Where's the Risk? The Forward Premium Bias, the Carry-Trade Premium, and Risk-Reversals in General Equilibrium

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Intro

- We study whether three empirical regularities of international currency returns can be understood within a common framework
- The empirical regularities
  1. Downward forward premium bias
  2. Carry trade return
  3. Long-run risk reversal
- The framework
  - Fairly standard two-country DSGE NK model
  - Role of asymmetric unit-root productivity
  - Role of monetary policy

Downward forward premium bias

- Regression evidence against uncovered interest parity
- A long History.[1] $\beta < 1$ (or sometimes $(\beta < 0)$) in

$$\Delta \ln S_{1,2,t+1} = \alpha + \beta \left(i_{1,t} - i_{2,t} \right) + \epsilon_{t+1}$$

- Mainstream hypothesis: Caused by a time-varying risk premium

[1] Bilson (1981), Fama (1984)

Carry Trade

- Academic interest for about a decade[2]
- Go short the low interest currency, go long the high interest currency, ignore the exchange rate. Generates a systematically profitable trading strategy.
- High interest currency pays the excess return. Must be risky
  - Empirical work looks for priced risk factors.
  - Focused on the cross-section of carry returns
  - Less extensive: Modeling the carry
- Carry and forward premium bias are connected but not the same

[2] Lustig-Verdelhan, Burnside et al.

FP Bias v. Risk Premium

If n_{t+1} is nominal stochastic discount factor,

- Forward premium bias

$$n_{2,t+1} - n_{1,t+1} = \alpha_0 + \beta_0 \left(E_t \left(n_{2,t+1} - n_{1,t+1} \right) \right) + \epsilon_{t+1}.$$

- Risk premium/carry trade excess return

$$\left(i_{1,t} - i_{2,t} - E_t \Delta \ln \left(S_{1,2,t+1} \right) \right) = \frac{1}{2} \left(Var_t \left(n_{2,t+1} \right) - Var_t \left(n_{1,t+1} \right) \right).$$

Long-run risk reversal

- Relatively new idea, identified and explained by Charles Engel (2016)
  - Let there be forward premium bias or profitable carry
  - High interest country is risky because it pays an excess return
  - But high interest means strong currency.[3] Strength should indicate safety. Safe currency should pay negative premium.
- How to reconcile contradictory implications? Risk reversal

[3] Riksbank 1992, Korea 1997

Recent Literature

- Forward premium bias
  - Endowment models: Verdelhan (2010) (habit persistence), Bansal and Shaliastovich (2013) (LRR) Backus, Gavazzoni, Telmer, and Zin (2013). Inflation has no welfare effects in these models.
  - Small-open economy: Chinn and Zhang (2015).
- Carry trade
  - Empirical: Lustig-Verdelhan (2007), Lustig, Roussanov, and Verdelhan (2014),Burnside, Eichenbaum, Kleshchelski, and Rebelo,(2011), Della Corte, Riddiough, and Sarno (2016), Menkhoff, Sarno, Schmeling, and Schrimpf(2013), Berg and Mark (2017a, 2017b),
  - Structural Models: Hassan (2013), Ready, Roussanov, and Ward (2017)
- Risk reversal
  - Engel (2016), Valchev (2015)

Our paper

1. How far can 2-country DSGE NK macro model go in jointly explaining the three return facts?
2. Can we model a common macro source of risk underlying these return patterns?

Our paper asks

- Why General Equilibrium?
  - Risk is 'baked in' the endowment based LRR models
  - Evidence for LRR in consumption is tenuous, at best (Ma (2013)
  - People 'care' about inflation in GE
- Country-level heterogeneity
  - Productivity
  - Monetary policy–hence NK model
- Summary of results
  - Complete or incomplete markets model with productivity and monetary policy heterogeneity
  - High risk aversion

General Features of the Model

- Two-country DSGE New Keynesian macro model
- Labor, no capital. Sticky goods prices (Calvo)
- Exporters engage in local-currency pricing (LCP)
- Recursive utility (Epstein-Zin)
- Productivity driven by unit-root process

Households

$$\text{Utility: } V_t = (1-\beta)\left[\ln(c_t) - \eta\frac{\ell_t^{1+\chi}}{1+\chi}\right] - \frac{\beta}{\alpha}\ln\left[E_t\left(e^{-\alpha V_{t+1}}\right)\right]$$

