Common Risk Factors in Currency Markets

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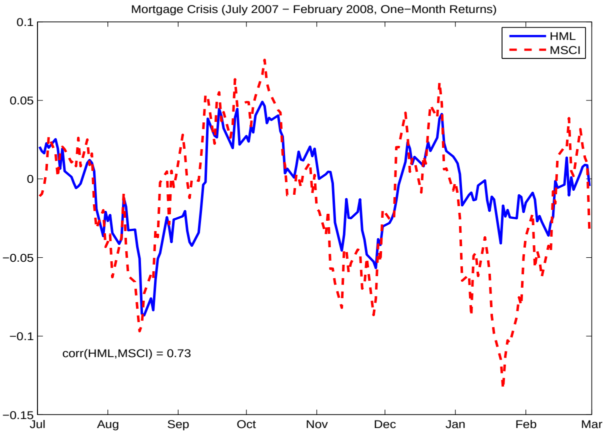
Subprime Mortgage Crisis: Currency Portfolios



Carry Trade and US Stock Market Returns during the Mortgage Crisis - July 2007 to March 2008.

Literature

- **Risk-based explanations**: Hansen and Hodrick (1980), Fama (1984), ...,

  Bansal and Dahlquist (2000), Backus, Foresi and Telmer (2001), Harvey and Solnik and Zhou (2002), Alvarez and Atkeson and Kehoe (2005), Verdelhan (2005), Graveline (2006), Campbell, de Medeiros and Viceira (2006), Bansal and Shaliastovich (2006), Lustig and Verdelhan (2007), Hau and Rey (2007), Gabaix and Farhi (2007), Colacito (2008).

- **Other explanations**: Froot and Thaler (1990), Lyons (2001), Gourinchas and Tornell (2004), Bachetta and van Wincoop (2006), Frankel and Poonawala (2006), Sarno, Leon and Valente (2007), Plantin and Shin (2007), Burnside, Eichenbaum and Rebelo (2006, 2007a, 2007b, 2008).

Our Findings

- **Large** excess returns after bid/ask spreads.
- **These excess returns are risk premia:**
  - **A single risk factor**, HML_{FX}, explains the cross-sectional variation in excess returns.
  - These excess returns are **predictable**, and the expected excess returns are **counter-cyclical** (similar to bond and stock markets).

Understanding our Findings

- Using a standard affine no-arbitrage model of N currencies (a la CIR), we show that:
  - By **building portfolios** of currency forward contracts, we extract the innovations to the SDF that are priced;
  - HML_{FX} measures the exposure to **common** innovations or **world risk**.
- A reasonably calibrated version of the model reproduces our findings:
  - **High interest rate currencies** are **more** exposed to **world risk**;
  - Sorting on interest rates $\sim$ sorting on exposure to **world risk**.

Outline

1. Summary
   - Example
   - Main Findings
2. Portfolios of Currency Excess Returns
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3. Cross-sectional Asset Pricing
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   - Non-US Investors
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   - Calibrated Model
5. Predictability
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   - Counter-cyclical Expected Excess Returns
6. Conclusion

Currency Excess Returns

- s_t: Log of spot exchange rate in units of foreign currency per dollar (when s increases, the dollar appreciates).
- f_t: Log of one-month forward exchange rate in units of foreign currency per dollar
- Log excess return on buying foreign currency forward and selling it in spot market:

$$rx_{t+1} = f_t - s_{t+1}$$

$$rx_{t+1} = -\Delta s_{t+1} + f_t - s_t \simeq -\Delta s_{t+1} + i_t^* - i_t.$$

  - $f_t - s_t \simeq i_t^* - i_t$: forward discount
  - $-\Delta s_{t+1}$: % appreciation of the foreign currency

