# The Share of Systematic Variation in Bilateral Exchange Rates


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# Portfolios vs Individual Currencies

- Quick reminder of LRV (2011):
    - Portfolios of countries sorted by interest rates
    - Carry risk factors: a slope factor $HML_{FX}$, or a measure of global volatility on equity markets (no exchange rates)

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Panel I: Portfolio Excess Returns | | | |
| *Mean* | −1.54 | 0.13 | 1.48 | 3.90 | 4.23 | 7.17 |
| *s.e.* | [1.61] | [1.49] | [1.52] | [1.64] | [1.84] | [2.05] |
| | | | Panel II: Carry Factor $HML_{FX}$ Betas | | | |
| $\beta_{HML}$ | −0.39 | −0.12 | −0.13 | −0.01 | 0.03 | 0.61 |
| *s.e.* | [0.02] | [0.03] | [0.02] | [0.03] | [0.03] | [0.02] |
| | | | Panel III: Global Equity Vol Betas | | | |
| $\beta_{Vol}$ | 0.19 | 0.13 | 0.05 | 0.02 | 0.03 | −0.42 |
| *s.e.* | [0.07] | [0.06] | [0.08] | [0.08] | [0.08] | [0.15] |
| | | | Panel IV: Dollar Betas | | | |
| $\beta_{Dollar}$ | 0.98 | 0.99 | 1.02 | 0.94 | 1.01 | 1.07 |
| *s.e.* | [0.04] | [0.04] | [0.03] | [0.04] | [0.04] | [0.07] |

- **What about individual currencies?**
    - Let's use portfolios to extract information from currency markets and use that to study bilateral exchange rates...

# This Paper

- **Two variables account for 20% to 90% of the monthly bilateral exchange rate movements.**
  - The two variables are: the Dollar and the Carry, built from other exchange rates and interest rates.
  - They are **risk** factors: the Dollar factor accounts for a new, large cross-section of average currency excess returns
- **Preference-free interpretation and implications in complete markets**
  - **Two** kinds of global shocks
  - **Large shares of global shocks in exchange rate dynamics, as well as large cross-country differences**
    - Bring back the FX volatility puzzle (cf Backus and Smith, 1993, Brandt, Cochrane, and Santa-Clara, 2006).

# Literature

- **Deviations from UIP**: from Tryon (1979), Hansen and Hodrick (1980), Bilson (1981), Fama (1984), ..., to Bansal (1997), Backus, Foresi, and Telmer (2001), Verdelhan (2010), Bansal and Shaliastovich (2011), Colacito and Croce (2011), Farhi and Gabaix (2011), Engel (2012), Chernov, Graveline, and Zviadadze (2013).
    - *Portfolios of currencies*: Lustig and Verdelhan (2005, 2007), Burnside et al. (2008), DeSantis and Fornari (2008), Jurek (2008), Farhi et al. (2009), Hoffmann and Suter (2010), Lustig, Roussanov, and Verdelhan (2011, 2012), Ang and Chen (2011), Galsband and Nitschka (2011), Hu, Pan, and Wang (2011), Christiansen, Ranaldo, and Soderlind (2011), Kozak (2011), Gilmore and Hayashi (2011), Menkhoff, Sarno, Schmeling, and Schrimpf (2012, 2012), Mueller, Stathopoulos, and Vedolin (2012), Hassan and Mano (2012), Chabi-Yo and Song (2012), Maggiori (2012), Dobrynskaya (2012), and Lettau, Weber, and Maggiori (2013).

- **Common factors in other markets**:
  *Equity*: Roll (1988);
  *Bonds*: Steeley (1990), and Litterman and Scheinkman (1991).

# Outline

# Intuition From Complete Markets

- Euler equation for the foreign and U.S. investor buying any asset $R^i$ that pays off in foreign currency:

$$E_t[M_{t+1}^{real} R^i Q_t / Q_{t+1}] = 1,$$
$$E_t[M_{t+1}^{real,i} R^i] = 1,$$

  where $Q$ is in foreign good per U.S. good ($S$ is in foreign currency per dollar).

- When markets are complete, the pricing kernel is unique.