$\beta \in (0,1)$ $\eta > 0$, $\chi > 0$, Frisch elasticity $1/\chi$, $\alpha \in \mathbb{R}$, IES=1.

$$RRA = \alpha + \left(\frac{1}{1+\frac{\eta}{\chi}}\right).$$

$$\text{Real SDF: } M_{t+1} = \beta\left(\frac{c_t}{c_{t+1}}\right)\left(\frac{e^{-\alpha V_{t+1}}}{E_t\left(e^{-\alpha V_{t+1}}\right)}\right)$$

$$\text{Nominal SDF: } N_{t+1} = M_{t+1}e^{-\pi_{t+1}}$$

Complete Markets

Nominal state-contingent bond, in country 1 currency

$$\text{Nominal bond Euler: } \frac{1}{1+i_t} = E_t\left(M_{t+1}e^{-\pi_{t+1}}\right)$$

$$\text{Nominal exra: } \frac{S_{1,2}\left(\omega^{t+1}\right)}{S_{1,2}\left(\omega^{t}\right)} = \frac{M_2\left(\omega_{t+1}|\omega^t\right)e^{-\pi_2\left(\omega^{t+1}\right)}}{M_1\left(\omega_{t+1}|\omega^t\right)e^{-\pi_1\left(\omega^{t+1}\right)}}$$

$$\text{Real exra (def): } Q_{1,2}\left(\omega^t\right) = \frac{S_{1,2}\left(\omega^t\right)P_2\left(\omega^t\right)}{P_1\left(\omega^t\right)}$$

$$\text{Real exra: } \frac{Q_{1,2}\left(\omega^{t+1}\right)}{Q_{1,2}\left(\omega^{t}\right)} = \frac{M_2\left(\omega_{t+1}|\omega^t\right)}{M_1\left(\omega_{t+1}|\omega^t\right)}$$

$$\text{Labor: } \eta\tilde{c}\left(\omega^t\right)\ell\left(\omega^t\right)^{\chi} = \frac{\tilde{W}\left(\omega^t\right)}{P\left(\omega^t\right)}$$

Complete Markets

$$\frac{Q_{1,2}\left(\omega^{t+1}\right)}{Q_{1,2}\left(\omega^{t}\right)} = \left(\frac{M_2\left(\omega_{t+1}|\omega^t\right)}{M_1\left(\omega_{t+1}|\omega^t\right)}\right)\left(\frac{G_1\left(\omega^t\right)}{G_2\left(\omega^t\right)}\right)$$

$$\frac{S_{1,2}\left(\omega^{t+1}\right)}{S_{1,2}\left(\omega^{t}\right)} = \left(\frac{M_2\left(\omega_{t+1}|\omega^t\right)e^{-\pi_2\left(\omega^{t+1}\right)}}{M_1\left(\omega_{t+1}|\omega^t\right)e^{-\pi_1\left(\omega^{t+1}\right)}}\right)\left(\frac{G_1\left(\omega^t\right)}{G_2\left(\omega^t\right)}\right)$$

$$\frac{1}{1+i\left(\omega^t\right)} = \left(\frac{\beta}{G\left(\omega^t\right)}\right)E_t\left(M\left(\omega_{t+1}|\omega^t\right)e^{-\pi\left(\omega^{t+1}\right)}\right)$$

Incomplete Markets

Countries each issue tradable, zero-net supply, nominal non-state contingent bond.

$$\text{Home Bond Euler: } \frac{1}{(1+i_{i,t})} = E_t M_{i,t+1} e^{-\pi_{i,t+1}}$$

$$\text{Foreign Bond Euler: } \left(\frac{1+\tau\left(\frac{Q_{i,j,t}}{P_{j,t}}\right) B_{i,j,t}}{(1+i_{j,t})} \right) = E_t M_{i,t+1} e^{-\pi_{j,t+1}} \frac{Q_{i,j,t+1}}{Q_{i,j,t}}$$

$$\text{Nom Exra (implicit): } \frac{S_{1,2,t}}{S_{1,2,t-1}} = \frac{Q_{1,2,t}}{Q_{1,2,t-1}} \frac{e^{\pi_{1,t}}}{e^{\pi_{2,t}}} \tag{1}$$

