$

$$\Delta s_{t+1} = \mu_s + \Phi_{sx} x_t + \Sigma_{sx}\varepsilon_{t+1} + \Sigma_s \eta_{t+1}$$

Yield solution:

$$y_t^{(n)} = a(n) + b_{n,x}^{'} x_t, y_t^{(n)*} = a(n)^* + b(n)^{*'} x_t$$

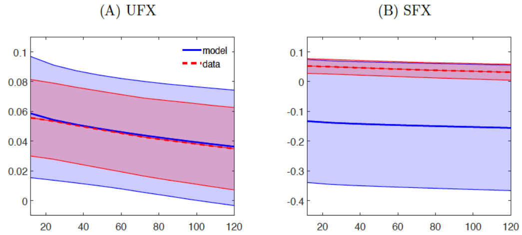
- λ_t: price of risk with ε_{t+1}, shocks that bonds are exposed to
- γ_{t+1}: price of risk with η_{t+1}, shocks that bonds are not exposed to
- x_t potentially includes variables of both countries

Estimation

- Choice of x_t: 2 PCs of yields (US) and yield spreads (against German, UK, Australian, Japanese)
- Require the change of exchange rate for these four currencies to be fit perfectly - attribute to η
- Name the model with η UFX model, the model without η SFX model
- Why is the UFX model useful? An application on international yield curve modeling
  - How much yield difference news comes from news on expected currency depreciation rates, and how much from news on currency risk premium?

Connecting to Lustig, Stathopolous and Verdelhan (2019)

- LSV: the cross-sectional carry returns decline with the maturity of bonds used in the trading strategy
  - Implication: offsetting term premia and currency risk premia



Notes: We plot the unconditional average annual return of a cross-sectional carry trade as a function of maturity of the bonds that are used for borrowing and lending. The trading strategy uses the slope of the yield curve (120-month yield minus 12-month yield) as the sorting variable to create cross-sectional dispersion.

Crash Risk

- A common narrative of carry trade: picking up nickels in front of a steam roller
  - Peso problem: a finite sample issue, potentially risk premium can be zero, observed to be positive because of luck (see Lewis, 2007 Palgrave)
  - Crash risk: the risk premium compensates crash risk
- Evidence shown in Lustig Roussanov Verdelhan (2011) shows carry trade is not just about crash risk
- A more formal assessment: how about option-protected carry trade portfolios?

Does Crash Risk Explain Currency Return? Jurek (2014 JFE)

Table 6

Returns to the crash-neutral currency carry trade portfolios in G10 currencies: Fixed moneyness hedging.

This table reports summary statistics for returns to the *crash-neutral* G10 currency carry trade portfolios in G10 currencies. The portfolio composition is determined by sorting currencies on the basis of their prevailing one-month LIBOR rate, and going long (short) currencies with high (low) interest rates. The composition of the portfolio is rebalanced monthly, and the allocations to individual currencies are spread-weighted. The returns to the carry trade portfolios are reported unhedged, hedged at 10-delta (CN(10δ)), 25-delta (CN(25δ)), and with options that are 3.5% out-of-the-money. In all cases, the FX option hedge is established using the smallest possible number of unique currency options by matching the long and short exposures into pairings on the basis of their allocations in an unhedged carry portfolio (hierarchical hedging). The table reports the average/maximum/minimum of the option deltas, δ, used in hedging overlay, as well as the corresponding statistics for the absolute distance of their strike to the forward rate ($m=(F_t-K_{t,p})/F_t$). The prices of options at fixed moneyness are computed on the basis of implied volatility functions, which have been interpolated using the vanna–volga method, and extrapolated by appending flat tails for strikes below (above) the 10δ put (call). Monthly returns are computed over the period from January 1999 to June 2012 (N=162 months), with and without imposing dollar-neutrality. Means, volatilities, and Sharpe ratios (SR) are annualized; t-statistics reported in square brackets. *Minimum* is the smallest observed monthly return. *Difference* reports the difference in the mean return of the unhedged and hedged portfolios (t-statistics in brackets). *Share* (ϕ) captures the share of the jump risk premium in the total currency excess return, and is computed as the ratio of the difference between the unhedged and hedged portfolio returns, and the unhedged portfolio return.

	Non-dollar-neutral (SPR)				Dollar-neutral (SPR-$N)			
	Unhedged	CN(10δ)	CN(25δ)	CN(3.5% OTM)	Unhedged	CN(10δ)	CN(25δ)	CN(3.5% OTM)
Avg. δ	–	0.10	0.25	0.14	–	0.10	0.25	0.14
Min. δ	–	0.10	0.25	0.00	–	0.10	0.25	0.00
Max. δ	–	0.10	0.25	0.42	–	0.10	0.25	0.42
Avg. m	–	4.7%	2.3%	3.5%	–	4.7%	2.3%	3.5%
Min. m	–	1.5%	0.7%	3.5%	–	1.5%	0.7%	3.5%
Max. m	-	24.1%	11.2%	3.5%	–	24.1%	11.2%	3.5%
Mean	0.0558	0.0524	0.0503	0.0416	0.0496	0.0441	0.0415	0.0344
	[2.19]	[2.07]	[1.95]	[2.09]	[1.92]	[1.70]	[1.58]	[1.69]
Volatility	0.0938	0.0931	0.0945	0.0733	0.0951	0.0950	0.0964	0.0746
Skewness	−1.13	−0.42	0.00	−0.07	−1.08	−0.39	0.00	−0.06
Minimum	−0.1383	−0.0962	−0.0765	−0.0539	−0.1394	−0.0956	−0.0772	−0.0547
Difference	–	0.0034	0.0055	0.0142	–	0.0055	0.0081	0.0151
	–	[0.77]	[0.60]	[1.45]	–	[1.21]	[0.88]	[1.55]
Share	–	0.0617	0.0989	0.2540	–	0.1109	0.1636	0.3055

4. Structural macro-finance models of currency risk premia

A Basic Two-country, Two-good Model

- Two countries, home and foreign
- Home produces X, foreign produces Y
- Consumption aggregation

$$C = C_x^{\alpha} C_y^{1-\alpha}, C^* = (C_x^*)^{1-\alpha} (C_y^*)^{\alpha}$$

  $\alpha > 1/2$ captures consumption home bias
- Log utility on consumption basket (incomplete market)

$$\max_{C_{x,t}, C_{y,t}} E \sum_{t=0}^{\infty} \beta^t \left(\alpha \ln C_{x,t} + (1-\alpha) \ln C_{y,t} \right)$$

$$s.t. : P_{x,t} C_{x,t} + P_{y,t} C_{y,t} + q_{B,t} B_{t+1} = P_{x,t} X_t + B_t$$

- Market clearing

$$C_{x,t} + C^*_{x,t} = X_t, C_{y,t} + C^*_{y,t} = Y_t$$

Optimization

- Euler equations

$$q_{B,t} = E_t \frac{\beta C_t P_t}{C_{t+1} P_{t+1}} = E_t \frac{\beta C_t^* P_t^*}{C_{t+1}^* P_{t+1}^*}$$

where P_t, P_t^* are the price indices of aggregate consumption in home and foreign countries

$$P_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)} P_{x,t}^{\alpha} P_{y,t}^{1-\alpha}, P_t^* = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)} P_{x,t}^{1-\alpha} P_{y,t}^{\alpha}$$

- Intratemporal equation

$$\frac{\alpha}{1-\alpha} \frac{C_{y,t}}{C_{x,t}} = \frac{P_{x,t}}{P_{y,t}} = \frac{1-\alpha}{\alpha} \frac{C_{y,t}^*}{C_{x,t}^*}$$

Terms of Trade and Real Exchange Rate

- Terms of trade: ratio of imported and exported good price

$$ToT_t = \frac{P_{y,t}}{P_{x,t}}$$

- RER: ratio of prices of consumption basket

$$Q_t = \frac{P_t}{P_t^*} = \left(\frac{P_{x,t}}{P_{y,t}}\right)^{2\alpha-1}$$

In logs, $q_t \propto tot_t$. In the data, q_t is much more volatile than tot_t and the two are only weakly correlated

Financial Autarky

- When the financial market is closed, trade balance is zero every period

$$P_{x,t}(X_t - C_{x,t}) = P_{y,t}C_{y,t}$$

- Plug into the equilibrium conditions

$$C_{x,t} = \alpha X_t,\ C^*_{x,t} = (1-\alpha)X_t,\ C_{y,t} = (1-\alpha)Y_t,\ C^*_{y,t} = \alpha Y_t$$

$$\frac{P_{x,t}}{P_{y,t}} = \frac{Y_t}{X_t}$$

Complete Market

$$\frac{\alpha}{C_{x,t}} = \frac{1-\alpha}{C^*_{x,t}}, \frac{\alpha}{C_{y,t}} = \frac{1-\alpha}{C^*_{y,t}}$$

$$C_{x,t} + C^*_{x,t} = X_t, C_{y,t} + C^*_{y,t} = Y_t$$

- Solution: the same as the autarkic case
- Cole and Obstfeld (1991) result: financial market not matter
- Relative price change is a natural hedge
  - X_t low, its price high, income does not fluctuate, stablizing relative demand
  - Households **share** income risks in autarky through the relative price of goods
- Small welfare gain of financial market even if with CRRA+CES

Backus-Smith (1993) Puzzle

- The two Euler equations

$$q_{B,t} = E_t \frac{\beta C_t P_t}{C_{t+1} P_{t+1}} = E_t \frac{\beta C_t^* P_t^*}{C_{t+1}^* P_{t+1}^*}$$