Data

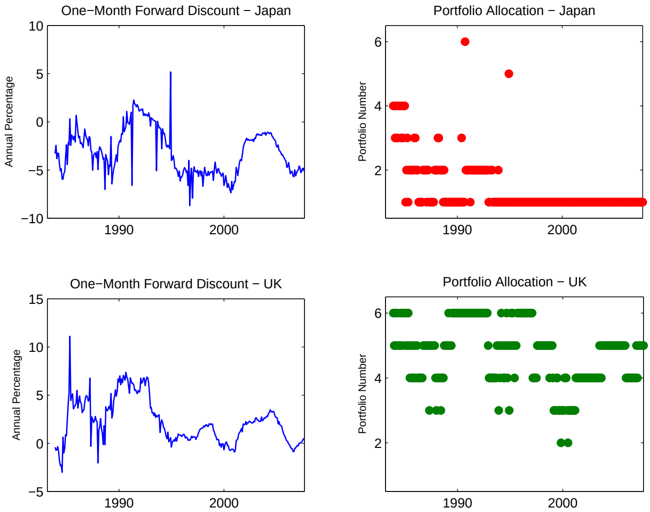
- Data from Barclays and Reuters.
- Start from daily spot and forward exchange rates in US dollars.
- Build end-of-month series from November 1983 to March 2008.
- Sample of 37 developed and emerging countries: Australia, Austria, Belgium, Canada, Hong Kong, Czech Republic, Denmark, Euro area, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Kuwait, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, United Kingdom.
- Sample of 15 developed countries: Australia, Belgium, Canada, Denmark, Euro area, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland and United Kingdom.

Currency Portfolios

- At the end of each month t, sort all currencies in 6 portfolios on forward discounts $f_t - s_t$.
- Portfolios are ranked from low to high forward discounts $f_t - s_t$.
- Compute the log currency excess return rx^j_{t+1} for each portfolio $j = 1, 2 \ldots, 6$ by averaging:

$$rx^j_{t+1} = \frac{1}{N_j} \sum_{i \in P_j} rx^i_{t+1}.$$

Portfolio Allocation



Cross-section

- Higher forward discounts mean higher returns:

Portfolio	1	2	3	4	5	6
			Excess Return: rx^j (without b-a)			
Mean	−2.92	0.02	1.40	3.66	3.54	**5.90**
SR	−0.36	0.00	0.19	0.49	0.45	**0.64**
			Excess Return: rx^j_{net} (with b-a)			
Mean	−1.70	−0.95	0.12	2.31	2.04	**3.14**
SR	−0.21	−0.13	0.02	0.31	0.26	**0.34**
			High-minus-Low: $rx^j_{net} - rx^1_{net}$ (with b-a)			
Mean		0.75	1.82	4.00	3.73	**4.83**
SR		0.14	0.33	0.60	0.59	**0.54**

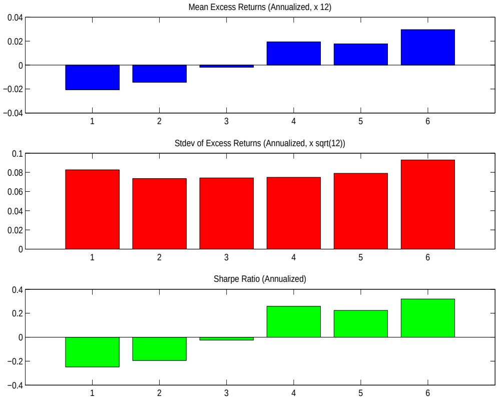
Annualized monthly returns. Monthly data. Sample is 11/1983 - 03/2008.

Developed Countries

Portfolio	1	2	3	4	5
	Excess Return: rx^j (without bid-ask)				
Mean	−0.60	2.06	4.62	3.74	**5.67**
SR	−0.06	0.21	0.49	0.42	**0.61**
	Excess Return: rx^j_{net} (with bid-ask)				
Mean	0.53	1.00	3.21	2.48	**3.96**
SR	0.05	0.10	0.34	0.28	**0.43**
	Long-Short: $rx^j_{net} - rx^1_{net}$				
Mean		0.47	2.68	1.95	**3.44**
SR		0.07	0.41	0.26	**0.39**

Notes: Annualized monthly returns. Monthly Data. Sample is 11/1983 - 03/2008.

