Sources of Risk in Currency Returns

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Excess currency returns

- Borrow \( \$e^{-r_t} \) at the interest rate \( r_t \)

- The exchange rate is \( S_t \) (pay \( \$S_t \) for £1)

- Convert \( \$ \) into \( \£1/S_t \cdot e^{-r_t} \) and invest for one period at the UK interest rate \( \tilde{r}_t \)

- At the end of the period, receive \( \£1/S_t \cdot e^{	ilde{r}_t-r_t} \)

- Convert the cash back into \( \$S_{t+1}/S_t \cdot e^{	ilde{r}_t-r_t} \) at the prevailing exchange rate \( S_{t+1} \)

- Finally, repay the loan with interest, i.e., one unit of the domestic currency

- In this paper, we will always treat USD as a domestic currency
Which types of risk affect currency returns?

AUD

CHF

GBP

JPY
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AUD

CHF

GBP

JPY
## Basic properties of excess currency returns

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std Dev</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Nobs</th>
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<td><strong>AUD</strong> Return</td>
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<td>5.6832</td>
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<tr>
<td>Δ√IV</td>
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<td><strong>JPY</strong> Return</td>
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How important are these risks?

- We quantify relative importance of the different sources of risk
  1. Stochastic variance
  2. Jumps in currencies
  3. Jumps in variance
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- We quantify relative importance of the different sources of risk
  - 1. Stochastic variance
  - 2. Jumps in currencies
  - 3. Jumps in variance

- We estimate a joint model of FX/IV using Bayesian MCMC
  - Main advantage: jump times and sizes are a by-product of estimation
Relation to Uncovered Interest Parity

- $s_t$ is the log spot exchange rate
- $f_t$ is the log one-period forward exchange rate
- $r_t$ is the domestic, or low, one-period bond yield
- $\tilde{r}_t$ is the foreign, or high, one-period bond yield
- UIP:

$$E_t(s_{t+1} - s_t) = f_t - s_t \equiv r_t - \tilde{r}_t$$

- Fama’s regression:

$$y_{t+1} = (s_{t+1} - s_t) - (r_t - \tilde{r}_t) = \alpha + \beta(r_t - \tilde{r}_t) + \varepsilon_{t+1}$$

- $\hat{\beta} \approx -3$, hence the puzzle
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- $\hat{\beta} \approx -3$, hence the puzzle
- This paper does not explain the puzzle
- This paper makes a first step by analysing $\varepsilon_{t+1}$
Summary of findings

Three types of jumps:

1. Variance: probability is affected by the variance itself
2. USD depreciation (up): probability is affected by the US interest rate
3. USD appreciation (down): probability is affected by the non-US interest rate
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- Jumps in FX are connected to major macro and political news
- Jumps in variance are not – “economic uncertainty”
- Jumps contribute 25%, on average to the total currency risk; can be as high as 40%
- Estimated currency risk premiums are in conflict with baseline equilibrium models
The Model
$y_{t+1} = \mu_t + v_t^{1/2} w_{t+1}^s + z_{t+1}^u - z_{t+1}^d$
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\[ y_{t+1} = \mu_t + \nu_t^{1/2} w_{t+1}^s + z_{t+1}^u - z_{t+1}^d \]

\[ \nu_{t+1} = (1 - \nu) \nu + \nu \nu_t + \sigma_\nu \nu_t^{1/2} w_{t+1}^\nu + z_{t+1}^\nu \ [corr_t(w_{t+1}^s, w_{t+1}^\nu) = \rho] \]
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\[ y_{t+1} = \mu_t + v_t^{1/2} w_{t+1}^s + z_{t+1}^u - z_{t+1}^d \]
\[ v_{t+1} = (1 - \nu) v + \nu v_t + \sigma_v v_t^{1/2} w_{t+1}^v + z_{t+1}^v \quad [corr_t(w_{t+1}^s, w_{t+1}^v) = \rho] \]
\[ h_t^k = h_0^k + h_r^k r_t + \tilde{h}_r^k \tilde{r}_t + h_v^k v_t, \quad k = u, d, v \quad [\text{jump intensity}] \]
\[ z_t^k \sim \mathcal{E}xp(\theta_k), \quad k = u, d, v \quad [\text{jump size}] \]
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Implied Variance
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- It is extremely hard to pin down the specification of jumps