Normalize $P_t = 1$, so $P_t^* = 1/Q_t$, rewrite as

$$E_t(M_{t+1} R_{B,t+1}) = E_t(M_{t+1}^* \frac{R_{B,t+1} Q_{t+1}}{Q_t}) = 1$$

  - Recall that in complete market $\Delta q_{t+1} = m_{t+1} - m_{t+1}^*$, consumption is perfectly correlated with exchange rate
  - This pattern holds in almost all consumption-based models even when markets are incomplete
  - Examples: Heathcote and Perri (2002, JME); Chari, Kehoe and McGrattan (2002, RES), a departure in Corsetti, Dedola and Leduc (2008, RES)

Risk Sharing and Persistence of Shocks: Baxter and Crucini (1993)

- In more general contexts, financial market improves risk sharing
- Two forms of financial market: complete market and incomplete market (bond)
  - Similar welfare gain when shocks are transitory
  - Large welfare gain under complete markets if shocks are (near) permanent

Exchange Rate Volatility

- Macro model benchmark: exchange rates are too volatile
  - Exchange rate volatility is a magnitude higher than the volatility of macro variables, such as consumption, output, etc (Chari, Kehoe and McGrattan, 2002 RES)
- Asset pricing model benchmark: exchange rates are too smooth (Brandt, Cochrane and Santa Clara, 2006 JME)

$$\Delta q_{t+1} = m_{t+1} - m^*_{t+1}$$

  - By Hansen-Jaganathan bounds, $sd(m_{t+1}) \geq 0.5$, $sd(\Delta q_{t+1}) \approx 10\%$, implying a correlation of SDF close to 1
  - Macro variables (consumption, output, etc) are far from being almost perfectly correlated

Connecting Macro-Finance Models to SDF Approach

- Typically, IRBC models have a hard time matching stock market anomalies as well as exchange rate anomalies
  - A manifestation of the equity premium puzzle
- From the finance literature, we know what conditions SDFs should satisfy to account for exchange rate anomalies
  - Macro-finance models: endogenous SDF
  - Three categories of complete-market models
    - Earth-Mars model: SDF derived for each country independently
    - Symmetric countries with endogenous consumption risk sharing (Time-series puzzle)
    - Asymmetric countries with endogenous consumption risk sharing (Both time-series and cross-section puzzle)

The First Category: Colacito and Croce (2011 JPE)

- Two countries: Earth and mars
  - Consume and produce completely different goods
  - Financial market is open and agents are allowed to hold assets issued in both planets
  - Benefit (and cost): simple, no need to solve for optimal risk sharing
- Research question: why are SDFs so correlated without correlated fundamentals?
  - SDF correlation: Brandt, Cochrane and Santa Clara (2006)
  - Stock return correlation: mich higher than correlation of fundamentals
- Answer: correlated long-run risk + EZ preference

The Model

- Two countries, each with EZ preference
- Macro dynamics

$$\Delta c_t = \mu_c + x_{t-1} + \varepsilon_{c,t}$$

$$\Delta d_t = \mu_d + \lambda x_{t-1} + \varepsilon_{d,t}$$

$$x_t = \rho_x x_{t-1} + \varepsilon_{x,t}$$

  Foreign country is symmetric

- Exchange rate innovation

$$\Delta s_{t+1} - E_t \Delta s_{t+1} = \frac{\kappa_c(1-\gamma\psi)}{\psi(1-\rho_x\kappa_c)}(\varepsilon^*_{x,t+1} - \varepsilon_{x,t+1}) - \gamma(\varepsilon^*_{c,t+1} - \varepsilon_{c,t+1})$$

- Key: highly correlated LRR

Related Literature

- Habit model: Verdelhan (2010, JF)
- Another LRR model: Bansal and Shaliastovich (2013, RFS)
- Production-based model: Gourio, Siemer and Verdelhan (2013, JIE)

Hassan, Mertens and Wang (2024)

- The composition of currency risk premia: interest rate differential or expected appreciation of high-interest-rate currencies
  - In the data: almostly entirely from interest rate differentials
  - In habit and long-run risk models: mostly from expected appreciation of high-interest-rate currencies
- This tension challenges **all** exchange rate models under complete markets

The Second Category: Colacito and Croce (2013 JF)

- Endogenous risk sharing between two symmetric countries
  - Backus-Smith puzzle (remain in the JPE paper)
  - Forward premium puzzle
  - The key economics relies on the endogenous risk sharing

The Model

- Two countries, EZ preference over the consumption basket
- Home country endowed with X_t, foreign country endowed with Y_t, consumption aggregation

$$C_t^h = (x_t^h)^\alpha (y_t^h)^{1-\alpha}, C_t^f = (x_t^f)^{1-\alpha} (y_t^f)^\alpha$$

- Endowment dynamics

$$\log X_t = \mu_x + \log X_{t-1} + z_{1,t-1} + \tau(\log Y_{t-1} - \log X_{t-1}) + \varepsilon_{x,t}$$

$$\log Y_t = \mu_y + \log Y_{t-1} + z_{2,t-1} - \tau(\log Y_{t-1} - \log X_{t-1}) + \varepsilon_{y,t}$$

$$z_{j,t} = \rho_j z_{j,t-1} + \varepsilon_{j,t}$$

Solution

- Under complete market, solve a planner's problem

$$\max_{x_t^h, x_t^f, y_t^h, y_t^f} \Lambda = \mu U_0^h + (1-\mu) U_0^f$$

$$s.t.: x_t^h + x_t^f = X_t, y_t^h + y_t^f = Y_t$$

- With recursive preference, this is no longer a static problem and the planner cannot optimize period by period
- Solving EZ preference with heterogeneous agents under complete markets
  - Discrete time this paper, also Anderson (2005 JET); continuous time see Dumas, Uppal and Wang 2000 JET)
- Define a stochastic Pareto weight S_t

$$S_t = S_{t-1} \frac{M_t^h}{M_t^f} \left(\frac{C_t^h / C_{t-1}^h}{C_t^f / C_{t-1}^f} \right)$$

and allocation share can be expressed as functions of S_t

Efficient Risk Sharing

$$x_t^h = \alpha X_t \left[1 + \frac{(1-\alpha)(S_t - 1)}{1 - \alpha + \alpha S_t} \right], y_t^h = (1-\alpha) Y_t \left[1 + \frac{\alpha (S_t - 1)}{\alpha + (1-\alpha) S_t} \right]$$

- S_t increase mean home agents get higher Pareto weight and thus consume more
- Both positive short-run and long-run growth shocks lower S_t

Utility Risk and EZ Preference

- We can approximate the EZ preference as

$$V_t = (1-\delta)\frac{C_t^{1-1/\psi}}{1-1/\psi} + \delta E_t[V_{t+1}] - \frac{\theta\delta}{2}\frac{var_t[V_{t+1}]}{E_t[V_{t+1}]}$$

- Agents willing to give up today's consumption for safer future consumption profile
  - Either due to short-run or long-run consumption growth shock

S_t Dynamics

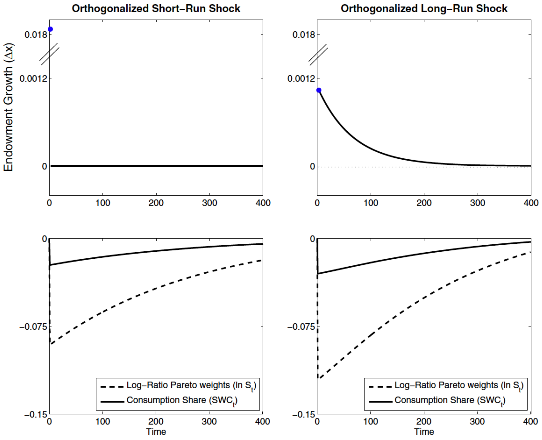


Figure 2. World consumption share when IES = 1.5. This figure shows the impulse response function of the log of the ratio of the Pareto weights, $\log(S_t)$, and the world consumption share of the home country, SWC_t. Shocks to the home country good endowment, Δx, materialize at time 1. Domestic and foreign shocks are cross-country correlated in the model. In this figure, we focus on their orthogonal component and use standard deviations $\sigma\sqrt{1-\rho_{xy}^2}$ and $\sigma_x\sqrt{1-\rho_{12}^2}$ for short- and long-run news, respectively. All parameters are calibrated to the values reported in Table II for specification (1).

Backus-Smith Correlation

- Positive shock of $\varepsilon_{x,t}$
  - Consumption increases in both countries, home increases more than foreign
  - Home currency depreciates, i.e. $corr(\Delta c^* - \Delta c, \Delta e) < 0$
- Positive shock of $\varepsilon_{1,t}$
  - Lower S_t so that home reduce consumption and foreign increase consumption
  - Home currency depreciates, i.e., $corr(\Delta c^* - \Delta c, \Delta e) > 0$

Impulse Responses

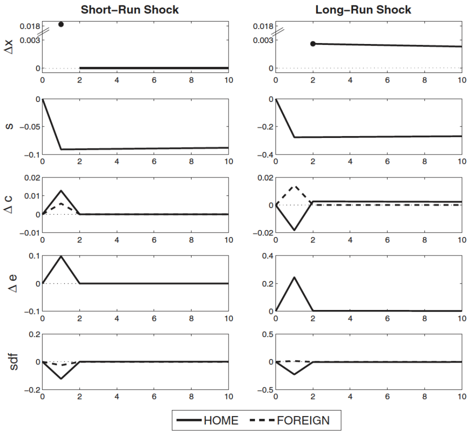


Figure 5. Impulse response functions when IES = 1.5. This figure shows the impulse response functions of Pareto weights, consumption, exchange rate, and stochastic discount factors to a shock to the home endowment for both the home country (solid line) and the foreign country (dashed line). All parameters are calibrated to the values reported in Table II for specification (1). Shocks materialize only in the home country, and only at time 1. Shocks are not orthogonalized; we consider a positive σ shock in the short-run, and a positive σ_x shock for the long-run.