- Thus the change in exchange rate is (in logs):

$$\Delta q^i = m^{real} - m^{real,i}$$
$$\Delta s^i = \Delta q^i - \pi + \pi^i = m - m^i.$$

# A Thought Experiment: Local vs. World Shocks

- Complete markets:

$$\Delta s^i_{t+1} = m_{t+1} - m^i_{t+1}.$$

- Decompose each pricing kernel into country-specific and world shocks:

$$\Delta s^i_{t+1} = \overbrace{m^{US-spec.}_{t+1} + m^W_{t+1}}^{m_{t+1}} - \overbrace{m^{i-spec.}_{t+1} - m^{W,i}_{t+1}}^{m^i_{t+1}},$$

- By construction: $cov(m^{i-spec.}, m^{j-spec.}) = 0$ and $cov(m^{i-spec.}, m^{W,j}) = 0$, for any $i, j$
- Countries may differ by their exposure to world shocks: $m^{W,i}_{t+1} \neq m^{W,j}_{t+1}$
- Several kinds of world shocks may exist ($m^{W,i}_{t+1}$ is a vector)
- Toy model example: With power utility, $m_{t+1} = \gamma \Delta c_{t+1}$ where $\Delta c_{t+1}$ is driven by global shocks (global TFP, oil, and global uncertainty/volatility?) + country-specific shocks.

# Carry Risk Factor

- Recall:

$$\Delta s^i_{t+1} = m^{US-spec.}_{t+1} + m^W_{t+1} - m^{i-spec.}_{t+1} - m^{W,i}_{t+1}$$

- In the data, portfolios of countries sorted by their interest rates deliver a cross-section of average currency excess returns
  - The higher the interest rate, the larger the beta on the carry trade risk factor (or its proxy, a measure of global equity volatility)
- The Carry factor exists if and only if SDFs differ in their loadings on global shocks (cf LRV, 2011):

$$\begin{aligned} Carry_{t+1} &= \frac{1}{N_H}\sum_{i\in H}\Delta s^i_{t+1} - \frac{1}{N_L}\sum_{i\in L}\Delta s^i_{t+1} \\ &= \frac{1}{N_H}\sum_{i\in H} m^{W,i}_{t+1} - \frac{1}{N_L}\sum_{i\in L} m^{W,i}_{t+1} \end{aligned}$$

- Carry factor: exposure to global shocks that are priced globally.
- How much does it matter for bilateral exchange rates?

# Another Global Risk Factor?

- Recall:

$$\Delta s^i_{t+1} = m^{US-spec.}_{t+1} + m^W_{t+1} - m^{i-spec.}_{t+1} - m^{W,i}_{t+1}$$

- Think about the average change in exchange rates. In large baskets of currencies, foreign country-specific shocks average out (if LLN applies).

$$Dollar_{t+1} = \frac{1}{N}\sum_i \Delta s^i_{t+1} = m^{US-spec.}_{t+1} + m^W_{t+1} - \frac{1}{N}\sum_i m^{W,i}_{t+1}.$$

- Dollar factor (i.e. average change in exchange rates defined w.r.t. the U.S. dollar): exposure to U.S. and global shocks
- How do bilateral exchange rates co-move with the Dollar factor?

$$cov(\Delta s^i, Dollar) \quad = \quad ... - \underbrace{cov(m^{W,i}, m^W - \frac{1}{N}\sum_i m^{W,i})}_{\text{only term that depends on } i}.$$

- How many global shocks do we need to understand bilateral exchange rates?

# Estimating Systematic Currency Variation

- Let's use information from currency portfolios:
  - Sort all currencies on their interest rates (excluding the one under study) and form 6 baskets:
  - Carry Factor: at each date $t$, consider the average change in exchange rates of all currencies in the last portfolio minus the average change in exchange rates of all currencies in the first portfolio. $\Rightarrow$ dollar-neutral
  - Dollar Factor: average change in exchange rates across all portfolios (all exchange rates against the U.S. dollar)

- Contemporaneous Tests:

$$\begin{aligned}\Delta s_{t+1} &= \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t) Carry_{t+1} + \delta Carry_{t+1} \\ &+ \tau Dollar_{t+1} + \varepsilon_{t+1},\end{aligned}$$

- These are **not** predictive regressions!

