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

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Motivation

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

Motivation

- Consider standard international macroeconomics model:
  - EH and UIP hold, up to constant risk premia.
  - EH: yield curve in each country controlled by local short rate.
  - UIP: exchange rate absorbs deviations between short rates. 'Mundellian' insulation.
  - QE and FX interventions have no effect, at home and abroad.

- Casting doubt on the model:
  - Violations of UIP (Bilson 1981, Fama 1984). Profitability of currency carry trade (CCT).
  - Violations of EH (Fama-Bliss 1987, Campbell-Shiller 1991). Profitability of bond carry trade (BCT).
  - Risk premia in bond and currency markets are connected (Chen-Tsang 2013, Lustig-Stathopoulos-Verdelhan 2019, Chernov-Creal 2020, Lloyd-Marin 2020).
  - QE affects exchange rate and bond yields, at home and abroad.

This Paper

- Two-country model with partly segmented bond and currency markets.
  - Investor clienteles in each market.
  - Segmentation is partly overcome by risk-averse 'global rate arbitrageurs'.

- Replicate predictability patterns of bond and currency returns.
- Sharply different implications for monetary policy transmission than standard model.
  - QE purchases lower domestic and foreign bond yields and depreciate the currency.
  - Conventional policy is transmitted to domestic and foreign bond yields, but transmission to foreign yields is weaker than for QE.
- Findings are consistent with empirical disconnect between exchange rate and bond yields.

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) $P_{jt}^{(\tau)}$. Yield to maturity $y_{jt}^{(\tau)} = -\log P_{jt}^{(\tau)} / \tau$.
- Exogenous nominal short rate $i_{jt} = \lim_{\tau \to 0} y_{jt}^{(\tau)}$.

Arbitrageurs

- Wealth W_t (in H currency).
- W_{Ft} position in assets of country F (in H currency).
- $X_{jt}^{(\tau)} d\tau$ position in bonds of country j with maturities in $[\tau, \tau + d\tau]$ (in H currency).
- Instantaneous mean-variance optimization (limit of OLG model)

$$\max_{\{X_{Ht}^{(\tau)}, X_{Ft}^{(\tau)}\}_{\tau \in (0,T)}, W_{Ft}} \mathbb{E}_t(dW_t) - \frac{a}{2}\mathbb{V}\mathrm{ar}_t(dW_t).$$

- 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 of country j and maturity τ (in H 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 assets of country F (in H currency):

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

  - 'Demand for foreign currency.'
  - Currency demand elastic in the *real* exchange rate $e_t p_{Ft}/p_{Ht}$.

- Exogenous bond and currency demand risk factors: β_{jt} and γ_t.
  - Can accommodate correlation between bond and currency demand.

- 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

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

- Foreign currency

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

Risk Factors and Dynamics

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

- Linear mean-reverting dynamics

$$\mathrm{d}\mathrm{q}_t = \boldsymbol{\Gamma}\left(\overline{\mathrm{q}} - \mathrm{q}_t\right)\mathrm{d}t + \boldsymbol{\Sigma}\,\mathrm{d}\mathrm{B}_t\,,$$

  where

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

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

  $(\boldsymbol{\Gamma}, \boldsymbol{\Sigma})$ are 5×5 matrices, the eigenvalues of $\boldsymbol{\Gamma}$ are positive, and the Brownian motions are independent.

Simple Cases

1. Benchmark: Risk-Neutral Arbitrageurs

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

- EH holds:

$$\mathbb{E}_t dP^{(\tau)}_{Ht} / P^{(\tau)}_{Ht} = i_{Ht} \quad ; \quad \mathbb{E}_t dP^{(\tau)}_{Ft} / P^{(\tau)}_{Ft} = i_{Ft}.$$

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

- UIP holds:

$$\mathbb{E}_t de_t / e_t = i_{Ht} - i_{Ft}.$$

  - '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 ($\beta_{jt} = \gamma_t = 0$) and diagonal $(\boldsymbol{\Gamma}, \boldsymbol{\Sigma})$.