SDF

$$m_{t+1}^i = \log \delta - \frac{1}{\psi} \Delta c_{t+1}^i + \left(\frac{1}{\psi} - \gamma \right) \log \tilde{U}_{t+1}^i$$
$$- \frac{1/\psi - \gamma}{1 - \gamma} \log E_t \left[\exp((1-\gamma) \log \tilde{U}_{t+1}^i) \right]$$

where $\tilde{U}_{t+1}^i$ is U_{t+1}^i scaled by the consumption basket

The Forward Premium Anomaly

- Interest rate differential

$$r_t^h - r_t^f = \frac{1}{\psi}\left(E_t(\Delta c_{t+1}^h - \Delta c_{t+1}^f)\right) + \frac{1}{2}\left(1 - \frac{1}{\psi}\right)\left(\frac{1}{\psi} - \gamma\right)\left(V_t[\log \tilde{U}_{t+1}^h] - V_t[\log \tilde{U}_{t+1}^f]\right) + \ldots$$

- Expected exchange rate change

$$E_t[\Delta e_{t+1}] = E_t[m_{t+1}^f - m_{t+1}^h]$$

$$= \frac{1}{\psi}\left(E_t(\Delta c_{t+1}^h - \Delta c_{t+1}^f)\right) + \frac{1}{2}(1-\gamma)\left(\frac{1}{\psi} - \gamma\right)\left(V_t[\log \tilde{U}_{t+1}^h] - V_t[\log \tilde{U}_{t+1}^f]\right)$$

If interest rate differentials and expected exchange rate are driven by the second term of conditional volatility (LRR shock), we get the forward premium puzzle that higher interest rate currencies tend to appreciate in expectation

Calibration and Quantitative Results

Table II

Results with Complete Markets

Data sources are described in Section I. In Panel A, we report our annual calibration. Panel B reports the main moments for our six specifications featuring different IES values. For specification (2), we impose $\sigma_x = 0$ and $\rho_{xy} = 0.35$ so that the cross-country correlation of the output growth rates remains unchanged. The currency return is defined as $r_{FX,t+1} = \Delta e_{t+1} + r^f_{f,t} - r^h_{f,t}$. The equity excess return, $r^{ex}_{d,t}$, is defined as $r^{ex}_{d,t} = \lambda r^{ex}_{c,t} + \epsilon^i_t$, $i \in \{h, f\}$, where $\lambda = 3$, $r^{ex}_{c,t}$ is the excess return on the consumption claim, and $\epsilon^i_t \sim_{i.i.d.} N(0, 0.15^2)$ captures dividend-specific shocks. SWC refers to the share of world consumption. NX denotes net exports. A/X denotes the net international investment position.

Panel A: Calibration of Common Parameters

μ	σ	σ_x	ρ	ρ_{12}	ρ_{xy}	τ	α	δ	γ
2.00%	1.87%	14%σ	0.985	0.90	0.05	0.05%	0.97	0.98	8

Panel B: Main Moments

		(with LRR)	(no LRR)	(with LRR)			
Specification	DATA	(1)	(2)	(3)	(4)	(5)	(6)
IES (ψ)		1.5	1.5	2	1	0.67	$1/\gamma$
Std (Δc)	1.86	2.18	1.64	2.07	2.44	2.28	2.01
Std (Δc)/Std (Δx)	0.87	0.99	0.88	0.94	0.99	0.99	0.91
ACF$_1$ (Δc_t)	0.38	0.27	0.00	0.30	0.22	0.24	0.32
corr (Δc^h_t,Δc^f_t)	0.55	0.51	0.78	0.65	0.33	0.37	0.78
Std(SWC)/Std(Δx)	3.18	3.78	2.09	3.64	4.27	4.11	2.57
E[r_f]	1.25	1.82	2.93	1.01	3.20	5.40	16.55
Std[r_f]	1.15	0.69	0.00	0.38	1.16	1.54	9.17
corr($r^h_{f,t}$, $r^f_{f,t}$)	0.64	0.84	−1.00	0.72	0.89	0.90	0.97
Std[M]/E[M]		27.53	13.05	16.98	70.14	87.55	16.25
Std (Δe_t)	11.65	15.32	8.01	15.41	18.14	17.22	10.89
corr($\Delta c^h_t - \Delta c^f_t$, Δe_t)	−0.02	−0.11	1.00	0.07	−0.51	−0.41	1.00
β_{UIP}	−0.72	−0.50	−234.13	−0.40	−1.37	−1.13	1.02
E($r^{ex}_{d,t}$)	6.80	5.22	0.07	8.13	−1.24	−8.34	−1.36
corr($r^{ex}_{d,t+1}$,$r_{FX,t}$)	−0.05	0.05	0.01	−0.03	−0.01	−0.05	−0.05
Std (A/X)/Std (Δx)	16.01	22.02	24.28	10.43	58.27	81.09	4.30
Std (NX/X)/Std (Δx)	0.20	0.62	0.27	0.58	0.78	0.71	0.36

Related Literature

- Habit model with risk sharing : Heyerdahl-Larsen (2014 RFS) and Stathopolous (2017 RFS)
- Rare disaster: Farhi and Gabaix (2016 QJE)
- Followup work on long-run risk models in international finance
  - Capital flows with investment: Colacito, Croce, Ho and Howard (2018 AER)
  - The transmission of volatility risk and tradeoff between volatility and consumption: Colacito, Croce, Liu and Shaliastovich (2022 RFS)

The Third Category: Colacito, Croce, Gavazzoni and Ready (2018 JF)

- Asymmetric countries: aiming to address the cross-sectional currency risk premia
- Why are countries different? Long-run risk exposure
  - How to measure the LRR exposure?
  - Connecting back to the heterogeneus δ implication in LRV: higher LRR exposure leads to higher exposure

Short-run and Long-run Shock: Empirics

$$\Delta GDP_t^i = \phi pd_{t-1}^i + \sigma \varepsilon_t^i$$

where we denote $z_t^i = \phi pd_{t-1}^i$ and z_t^i follows

$$z_t^i = \rho_z z_{t-1}^i + \varphi_e \sigma \varepsilon_{z,t}^i$$

Exposure

$$\Delta GDP_t^i = (1 + \beta_{\Delta y}^i)\overline{\Delta GDP_t^i} + \xi_t^i$$

$$z_t^i = (1 + \beta^i)\overline{z_t^i} + \zeta_t^i$$

Empirical Evidence

Table I

Dynamics of Endowments and Predictive Components

Panel A reports estimates for the parameters of the endowment process reported in equation (1). The parameters are estimated using the longest available sample for each country, as described in Section I. Panel B reports estimates for the exposure of each country's GDP growth rate to the global GDP growth rate (see equation (2)). The sample is 1970 to 2013. Panel C reports estimates for the exposure of each country's predictive component of GDP to the global predictive component (see equation (3)). The sample is 1987 to 2013. The numbers in square brackets are the *p*-values associated with the null hypothesis that the estimated exposure in the first half of the sample (1987 to 2000) is different from the estimated exposure in the second half of the sample (2001 to 2013). In all panels, the numbers in parentheses are heteroskedasticity-adjusted standard errors. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Estimation of Predictive Components

	ϕ	ρ_x	σ	φ_e
Parameters	0.005***	0.773***	0.020***	0.058***
(*SE*)	(0.000)	(0.006)	(0.000)	(0.001)

Panel B: Exposure to Global Endowment Risk

	NZ	AUS	UK	GER	CAN	NOR	JPN	SUI	USA
$\beta^i_{\Delta y}$	−0.28	−0.18	0.05	−0.12	0.14*	0.61**	0.15	−0.11	−0.11
(*SE*)	(0.299)	(0.234)	(0.164)	(0.218)	(0.085)	(0.269)	(0.269)	(0.177)	(0.104)

Panel C: Exposure to Global Long-Run Risk

	NZ	AUS	UK	GER	CAN	NOR	JPN	SUI	USA	SWE
β^i	−0.51***	−0.44***	−0.08	−0.02	0.00	0.08	0.12	0.26**	0.27*	0.33**
(*SE*)	(0.154)	(0.064)	(0.098)	(0.094)	(0.131)	(0.173)	(0.165)	(0.130)	(0.166)	(0.148)
Chow	[0.109]	[0.245]	[0.299]	[0.841]	[0.729]	[0.506]	[0.802]	[0.667]	[0.596]	[0.385]

A Symmetric Model with Asymmetry

- A N-country version of Colacito and Croce (2013)

$$C_t^i = \left(x_{i,t}^i\right)^{\alpha} \Pi_{j \neq i} \left(x_{j,t}^i\right)^{\frac{1-\alpha}{N-1}}$$

- Endowment

$$\log X_t^i = \mu_x + \log X_{t-1}^i + z_{i,t-1} + \tau \left[\log X_{t-1}^i - \frac{1}{N} \log \left(\sum_{j=1}^{N} X_{j,t} \right) \right] + \varepsilon_{i,t}^X$$

$$z_{i,t} = \rho_i z_{i,t-1} + \varepsilon_{i,t}^z$$

$$\varepsilon_{i,t}^z = (1 + \beta_{i,t-1}^z) \varepsilon_{global,t}^z + \varepsilon_{i,t}^{\tilde{z}}$$

where $\beta_{i,t}^z$ is a highly persistent AR(1) process

- Stationarity requires symmetric countries, but we are interested in asymmetric countries
  - A short-sample with persistent heterogeneity in $\beta_{i,t}^z$

Quantitative Results

Table III

Simulated Moments with Heterogeneous Exposure

The table reports both empirical moments computed using the data set described in Section I and simulated moments from the model with both heterogeneous and homogeneous exposure. All parameters are set to their benchmark values reported in Table II. For the CRRA case, we set $\gamma = 1/6.5$. Panel A reports the moments for the dynamics of exogenous endowment growth rates. Panel B reports the moments of the consumption growth rate within each country. Panel C reports the cross-country moments for each country pair. Panel D reports the median moments for the risk-free rates (r_f), SDFs (M), NFA-to-output (NFA/X), slope coefficient of the UIP regressions (β_{UIP}), and average currency risk premium (E[HML]). In Panel E, we report cross-sectional standard deviations for the listed moments. CoV denotes the cross-sectional coefficient of variation.

