

A Preferred-Habitat Model of Term Premia, Exchange Rates and Monetary Policy Spillovers

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CRETE Conference - July 2021

Motivation

- Big question: How does monetary policy (conventional and unconventional) transmit domestically and internationally?

Motivation

- Consider 'off-the-shelf' open economy macro model:
 - Little role for time-varying risk premia (first order constant)
 - Uncovered Interest Parity (UIP) and Expectation Hypothesis (EH) hold
 - EH: yield curve in each country controlled by local policy rate
 - UIP: exchange rate absorbs any deviation between policy rates (at any maturity).
 - 'Mundellian' insulation
 - QE and FX interventions have no effect (at home or abroad)
- Casting doubt on the model:
 - Time-varying risk premia in currency markets (UIP puzzle, Fama) and bond markets (violations of EH, Fama and Bliss)
 - Currency and bond risk premia **deeply connected** (Lloyd & Marin 2019, Lustig et al 2019, Chernov and Creal 2020...)
 - Effect of unconventional monetary policy on FX and yields (home and foreign).

- On the theory side:
 - Standard representative agent no-arbitrage models have a hard time...
 - Recent literature emphasizes the optimization of financial intermediaries and the constraints they face (Gabaix & Maggiori 2015, Itskhoki & Mukhin 2019, Koijen & Yogo 2020)
 - General sense that 'some' limits to arbitrage is key to explain e
 - Revives an old literature on portfolio-balance (Kouri 1982, Jeanne & Rose 2002)
- **This paper**: introduce risk averse arbitrageurs, able to invest in fixed-income and currency markets (global hedge funds, fixed income desks of broker-dealers, multinational corporations, central banks...)
- Formally: Two-country version of Vayanos & Vila's (2021) **preferred-habitat model**.
- Contemporaneous paper by Greenwood et al (2020) in discrete time with two bonds.

1. Can reproduce empirical facts about bond and currency risk premia, both qualitatively and (to some extent) quantitatively
2. When markets are segmented, rich transmission of monetary policy shocks (conventional and unconventional) via exchange rate and term premia
3. General message: floating exchange rates provide limited insulation.
Failure of Friedman-Obtsfeld-Taylor's Trilemma

Framework is very rich. Can use it to answer more ambitious questions (not there yet):

- (a) plunge into standard open economy macro model (Ray 2019)
- (b) think about deviations from LOP (from UIP to CIP)

Set-Up

Set-Up: Two-country Vayanos & Vila (2021)

- Continuous time $t \in (0, \infty)$, 2 countries $j = H, F$
- Nominal exchange rate e_t : H price of F (increase \equiv depreciation of H 's currency)
- In each country j , continuum of zero coupon bonds in zero net supply with maturity $0 \leq \tau \leq T$, and $T \leq \infty$
- Bond price (in local currency) $P_{jt}^{(\tau)}$, with yield to maturity $y_{jt}^{(\tau)} = -\log P_{jt}^{(\tau)} / \tau$
- Exogenous *nominal* short rate (policy rate) $i_{jt} = \lim_{\tau \rightarrow 0} y_{jt}^{(\tau)}$

Arbitrageurs and Preferred-Habitat Investors

Three types of investors:

- Home and foreign preferred-habitat **bond investors**
[demand bonds of a specific country \times maturity]
- **Currency traders**
[demand currency at spot or forward market]
- **Arbitrageurs**
[trade both currencies, and bonds of both countries and all maturities]

Arbitrageurs

- Wealth W_t (in Home currency)
- W_{Ft} invested in country F (in Home currency)
- $X_{jt}^{(\tau)}$ invested in bond of country j and maturity τ (in Home currency)
- Instantaneous mean-variance optimization (limit of OLG model)

$$\max_{\{X_{Ht}^{(\tau)}, X_{Ft}^{(\tau)}\}_{\tau \in (0, T)}, W_{Ft}} \mathbb{E}_t(dW_t) - \frac{\alpha}{2} \text{Var}_t(dW_t)$$

- Law of Motion:

$$\begin{aligned} dW_t = & W_t i_{Ht} dt + W_{Ft} \left(\frac{de_t}{e_t} + (i_{Ft} - i_{Ht}) dt \right) \\ & + \int_0^T X_{Ht}^{(\tau)} \left(\frac{dP_{Ht}^{(\tau)}}{P_{Ht}^{(\tau)}} - i_{Ht} dt \right) d\tau + \int_0^T X_{Ft}^{(\tau)} \left(\frac{d(P_{Ft}^{(\tau)} e_t)}{P_{Ft}^{(\tau)} e_t} - \frac{de_t}{e_t} - i_{Ft} dt \right) d\tau \end{aligned}$$

Key insight: Risk averse arbitrageurs' holdings increase with expected return.

