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?

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- 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).

Motivation

- 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 'global rate arbitrageur' able to invest in fixed-income and currency market (global hedge fund, fixed income desk of broker-dealer, multinational corporation, 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.

Findings

1. Can reproduce qualitative facts about bond and currency risk premia
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) $i_{jt} = \lim_{\tau \to 0} y_{jt}^{(\tau)}$:

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

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]
- Global rate arbitrageurs
  [trade both currencies, and bonds of both countries and all maturities]

Global 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)

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

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

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

  - $\theta_j(\tau) \geq 0, \beta_{jt} > 0 \iff$ decrease in net demand for bonds of maturity τ.
- Demand for foreign currency (spot) (in Home currency):

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

  - 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: risk factors $dB_{\beta jt}$ and $dB_{\gamma t}$.
- Assume constant inflation rates π_F and π_H. Non-stationary nominal exchange rate.

Key insight: Price-elastic habitat traders change their positions in response to price changes.

Market Clearing

- Home bonds

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

- Foreign bonds

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

- Currency Market

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

- 5 risk factors: short rates (dB_{ijt}), bond demands ($dB_{\beta jt}$) and currency demand ($dB_{\gamma t}$)

Risk Neutral Global Rate Arbitrageur (aka Standard Model)

1. Benchmark: Risk Neutral Arbitrageurs

Suppose 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:

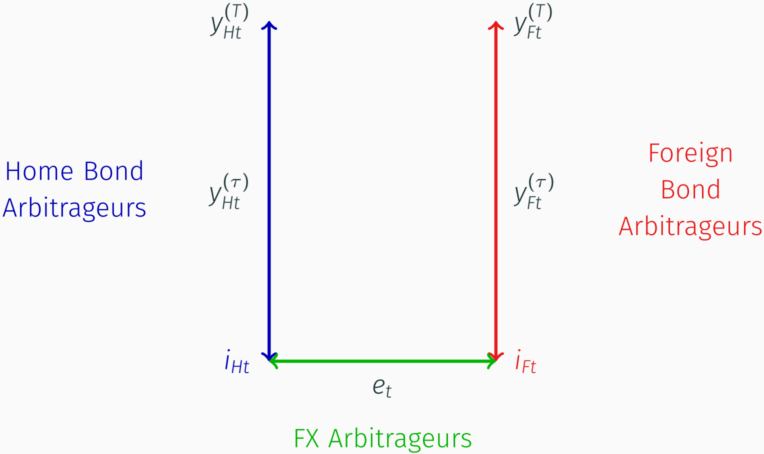
$$\frac{1}{dt}\mathbb{E}_t \frac{de_t}{e_t} = i_{Ht} - i_{Ft} \quad ; \quad \log e_t = \frac{i_{Ft}}{\kappa_{iF}} - \frac{i_{Ht}}{\kappa_{iH}} + (\pi_H - \pi_F)t - C_e$$

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

Segmented Arbitrage

2. Segmented Arbitrage and No Demand Shocks ($\beta_{jt} = \gamma_t = 0$)

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



Assume also that i_{Ht} and i_{Ft} are independent.

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)

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: $A_{ij}(\tau) < (1 - e^{-\kappa_{ij}\tau})/(\tau\kappa_{ij})$.
- Bond prices in country j only respond to country j short rates (no spillover).
- 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.

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

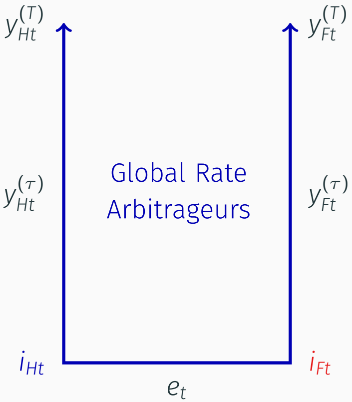
- A country with a permanently higher real rate $\bar{i}_j - \pi_j$ has a permanently stronger currency, lower demand from currency traders, and a permanently higher currency risk premium.

$\Longrightarrow$ Differences in long run real rates absorbed into currency risk premium.