Portfolios of Currency Excess Returns



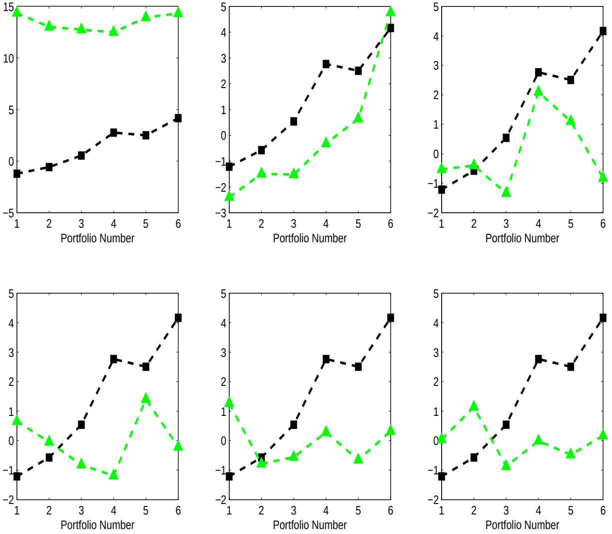
Large sample, 11/1983-03/2008, after bid-ask spreads.

Principal Components

Portfolio	Principal component	
	1	2
1	0.43	**0.41**
2	0.39	**0.26**
3	0.39	**0.26**
4	0.38	**0.05**
5	0.42	**-0.11**
6	0.43	**-0.82**
% Var.	70.07	12.25

The sample period is 11/1983 - 03/2008.

Covariances (PC, Excess Returns)



Cross-Sectional Asset Pricing

- Rx^j_{t+1} has a zero price:

$$E[M_{t+1}Rx^j_{t+1}] = 0.$$

- M is linear in the pricing factors f:

$$M_{t+1} = 1 - b(\mathbf{f}_{t+1} - \mu),$$

where b is the vector of factor loadings.

Risk Factors

- Two principal components explain 85 % of excess returns' variations.
- $\Rightarrow$ Two candidate risk factors:
  - level or **dollar** factor:

$$RX_{FX,t} = \frac{1}{6}\sum_{i=1}^{6} Rx_t^i.$$

  - slope or **carry-trade** factor:

$$HML_{FX,t} = Rx_t^6 - Rx_t^1.$$

- $\Rightarrow$ Investing in currencies is like placing *HML* bets.

No Arbitrage Restrictions

- The Euler equation $E[MRx^j] = E[Rx^j - b(f-\mu)Rx^j] = 0$ implies that:

$$E[Rx^j] = \Sigma_{ff} b \frac{E[(f-\mu)Rx^j]}{\Sigma_{ff}}.$$

- β-pricing model:

$$E[Rx^j] = \lambda' \beta^j,$$

- No arbitrage implies:

$$\lambda_{HML} = E[HML_{FX}],$$

and

$$\lambda_{RX} = E[RX_{FX}].$$

Risk Prices

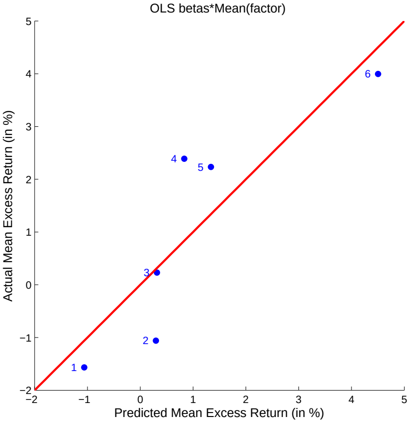
	λ_{HML}	λ_{RX}	b_{HML}	b_{RX}	R^2	$RMSE$	χ^2
FMB	**5.46**	**1.35**	0.58	0.26	69.28	0.95	
	[1.82]	[1.34]	[0.19]	[0.25]			13.02
	(1.83)	(1.34)	(0.20)	(0.25)			14.32
Mean	**5.37**	**1.36**					

Notes: Monthly Data. Sample is 11/1983 - 03/2008.

α in the Carry Trade? Significant βs?