- We also add information from options:

\[ IV_t = \alpha_{iv} + \beta_{iv} v_t + \text{error} \]
Implied Variance

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- Use time-series of daily carry returns and one-month at-the-money IVs to estimate parameters and state realizations
The preferred model
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\[ y_{t+1} = \mu_0 + \mu_r (r_t - \tilde{r}_t) + \mu_v v_t + \nu_t^{1/2} w_{t+1}^s + z_{t+1}^u - z_{t+1}^d \]
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\[ z_{t}^{u,d} \sim \mathcal{E}xp(\theta), \quad z_t^v | j \sim \mathcal{E}xp(\theta_v) \]
The preferred model

\[
\begin{align*}
    y_{t+1} &= \mu_0 + \mu_r (r_t - \tilde{r}_t) + \mu_v \nu_t + \nu_t^{1/2} w_{t+1}^s + z_{t+1}^u - z_{t+1}^d \\
    \nu_{t+1} &= (1 - \nu) \nu + \nu \nu_t + \sigma_v \nu_t^{1/2} w_{t+1}^v + z_{t+1}^v \\
    h_t^u &= h_0 + h_r r_t, \quad h_t^d = h_0 + h_r \tilde{r}_t, \quad h_t^v = h_0^v + h_v \nu_t \\
    z_t^{u,d} &\sim \mathbb{E}xp(\theta), \quad z_t^v | j \sim \mathbb{E}xp(\theta_v)
\end{align*}
\]

- Implications:
  - On average, 1.3 to 2.6 jumps in variance per year; average jump size increases vol by 20% to 40%
  - On average, 0.4 to 1.3 jumps in currencies per year; average jumps size is 1.2% to 1.6%
  - Third cumulant \( \kappa_3(t)(s_{t+1} - s_t) = 6\theta^3 h_r (r_t - \tilde{r}_t) \)
  - The loading \( \mu_r \approx -3 \) as in Fama’s regression
GBP excess returns, estimated states, jump intensities

(a) Excess return

(b) Volatility

(c) Jumps in excess return

(d) Jumps in volatility
Contribution to total risk
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- What is total risk?
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- Variance, skewness, kurtosis, etc. capture different aspects of risk
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- We use entropy (a.k.a. generalised variance):

$$L_t(S_{t+n}/S_t) = \log E_t(e^{s_{t+n}-s_t}) - E_t(s_{t+n} - s_t)$$
Contribution to total risk

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\[
L_t(S_{t+n}/S_t) = \log E_t(e^{s_{t+n}-s_t}) - E_t(s_{t+n} - s_t)
\]

- Intuition:

\[
L_t = \kappa_2 t(s_{t+n} - s_t)/2! + \kappa_3 t(s_{t+n} - s_t)/3! + \kappa_4 t(s_{t+n} - s_t)/4! + \ldots,
\]

where \(\kappa_j\) is the \(j\)th cumulant of \(s_{t+n} - s_t\)
Decomposition of entropy
Decomposition of entropy

AUD

CHF

GBP

JPY
Risk Premiums

AUD


FX risk premium

-0.03 0.01 0.05 0.09

CHF


Var risk premium

-0.4 0.0 0.1

GBP


FX risk premium

-0.6 0.03 0.06

JPY


Var risk premium

-0.4 0.0 0.2
Risk Premiums

AUD

CHF

GBP

JPY
Interesting challenges for theory
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- Ex-ante FX risk premia from the non-US perspective do not conform to the basic intuition
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- Probabilities of jumps in FX vs variance are different in economically meaningful way

- Ex-ante FX risk premia from the non-US perspective do not conform to the basic intuition

- What is the economic mechanism generating the positive variance premiums?
Summary

- We study risks in carry returns
  - Identify and describe sources of risks
  - Measure risk premiums (RP)
  - Compare the dynamics of RP with the predictions of the structural models
We study risks in carry returns

Identify and describe sources of risks

Measure risk premiums (RP)

Compare the dynamics of RP with the predictions of the structural models

We find that

Both normal and jump risks are important

Jump risks have time-varying nature

Jumps in FX can be linked to news. Jumps in vol cannot

Jumps are not necessarily idiosyncratic

Estimated dynamics of RP pose challenges for structural models
Literature Review

- Joint currency/implied variance time-series analysis w/o jumps
  - Brandt and Santa-Clara (2002); Graveline (2006)
- Hedging jump risk with options
  - Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011); Jordà and Taylor (2009); Jurek (2009)
  - Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan (2009)
- Option-based models of currencies with jumps in FX only
  - Bates (1996); Carr and Wu (2007)
  - Bakshi, Carr, and Wu (2008)
- Equilibrium models of FX with jumps
  - Farhi and Gabaix (2008); Guo (2007); Plantin and Shin (2011)
- News and FX
  - Andersen, Bollerslev, Diebold, and Vega (2003)
- Jumps in variance of equity returns
  - Broadie, Chernov, and Johannes (2007); Duffie, Pan, and Singleton (2000); Eraker, Johannes, and Polson (2003)
- Entropy as generalised variance
  - Alvarez and Jermann (2005); Backus, Chernov, and Martin (2011); Backus, Chernov, and Zin (2011); Martin (2011)
## Diagnostics: An AUD example