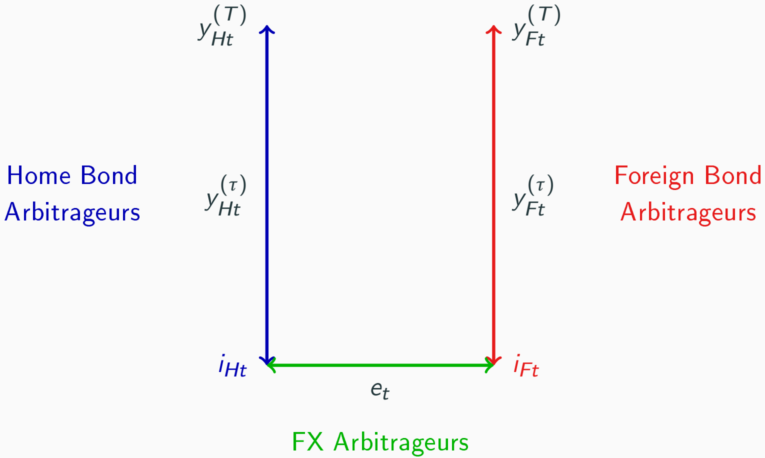
- Short rates i_{Ht} and i_{Ft} are independent.
- Write short-rate process as

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

- 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. UIP Deviations and CCT

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

Proposition (Segmented Arbitrage, UIP Deviations and CCT)

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-Maggiori 2015.

- when $i_{Ft} \uparrow$, arbitrageurs want to invest more in the CCT.
- Foreign currency appreciates ($e_t \uparrow$).
- As $e_t \uparrow$, price-elastic currency traders reduce holdings ($\alpha_e > 0$): $Z_{et} \downarrow$.
- Currency arbitrageurs increase their holdings $W_{Ft} \uparrow$, which requires a higher CCT return.

2.b. EH Deviations and BCT

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

Proposition (Segmented Arbitrage, EH Deviations and BCT)

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}.
  (EH deviation)

Intuition: Similar to Vayanos-Vila 2021.

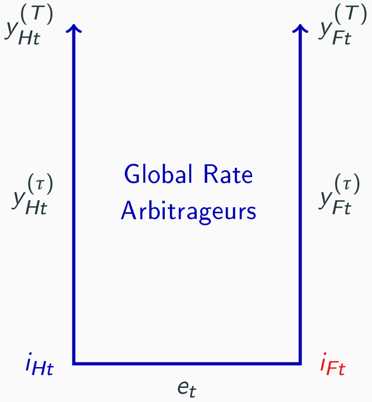
- When $i_{jt} \downarrow$, arbitrageurs want to invest more in the BCT.
- Bond prices increase $(P_{jt}^{(\tau)} \uparrow)$.
- As $P_{jt}^{(\tau)} \uparrow$, price-elastic habitat bond investors $(\alpha_j(\tau) > 0)$ reduce holdings: $Z_{jt}^{(\tau)} \downarrow$.
- Bond arbitrageurs increase their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

QE, FX Interventions

Assume $a > 0$.

- 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.

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



UIP/EH deviations and Carry Trades

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: BCT_F increases with i_{Ht}.

Intuition: Bond and currency 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 ($\text{BCT}_j \downarrow$).

⚠ Reduces yields in the other country (when $\alpha_e > 0$), and depreciates the currency ($\text{BCT}_{j'} \downarrow$, 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 ($\text{BCT}_H \downarrow$) and increases them in Foreign ($\text{BCT}_F \uparrow$).

  - 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.
- FX interventions in one country affect yield curves in both countries.
- Imperfect insulation even with floating rates.
- Failure of the Classical Trilemma.

The Full Model

The Full Model: Adding Demand Shocks

- Recall the 5-factor dynamics

$$\mathrm{d}\mathrm{q}_t = \boldsymbol{\Gamma}\left(\overline{\mathrm{q}} - \mathrm{q}_t\right)\mathrm{d}t + \boldsymbol{\Sigma}\,\mathrm{d}\mathrm{B}_t\,,$$

where

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

- Postulate affine solution:

$$-\log P_{jt}^{(\tau)} = \mathrm{q}_t^T \mathrm{A}_j(\tau) + C_j(\tau) \quad ; \quad -\log e_t = \mathrm{q}_t^T \mathrm{A}_e + C_e.$$

- Parametrize Demand Functions:

$$\alpha_j(\tau) \equiv \alpha_{j0}\exp(-\alpha_{j1}\tau) \quad ; \quad \theta_j(\tau) \equiv \theta_{j0}\theta_{j1}^2\tau\exp(-\theta_{j1}\tau).$$

- Assume a simple structure for $\boldsymbol{\Gamma}$ and $\boldsymbol{\Sigma}$:
  - Diagonal $\boldsymbol{\Gamma}$, except for feedback from i_{Ht} and i_{Ft} to γ_t;
  - Diagonal $\boldsymbol{\Sigma}$ (independent factors) except for correlation between i_{Ht} and i_{Ft} (observable).