- The currency on the l.h.s is **not** in any basket on the r.h.s.

# Monthly Changes in Exchange Rates (I/II)

$$\Delta s_{t+1} = \alpha + \beta(i_t^{\star} - i_t) + \gamma(i_t^{\star} - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Dollar_{t+1} + \varepsilon_{t+1}$$

| Country | $\alpha$ | $\beta$ | $\gamma$ | $\delta$ | $\tau$ | $R^2$ | $R^2_{\$}$ | $R^2_{no\ \$}$ | $W$ | $N$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 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] | | |

# Monthly Changes in Exchange Rates (II/II)

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Dollar_{t+1} + \varepsilon_{t+1}$$

| Country | $\alpha$ | $\beta$ | $\gamma$ | $\delta$ | $\tau$ | $R^2$ | $R^2_{\$}$ | $R^2_{no\ \$}$ | $W$ | $N$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 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] | | |
| U.K. | 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] | | |

# Cautionary Notes

- Large shares of systematic variation in individual exchange rates do not mean that:
  - changes in exchange rates are easy to predict;
  - exchanges rates are not random walks
- They simply mean that shocks are correlated.

# Are the Carry and Dollar **risk** factors? Yes!

- We already know that the carry factor is a risk factor.
- I turn now to some new evidence on the dollar risk.
  - Asset pricing: the Dollar factor accounts for a (new) cross-section of currency excess returns;
  - Link to other asset markets: currency $R^2$s linked to shares of systematic risk in equity and bond markets. [In the paper, but not in the presentation today.]
- Note: A characteristics-based/behavioral story cannot be proved wrong (cf Daniel and Titman, 1996, 2001).

# Portfolios of Countries Sorted by Dollar Exposures

- LRV (2012): the average forward discount predicts the aggregate dollar return.
- New portfolios:
  - At each date $t$, regression on a 60-month rolling window that ends in period $t-1$.

    $$\Delta s_{t+1} = \alpha_t + \beta_t (i_t^\star - i_t) + \gamma_t (i_t^\star - i_t) Carry_{t+1} + \delta_t Carry_{t+1} + \tau_t Dollar_{t+1} + \varepsilon_{t+1}$$

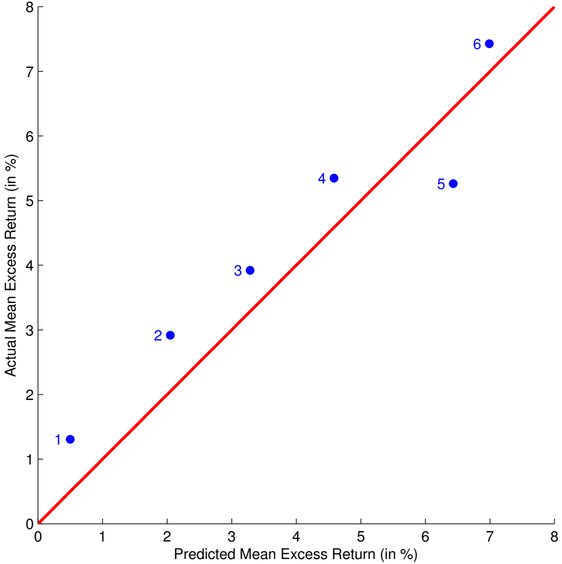
  - Currencies are then sorted into 6 groups at time $t$ based on the slope coefficients $\tau_t$.
  - Portfolio 1 contains currencies with the lowest $\tau$s. Portfolio 6 contains currencies with the highest $\tau$s.
  - At each date $t$ and for each portfolio, the investor goes long if the average forward discount (AFD) is positive and short otherwise.
- Conditional asset pricing with a single risk factor: $AFD_t Dollar_{t+1}$.