Preferred-Habitat Bond Investors and Currency Traders

- Demand for bonds in currency j , of maturity τ (in Home currency):

$$Z_{jt}^{(\tau)} = -\alpha_j(\tau) \log P_{jt}^{(\tau)} - \theta_j(\tau) \beta_{jt}$$

- Bond demand elastic in the price $P_{jt}^{(\tau)}$.

- Demand for foreign currency (spot) (in Home currency):

$$Z_{et} = -\alpha_e (\log(e_t) + \log(p_{Ft}) - \log(p_{Ht})) - \theta_e \gamma_t,$$

- Can accommodate forward demand. Under CIP, equivalent to spot + H and F bond trades.
- Currency demand elastic in the *real* exchange rate $e_t p_{Ft} / p_{Ht}$.
- Exogenous bond and FX demand risk factors: β_{jt} and γ_t .
- Assume constant inflation rates π_F and π_H . Non-stationary nominal exchange rate.

Market Clearing

- Home bonds

$$X_{Ht}^{(\tau)} + Z_{Ht}^{(\tau)} = 0$$

- Foreign bonds

$$X_{Ft}^{(\tau)} + Z_{Ft}^{(\tau)} = 0$$

- Currency Market

$$W_{Ft} + Z_{et} = 0$$

Risk Factors and Dynamics

- 5 risk factors: short rates (i_{jt}), bond demands (β_{jt}) and currency demand (γ_t)
- Linear mean-reverting dynamics

$$d\mathbf{q}_t = -\mathbf{\Gamma} (\mathbf{q}_t - \bar{\mathbf{q}}) dt + \mathbf{\Sigma} d\mathbf{B}_t,$$

where

$$\mathbf{q}_t = \begin{bmatrix} i_{Ht} & i_{Ft} & \beta_{Ht} & \beta_{Ft} & \gamma_t \end{bmatrix}^\top,$$

$$\mathbf{B}_t = \begin{bmatrix} B_{iHt} & B_{iFt} & B_{\beta Ht} & B_{\beta Ft} & B_{\gamma t} \end{bmatrix}^\top,$$

($\mathbf{\Gamma}$, $\mathbf{\Sigma}$) are 5×5 matrices, and the eigenvalues of $\mathbf{\Gamma}$ are negative.

Simple Cases

1. Risk-Neutral Arbitrageurs

Assume that arbitrageurs are risk-neutral: $a = 0$.

- EH holds:

$$\frac{1}{dt} \mathbb{E}_t \frac{dP_{Ht}^{(\tau)}}{P_{Ht}^{(\tau)}} = i_{Ht} \quad ; \quad \frac{1}{dt} \mathbb{E}_t \frac{dP_{Ft}^{(\tau)}}{P_{Ft}^{(\tau)}} = i_{Ft} \quad ; \quad y_{jt}^{(\tau)} = \frac{1 - e^{-\kappa_{ij}\tau}}{\tau \kappa_{ij}} i_{jt} + C_j(\tau)$$

- Home yield curve independent from Foreign short-rate shocks.
- No effect of QE on yield curve, at Home or Foreign

- UIP holds:

$$\frac{1}{dt} \mathbb{E}_t \frac{de_t}{e_t} = i_{Ht} - i_{Ft} \quad ; \quad \log e_t = \frac{i_{Ft}}{\kappa_{iF}} - \frac{i_{Ht}}{\kappa_{iH}} + (\pi_H - \pi_F)t - C_e$$

- 'Mundellian' insulation: shock to short rates 'absorbed' into the exchange rate.
- Classical Trilemma: capital flows and floating exchange rates deliver monetary autonomy.