Estimation via Maximum Likelihood

Data: H: US, F: Eurozone. Quarterly data on dollar/euro exchange rate, US and German bond yields, 06/1986-04/2021.

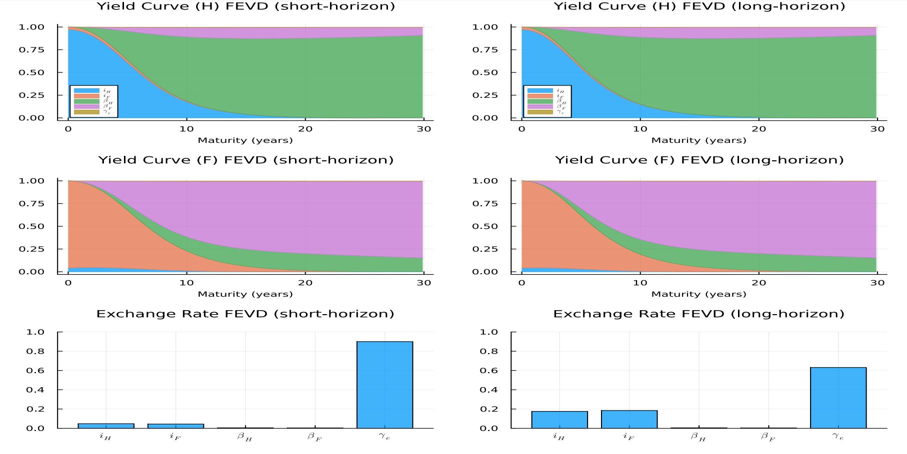
Procedure:

- Discretize process for risk factors q_t.
- Observe $K \times 1$ vector $\mathrm{p}_t = A(\mathrm{q}_t - \overline{\mathrm{q}})$ of demeaned log exchange rate and bond yields.
- Deduce discrete dynamics of p_t and maximize log-likelihood.
- GMM yields similar estimates.

Notes:

- a cannot be estimated independently of α's and θ's. Calibrate $a = \gamma/W$ so that W represents between 5% and 20% of GDP ($a = 10$ vs. $a = 40$).
- (α_1, θ_1) not well identified. Need data on trading volume, which is not affine in q_t. Take (α_1, θ_1) from GMM or previous literature. Results are insensitive to (α_1, θ_1).
- Twelve parameters left to estimate: $(\kappa_{iH}, \kappa_{iF}, \sigma_{iH}, \sigma_{iF}, \sigma_{iH,iF})$ (short rate), $(\alpha_0, \kappa_\beta, \theta_0 \sigma_\beta)$ (bonds), and $(\alpha_e, \kappa_\gamma, \theta_e \kappa_{\gamma,iH}, \theta_e \kappa_{\gamma,iF}, \theta_e \sigma_\gamma)$ (currency).

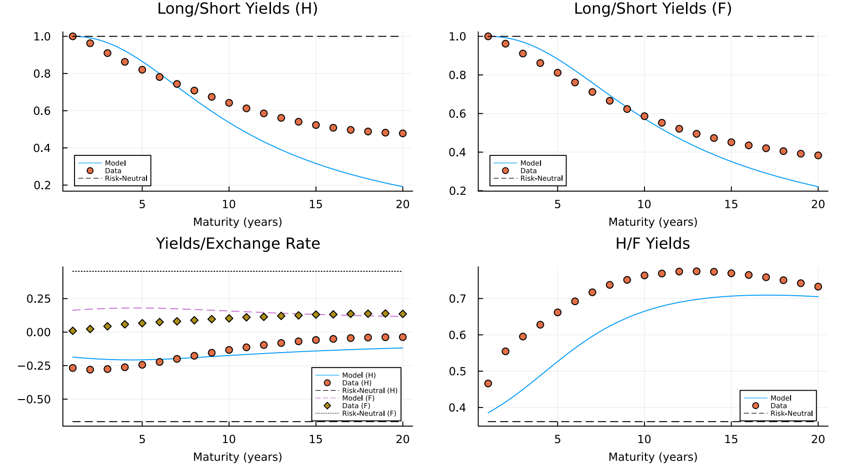
Variance Decomposition of Bond and Currency Returns