			Homogeneous	Heterogeneous	
	Data	*SE*	EZ	EZ	CRRA
Panel A: Endowment Growth					
Std(Δx)	2.10	0.26	1.93	1.95	1.95
ACF$_1$(Δx)	0.21	0.13	0.29	0.30	0.35
corr(Δx_t^h, Δx_t^f)	0.23	0.06	0.43	0.40	0.40
Panel B: Single-Country Moments					
Std(Δc)	1.91	0.25	1.78	1.96	1.74
ACF$_1$ (Δc)	0.46	0.11	0.31	0.28	0.30
Panel C: Bilateral Moments					
corr(Δc_t^h, Δc_t^f)	0.24	0.05	0.55	0.38	0.59
Std (Δe)	9.10	0.91	14.65	17.01	10.07
corr(m, m^f)			0.94	0.85	0.59
Std(NX/X)	5.12	0.74	0.47	1.48	1.00
ACF$_1$(NX/X)	0.92	0.06	0.86	0.90	0.94
Panel D: Financial Variables					
E(r_f)	2.16	0.74	2.26	2.13	11.79
Std[r_f]	2.88	0.41	1.04	1.14	11.74
corr(r_f^h, r_f^f)	0.57	0.05	0.92	0.71	0.89
Std(NFA/X)/Std(Δx)	18.58	2.95	11.34	25.76	10.29
ACF$_1$(NFA/X)	0.99	0.05	0.81	0.88	0.74
β_{UIP}	−0.94	0.48	−5.54	−4.62	0.78
E(HML)	3.20	1.10	0.11	3.01	0.13
Panel E: Cross-Sectional Standard Deviation					
Std(Δc)	0.45	0.12	0.06	0.21	0.09
E(r_f)	1.27	0.26	0.18	0.54	2.86
Std(r_f) (CoV)	0.42	0.08	0.03	0.46	0.34
Std(NFA/X)/Std(Δx) (CoV)	0.55	0.09	0.01	0.68	0.74
Std(NX/X) (CoV)	0.52	0.09	0.02	0.61	0.48
β_{UIP} (CoV)	0.87	0.29	1.30	1.16	0.58
Std (Δe) (CoV)	0.21	0.04	0.03	0.41	0.04

Impulse Responses

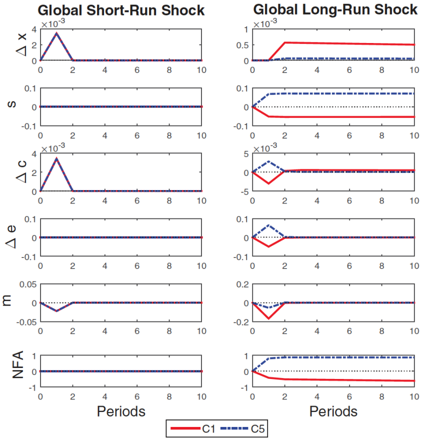


Figure 2. Impulse response functions under heterogeneous exposure. The left (right) panels report the response of endowment growth ($\Delta \log X^i$), relative Pareto weights with respect to country 3 ($\log S_j/S_3$), consumption growth (Δc_i), exchange rate growth (Δe_3^i), SDFs (m_i), and NFA (A_i/X_i) to a one-standard-deviation short-run (long-run) global shock. All panels correspond to the case in which the economy consists of five countries ($i = 1, \ldots, 5$). The exchange rate is measured with respect to country 3, implying that $\Delta e < 0$ for country 1 denotes a depreciation of its real exchange rate with respect to country 3. Country 1 (5) is initialized with an exposure to long-run shocks of 0.65 (−0.65). (Color figure can be viewed at wileyonlinelibrary.com)

NFA Exposure

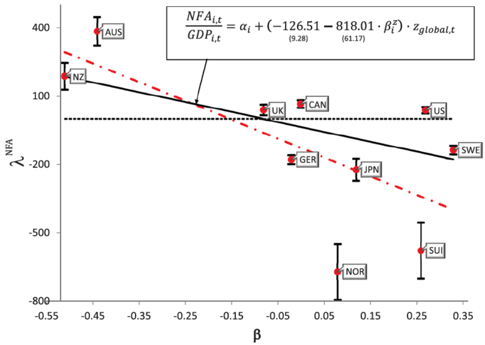


Figure 7. NFA exposure. Each dot represents the estimated sensitivity of a country's NFA-to-GDP ratio with respect to global long-run risk plotted (see equation (17), coefficient λ_i^{NFA}). For each dot, the vertical line represents the 90% confidence interval associated to the estimated coefficient. The dashed line corresponds to the point estimate of the line $\vartheta_0^{NFA} + \vartheta_1^{NFA} \cdot \beta_i^z$ in equation (18). The solid line represents the model prediction. The estimated βs are reported in Table I. Standard errors are adjusted for heteroskedasticity. (Color figure can be viewed at wileyonlinelibrary.com)

Explanation to the Concealed Carry: Andrews et al (2023 JFE)

- Heterogeneous exposures to global growth shock and inflation shock
  - Growth shock exposures lead to traditional carry (dominant pre-08)
  - Inflation shock exposures lead to slope carry (dominant post-08)

Related Literature

- Hassan (2013 JF): large countries have more volatile SDFs - hard to insure
- Richmond (2019 JF): central countries in trade networks have more volatile SDFs
- Ready, Roussanov and Ward (2018 JF): final good producers have more volatile SDFs relative to commodity producers
  - Commodity trade cost and substitution between producing commodity and final good
- Jiang (2022 RFS): More cyclical fiscal countries have more volatile SDFs

5. Exchange rates with international financial market frictions

Gabaix and Maggiori (2015 QJE)

Why Financial Intermediaries?

- FX transactions are largely condcuted by financial institutions
- Recent intermediary asset pricing literature highlights intermediary financial wealth driver of asset returns
- Convincing evidence on the leverage constraint and CIP deviation (Du, Tepper and Verdelhan, 2018 JF)
- A frictional international financial market brings us closer to an exchange rate model reconciling various exchange rate puzzles (Itskhoki and Mukhin, 2021 JPE)

Exchange Rates with Intermediaries: Gabaix and Maggiori (2015 QJE)

- Two countries, US and Japan
- Two periods, $t = 0, 1$
- US Households

$$\theta_0 \ln C_0 + \beta E[\theta_1 \ln C_1]$$

$$C_t = [(C_{NT,t})^{\chi_t}(C_{Ht})^{a_t}(C_{Ft})^{\iota_t}]^{\frac{1}{\theta_t}}$$

  - $C_{NT,t}$: consumption of tradable goods (US)
  - C_{Ht}: consumption of domestic tradable
  - C_{Ft}: consumption of Japan tradable
  - Simplification: $\theta_t = \chi_t + a_t + \iota_t$, $Y_{NT,t} = \chi_t$
  - Use the nontradable as the numeraire $p_{NT,t} \equiv 1$
  - Consumption of Japanese tradables, define p_{Ft} the dollar price of Japanese tradable

$$p_{Ft} C_{Ft} = \iota_t$$

Japanese Household Optimization

- Consumption basket

$$C_t^* = \left[(C_{NT,t}^*)^{\chi_t^*} (C_{Ht}^*)^{\xi_t} (C_{Ft}^*)^{a_t^*} \right]^{\frac{1}{\theta_t^*}}$$

- Simplification: $\theta_t^* = \chi_t^* + a_t^* + \xi_t$ and $Y_{NT,t}^* = \chi_t^*$
- The (yen) value of US export

$$p_{Ht}^* C_{Ht}^* = \xi_t$$

- Dollar value of US export (define e_t the price of yen)

$$NX_t = e_t \xi_t - \iota_t$$

  - The more appreciated yen (higher e_t), the higher US NX_t (demand for US export) is
- For both countries, $\beta R = 1$ and $\beta^* R^* = 1$ since $\chi_= Y_{NT,t}$ and $\chi_t^* = Y_{NT,t}^*$

Exchange Rate Under Financial Autarky

- Under financial autarky, net export equals zero
- Exchange rate

$$e_t = \frac{\iota_t}{\xi_t}$$

Yen appreciates if Japan's demand for US tradable good ξ_t decreases or if US demand of Japanese tradable good ι_t increases