2 and 3. No Demand Shocks

Assume no demand shocks ($\beta_{jt} = \gamma_t = 0$).

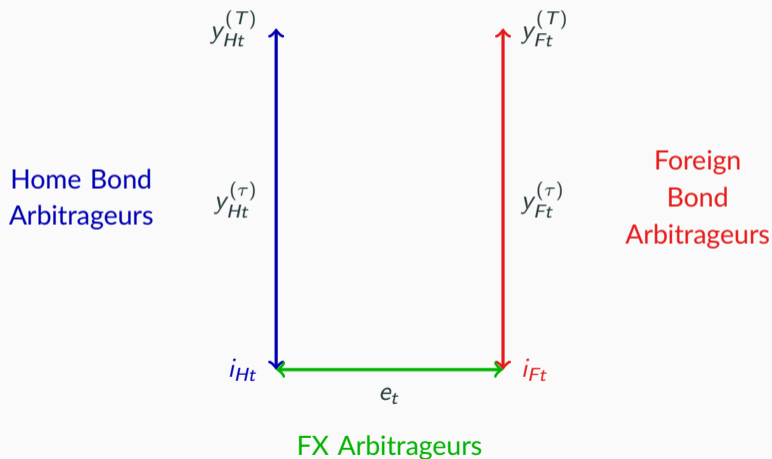
- Write short-rate process as

$$di_{jt} = \kappa_{ij}(\bar{i}_j - i_{jt})dt + \sigma_{ij}dB_{ijt}$$

- Assume that i_{Ht} and i_{Ft} are independent
- Analytical results and closed-form solutions

2. Segmented Arbitrage and No Demand Shocks

Assume foreign currency and bonds are traded by **three disjoint sets of arbitrageurs**.



2.a. Currency Carry Trade (CCT) and UIP Deviations

Postulate: $\log e_t = A_{iFe} i_{Ft} - A_{iHe} i_{Ht} - C_e + (\pi_H - \pi_F)t$

Proposition (Segmented Arbitrage, Currency Carry Trade and UIP Deviations)

When arbitrage is segmented, risk aversion $a > 0$ and FX price elasticity $\alpha_e > 0$

- Attenuation: $0 < A_{ije} < 1/\kappa_{ij}$
- CCT expected return $\mathbb{E}_t de_t/e_t + i_{Ft} - i_{Ht}$ decreases in i_{Ht} and increases in i_{Ft} (UIP deviation)

Intuition: Similar to Kouri (1982), Gabaix and Maggiori (2015)

- when $i_{Ft} \uparrow$, demand for CCT increases.
- Foreign currency appreciates ($e_t \uparrow$)
- As $e_t \uparrow$, price elastic FX traders reduce holdings ($\alpha_e > 0$): $Z_{et} \downarrow$
- FX arbitrageurs increase their holdings $W_{Ft} \uparrow$, which requires a higher CCT return.

2.b. Bond Carry Trade (BCT) and EH Deviations

Postulate: $\log P_{jt}^{(\tau)} = -A_{ij}(\tau)i_{jt} - C_j(\tau)$

Proposition (Segmented Arbitrage and Bond Carry Trade)

When arbitrage is segmented, $a > 0$ and $\alpha(\tau) > 0$ in a positive-measure subset of $(0, T)$:

- Attenuation: $A_{ij}(\tau) < (1 - e^{-\kappa_{ij}\tau})/\kappa_{ij}$.
- Bond prices in country j only respond to country j short rates (no spillovers).
- BCT_j expected return $\mathbb{E}_t dP_{jt}^{(\tau)} / P_{jt}^{(\tau)} - i_{jt}$ decreases in i_{jt}

Intuition: Similar to Vayanos & Vila (2021)

- When $i_{jt} \downarrow$ arbitrageurs want to invest more in the BCT
- Bond prices: $P_{jt}^{(\tau)} \uparrow$
- As $P_{jt}^{(\tau)} \uparrow$, price-elastic habitat bond investors ($\alpha_j(\tau) > 0$) reduce their holdings: $Z_{jt}^{(\tau)} \downarrow$
- Bond arbitrageurs increase their holdings, which **requires a higher BCT return**.