Goods Demand

- Continuum of intermediate goods firms $f \in [0, 1]$
- $c_{i,j,t}$ consumed in i, made in j

$$c_{i,j,t} = \left[\int_0^1 c_{i,j,t}\left(f\right)^{\frac{\sigma-1}{\sigma}} df \right]^{\frac{\sigma}{\sigma-1}},$$

$$P_{i,j,t} = \left[\int_0^1 p_{i,j,t}\left(f\right)^{1-\sigma} df \right]^{\frac{1}{1-\sigma}}$$

$$c_{i,t} = \left(d^{\frac{1}{\mu}} c_{i,i,t}^{\frac{\mu-1}{\mu}} + \left(1-d\right)^{\frac{1}{\mu}} c_{i,j,t}^{\frac{\mu-1}{\mu}} \right)^{\frac{\mu}{\mu-1}}$$

$$P_{i,t} = \left[d P_{i,i,t}^{1-\mu} + \left(1-d\right) P_{i,j,t}^{1-\mu} \right]^{\frac{1}{1-\mu}}$$

Production

Production fn: $y_{i,t}(f) = A_{i,t}\ell_{i,t}(f)$

Total costs: $\dfrac{W_{i,t}}{P_{i,t}}\ell_{it}\left(f\right)$

Demand determined output: $y_{i,t}\left(f\right) = c_{i,i,t}\left(f\right) + c_{i,j,t}\left(f\right)$

LCP Price Setting

Choose $p_{i,i,t}$ and $p_{j,i,t}$ to maximize

$$E_t \sum_{s=0}^{\infty} (\alpha_c \beta)^s M_{i,t,t+s} \left[\begin{array}{c} \frac{e^{-s\bar{\pi}_i} p_{i,i,t}(f)}{P_{i,t+s}} c_{i,i,t+s}(f) + \frac{Q_{i,j,t+s} p_{j,i,t}(f) e^{-s\bar{\pi}_j}}{P_{j,t+s}} c_{j,i,t+s}(f) \\ - \frac{W_{i,t+s}}{P_{i,t+s}} \ell_{i,t+s}(f) \end{array} \right],$$

Monetary Policy with Interest Rate Smoothing

Potential (log) GDP

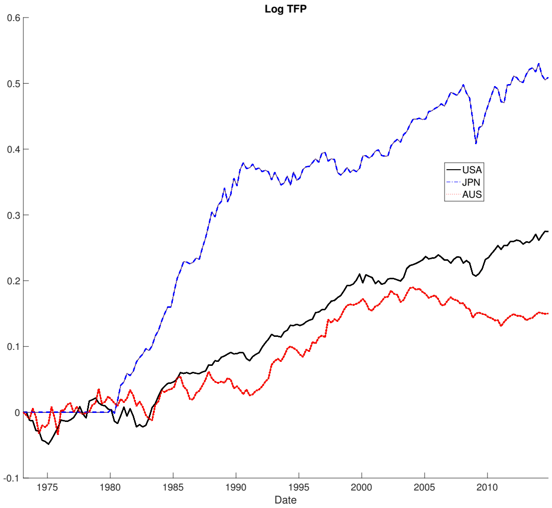
$$\ln\left(\bar{y}_{j,t}\right) = \rho_y \ln\left(\bar{y}_{j,t-1}\right) + \left(1 - \rho_y\right) \ln\left(y_{j,t}\right)$$

'Taylor Rule'

$$\begin{aligned} i_{j,t} = {} & \left(1 - \delta_j\right) \bar{\imath} + \delta_j i_{j,t-1} \\ & + \left(1 - \delta_j\right) \left[\xi_j \left(\pi_{j,t} - \pi^*{}_j\right) + \zeta_j \left(\ln\left(y_{j,t}\right) - \ln\left(\bar{y}_{j,t}\right)\right)\right] \end{aligned}$$