Global Intermediaries

- With an international financial market, either country is able to run trade surplus
  - Trade surplus: capital outflow
  - Trade deficit: capital inflow
  - Trade balance = net capital flows
- The main innovation in this paper: the capital flow is **intermediated** by a global financier (intermediary) that faces constraints and requires compensation
  - A unit of mass of global financiers
  - Agents (randomely) from two countries run the intermediary
  - No capital, trade two bonds, with q_0 dollar and $-\frac{q_0}{e_0}$ yen
  - At period end, repay the profits to the household owners

The Global Intermediaries' Problem

$$\max_{q_0} V_0 = E\left[\beta\left(R - R^*\frac{e_1}{e_0}\right)\right] q_0$$

$$s.t.: \frac{V_0}{e_0} \geq \Gamma\left(\frac{q_0}{e_0}\right)^2$$

where $\Gamma = \gamma\left(var(e_1)\right)^{\alpha}$

- The constraint is written in yen
- $|\frac{q_0}{e_0}|$, the position in yen
- $\Gamma|\frac{q_0}{e_0}|$, the "divertable" share in yen
- The constraint: similar to Gertler and Karadi (2011)

Aggregate Demand of Dollar Assets

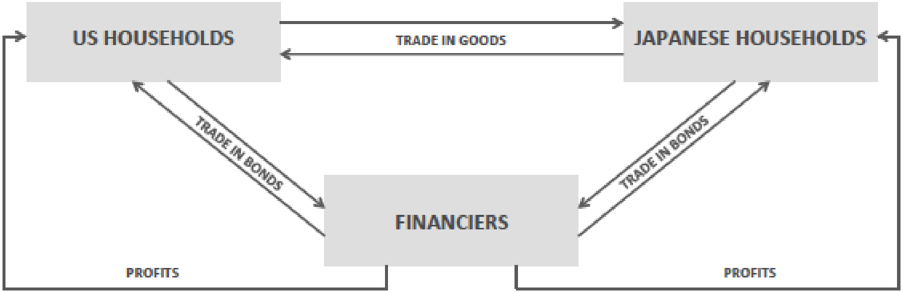
Solution to the global intermediaries' problem

$$q_0 = \frac{1}{\Gamma} E\left[e_0 - e_1 \frac{R^*}{R}\right]$$

- The term in the bracket: excess return of borrowing yen and investing in dollar
- The global intermediary requires compensation for intermediating capital flow, and the compensation increases with the flow q_0
- Γ governs the sensitivity: when Γ is small, the global intermediary is willing to intermediate less capital for given expected excess return

Flow Diagram

Figure I: Basic Structure of the Model



The players and structure of the flows in the goods and financial markets in the Basic Gamma Model.

Exchange Rate in General Equilibrium

Further simplify: $\beta = \beta^* = R = R^* = 1$, and $\xi_t = 1$

$$q_0 = \frac{1}{\Gamma} E\left(e_0 - e_1\right)$$

$$q_0 = -(e_0 - \iota_0)$$

$$e_1 - \iota_1 = q_0$$

Solve for e_0 and e_1 as

$$e_0 = \frac{(1+\Gamma)\iota_0 + E(\iota_1)}{2+\Gamma}$$

$$e_1 = \frac{\iota_0 + (2+\Gamma)\iota_1 - E(\iota_1)}{2+\Gamma}$$

Two Polar Cases

- $\Gamma = 0$, UIP holds and the intermediary absorbs whatever flow in the market

$$e_0 = \frac{\iota_0 + E(\iota_1)}{2}, e_1 = \frac{\iota_0 + 2\iota_1 - E(\iota_1)}{2}$$

- $\Gamma = \infty$, the intermediary does not intermediate any capital flow, financial autarky

$$e_0 = \iota_0, e_1 = \iota_1$$

The Economics

- If ι_0 exceeds $E(\iota_1)$, US demands more Japanese tradable good in period 0
- Absent any friction, there should be an capital inflow and US borrows from Japan
- However, the capital flow from Japan into US must be intermediated by the global intermediary. To ensure the global intermediary is willing to hold a long dollar position, dollar has to offer a higher return, i.e., $E(e_1) < e_0$
- As the yen exchange rate e_0 is higher with frictions than without frictions, the US import less than the frictionless case, or q_0 is reduced as a feedback mechanism

The Effect of Financial Disruption on Exchange Rates

- When there is a financial disruption, i.e., Γ increases, the currency of net debtor depreciates and the currency of net creditor appreciates
  - The intermediary lends to the borrower expecting a higher appreciation for intermediation compensation

The Role of Portfolio Flows

- In the basic model, exchange rate is jointly determined by the US demand of net import and the risk compensation required by the global intermediaries
- The compensation depends on the quantity of flows, q_0
- Extension: suppose there is an exogenous Japanese household flow into USD bonds, f^*, funded by $-f^*/e_0$ in yen bonds, the equations becomes

$$q_0 = \frac{1}{\Gamma} E(e_0 - e_1), q_0 = -(e_0 - \iota_0) - f^*, e_1 - \iota_1 - f^* = q_0$$

  - Capital flow that the intermediary needs to absorb is Japanese households' demand of USD bonds, net of the exogenous flow of the Japanese households
  - Solve for

$$e_0 = \frac{(1+\Gamma)\iota_0 + E(\iota_1) - \Gamma f^*}{2+\Gamma}$$

  - With the exogenous portfolio flow $f^* > 0$, the intermediary has to absorb less capital flows, and e_0 is higher than $f^* = 0$

Gross Flow, Net Flow, and Intermediary Balance Sheet

- f^* does not directly change the net flow (determined by export and import)
  - Indirect effect through exchange rate
  - But what determines exchange rate is not the demand of net capital flows, but the gross capital flows that need to be intermediated by the global intermediary
  - What should we relate to exchange rate in the data is not the net foreign asset positions, but the intermediary's balance sheet

Exchange Rate Disconnect

- Under the intermediary view, exchange rates are pinned down by financial forces, and have weak relation with macro factors
- Determination: f and Γ
  - For different countries with similar fundamentals, different "unintermediated" capital flows f can make exchange rate behaviors sharply different
  - Evidence on the financial determinant of exchange rates: listed in Maggiori (2022) recent handbook chapter

Carry Trade

- Carry trade expected return

$$\bar{R}^c = \Gamma \frac{R^*/RE[\iota_1] - \iota_0}{(R^* + \Gamma)\iota_0 + R^*/RE[\iota_1]}$$

  - Interest rate differential
  - Net creditor/debtor
  - The international financial market friction
- Theoretical underpinnings on ‘intermediary-based” tests of currency risk premia

FX Intervention

- The role of FX intervention: similar to the exogenous portfolio flows, e.g., what if the Japanese government buys q^* USD and sells q^*/e_0 yen?
- Alter the amount of intermediation by the global intermediary, thus appreciating dollar and depreciating yen
  - The key insight of Gabaix-Maggiori model: intermediary balance sheet is the key determinant of exchange rate
  - Bring it into the general equilibrium macro framework
- Note that it affects e_0 and e_1, but not the average exchange rate as the government has to take the opposite position in the next period

CIP Deviation

- CIP deviation

$$x = -(-i - s + i^* + f)$$

  - Before the crisis, largely zero
  - After the crisis, large and persistent deviations, $x < 0$
- If Γ is zero for CIP trade, CIP holds (e.g., if Γ depends on the variance of f)
- If Γ is positive even with riskless f, there is CIP deviation
- CIP deviation driven by the intermediary's balance sheet constraint

Intermediation and CIP Deviation

- Convincing, powerful aggregate evidence (Du, Tepper and Verdelhan, 2018 JF)

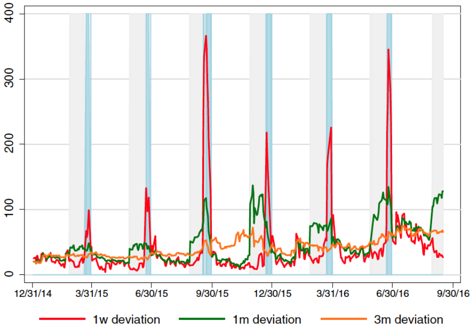


Figure 5. Illustration of quarter-end dynamics of CIP deviations. The blue-shaded area denotes the dates for which the settlement and maturity of a one-week contract spans two quarters. The gray-shaded area denotes the dates for which the settlement and maturity dates of a one-month contract spans two quarters but excludes the dates in the blue-shaded area. The figure plots the one-week, one-month, and three-month Libor CIP deviations for the yen (in absolute values) in red, green, and orange, respectively. (Color figure can be viewed at wileyonlinelibrary.com)

- Micro evidence: Cenedese, Della Corte, and Wang (2020 JF)

Quantitative Exploration of an Intermediary Model

- Fang and Liu (2021, JFE): a quantitative model that jointly matches intermediary characterstics, macro dynamics, and exchange rates
- Gertler and Karadi+ Gabaix and Maggiori
  - Households deposit in local intermediaries
  - Local intermediaries invest in risky assets in both countries, as well as an international bond
  - Both intermediaries are subject to a leverage constraint, driven by the volatility in the economy

$$\ln \theta_t = \log \theta_0 + \theta_1 \log \sigma_{xt}, \log \theta_t^* = \log \theta_0 + \theta_1 \log \sigma_{yt}$$

  - Two-period intermediary, each period net worth η
  - Estimate the model using SMM

Flow Diagram

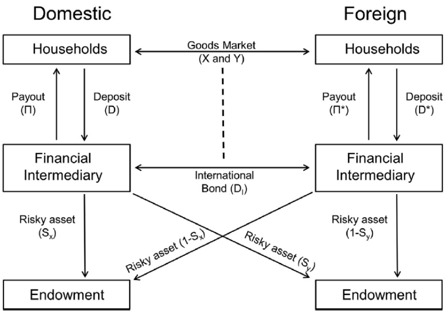


Fig. 1. Model structure. The figure shows the structure of the model in a circular flow diagram.