Macro Implications of the Segmented Model

Assume $a > 0$, $\theta_j(\tau) > 0$ and $\theta_e > 0$.

- An unexpected **increase in bond demand** in country j (e.g. QE_j) reduces yields in country j . It has no effect on bond yields in the other country or on the exchange rate.
- An unexpected **increase in demand for foreign currency** (e.g. *sterilized intervention*) causes the foreign currency to appreciate. It has no effect on bond yields in either country.

Open Economy Macro Implications:

- Changes in Home monetary conditions (conventional or QE) have no effect on the foreign yield curve. **Full insulation**.
- Insulation is even stronger in the case of QE: exchange rate is unchanged.
- **Trilemma?** No, this result arises because of markets segmentation (limited capital flows), not because of floating exchange rates.

An aside: A 'Neo-Fischerian' theory of exchange rates

Consider the case where $a > 0$.

- Currency risk premia:

$$\frac{1}{dt} \mathbb{E} \frac{de_t}{e_t} = i_{Ht} - i_{Ft} - \Psi_t$$

- The real exchange rate $e_t p_{Ft} / p_{Ht}$ is stationary regardless of the long run real interest rates in H and F.

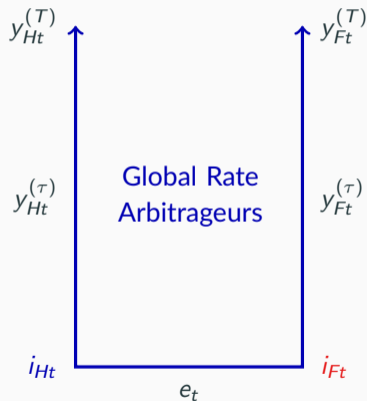
$$\frac{1}{dt} \mathbb{E} \frac{de_t}{e_t} + \pi_F - \pi_H = 0 = (\bar{i}_H - \pi_H) - (\bar{i}_F - \pi_F) - \Psi$$

- A country with a permanently higher real rate $\bar{i}_j - \pi_j$ has a permanently stronger currency, lower demand from currency traders, and a permanently higher currency risk premium.

⇒ Differences in long run real rates absorbed into currency risk premium.

3. Global Arbitrage and No Demand Shocks

Assume that the same arbitrageurs can invest in bonds (H and F) and FX.




Carry Trades and UIP/EH deviations

Proposition (Global Arbitrage and Carry Trades (CCT/BCT))

when arbitrage is global, risk aversion $a > 0$ and price elasticities $\alpha_e, \alpha_j(\tau) > 0$:

$$\log P_{jt}^{(\tau)} = -A_{ijj}(\tau)i_{jt} - A_{ijj'}(\tau)i_{j't} - C_H(\tau); \log e_t = A_{iFe}i_{Ft} - A_{iHe}i_{Ht} - C_e + (\pi_H - \pi_F)t$$

- Previous propositions hold: CCT and BCT_H return decrease with i_{Ht} , but attenuation is stronger than with segmented markets.
-  Cross-country linkages: when $\alpha_e > 0$, BCT_F increases with i_{Ht} .

Intuition: Bond and FX Premia Cross-Linkages

- When $i_{Ht} \downarrow$ global arbitrageurs invest more in CCT and BCT_H .
- e and $W_{Ft} \uparrow$: increased FX exposure (risk of $i_{Ft} \downarrow$).
- Hedge by investing more in BCT_F [price of foreign bonds increases when i_{Ft} drops]: foreign yields decline and BCT_F decreases.

QE, FX Interventions: Importance of Bond and FX Premia Cross-Linkages

Assume $a > 0$ and $\alpha_j(\tau) > 0$.