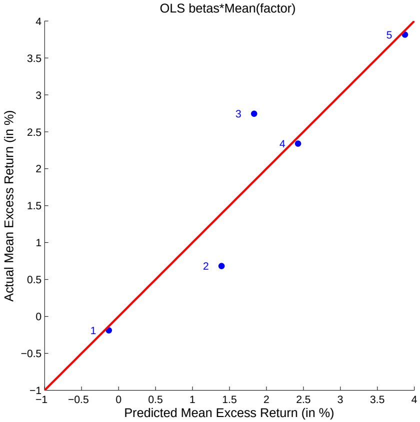
Portfolio	α_0^j	β_{HML}^j	β_{RX}^j	R^2	$\chi^2(\alpha)$	$p - value$
1	−0.56	−0.39	1.06	91.36		
	[0.52]	[0.02]	[0.03]			
2	−1.21	−0.13	0.97	78.54		
	[0.76]	[0.03]	[0.05]			
3	−0.13	−0.12	0.95	73.73		
	[0.82]	[0.03]	[0.04]			
4	1.62	−0.02	0.93	68.86		
	[0.86]	[0.04]	[0.06]			
5	0.84	0.05	1.03	76.37		
	[0.80]	[0.04]	[0.05]			
6	−0.56	0.61	1.06	93.03		
	[0.52]	[0.02]	[0.03]			
All					10.11	0.12

Model Fit



The predicted excess return is the OLS estimate of β times the sample mean of the factors. All returns are annualized.

Model Fit - Developed Countries

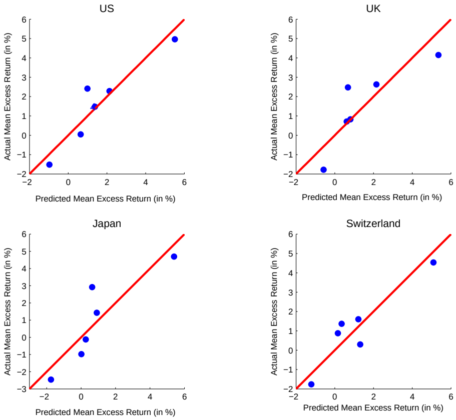


The predicted excess return is the OLS estimate of β times the sample mean of the factors. All returns are annualized.

Robustness Checks

- Foreign Investors;
- Sub-samples (Time-windows and countries);
- Beta-sorted portfolios;
- Daniel and Titman (2005)'s critique;

Model Fit - Foreign Investors



The predicted excess return is the OLS estimate of β times the sample mean of the factors. All returns are annualized.

Beta-Sorted Currency Portfolios

Portfolio	1	2	3	4	5	6
			Forward Discount: $f^j - s^j$			
Mean	-1.45	-0.36	0.81	0.99	1.49	3.18
Std	0.78	0.56	1.24	0.64	0.81	1.28
			Excess Return: rx^j (without b-a)			
Mean	-0.09	0.79	2.04	2.75	2.91	3.06
SR	-0.01	0.10	0.28	0.41	0.36	0.41
			High-minus-Low: $rx^j - rx^1$ (without b-a)			
Mean		0.87	2.13	2.84	2.99	3.15
SR		0.17	0.34	0.39	0.34	0.34

Notes: Data are monthly, from Barclays and Reuters (Datastream). The sample period is 11/1983 - 03/2008.

How to interpret our results?

- To answer this question, we build a toy model:
  - N countries;
  - In each country, the SDF a la Cox, Ingersoll and Ross (1981) is driven by two risk factors:
    - a country-specific factor,
    - a world factor;
  - One source of **heterogeneity**: countries differ in their loadings on the world factor.
- In this setting:
  - HML_{FX} measures the exposure to the world factor;
  - RX measures the exposure to the country-specific factor;
  - We reproduce our asset pricing and predictability results.

Factor Model

- N countries. In each country i, the log SDF m_i follows the law of motion:

$$-m_{t+1}^i = \lambda^i z_t^i + \sqrt{\gamma^i z_t^i} u_{t+1}^i + \tau^i z_t^w + \sqrt{\delta^i z_t^w} u_{t+1}^w.$$

- Country-specific volatility:

$$z_{t+1}^i = (1-\phi^i)\theta^i + \phi^i z_t^i + \sigma^i \sqrt{z_t^i} v_{t+1}^i.$$

- World volatility:

$$z_{t+1}^w = (1-\phi^w)\theta^w + \phi^w z_t^w + \sigma^w \sqrt{z_t^w} v_{t+1}^w.$$

- All shocks uncorrelated across countries, *iid* gaussian, with zero mean and unit variance.