Quantitative Performance

Table 1
Estimation results.
The table shows the sample moments in the data and implied population moments in the model. Panel A reports the targeted moments in the SMM estimation. Panel B reports additional untargeted moments. Panel C reports the moments related to the new implications of the model.

Moments	Data	Model
Panel A. SMM target moments		
$sd(\Delta c)$	1.83	2.01
$P_y C_y / C$	0.17	0.16
S_x	0.85	0.89
$sd(NX/GDP)$	1.72	1.98
$sd(\log(\sigma_x))$	0.23	0.21
r_f	0.74	0.73
$r_s - r_f$	0.98	0.99
ϕ	0.12	0.12
$corr(\Delta q,\ \Delta c - \Delta c^*)$	-0.05	-0.05
β_{fp}	2.05	1.63
$sd(\Delta q)$	8.03	5.27
r_{cip}	-0.25	-0.25
$sd(r_{cip})$	0.27	0.23
Panel B. Additional moments		
$sd(r_f)$	1.16	0.42
$sd(r_s - r_f)$	0.71	3.69
$corr(NX/GDP_t, NX/GDP_{t-1})$	0.99	0.99
$sd(\phi)$	0.03	0.01
$corr(\phi_t, \phi_{t-1})$	0.98	0.95
$r_{dolloar}$	5.34	2.19
SR_{dollor}	0.61	0.41
Panel C. New implications		
$\beta_{cip,-\Delta q}$	-2.02	-1.47
$\beta_{cip,\sigma}$	-0.21	-1.01
$corr(q, TED_{us} - TED_f)$	-0.36	-0.27
$corr(\Delta q, \Delta(TED_{us} - TED_f))$	-0.44	-0.61
$\beta_{cf,TED_{us}-TED_f}$	-0.88	-0.31
$\beta_{rx,\sigma}$	0.23	0.10
$\beta_{rx,cp}$	-0.34	-0.15

Sensitivity Analysis

Table 3
Sensitivity analysis.
The table shows the sample moments in the data and model-implied population moments. The "Benchmark" column shows the moments in the benchmark model with the parameter estimated from SMM. $\theta_0 = 0.118$, $\theta_1 = 0.392$, and $\eta = 19.854$. The other columns report the moments when we take different parameter values shown in the table and fix the other parameters at the benchmark.

Moments	Data	Benchmark	$\theta_0 = 0.10$	$\theta_0 = 0.15$	$\theta_1 = 0$	$\theta_1 = 0.6$	$\eta = 15$	$\eta = 25$
$sd(\Delta c)$	1.83	2.01	1.96	2.07	1.68	2.33	2.00	2.01
$P_y C_y / C$	0.17	0.16	0.16	0.17	0.17	0.16	0.17	0.16
S_x	0.85	0.89	0.90	0.87	0.88	0.89	0.87	0.91
$sd(NX/GDP)$	1.72	1.98	1.96	2.01	1.95	1.98	2.01	1.95
$sd(\log(\sigma_x))$	0.23	0.21	0.21	0.21	0.21	0.21	0.21	0.21
r_f	0.74	0.73	0.74	0.72	0.81	0.66	0.74	0.73
$r_s - r_f$	0.98	0.99	0.73	1.46	0.90	1.09	1.51	0.66
ϕ	0.12	0.12	0.10	0.15	0.12	0.12	0.11	0.12
$corr(\Delta q,\ \Delta c - \Delta c^*)$	-0.05	-0.05	0.03	-0.15	1.00	-0.43	-0.04	-0.06
β_{fp}	2.05	1.63	1.59	1.67	0.30	1.75	1.63	1.62
$sd(\Delta q)$	8.03	5.27	5.08	5.56	3.82	6.67	5.25	5.28
r_{cip}	-0.25	-0.25	-0.20	-0.34	-0.18	-0.32	-0.33	-0.20
$sd(r_{cip})$	0.27	0.23	0.20	0.27	0.02	0.31	0.25	0.21

Other Frictions

- Segmented market
  - Alvarez, Atkeson and Kehoe (2009 RES), Chien, Lustig and Naknoi (2019 JME)
- Infrequent portfolio decisions
  - Bacchetta and van Wincoop (2010 AER, 2021 JIE), Bacchetta, Davenport and van Wincoop (2022 JIE), Bacchetta, van Wincoop and Young (2023 RES), Bacchetta, Tieche and van Wincoop (2023 RFS)
- Information frictions
  - Gourinchas and Tornell (2004 JIE), Brennan and Cao (1997 JF), Albuquerque, Bauer and Schneider (2007 RES), Dumas, Lewis and Osambela (2017 RFS)

6. Convenience yield and exchange rates

Jiang, Krishnamurthy and Lustig (2021 JF; 2023 RES)

The Augmented Present Value Relation

$$s_t = E_t \sum_{\tau=0}^{\infty}(y^{\$}_{t+\tau} - y^{*}_{t+\tau}) - E_t \sum_{\tau=0}^{\infty} rp^{*}_{t+\tau} + E_t \sum_{\tau=0}^{\infty}(\lambda^{\$,*}_{t+\tau} - \lambda^{*,*}_{t+\tau}) + E_t \left[\lim_{T\to\infty} s_{t+T} \right]$$

- Dollar exchange rate appreciates if
  - PV of US interest rate is high
  - PV of US Treasury's convenience yield is high
  - Risk premia of investing in foreign currency bond is low
- Measuring convenience yield: Jiang, Krishnamurthy and Lustig (2021, JF)

Jiang, Krishnamurthy and Lustig (2021 JF) Treasury Basis

- Treasury basis

$$x_t^{Trea} = -(-y - s + y^* + f)$$

  A negative x_t^{Trea} means foreigner attach higher value of US Treasury in the cash market than the synthetic US Treasury

- Assume the synthetic US Treasury has convenience yield of $\beta(\lambda_t^{\$,*} - \lambda_t^{*,*})$
- Treasury basis and convenience yield of US Treasuries

$$x_t^{Trea} = (1 - \beta)(\lambda_t^{\$,*} - \lambda_t^{*,*})$$

Convenience Yield and Exchange Rate

Table III

Average Treasury Basis and the USD Spot Nominal Exchange Rate

This table presents the regression result in which the dependent variable is the quarterly change in the log of the spot USD exchange rate against a basket. In Panel A, the independent variables are the innovation in the average Treasury basis, $\Delta\bar{x}^{Treas}$, as a log yield (i.e., 50 bps is 0.005), the lagged value of the innovation, the innovation in the LIBOR basis, and the innovation in the U.S.-to-foreign Treasury yield differential. Panel B includes the quarterly change in the VIX (in percentage units). The data are quarterly. The constant term is omitted. OLS standard errors are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Panel A: Benchmark Results

	1988Q1–2017Q2					1988Q1–2007Q4		2008Q1–2017Q2	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta\bar{x}^{Treas}$	−10.20***		−10.23***		−9.81***	−8.48***		−14.93***	
	(2.09)		(1.98)		(1.73)	(2.62)		(3.20)	
$\Delta\bar{x}^{Libor}$		−2.85					4.63		−13.51***
		(3.09)					(4.22)		(4.05)
Lag $\Delta\bar{x}^{Treas}$			−6.92***		−6.47***				
			(1.97)		(1.73)				
$\Delta(y^{\$} - \bar{y}^{*})$				3.76***	3.57***				
				(0.71)	(0.60)				
Observations	117	117	116	117	116	80	80	37	37
R^2	0.17	0.01	0.25	0.20	0.43	0.12	0.02	0.38	0.24

Panel B: Control for VIX

	1988Q1–2017Q2					1988Q1–2007Q4		2008Q1–2017Q2	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta\bar{x}^{Treas}$	−9.62***		−9.22***		−9.66***	−7.10**		−10.44***	
	(2.40)		(2.31)		(1.94)	(3.14)		(3.35)	
$\Delta\bar{x}^{Libor}$		−1.89					5.19		−8.07**
		(3.09)					(4.10)		(3.94)
Lag $\Delta\bar{x}^{Treas}$			−7.06***		−4.33**				
			(2.28)		(1.95)				
$\Delta(y^{\$} - \bar{y}^{*})$				4.71***	4.48***				
				(0.73)	(0.66)				
Δvix	0.05	0.09	0.06	0.12**	0.08	−0.12	−0.13	0.21***	0.26***
	(0.07)	(0.07)	(0.06)	(0.06)	(0.05)	(0.10)	(0.10)	(0.08)	(0.08)
Observations	109	109	109	109	109	72	72	37	37
R^2	0.15	0.02	0.22	0.29	0.46	0.09	0.05	0.50	0.42

Estimating β

1. Directly from the regression coefficient in the previous table, which is equal to $\frac{1}{(1-\phi_a)(1-\beta)}$: β=0.90
2. Long-run interest rate differential: $\lambda_t^{\$,*} - \lambda_t^{*,*} = 1.89\%$
3. Using an identified monetary policy shock as an instrument for convenience yield change, controlling for interest rate differential, $\beta = 0.91$
   - Assuming PV of risk premia does not change with the monetary policy shock

Takeaway: Most convenience yield comes from the dollar, not from the US Treasuries