- QE: Unexpected QE_j reduces yields in country j , as before ($BCT_j \downarrow$).
- ⚠ Reduces yields in the other country (when $\alpha_e > 0$), and depreciates the currency. ($BCT_{j'} \downarrow, CCT \downarrow$)
 - To accommodate QE_j , arbitrageurs go short bonds in country j .
 - Hedge by investing in the other country's currency since it appreciates when i_{jt} drops.
 - Hedge currency position by investing in the other country's bonds.
- *Sterilized intervention*: Unexpected purchase of foreign currency causes the foreign currency to appreciate ($CCT \downarrow$).
- ⚠ Lowers bond yields at Home ($BCT_H \downarrow$) and increases them in Foreign ($BCT_F \uparrow$).
 - To accommodate intervention, arbitrageurs hold less Foreign and more Home currency.
 - More exposed to a decline in i_{Ht} and an increase in i_{Ft}
 - Hedge by investing more in Home bonds and less in Foreign bonds

Open Economy Macro Implications

- Home monetary policy (conventional or QE) affect yield curves in Home and Foreign as well as the exchange rate.
- Imperfect insulation even with floating rates.
- QE or FX interventions in one country affects monetary conditions in both countries and depreciate the currency.
- Failure of the Classical Trilemma.

Hybrid and Long-Horizon CCT

CCT using bonds of maturity τ instead of short rates (Lustig et al, 2019).

$$\begin{aligned} \frac{1}{dt} \left[\mathbb{E}_t \left(\frac{d(P_{Ft}^{(\tau)} e_t)}{P_{Ft}^{(\tau)} e_t} \right) - \mathbb{E}_t \left(\frac{dP_{Ht}^{(\tau)}}{P_{Ht}^{(\tau)}} \right) \right] &= \mu_{Ft}^{(\tau)} - \mu_{Ht}^{(\tau)} + \mu_{et} \\ &= (\mu_{et} + i_{Ft} - i_{Ht}) + (\mu_{Ft}^{(\tau)} - i_{Ft}) - (\mu_{Ht}^{(\tau)} - i_{Ht}) \end{aligned}$$

Proposition (Hybrid CCT)

The expected return $\mu_{Ft}^{(\tau)} - \mu_{Ht}^{(\tau)} + \mu_{et}$ of the hybrid currency carry trade:

- Decreases in the Home short rate i_{Ht} and increases in the Foreign short rate i_{Ft}
- Declines (in absolute value) with maturity τ and converges to zero as τ goes to infinity.

Intuition: When i_{Ht} low and i_{Ft} is high, Home BCT is high, Foreign BCT is low. Hence using long maturity bonds reduces the expected return on hybrid CCT.

Long-Horizon CCT

CCT using bonds of maturity τ and holding for τ years (Chinn & Meredith 2004). Annualized expected return is difference between foreign and home long bond yields in home currency:

$$LCCT(\tau) = \mathbb{E}_t \left[\frac{1}{\tau} \log \frac{e_{t+\tau}}{e_t} \right] + y_{Ft}^{(\tau)} - y_{Ht}^{(\tau)}$$

Proposition (Long-Horizon CCT)

- The expected return $LCCT(\tau)$ of the long-horizon currency carry trade declines (in absolute value) with maturity τ and converges to zero as τ goes to infinity.
- The coefficient of a regression of $\log(e_{t+\tau}/e_t)/\tau$ on $y_{H,t}^{(\tau)} - y_{Ft}^{(\tau)}$ is positive but below 1 for $\tau \rightarrow 0$, and converges to 1 as τ goes to infinity

Intuition: Stationarity of exchange rate.

Implication: Long-horizon UIP holds, as in the data.

The Full Model

The Full Model: Adding Demand Shocks

- Recall the 5-factor dynamics

$$d\mathbf{q}_t = -\mathbf{\Gamma} (\mathbf{q}_t - \bar{\mathbf{q}}) dt + \mathbf{\Sigma} d\mathbf{B}_t,$$

where

$$\mathbf{q}_t = \begin{bmatrix} i_{Ht} & i_{Ft} & \beta_{Ht} & \beta_{Ft} & \gamma_t \end{bmatrix}^\top.$$

- Postulate affine solution:

$$-\log P_{jt}^{(\tau)} = \mathbf{q}_t^\top \mathbf{A}_j(\tau) + C_j(\tau) \quad , \quad -\log e_t = \mathbf{q}_t^\top \mathbf{A}_e + C_e$$

- Parametrize Demand Functions:

$$\alpha_j(\tau) \equiv \alpha_{j0} \exp(-\alpha_{j1}\tau) \quad ; \quad \theta_j(\tau) \equiv \theta_{j0}\tau \exp(-\theta_{j1}\tau)$$

- Assume a simple structure for $\mathbf{\Gamma}$ and $\mathbf{\Sigma}$:

- Diagonal $\mathbf{\Gamma}$, except for feedback from r_{Ht} and r_{Ft} to γ_t ;
- Diagonal $\mathbf{\Sigma}$ (independent factors) except for correlation between r_{Ht} and r_{Ft} (observable).