Productivity

Figure: Log TFP



Productivity

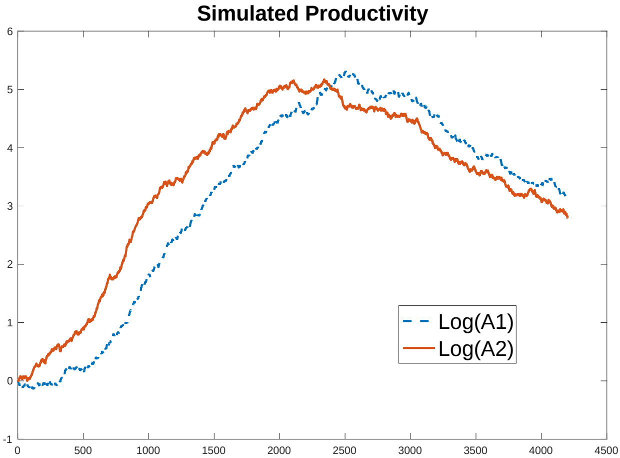
Let $a_{j,t} = \ln(A_{j,t})$

$$
\begin{aligned}
\Delta a_{1,t} &= -\psi_1 \left(a_{1,t-1} - a_{2,t-1}\right) + \sigma_1 \epsilon_{1,t} \\
\Delta a_{2,t} &= -\psi_2 \left(a_{1,t-1} - a_{2,t-1}\right) + \sigma_2 \epsilon_{2,t} \\
z_t &= a_{1,t} - a_{2,t} = \left(1 + \psi_2 - \psi_1\right) z_{t-1} + \left(\sigma_1 \epsilon_{1,t} - \sigma_2 \epsilon_{2,t}\right)
\end{aligned}
$$

- $\epsilon_{i,t} \overset{i.i.d}{\sim} N(0,1)$,
- $\sigma_i > 0$, for $i = \{1,2\}$,
- $0 < \psi_2 < \psi_1 < 1$

Productivity

Figure: Simulated Series of Log TFP



Productivity and Parameter Values

α_c	d	σ	μ	χ	β	ψ_1	ψ_2
0.8	0.85	10	1.5	3	0.99	0.003	0.0027

	δ_1	δ_2	ξ_1	ξ_2	ζ_1	ζ_2	ρ_y
symmetric	0.9	0.9	1.5	1.5	0.5	0.5	0.9
risky	0.9	0.9	1.2	1.5	0.5	0.0	0.9

$$RRA : 10 \text{ to } 60$$
$$\bar{\ell} = 1$$

Forward premium bias (or puzzle?)

Table: Fama Regression–Forward Premium Puzzle/Bias in the Data

Country 2	α_0	t-stat	β_0	t-stat	R^2
Australia is Country 1					
Canada	0.004	1.131	-0.507	-1.385	0.005
Great Britain	0.000	-0.012	0.047	0.100	0.000
Japan	0.005	1.074	0.278	1.088	0.003
Korea	-0.006	-0.927	-0.109	-0.203	0.000
Norway	-0.003	-0.622	1.318	1.850	0.021
New Zealand	-0.001	-0.301	-0.176	-0.347	0.001
Switzerland	0.010	1.030	-0.059	-0.071	0.000
Sweden	-0.004	-0.603	1.645	1.535	0.038
United States	0.005	1.035	-0.487	-1.160	0.005

The regression is $\Delta \ln(S_{1,2,t+1}) = \alpha_0 + \beta_0(i_{1,t} - i_{2,t}) + \epsilon_{t+1}$.

Forward premium bias (or puzzle?)

Table: Fama Regression–Forward Premium Puzzle/Bias in the Data

Country 2	α_0	t-stat	β_0	t-stat	R^2
		Japan is Country 1			
Australia	-0.005	-1.074	0.278	1.088	0.003
Canada	-0.006	-0.960	0.056	0.138	0.000
Great Britain	-0.008	-1.340	0.040	0.115	0.000
Korea	0.006	0.413	0.697	1.106	0.011
Norway	0.021	1.935	2.081	1.884	0.037
New Zealand	-0.003	-0.255	0.422	0.699	0.004
Switzerland	0.002	0.330	-0.059	-0.176	0.000
Sweden	0.020	1.252	2.533	1.363	0.046
United States	-0.007	-1.244	-0.171	-0.411	0.001

The regression is $\Delta \ln(S_{1,2,t+1}) = \alpha_0 + \beta_0(i_{1,t} - i_{2,t}) + \epsilon_{t+1}$.