Real Interest Rates and Real Exchange Rates

- Real Interest Rates:

$$r_t^i = -E_t(m_{t+1}^i) - \frac{1}{2}Var_t(m_{t+1}^i),$$
$$= \left(\lambda^i - \frac{1}{2}\gamma^i\right) z_t^i + \left(\tau^i - \frac{1}{2}\delta^i\right) z_t^w.$$

- Financial markets are complete, but some friction in the goods markets prevent perfect risk-sharing across countries.

Currency Risk Premia

- Real exchange rate:

$$\Delta q^i_{t+1} = m_t - m^i_t$$

- The log currency excess return rx^i for a home investor who buys risk-free bonds in country i is:

$$rx_{i,t+1} = -\Delta q^i_{t+1} + r^i_t - r_t.$$

- The expected excess return is thus:

$$E_t[rx^i_{t+1}] + \frac{1}{2} Var_t[rx^i_{t+1}] \quad = \quad \sqrt{\delta^i} \left(\sqrt{\delta} - \sqrt{\delta^i} \right) z^w_t + \gamma z_t.$$

  - Variation in δ^i is **necessary** for cross-sectional variation in currency risk premia.

Carry and Dollar Risk Factors

- Risk factors:

$$
\begin{aligned}
hml_{t+1} &= \frac{1}{N_H}\sum_{i\in H} rx^i_{t+1} - \frac{1}{N_L}\sum_{i\in L} rx^i_{t+1}. \\
\overline{rx}_{t+1} &= \frac{1}{N}\sum_{i} rx^i_{t+1}.
\end{aligned}
$$

- Real interest rates are:

$$
r^i_t = \left(\lambda - \frac{1}{2}\gamma\right) z^i_t + \left(\tau - \frac{1}{2}\delta^i\right) z^w_t.
$$

  - Real interest rates decline when z^w increases if:

$$
0 < \tau < \frac{1}{2}\delta^i,
$$

Risk Factors in the Model: hml_{FX} and rx

- Use LLN in in each portfolio.

$$hml_{t+1} - E_t[hml_{t+1}] = \left(\overline{\sqrt{\delta_t^L}} - \overline{\sqrt{\delta_t^H}}\right)\sqrt{z_t^w}u_{t+1}^w$$

$$\overline{rx}_{t+1} - E_t[\overline{rx}_{t+1}] = \sqrt{\gamma}\sqrt{z_t}u_{t+1}$$

  - Carry trade risk factor *HML* measures exposure to the common shock u_{t+1}^w.
  - Dollar risk factor *RX* measures exposure to the US-specific risk factor u_{t+1}.

Cross-sectional Asset Pricing

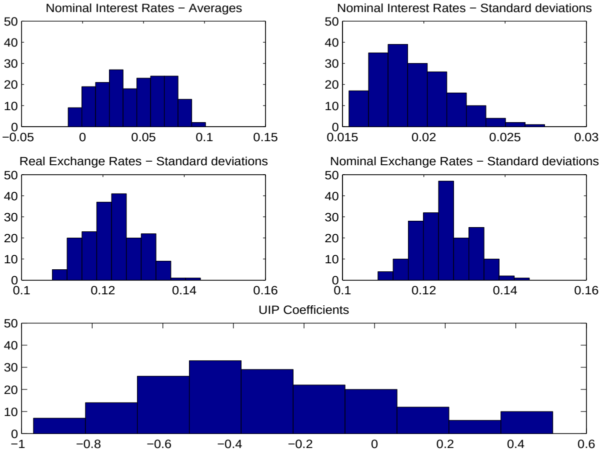
- Conditional betas of portfolio j:

$$\beta^j_{hml,t} = \frac{\sqrt{\delta} - \sqrt{\delta^j_t}}{\sqrt{\delta^L_t} - \sqrt{\delta^H_t}},$$

$$\beta^j_{rx,t} = 1.$$

- On average high δ^i currencies end up in low portfolios
  - ranking on interest rates => ranking on δ,
  - ranking on δ => ranking on β_{hml}.