US As a Safe Asset Supplier

- Under this convenience yield view, the US is supplying the world a safe asset
  - Central banks hold US Treasuries as reserves
  - Insitutional investors hold US Treasuries for safety and liquidity
- USD enjoys an "exorbitant privilege"
  - Exorbitant duty and the insurance view (Gourinchas, Rey and Govillot, 2017)
  - Reserve currency paradox (Maggiori 2017, AER)
- What supports the US Treasury as a safe asset?
  - Fundamentals? US is running an unprecedentedly high debt
  - A result of coordination? He, Milbradt, and Krishnamurthy (2019 AER)

Convenience Yield and International Finance “Puzzles”

- Jiang, Krishnamurthy and Lustig (2023 RES): a simple model that dollar bond convenience yields can explain a wide range of international finance “puzzles”
  1. Dollar funding advantage
  2. Dollar debt donimance
  3. Flight to dollar safety (and dollar appreciation)
  4. Global financial cycle
  5. US exorbitant privilege
  6. Dollar risk factor

US Block: Households and Firms

- OLG households, born and supply labor l_t, consume at $t+1$

$$\frac{1}{1+\rho} E_t[c_{t+1}] - l_t$$

- Production, with one period lag

$$f(l_t, k_t) = a_t(l_t + k_t)$$

  - Perfect substitute between labor and capital
- Price level p_t, in equilibrium wage is p_t
- Household budget constraint

$$p_{t+1} c_{t+1} = w_t l_t (1 + i_t)$$

US Block: Financial Frictions

- Each firm run by a manager with net worth n_t that exits with probability σ

$$\sum_{t=1}^{\infty}(1-\sigma)^{t-1}\sigma n_t$$

- Budget constraint

$$p_t n_t + b_t = w_t l_t + p_t k_t$$

  Firms combine borrowing and net worth to make factor payment

- Borrowing constraint using future output as collateral

$$b_t \leq \frac{\theta p_{t+1} f(k_t, l_t)}{1+i_t}$$

US Block: Production Size

$$l_t + k_t = \frac{n_t}{1 - \theta a_t (1 + i_t - \pi_t)^{-1}}$$

- The size of production is proportional to net worth n_t
- A lower real interest rate encourages production because it relaxes the borrowing constraint
- Assume fully sticky price, $\pi_t = 0$, so real rate is equal to nominal rate $\rightarrow$ the effect of monetary policy
- Individual net worth dynamics

$$n_{t+1} = f(l_t, k_t) - \theta f(l_t, k_t) = n_t \frac{a_t(1-\theta)}{1 - \theta a_t (1 + i_t - \pi_t)^{-1}}$$

- Aggregate net worth dynamics

$$N_{t+1} = (1-\sigma) N_t \frac{a_t(1-\theta)}{1 - \theta a_t (1 + i_t - \pi_t)^{-1}} + \sigma \hat{N}$$

US Block: Equilibrium

- Capital market clearing

$$K_t = N_t, p_t L_t = B_t$$

- Debt supply

$$B_t = \frac{\theta p_{t+1} Y_{t+1}}{1 + i_t}$$

- The effect of monetary policy shock
  - Monetary tightening $\rightarrow$ reduce debt capacity and thus dollar asset supply $\rightarrow$ downsize production size and future capital $\rightarrow$ future output lower

International Block: Convenience Yield, Intermediary and Dollar Liquidity

$$r_t + \lambda_t = r_t^* - (E_t e_{t+1} - e_t)$$

- λ_t is the convenience yield provided by US assets
- Financial intermediation: $\chi < 1$ banks take deposit $1 - 1$ and sell them to the world safe asset investors, providing dollar liquidity. In aggregate, they provide dollar liquidity and earn carry trade profit

$$Q_t = \chi B_t / p_t$$

- Convenience yield and dollar liquidity

$$\lambda_t = \lambda(Q_t), \lambda'(Q_t) < 0$$

Foreign Block: Households and Firms

Setup is similar to US

- Households

$$\frac{1}{1+\rho^*}E_t[c^*_{t+1}] - l^*_t$$

- Production

$$f(l^*_t, k^*_t) = a^*_t(l^*_t + k^*_t)$$

- Borrowing constraint

$$b^*_t \leq \frac{\theta p^*_{t+1} Y^*_{t+1}}{1+i^*_t}$$

- Production size

$$l^*_t + k^*_t = \frac{n^*_t}{1-\theta^* a^*_t(1+r^*_t)^{-1}}$$

- Net worth

$$\sum_{t=1}^{\infty}(1-\sigma^*)^{t-1}\sigma^* n^*_t$$

Foreign Block: Borrowing Choice

- Firms borrow in USD: US interest rate is lower due to convenience yield
- Assume γ funding from USD and the rest $1 - \gamma$ from local currency
- Foreign profits are exposed to exchange rate fluctuations: if USD appreciates, debt burden is higher and profits are lower
- Since foreign firms also supply dollar debt

$$\lambda_t = \lambda(Q_t + Q_t^*)$$

The reliance of convenience yield on debt supply amplifies the effect of shocks

US Monetary Policy Spillover

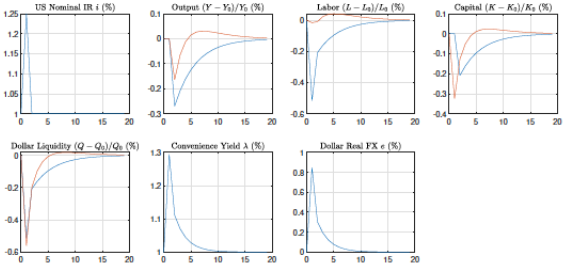


Figure 6: Impulse response to a U.S. monetary policy shock of 0.25%

We consider a 0.25% shock to i_t in period $t = 1$. In blue we plot the response of U.S. variables while in red we plot foreign variables. The output, labor, capital, and dollar liquidity are expressed as percentage deviations from their steady-state values. See Appendix Table A.1 for parameter values.

Channel: Exchange rate (UIP effect) and convenience yield (dollar liquidity)

US Real Spillover

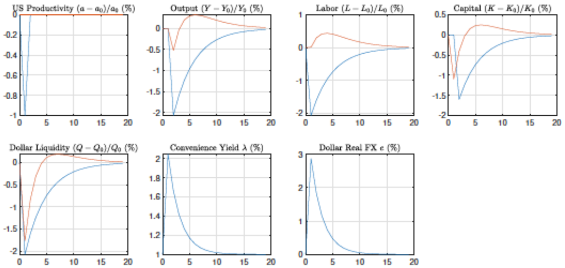


Figure 7: Impulse Responses to U.S. Productivity Shock.

We consider a -1% shock to the U.S. productivity a_t in period $t = 1$. In blue we plot the response of U.S. variables while in red we plot foreign variables. The output, labor, capital, and dollar liquidity are expressed as percentage deviations from their steady-state values. See Appendix Table A.1 for parameter values.

Channel: Convenience yield (dollar liquidity)

Foreign Financial Shock Spillover

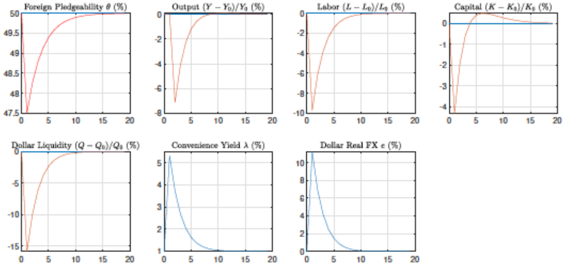


Figure 8: Impulse Responses to Foreign Pledgeability Shock

We reduce the foreign firms' cash flow pledgeability θ^* unexpectedly by 5% in period $t = 1$. The shock dissipates with autocorrelation of 0.7. In blue we plot the response of U.S. variables while in red we plot foreign variables.The output, labor, capital, and dollar liquidity are expressed as percentage deviations from their steady-state values. See Appendix Table A.1 for parameter values.

Channel: Convenience yield (dollar liquidity)

Answers to Puzzles

- Dollar funding advantage: convenience yield $\rightarrow$
- Dollar debt dominance
- Flight to dollar safety: lower dollar liquidity supply, higher convenience yield and stronger dollar
- Global financial cycle: US interest rate transmits to the foreign country through exchange rate due to currency mismatch
- US exorbitant privilege: foreigners borrow in dollar
- Dollar risk factor: currency mismatch exposes foreign countries' production to dollar exchange rate

Related Literature

- Kekre and Lenel (2024 AER): a quantitative model that uses dollar bond convenience yield to explain a wide array of international finance puzzles
- Valchev (2020 AEJ Macro): convenience yield explanation of short-run and long-run UIP, while convenience yield is endogenously determined by monetary-fiscal equilibrium forces
- Engel and Wu (2022 RES): an open-economy NK model augmented with convenience yield improves its empirical performance

7. International macroeconomics with new exchange rate models

Itskhoki and Mukhin (2021 JPE)

Itskhoki and Mukhin (2021 JPE)

- A financial shock in the Euler equation brings us very far in addressing exchange rate puzzles, many of which do not directly relate to the financial market
- A (quantitatively) necessary condition: consumption home bias
- The puzzles
    1. Disconnect (Meese-Rogoff,1983)
    2. PPP puzzle (Rogoff, 1996)
    3. ToT: weakly correlated with RER but markedly lower volatility
    4. Backus-Smith puzzle (Backus and Smith, 1993)
    5. Forward premioum puzzle (Fama, 1984)