Forward premium bias in the model

Table: Implied Slope in Fama Regression–Forward Premium Puzzle/Bias

A. Symmetric Benchmark Monetary Policies				
Risk Aversion	10	20	30	60
Complete	1.046	0.965	0.880	0.705
Incomplete	1.232	1.162	1.069	0.839
B. Alternative Monetary Policies				
	Policy Parameters			
ξ_1	1.5	1.5	2.0	2.0
ξ_2	0.5	0.0	0.5	0.9
ζ_1	1.2	1.2	1.2	1.2
ζ_2	0.5	0.5	0.5	0.5
	Risk Aversion is 60			
Complete	0.794	0.834	0.775	0.761
Incomplete	0.646	0.643	0.563	0.659

The Carry

Table: Monthly Currency Excess Return Summary Statistics (1973.04–2014.12): Developed Countries

	P_1	P_2	P_3	P_4	P_5	P_6
Mean Currency Excess Return	-1.188	-0.482	1.311	0.828	3.263	3.849
Mean Interest Rate Differential	-2.904	-1.297	0.024	1.144	2.590	6.736
Mean Exchange Rate Return	1.716	0.816	1.287	-0.316	0.674	-2.886

Notes: This table is taken from Berg and Mark (2017a). Developed countries include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Poland, Portugal, Singapore, South Korea, Spain, Sweden, Switzerland, Taiwan, United Kingdom, and United States.

A. Benchmark Monetary Policies				
	Complete Markets			
Risk Aversion	10	20	30	60
Gross Carry	-0.213	-0.533	-0.853	-1.763
	Incomplete Markets			
Risk Aversion	10	20	30	60
Gross Carry	0.091	-0.164	-0.420	-1.191
Net Carry 1	-0.104	-0.579	-1.054	-2.480
Net Carry 2	-0.087	-0.537	-0.989	-2.351

Model Implied Carry

Table: Carry Trade Returns

B. Alternative Monetary Policies Risk Aversion is 60				
	Policy Parameters			
ξ_1	1.5	1.5	2.0	2.0
ξ_2	0.5	0.0	0.5	0.9
ζ_1	1.2	1.2	1.2	1.2
ζ_2	0.5	0.5	0.5	0.5
	Complete Markets			
Gross Carry	2.531	2.388	2.770	2.876
	Incomplete Markets			
Gross Carry	2.515	2.393	2.594	2.698
Net Carry 1	1.063	0.938	1.142	1.240
Net Carry 2	1.248	1.297	1.163	1.217

Long-Run Risk Reversal: Engel (2016)

- Let $r_2 > r_1$. Currency 2 should be strong, strength implies safety, safety means negative premium. paid

  Forward premium bias says 2 is risky.

- Ex post excess return on country 2

$$\rho_{t+1} = r_{2,t} - r_{1,t} + \Delta \ln \left(Q_{1,2,t+1} \right)$$

- Forward premium bias says

$$E_S \equiv Corr \left(\left(E_t \rho_{t+1} \right), \left(r_{2,t} - r_{1,t} \right) \right) > 0.$$

- Long-run country 2 risk premium:
  $\sum_{j=0}^{\infty} E_t \left(\rho_{t+1+j} \right) = E_t \left(\sum_{j=0}^{\infty} \left(r_{2,t+j} - r_{1,t+j} \right) + \ln \left(Q_{1,2,\infty} \right) - \ln \left(Q_{1,2,t} \right) \right)$.
  Must be negatively correlated with real interest rate differential,

$$E_L \equiv Corr \left(E_t \left(\sum_{j=0}^{\infty} \rho_{t+1+j} \right), \left(r_{2,t} - r_{1,t} \right) \right) < 0.$$

Engel's Evidence

- Estimated VECM on $\ln(S_{1,2,t}), (i_{1,t} - i_{2,t}), (p_{1,t} - p_{2,t})$ generates expectations, E_S, E_L, for G7 with USD as base currency.
- Finds $E_L < 0$ in every instance.
- Log-linearized LRR models under complete markets are consistent with FP bias $E_S > 0$, but not the risk-reversal.