Distributions of Summary Statistics - Simulated Data



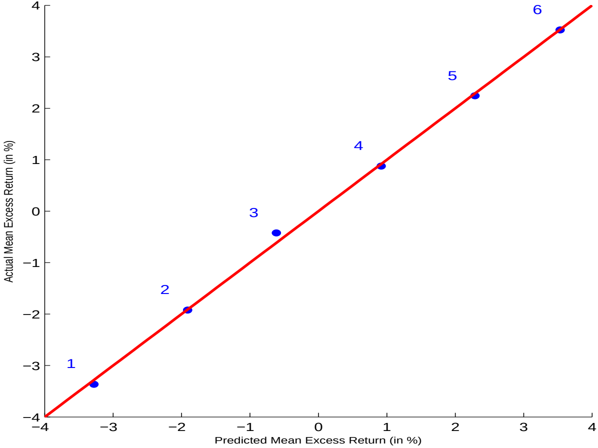
Portfolios - Summary statistics - Simulated Data

Portfolio	1	2	3	4	5	6
			Spot change: Δs^j			
Mean	-0.04	0.59	0.64	0.91	1.04	1.71
Std	9.55	8.83	8.28	8.35	8.81	9.45
			Forward Discount: $f^j - s^j$			
Mean	-3.41	-1.33	0.22	1.79	3.28	5.23
Std	1.45	1.31	1.24	1.11	1.07	1.07
			Excess Return: rx^j			
Mean	-3.36	-1.92	-0.42	0.88	2.24	3.52
SR	-0.35	-0.22	-0.05	0.10	0.25	0.37
			High-minus-Low: $rx^j - rx^1$			
Mean		1.44	2.94	4.24	5.61	6.89
SR		0.52	0.70	0.68	0.69	0.72

Portfolios - Asset Pricing - Simulated Data

	λ_{RX}	$\lambda_{HML_{FX}}$	b_{RX}	$b_{HML_{FX}}$	R^2	$RMSE$	χ^2
FMB	0.16	6.81	0.19	7.44	99.76	0.09	
	[0.26]	[0.31]	[0.39]	[0.33]			0.07
	(0.26)	(0.31)	(0.39)	(0.34)			1.19
Mean	**0.15**	**6.88**					

Portfolios of Currency Excess Returns - Simulated Data



Predictability

- I skip most of our predictability results today - they are in the paper and in a separate appendix though.
- I focus on two points:
  - Average forward discounts imply high R2s; no residual predictability in portfolio-specific discounts.
  - Expected excess returns are counter-cyclical.

Return Predictability: R^2

Portfolio	*1-month*	*2-month*	*3-month*	*6-month*	*12-month*
			Forward Discount		
1	4.30	4.64	8.03	25.30	25.93
6	2.56	3.07	3.82	5.72	10.03
			Average Forward Discount		
1	7.85	12.58	17.16	28.32	32.57
6	4.44	6.13	8.46	12.70	17.54
			Residual Predictability		
1	0.23	0.00	0.01	1.18	0.20
6	0.01	0.03	0.06	0.03	0.05

Notes: Data are monthly. Sample is 11/1983- 03/2008.

Predictability: Model

- Expected excess return in portfolio j:

$$rp_t^j = \frac{1}{2}\gamma\left(z_t - \overline{z_t^j}\right) + \frac{1}{2}\left(\delta - \overline{\delta^j}\right) z_t^w.$$

- LLN $\Rightarrow \overline{z_t^j}$ constant
- No foreign country-specific predictability
- $\Rightarrow$ Average forward discount predicts currency excess returns