<table>
<thead>
<tr>
<th></th>
<th>SV</th>
<th>SVJV</th>
<th>SVJVC-P</th>
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<td>(0.0021, 0.0070)</td>
<td>(0.0021, 0.0070)</td>
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## Diagnostics: A CHF example

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</tr>
<tr>
<td></td>
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<td>(0.0004, 0.0011)</td>
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<td>(-0.0024, 0.0040)</td>
<td>(-0.0038, 0.0047)</td>
<td>(-0.0094, 0.0037)</td>
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<tr>
<td><strong>skewness</strong>&lt;sup&gt;IV&lt;/sup&gt;</td>
<td>0.0352</td>
<td>0.0212</td>
<td>0.0215</td>
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<td>(-0.0443, 0.1146)</td>
<td>(-0.0565, 0.0995)</td>
<td>(-0.0568, 0.0998)</td>
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<tr>
<td><strong>kurtosis</strong>&lt;sup&gt;IV&lt;/sup&gt;</td>
<td>3.0710</td>
<td>3.0293</td>
<td>3.0296</td>
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<tr>
<td><strong>autocorrelation</strong>&lt;sup&gt;IV&lt;/sup&gt;</td>
<td>0.0791</td>
<td>0.0510</td>
<td>0.0510</td>
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<td></td>
<td>(0.0483, 0.1096)</td>
<td>(0.0204, 0.0814)</td>
<td>(0.0204, 0.0815)</td>
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<tr>
<td><strong>IVvar</strong></td>
<td>0.0011</td>
<td>0.0004</td>
<td>0.0004</td>
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<tr>
<td></td>
<td>(0.0007, 0.0019)</td>
<td>(0.0003, 0.0008)</td>
<td>(0.0003, 0.0008)</td>
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</tbody>
</table>
## Diagnostics: A JPY example

<table>
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<th>SV</th>
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<th>SVJVC-P</th>
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<td>skewness$^C$</td>
<td>0.3348</td>
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<td>0.1298</td>
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<td>(0.3060, 0.3650)</td>
<td>(0.3038, 0.3668)</td>
<td>(0.0799, 0.1800)</td>
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<td>kurtosis$^C$</td>
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<td>4.7148</td>
<td>3.6054</td>
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<td>(4.5982, 4.8361)</td>
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<td>autocorrelation$^C$</td>
<td>-0.0146</td>
<td>-0.0140</td>
<td>-0.0221</td>
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<td>(-0.0174, -0.0108)</td>
<td>(-0.0312, -0.0131)</td>
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<tr>
<td>skewness$^{IV}$</td>
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<td>0.0278</td>
<td>0.0311</td>
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<td>3.0430</td>
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<td>(2.9175, 3.2420)</td>
<td>(2.8940, 3.2100)</td>
<td>(2.8923, 3.2098)</td>
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<td>0.1042</td>
<td>0.0758</td>
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<td>(0.0443, 0.1070)</td>
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<tr>
<td>IVvar</td>
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<td>0.0029</td>
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<td>(0.0036, 0.0125)</td>
<td>(0.0017, 0.0059)</td>
<td>(0.0021, 0.0078)</td>
</tr>
</tbody>
</table>
JPY excess returns, estimated states, jump intensities

(a) Excess return

(b) Volatility

(c) Jumps in excess return

(d) Jumps in volatility
JPY excess returns, estimated states, jump intensities

(a) Excess return

(b) Volatility

(c) Jumps in excess return

(d) Jumps in volatility
AUD excess returns, estimated states, jump intensities

(a) Excess return

(b) Volatility

(c) Jumps in excess return

(d) Jumps in volatility
AUD excess returns, estimated states, jump intensities

(a) Excess return

(b) Volatility

(c) Jumps in excess return

(d) Jumps in volatility
CHF excess returns, estimated states, jump intensities

(a) Excess return

(b) Volatility

(c) Jumps in excess return

(d) Jumps in volatility
CHF excess returns, estimated states, jump intensities

(a) Excess return

(b) Volatility

(c) Jumps in excess return

(d) Jumps in volatility


Backus, David, Mikhail Chernov, and Stanley Zin, 2011, Sources of entropy in representative agent models, Working paper, NBER.


Bibliography IV

Farhi, Emmanuel, and Xavier Gabaix, 2008, Rare disasters and exchange rates, Working paper, NBER.