Model Implied Long-Run Risk Reversal

Table: Risk Reversal

A. Benchmark Monetary Policies				
	Complete Markets			
Risk Aversion	10	20	30	60
E_S	0.182	0.199	0.241	0.401
E_L	-0.099	-0.152	-0.210	-0.387
	Incomplete Markets			
Risk Aversion	10	20	30	60
E_S	-0.141	-0.115	-0.032	0.173
E_L	0.178	0.080	-0.032	-0.250

Model Implied Risk Reversal

Table: Risk Reversal

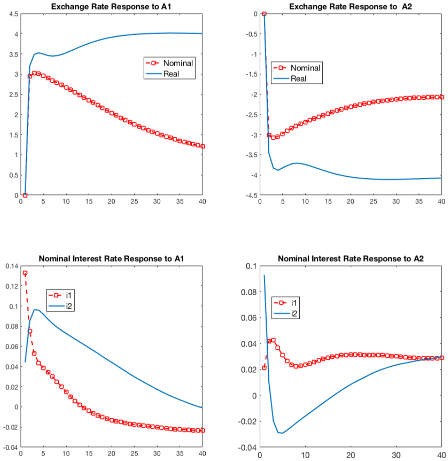
B. Heterogeneous Monetary Policies				
(Risk Aversion is 60)				
	Policy Parameters			
ξ_1	1.5	1.5	2.0	2.0
ξ_2	0.5	0.0	0.5	0.9
ζ_1	1.2	1.2	1.2	1.2
ζ_2	0.5	0.5	0.5	0.5
	Complete Markets			
E_S	0.299	0.272	0.230	0.220
E_L	-0.306	-0.275	-0.241	-0.235
	Incomplete Markets			
E_S	0.454	0.498	0.428	0.407
E_L	-0.464	-0.508	-0.439	-0.417

Stationary Symmetric Productivity

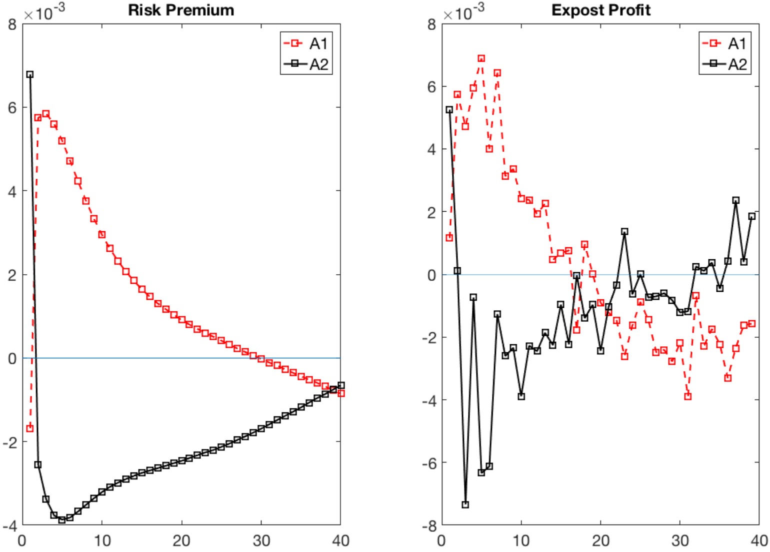
ρ_A	0.90	0.96	0.98	0.99
	Complete Markets			
Fama	0.986	0.987	0.985	0.979
Carry	0.014	0.040	0.085	0.155
E_S	-0.185	-0.229	-0.304	-0.403
E_L	-0.239	-0.196	-0.122	-0.037
	Incomplete Markets			
Fama	0.997	0.999	0.999	0.990
Gross Carry	0.092	0.093	0.078	0.146
Net Carry 1	0.067	0.031	-0.057	-0.187
Net Carry 2	0.066	0.026	-0.060	-0.141
E_S	-0.196	-0.243	-0.311	-0.425
E_L	-0.104	-0.048	0.003	0.037

Note: Risk Aversion is 60. Monetary policy parameters are $\xi_1 = 2.0, \xi_2 = 1.2, \zeta_1 = 0.9, \zeta_2 = 0.5$.