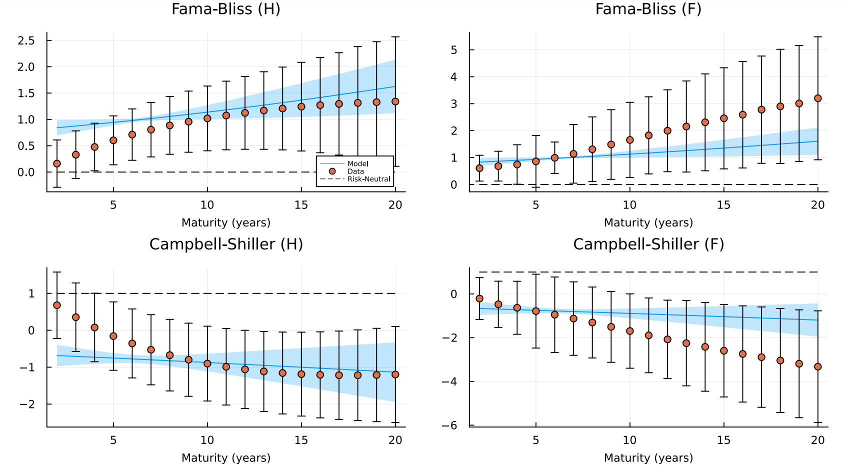
⚠ Long-maturity bond yields are connected across countries but are disconnected from the exchange rate. Yet, transmission of bond demand shocks occurs through currency market.

Intuition: Endogenous comovement arising from demand shocks.

Correlations Between Bond Yields and Exchange Rate

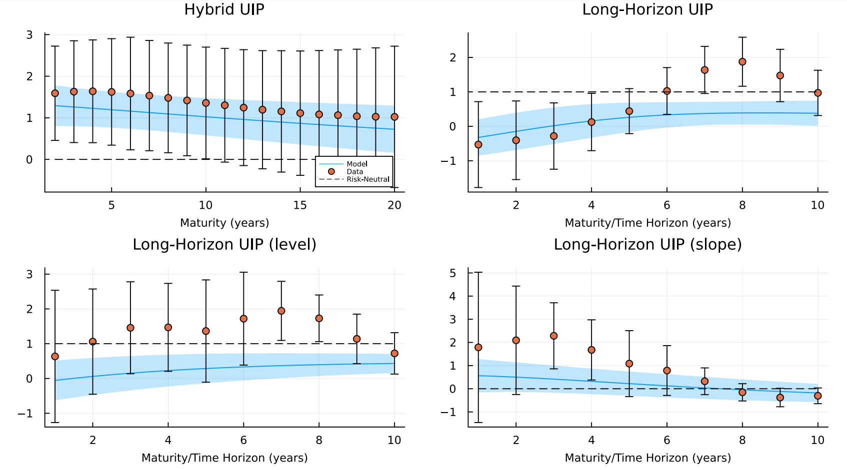


Regression Coefficients: EH



Positive slope-premia relationship.

Regression Coefficients: UIP



CCT's profitability declines if done with long-term bonds or over long horizon. Slope differential predicts CCT return.