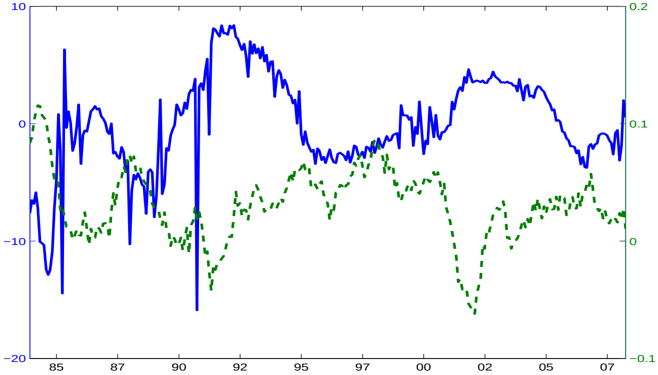
Business Cycle Properties: $Corr\left[\widehat{E}_t rx^j_{t+1}, y_t\right]$

$$\widehat{E}_t rx^j_{t+1} = \gamma^j_0 + \gamma^j_1 (f^j_t - s^j_t).$$

Portfolio	*IP*	*Pay*	*Help*	*Spread*	*slope*	*vol*
1	0.18	0.02	0.19	−0.21	0.04	−0.17
2	−0.57	−0.70	−0.41	0.34	0.42	−0.14
3	−0.61	−0.64	−0.37	0.33	0.47	−0.04
4	−0.57	−0.51	−0.30	0.26	0.42	0.09
5	−0.51	−0.39	−0.24	0.28	0.38	0.28
6	−0.14	−0.09	−0.05	0.17	0.15	0.52

Notes: Monthly Data. Sample is 11/1983 - 03/2008.

Forecasted Currency Excess Return and US Business Cycle

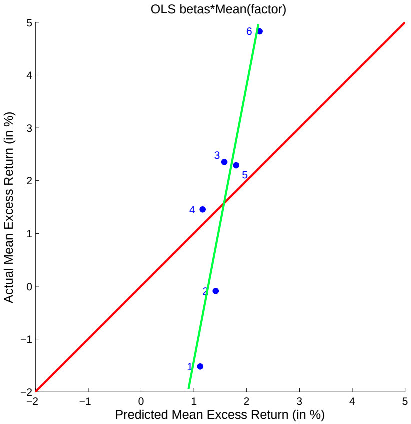


One-month ahead forecasted excess returns on portfolio 2 ($\widehat{E}_t rx^2_{t+1}$). All returns are annualized. The dashed line is the year-on-year log change in US Industrial Production Index.

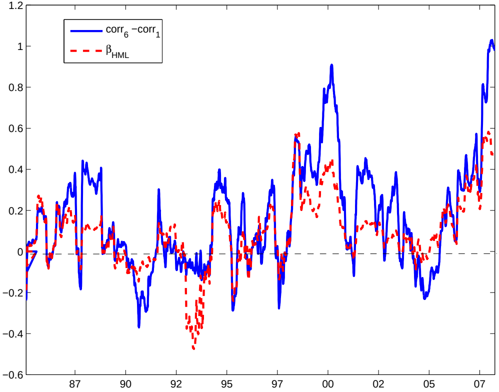
Conclusion

- Excess returns are large and predictable;
- Predictable variation is highly counter-cyclical;
- Cross-sectional variation is explained by a single risk factor;
- This suggests:
    - A common risk factor;
    - Heterogenous loadings on the common risk factor.

CAPM Model Fit



US Market Correlation 'Spread'



This figure plots $Corr_\tau[R^m_t, rx^6_t] - Corr_\tau[R^m_t, rx^1_t]$, where $Corr_\tau$ is the sample correlation over the previous 12 months $[\tau - 11, \tau]$. Monthly returns. Monthly data.

Portfolios of Countries in Burnside et al (2006)

Portfolio	1	2	3
	Spot change: Δs^j		
Mean	-0.83	-1.82	-1.19
Std	10.19	10.01	8.88
	Forward Discount: $f^j - s^j$		
Mean	-2.69	-0.59	2.58
Std	0.69	0.69	0.75
	Excess Return: rx^j (without b-a)		
Mean	-1.86	1.24	3.78
Std	10.26	10.10	8.90
SR	-0.18	0.12	0.42

Notes: Countries in the sample: Belgium, Canada, Euro area, France, Germany, Italy, Japan, Netherlands, Switzerland, and United Kingdom. The sample period is 11/1983 - 01/2007. Excess returns are computed without bid-ask spreads.