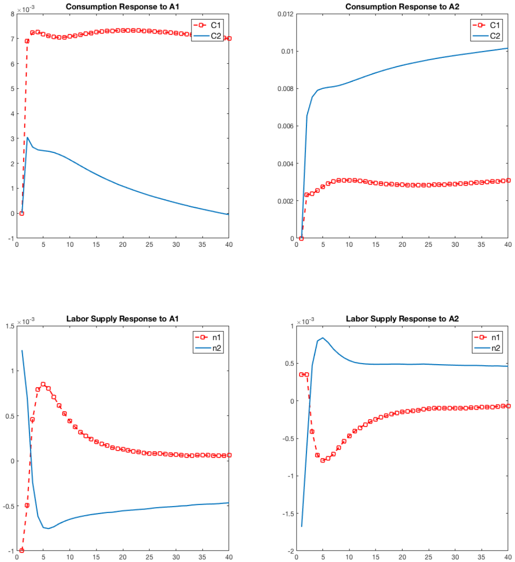
A couple of IRFs



A couple of IRFs



A couple of IRFs



Conclusion

What does the simplist general equilibrium macro model, with monetary policy, say about empirical patterns of international currency returns?

- Some sort of cross-country heterogeneity is essential
- A consistent, common source of risk
- TFP and monetary policy heterogeneity

Complete Markets and Carry Premium

$$m_{t+1} = -\Delta c_{t+1} - \alpha \left(V_{t+1} - \mu_t \left(V_{t+1} \right) \right) - \frac{\alpha^2 \sigma_t^2 \left(V_{t+1} \right)}{2}$$

$$m^*_{t+1} = -\Delta c^*_{t+1} - \alpha \left(V^*_{t+1} - \mu_t \left(V^*_{t+1} \right) \right) - \frac{\alpha^2 \sigma_t^2 \left(V^*_{t+1} \right)}{2}$$

$$\begin{aligned} E_t \left(r_t^* - r_t + \Delta s_{t+1} \right) &= \frac{\sigma^2 \left(m_{t+1} \right) - \sigma_t^2 \left(m^*_{t+1} \right)}{2} \\ &= \frac{\sigma_t^2 \left(\Delta c_{t+1} \right) + \alpha^2 \sigma_t^2 \left(V_{t+1} \right) + 2\alpha \gamma_t \left(\Delta c_{t+1}, V_{t+1} \right)}{2} \\ &- \frac{\sigma_t^2 \left(\Delta c^*_{t+1} \right) + \alpha^2 \sigma_t^2 \left(V^*_{t+1} \right) + 2\alpha \gamma_t \left(\Delta c^*_{t+1}, V^*_{t+1} \right)}{2} \end{aligned} \quad (2)$$

Complete Markets and FP Bias

$$\gamma_t\left(\Delta s_{t+1}, r_t - r_t^*\right) = E_t\left(m_{t+1}^* - m_{t+1}\right)\left(\mu_t\left(m_{t+1}^*\right) - \mu_t\left(m_{t+1}\right) + \frac{\sigma_t^2\left(m_{t+1}^*\right) - \sigma_t^2\left(m_{t+1}\right)}{2}\right)$$

$$\gamma_t\left(\Delta s_{t+1}, r_t - r_t^*\right) = E_t\left[\begin{array}{c}\left(\Delta c_{t+1} - \Delta c_{t+1}^*\right) + \alpha\left(V_{t+1} - \mu_t\left(V_{t+1}\right)\right) - \alpha\left(V_{t+1}^* - \mu_t\left(V_{t+1}^*\right)\right) \\ + \frac{\alpha^2}{2}\left(\sigma_t^2\left(V_{t+1}\right) - \sigma_t^2\left(V_{t+1}^*\right)\right)\end{array}\right]$$

$$\times\left[\begin{array}{c}\left[\mu_t\left(\Delta c_{t+1}\right) - \mu_t\left(\Delta c_{t+1}^*\right)\right] + \frac{\alpha^2}{2}\left[\sigma_t^2\left(V_{t+1}\right) - \sigma_t^2\left(V_{t+1}^*\right)\right] \\ + \frac{\overbrace{\sigma_t^2\left(\Delta c_{t+1}^*\right) - \sigma_t^2\left(\Delta c_{t+1}\right)}^{**} + \alpha^2\overbrace{\left(\sigma_t^2\left(V_{t+1}^*\right) - \sigma_t^2\left(V_{t+1}\right)\right)}^{**} + 2\alpha\overbrace{\left(\gamma_t\left(\Delta c_{t+1}^*, V_{t+1}^*\right) - \gamma_t\left(\Delta c_{t+1}, V_{t+1}\right)\right)}^{**}}{2}\end{array}\right]$$