# A Large Cross-Section of Dollar Excess Returns

| *Portfolio* | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| | | | Spot change: $\Delta s$ | | | |
| *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: $f - s$ | | | |
| *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] |
| *Std* | 3.34 | 5.38 | 6.68 | 7.62 | 10.20 | 10.64 |
| *SR* | 0.39 | 0.53 | 0.58 | 0.67 | 0.49 | 0.67 |

# Realized vs Predicted Excess returns

$E_t[M_{t+1}R^{e,i}_{t+1}] = 0$ implies $E_t[R^{e,i}_{t+1}] = -\frac{cov_t[R^{e,i}_{t+1}, M_{t+1}]}{E_t[M_{t+1}]} = \frac{-Var_t[M_{t+1}]}{E_t[M_{t+1}]} \times \frac{cov_t[R^{e,i}_{t+1}, M_{t+1}]}{Var_t[M_{t+1}]} = \lambda\beta^i$



# A Risk-Based Interpretation

- Interpreting the carry and dollar factors as risk factors:
  - The dollar factor accounts for the cross-section of currencies sorted by their dollar-exposure: dollar-risk is priced.
  - The carry factor accounts for the cross-section of interest rate-sorted portfolio returns
    - But not the cross-section of dollar-sorted portfolio returns
  - **No-arbitrage models of exchange rates need at least two kinds of global shocks!**
- **Shares of systematic currency risk appear significantly related to shares of systematic risk in equity and bond markets.**
  - Also related to measures of **comovement in GDP and consumption growth rates across countries.**
  - All empirical results in the paper. I skip them for this presentation.

# No-Arbitrage Implications

- Recall:

$$\begin{aligned} \Delta s^i_{t+1} &= m^{US-spec.}_{t+1} + m^W_{t+1} - m^{i-spec.}_{t+1} - m^{W,i}_{t+1} \\ Dollar_{t+1} &= \frac{1}{N}\sum_i \Delta s^i_{t+1} = m^{US-spec.}_{t+1} + m^W_{t+1} - \frac{1}{N}\sum_i m^{W,i}_{t+1}. \end{aligned}$$

- **Dollar factor: exposure to U.S. and global shocks**

- Dollar factor must depend on world shocks:

$$\begin{aligned} cov(\Delta s^i, Dollar) &= Var(m^{US-spec.}) + Cov(m^W, m^W - \frac{1}{N}\sum_i m^{W,i}) \\ &- \underbrace{cov(m^{W,i}, m^W - \frac{1}{N}\sum_i m^{W,i})}_{\text{only term that depends on } i}. \end{aligned}$$

- Foreign SDFs must differ in their exposure to these world shocks!

# Global Systematic Shocks in Bilateral Exchange Rates

- Global component of the dollar factor: long the high dollar beta portfolio and short the low dollar beta portfolio
  - long-short difference cancels out the U.S.-specific component of the Dollar factor

- Share of global shocks in bilateral exchange rates:

$$\Delta s_{t+1} = \alpha + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Dollar_{t+1}^{global} + \varepsilon_{t+1}$$

- **Large shares of global shocks in exchange rate changes, as well as large differences across countries**.
  - $R^2$s are 2 to 12 percentage points lower than in the previous contemporaneous FX regressions; $R^2$s now range from 18% to 87%.

- **Global component of the dollar factor also drives non-U.S.-based exchange rates**

# The Return of an Old Puzzle

- The Backus and Smith (1993) / Brandt, Cochrane, and Santa Clara (2006) puzzle:

$$\begin{aligned} \Delta s^i &= m - m^i, \\ Var(\Delta s^i) &= Var(m) + Var(m^i) - 2 * cov(m, m^i). \end{aligned}$$

- Recent explanation (Colacito and Croce, 2011):
    - SDFs are mostly driven by long run risk shocks, which are common across countries, and thus do not affect exchange rates (as differences in SDFs: $\Delta s^i = m - m^i$).
    - As a result, pricing kernels are volatile and equity risk premia are high, but exchange rates are not more volatile than in the data.

- But we need global shocks in exchange rates!
    - They account for a large share of exchange rates.
    - **The puzzle is back!**

# Conclusion

- **We can decompose changes in exchange rates using two intuitive RISK factors**
- **There are large cross-country differences in the shares of systematic currency risk**
  - They are related to measures of systematic risk on equity and bond markets
  - They point to the key role of two global shocks in exchange rates.
  - They call for heterogeneity in the SDFs' exposure to global shocks.
- **Bottom line: Systematic risk matters in currency markets.**
  - **We have new, precisely-measured moments of exchange rates and meaningful, challenging cross-country differences to study!**

Thank you!