Asset Pricing - Portfolios of Countries in Burnside et alii (2006)

Panel A: HML_{FX}			
λ_{HML}	β_1	β_2	β_3
6.62	-0.28	0.05	0.22
	[0.04]	[0.03]	[0.04]

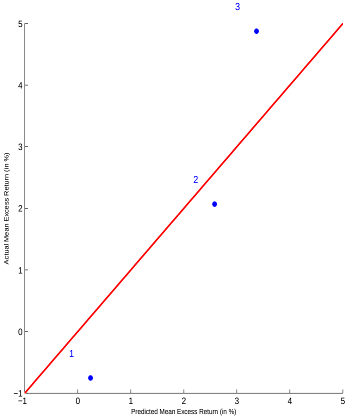
Panel B: RX			
λ_{RX}	β_1	β_2	β_3
2.06	1.00	1.07	0.92
	[0.04]	[0.03]	[0.04]

Panel C: Pricing errors			
	R^2	$RMSE$	$p-val$
	77.81	1.08	0.24

Notes: Market prices of risk are not estimated; sample means are used instead. The sample period is 11/1983 - 01/2007.

Excess returns are computed without bid-ask spreads.

Burnside et alii (2006)



Notes: The predicted excess return is the OLS estimate of β times the sample mean of the factors.

Burnside et alii (2006)

- Build one unique portfolio;
- Test our carry trade risk factor $HML_{FX,t}$ on their data set:

$$rx_t = c + \beta HML_{FX,t} + \epsilon_t.$$

$$\begin{aligned} \beta &= 0.48 \\ s.e &= 0.06 \\ R^2 &= 0.27 \end{aligned}$$

T-Bills

- Lustig and Verdelhan, 2007: build baskets of T-Bills (80 countries)
- Two issues:
  - financial openness,
  - defaults.

T-Bills

	λ_{HML}	λ_{RX}	b_{HML}	b_{RX}	R^2	$RMSE$	χ^2
				1953-2002			
GMM_1	4.10	0.25	8.39	−2.05	42.47	1.11	
	[1.25]	[1.10]	[2.76]	[3.60]			44.44
GMM_2	3.89	0.18	8.00	−2.13	42.09	1.11	
	[0.81]	[0.91]	[1.95]	[3.05]			45.47
FMB	4.10	0.25	8.22	−2.01	42.47	1.11	
	[1.17]	[0.84]	[2.34]	[2.54]			10.18
	(1.21)	(0.84)	(2.43)	(2.56)			24.16
$Mean$	**5.32**	0.128					

Notes: Annual data.

T-Bills

	λ_{HML}	λ_{RX}	b_{HML}	b_{RX}	R^2	$RMSE$	χ^2
				1971-2002			
GMM_1	6.20	0.31	9.25	−2.48	72.50	0.92	
	[2.07]	[1.93]	[3.29]	[4.17]			78.19
GMM_2	5.80	0.30	8.65	−2.29	72.13	0.92	
	[1.09]	[1.18]	[1.96]	[2.73]			80.26
FMB	6.20	0.31	8.96	−2.41	72.50	0.92	
	[1.66]	[1.30]	[2.37]	[2.55]			68.36
	(1.73)	(1.30)	(2.49)	(2.57)			86.28
Mean	**6.92**	0.255					

Notes: Annual Data

Consumption Betas

	β_c^{HML}	$p(\%)$	R^2	β_d^{HML}	$p(\%)$	R^2
	Panel A: Nondurables			*Panel B: Durables*		
	$HML_{FX,t+1} = \beta_0 + \beta_1 f_t + \epsilon_{t+1}$					
1953 – 2002	1.00		4.04	1.06		9.07
	[0.44]	2.23		[0.40]	0.89	
1971 – 2002	1.54		8.72	1.65		14.02
	[0.52]	0.28		[0.60]	0.63	

Notes: Annual data.