Policy Spillovers

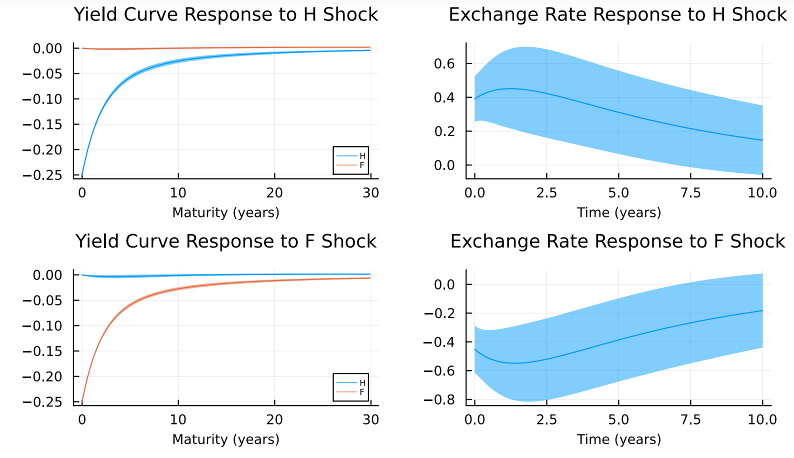
Conduct policy experiments:

- Monetary policy shock:
  - Unanticipated 25bp decrease in short rate (H or F).
  - Half-life = 1 year.
- QE shock:
  - Unanticipated positive demand shock (H or F) that represents about 10% of GDP.
  - Half-life = 7 years.
- Foreign exchange intervention:
  - Unanticipated purchases of foreign currency by central bank (home or foreign) that represents about 10% of GDP.
  - Half-life = 1 year.

Examine spillovers:

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

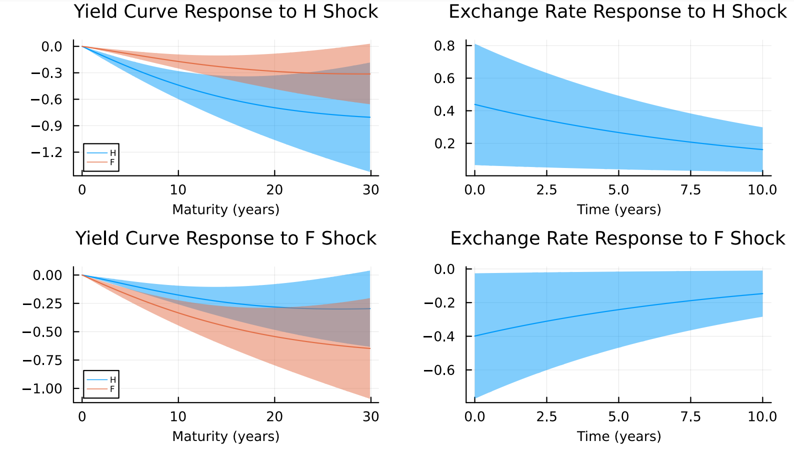
Monetary Shock Spillovers



Small spillover of conventional MP to international yields.

Intuition: Exchange rate is disconnected from long-maturity bond yields.

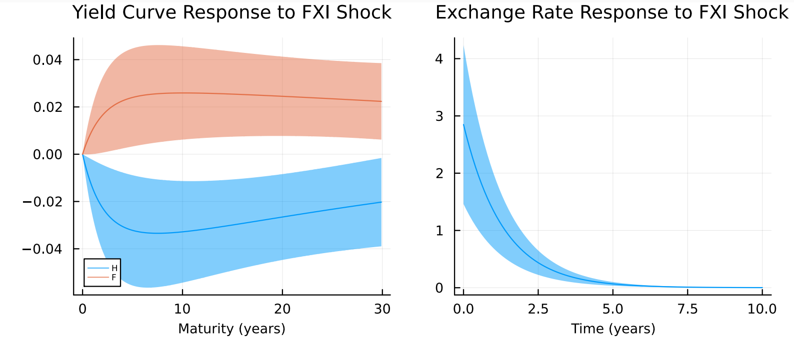
QE Shock Spillovers, $a = 40$



Large spillover of QE to international yields. Smaller spillovers to exchange rate.

Intuition: QE affects bond positions directly, and bond yields are connected across countries.

FXI Shock Spillovers, $a = 40$



Small spillovers of FXI to yields.

Intuition: Exchange rate is disconnected from long-maturity bond yields.

Conclusion

- Present an integrated framework to understand bond and currency risk premia.
- Tie together
  - Violations of UIP.
  - Violations of EH.
- Break the Classical Trilemma: monetary policy transmits to other countries via exchange rates and term premia.
- Next step: Embed into New Keynesian open-economy model.