Model Setup: Intertemporal

- Two countries, home and foreign, symmetric
- Household optimization problem

$$\max_{C_t, L_t, B_{t+1}} E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\varphi}}{1+\varphi} \right)$$

$$s.t.: P_t C_t + \frac{B_{t+1}}{R_t} \leq W_t L_t + B_t + \Pi_t$$

- Consumption-labor optimal choice

$$C_t^{\sigma} L_t^{1/\nu} = W_t / P_t$$

- Intertemporal optimality condition

$$1 = \beta R_t E_t \left\{ \left(C_{t+1}/C_t \right)^{-\sigma} P_t / P_{t+1} \right\}$$

Model Setup: Intratemporal

- Consumption is CES aggregator of varieties (produced in both home and foreign countries)

$$C_t = \left(\int_0^1 \left[(1-\gamma)^{\frac{1}{\theta}} C_{Ht}(i)^{\frac{\theta-1}{\theta}} + \gamma^{\frac{1}{\theta}} C_{Ft}(i)^{\frac{\theta-1}{\theta}} \right] di \right)^{\frac{\theta}{\theta-1}}$$

- Optimal variety demand (home)

$$C_{Ht}(i) = (1-\gamma) \left(\frac{P_{Ht}(i)}{P_t} \right)^{-\theta} C_t, \; C_{Ft}(j) = \gamma \left(\frac{P_{Ft}(j)}{P_t} \right)^{-\theta} C_t$$

- Similar for foreign demand of variety

$$C^*_{Ht}(i) = \gamma \left(\frac{P^*_{Ht}(i)}{P^*_t} \right)^{-\theta} C^*_t, \; C^*_{Ft}(j) = (1-\gamma) \left(\frac{P^*_{Ft}(j)}{P^*_t} \right)^{-\theta} C^*_t$$

Model Setup: Monopolistic Competitive Producers

- Production technology

$$Y_t = \exp(a_t) L_t, a_t = \rho_a a_{t-1} + \sigma_a \varepsilon_t^a$$

- Price setting

$$\max_{P_{Ht}(i), P^*_{Ht}(i)} \left(P_{Ht}(i) - MC_t\right) C_{Ht}(i) + \left(P^*_{Ht}(i)\mathcal{E}_t - MC_t\right) C^*_{Ht}(i)$$

Optimal price setting

$$P_{Ht}(i) = P_{Ht} = \frac{\theta}{\theta - 1} \exp(-a_t) W_t, P^*_{Ht}(i) = P^*_{Ht} = P_{Ht}/\mathcal{E}_t$$

Model Setup: Market Clearing

- Market clearing

$$Y_t = C_{Ht} + C^*_{Ht} = (1-\gamma)\left(\frac{P_{Ht}}{P_t}\right)^{-\theta} C_t + \gamma\left(\frac{P^*_{Ht}}{P^*_t}\right)^{-\theta} C^*_t$$

- Country balance of payment

$$NX_t = \frac{B_{t+1}}{R_t} - B_t, NX_t = \mathcal{E}_t P^*_{Ht} C^*_{Ht} - P_{Ft} C_{Ft}$$

- Terms of trade

$$\mathcal{S}_t = P_{Ft}/(\mathcal{E}_t P^*_{Ht})$$

- Assume fully sticky price, $\pi_t = 0$

Model Setup: Financial Market Segmentation

- Financial market is segmented: households cannot directly trade foreign bonds and have to be intermediated by intermediaries
- Foreign bond demand: household demand and noise trader's demand $\frac{N^*_{t+1}}{R^*_t} = n(\exp(\psi_t) - 1)$, where ψ_t follows

$$\psi_t = \rho_\psi \psi_{t-1} + \sigma_\pi \varepsilon^\psi_t$$

- Intermediaries conduct carry trade and earn excess return

$$\tilde{R}^*_{t+1} = R^*_{t+1} - R_t \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}$$

- Intermediaries have CARA preference

$$\max_{d^*_{t+1}} E_t \left\{ -\frac{1}{\omega} \exp\left(-\omega \frac{\tilde{R}^*_{t+1}}{P^*_{t+1}} \frac{d^*_{t+1}}{R^*_t} \right) \right\}$$

- Market clearing

$$B_{t+1} + N_{t+1} + D_{t+1} = 0, B^*_{t+1} + N^*_{t+1} + D^*_{t+1} = 0$$

Carry Trade Profit

$$i_t - i_t^* - E_t \Delta e_{t+1} = \chi_1 \psi_t - \chi_2 b_{t+1}$$

- b_{t+1} is domestic demand for domestic bonds, ψ_t is the negative of noise trader's demand for domestic bonds
- ψ_1 and ψ_2 satisfy
$$\psi_1 = \frac{n}{\beta} \frac{\omega \sigma_e^2}{m}, \psi_2 = \bar{Y} \frac{\omega \sigma_e^2}{m}$$
- A side remark: to address the exchange rate puzzles, we do not have to impose the specific micro foundation of Euler equation wedge ψ_t
- To proceed: two shocks a_t and ψ_t

RER/NER and PPP Puzzle

- In a fully sticky price model, RER=NER
- If ψ is sufficiently persistent and volatile, RER exhibit a volatile near-random-walk behavior
- Strong home bias: similar property for producer-price- and wage-based RER

The Backus-Smith Puzzle

- Productivity shock a_t
  - A higher a_t leads to higher home consumption and depreciated home currency (in standard models)
  - Consumption $\downarrow$, home appreciation
- Financial shock ψ_t
  - A higher ψ_t depreciates home currency, reduces real wage, labor supply and output
  - Domestic variety price proportional to wage (with a markup)
  - Consumption $\downarrow$, home depreciation
- Quantitative: the second channel is smaller than the first when home bias is strong

The Forward Premium Puzzle

- The interest rate differential with linearization

$$i_t - i_t^* = \sigma E_t \left[\Delta c_{t+1} - \Delta c_{t+1}^* \right]$$

- When ψ_t is strong enough to drive consumption
  - a depreciated home currency is associated with a higher expected consumption growth at home, a higher interest rate at home and an expected appreciation

Other Ingredients

- Price stickiness, pricing to market, ...
- Not the key to resolve these exchange rate puzzles
- Matter quantitatively
- The general methodology of “wedge”: Chari, Kehoe and McGrattan (2007 ECMA)

The Nature of the Financial Shock

- The nature of the financial shock does not matter for exchange rate puzzles
  - The intermediation friction as in Gabaix and Maggiori (2015)
  - The risk premium interpretation as in Colacito and Croce (2013)
  - The convenience yield as in Jiang, Krishnamurthy and Lustig (2021)
- To discipline the nature of the wedge, additional evidence is needed

Mussa Puzzle Evidence: Itskhoki and Mukhin (2023)

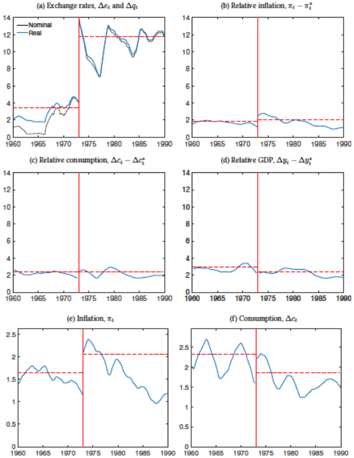


Figure 3: Macroeconomic volatility over time

Note: annualized standard deviations (in log points) for the RoW relative to the U.S. in panels a-d and for country-level variables in the RoW in panels e-f, estimated as triangular moving averages with a window over 18 months (panels a, b, e) or 10 quarters (panels c, d, f) before and after, treating 1973:01 as the end point for the two regimes; the dashed lines correspond to the average standard deviations under the two regimes. See Appendix Figure A2 for GDP and net exports.

Wedge Endogenous to Monetary Regime

- The Mussa puzzle evidence points to the direction that the wedge is endogenous to the monetary regime
  - With fixed exchange rate, the wedge is not there
  - With floating exchange rate, the wedge plays a significant role
  - Exchange rate volatility (risk) drives the wedge - leads to the intermediary risk premium interpretation

Reevaluating Exchange Rate Policies: Itskhoki and Mukhin (2023)

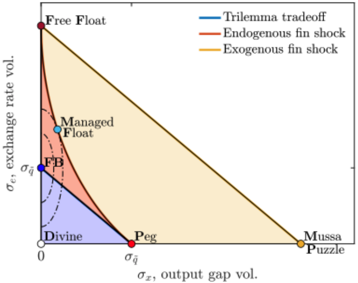


Figure 1: Exchange rate policy tradeoffs

Note: The figure plots the frontiers of output gap and exchange rate volatility, namely menus of (σ_x, σ_e) that can be chosen by monetary policy, in three types of models: (a) classic trilemma models where UIP holds, (b) models with endogenous UIP deviations driven by exchange rate risk, and (c) models with exogenous UIP (or CIP) shocks. FB corresponds to the first best (or a "Friedman float") with $\sigma_x = 0$ and $\sigma_e = \sigma_{\tilde{q}}$, the volatility of the first-best real exchange rate. The line segmented connecting FB and Peg corresponds to the classic Trilemma constraint when UIP holds. Free Float in models with UIP shocks features σ_e that combines macro-fundamental (blue) and financial (red and yellow) exchange rate volatility, and the first best is only feasible when FXI offset financial shocks. Dashed indifference curves are for the welfare loss function, and Managed Float is the optimal monetary policy rule in the absence of FXI. See the text for Divine (coincidence) and Mussa Puzzle points.

Understanding the nature of wedge that is endogenous to monetary regime is crucial for optimal policy design!