Estimation via Method of Moments

Data: H: US, F: Eurozone. Zero coupon monthly data from Gurkaynak et al (2007) and Bundesbank; Trading volume data for US primary dealers.

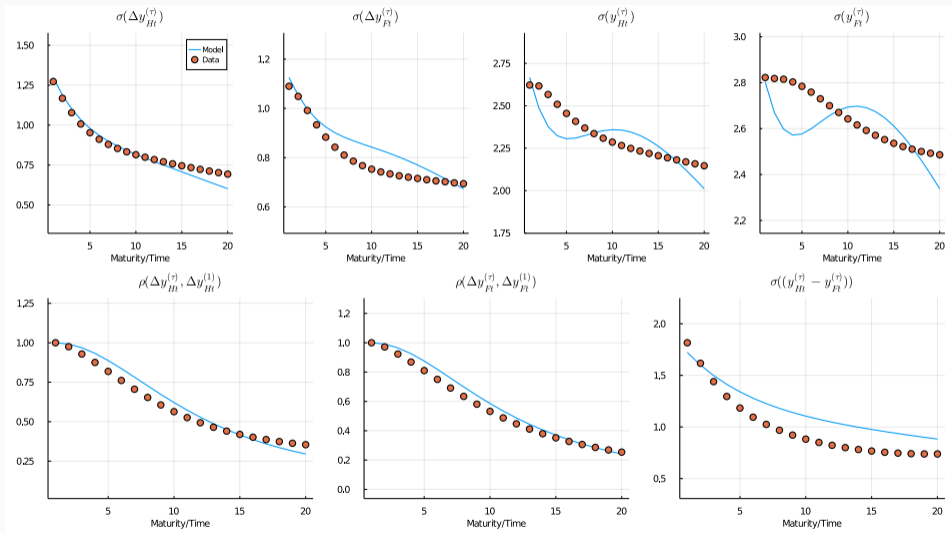
Targets:

- **Short rates:** $\text{Var}(y_j^{(1)}), \text{Var}(\Delta y_j^{(1)}), \text{Var}(y_H^{(1)} - y_F^{(1)})$
- **Long rates** (across maturities $\tau = 3\text{-month to } 20\text{-year}$):
 $\text{Var}(y_j^{(\tau)}), \text{Var}(\Delta y_j^{(\tau)}), \text{Cov}(\Delta y_j^{(\tau)}, \Delta y_j^{(1)}), \text{Var}(y_H^{(\tau)} - y_F^{(\tau)})$
- **Exchange rates:**
 $\text{Var}(\Delta \log e), \text{Cov}(\Delta \log e, \Delta y_j^{(1)}), \text{Cov}(\Delta \log e, y_H^{(1)} - y_F^{(1)}), \text{Cov}(\Delta^{(5)} \log e, y_H^{(5)} - y_F^{(5)})$
- **Trading volume:**
relative volume for US short maturities ($0 < \tau \leq 3$).

Model parameters estimated by minimizing distance between model-generated and empirical moments.

Note: α cannot be estimated independently of α 's and θ 's.

Model Fit



Model implies:

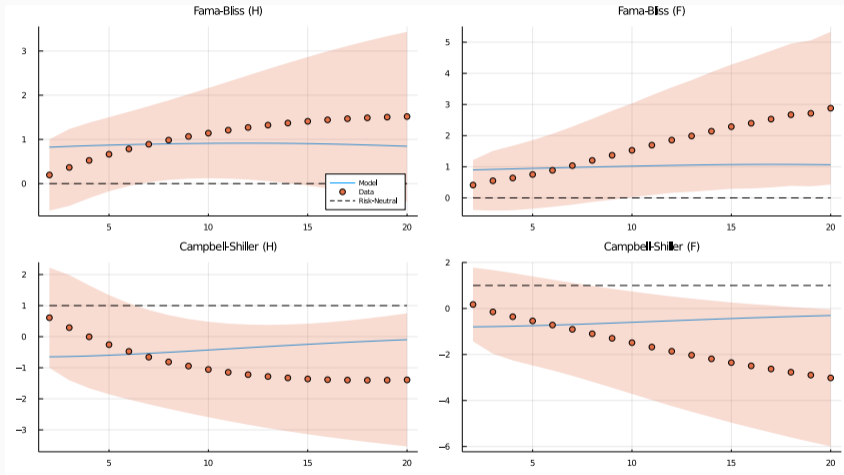
- positive coefficient in the Fama & Bliss (1987) regression ($b_{FB} = 0$ under EH):

$$\frac{1}{\Delta\tau} \log \left(\frac{P_{t+\Delta\tau}^{(\tau-\Delta\tau)}}{P_t^{(\tau)}} \right) - y_t^{(\Delta\tau)} = a_{FB} + b_{FB} \left(f_t^{(\tau-\Delta\tau, \tau)} - y_t^{(\Delta\tau)} \right) + e_{t+\Delta\tau}.$$

- coefficient smaller than 1 in the Campbell Shiller (1991) regression ($b_{CS} = 1$ under EH):

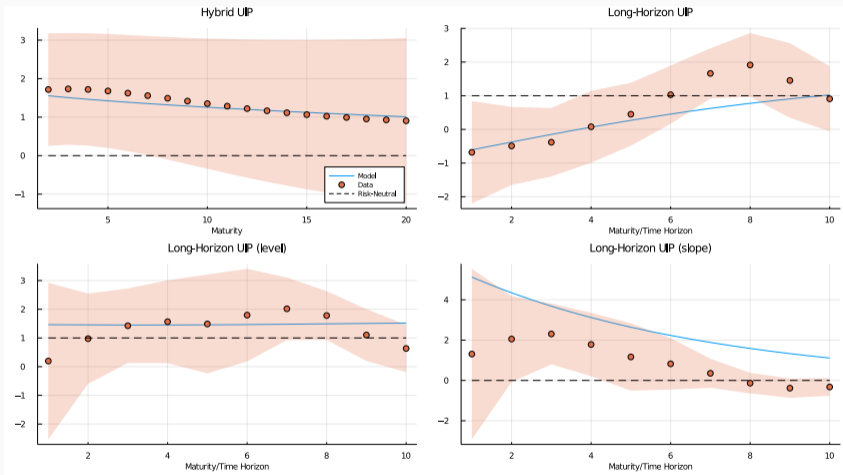
$$y_{t+\Delta\tau}^{(\tau-\Delta\tau)} - y_t^{(\tau)} = a_{CS} + b_{CS} \frac{\Delta\tau}{\tau - \Delta\tau} \left(y_t^{(\tau)} - y_t^{(\Delta\tau)} \right) + e_{t+\Delta\tau}.$$

Regression Coefficients: Term Structure



Implications: Positive slope-premia relationship.

Regression Coefficients: UIP



Implications: CCT is profitable, but profitability goes to zero if CCT is done with long-term bonds or over long horizon. Slope differential predicts CCT return.

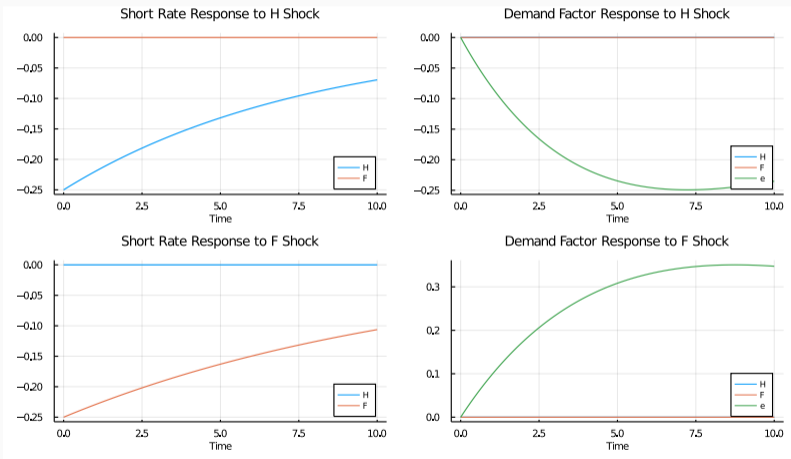
Conduct policy experiments:

- **Monetary policy shock:**
 - unanticipated 25bp decrease in policy rate (H and F)
 - half-life = 1 year
- **QE shock:**
 - unanticipated positive demand shock (H and F) that represents about 10% of GDP
 - half-life = 7 years
 - calibrate the risk aversion $a = \gamma/W$ so that W represents between 5% and 20% of GDP ($a = 10$ vs. $a = 40$).

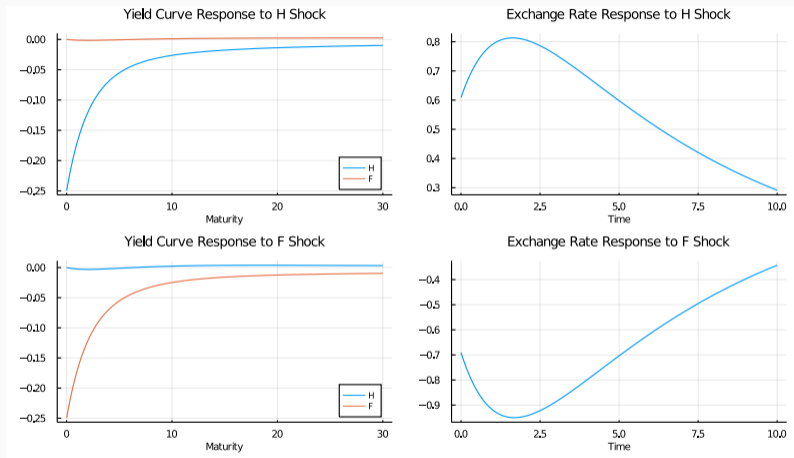
Examine **spillovers**:

- Across the yield curves (short and long rates; and across countries)
- To the exchange rate

Factor Responses to Monetary Shock

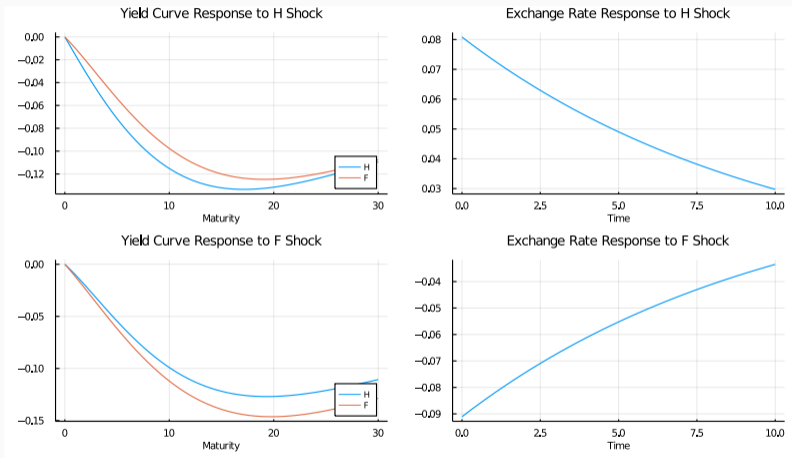


Monetary Shock Spillovers



Finding: Tiny cross-country spillover of conventional MP. Intuition: small α_j implies small changes in arbitrageurs' portfolios and small hedging demands.

QE Shock Spillovers, $\alpha = 10$



Implications: Large spillovers of QE, both to other country yields and exchange rate.

QE Shock Spillovers, $a = 40$



Implications: Large spillovers of QE, both to other country yields and exchange rate.

- Present an **integrated framework** to understand term premia and currency risk
- Tie together
 - Violations of UIP.
 - Violations of EH.
- Break the 'Friedman-Obstfeld-Taylor' Trilemma: monetary policy transmits to other countries via exchange rates and term premia.
- Extensions: (a) consider deviations from CIP, and (b) embed into New Keynesian open-economy model.