Global Rates Arbitrageur

3. Global Rate Arbitrage and No Demand Shocks ($\beta_{jt} = \gamma_t = 0$)

Assume now global rate arbitrageur can invest in bonds (H and F) and FX.



Assume i_{Ht} and i_{Ft} are independent.

3. Global Rate Arbitrageur and No Demand Shocks ($\beta_{jt} = \gamma_t = 0$)

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 bonds 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.

Empirical Implications: Generalized and Long-Horizon Carry Trade

Generalized Carry Trade (GCT)

Generalized version of CCT using τ bonds instead of short term rate (Lustig et al, 2019).

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

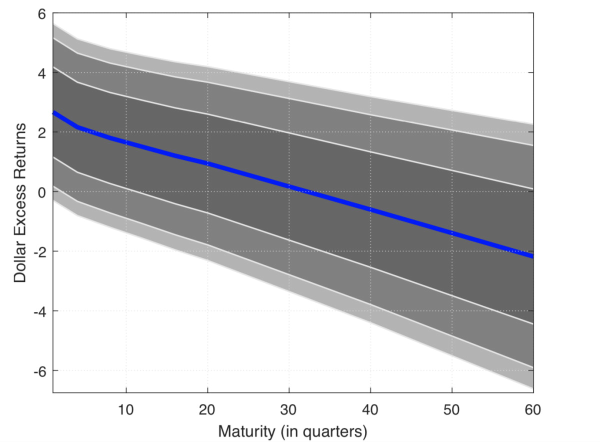
Proposition (Generalized Carry Trade)

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

- Decreases in the home country short rate i_{Ht} and increases in the foreign country short rate i_{Ft}
- Declines (in absolute value) with maturity τ and converge 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 GCT.

Generalized Carry Trade (in the Cross-Section)



From Lustig et al. (2019):

dollar log-excess return on long minus short bond risk premia, as a function of bond maturity.

3-months holding period, zero coupon bond.

Long-Horizon Currency Carry Trade (LCCT)

Long-horizon currency carry trade (LCCT) is the expected return on foreign vs home long bond yields (in home currency):

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

Proposition (Long-Horizon Carry Trade)

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

Implication: Long-horizon UIP holds, as in the data (Chinn & Meredith 2004).

The Full Model

The Full Model: Adding Demand Shocks $\beta_{jt} \neq 0$, $\gamma_t \neq 0$

- Allow for rich demand structure embodied in VCV of risk factors. DGP:

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

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

Postulate affine solution:

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

- Parametrize Demand Functions:

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

- Consider a simple structure for $\boldsymbol{\Gamma}$ and $\boldsymbol{\Sigma}$:
    - diagonal $\boldsymbol{\Gamma}$;
    - correlated short rates, i_{Ht}, i_{Ft}: $\Sigma_{i_H i_F} \neq 0$;
    - independent demand factors.

Estimation via Simulated Method of Moments

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

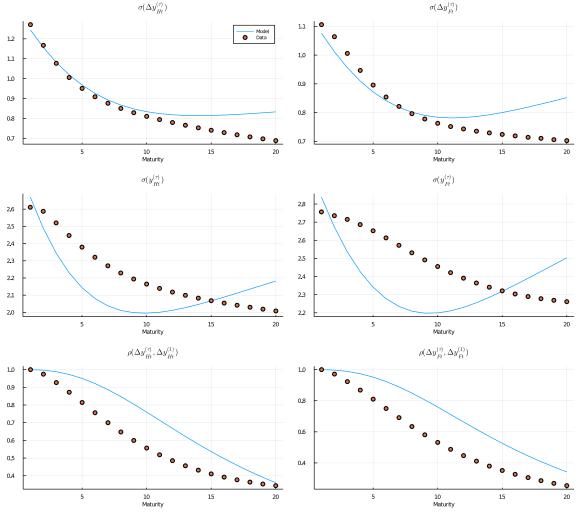
Targets:

- Short rates: $\mathbb{V}\text{ar}(y_j^{(1)})$ (detrended), $\mathbb{V}\text{ar}(\Delta y_j^{(1)})$, $\mathbb{C}\text{ov}(\Delta y_H^{(1)}, \Delta y_F^{(1)})$
- Exchange rates: $\mathbb{V}\text{ar}(\Delta \log e)$, $\mathbb{C}\text{ov}(\Delta \log e, \Delta^2 \log e)$, $\mathbb{C}\text{ov}(\Delta \log e, \Delta y_H^{(1)} - \Delta y_F^{(1)})$.
- Long rates (across maturities $\tau = 3$-month to 20-year): $\mathbb{V}\text{ar}(y_j^{(\tau)})$ (detrended),$\mathbb{V}\text{ar}(\Delta y_j^{(\tau)})$, $\mathbb{C}\text{ov}(\Delta y_j^{(\tau)}, \Delta y_j^{(1)})$,
- Trading volume: relative volume for US short maturities ($0 < \tau \leq 3$).

Model parameters estimated by SMM.

Note: a cannot be estimated independently.

Baseline Model Fit



Model implies:

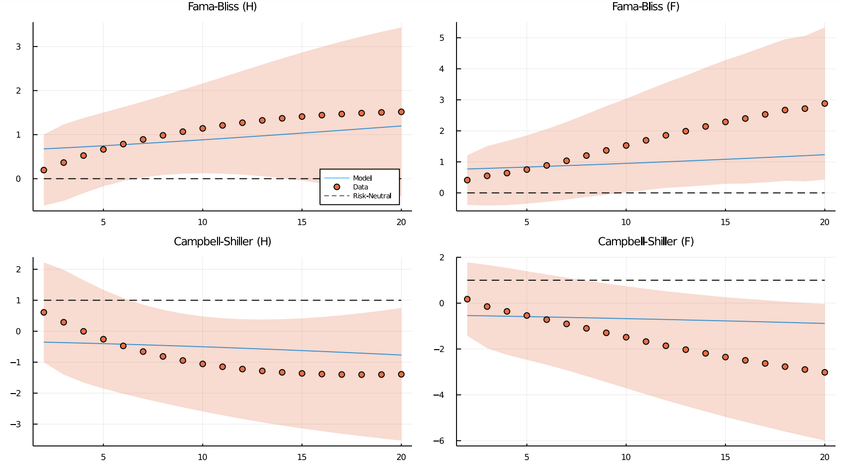
- positive coefficient in the Fama & Bliss (1987) regression ($b_{\text{FB}} = 0$ under EH):

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

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

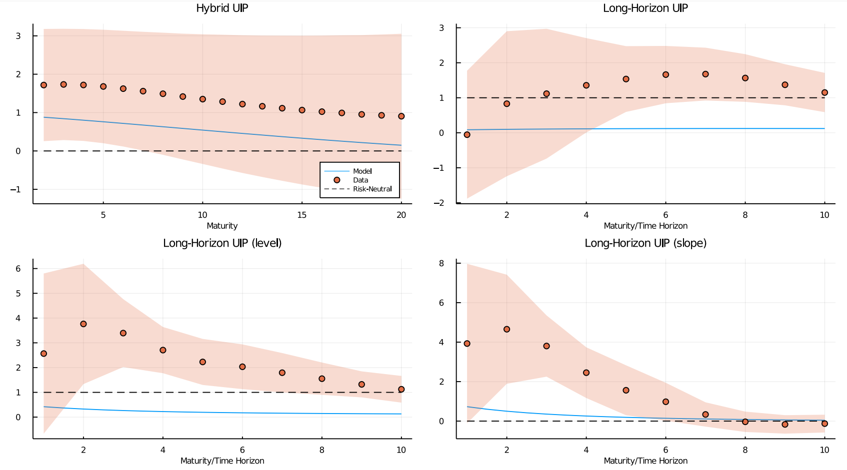
$$y_{t+\Delta\tau}^{(\tau-\Delta\tau)} - y_t^{(\tau)} = a_{\text{CS}} + b_{\text{CS}}\frac{\Delta\tau}{\tau-\Delta\tau}\left(y_t^{(\tau)} - y_t^{(\Delta\tau)}\right) + e_{t+\Delta\tau}.$$

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.

Policy Spillovers under the baseline model

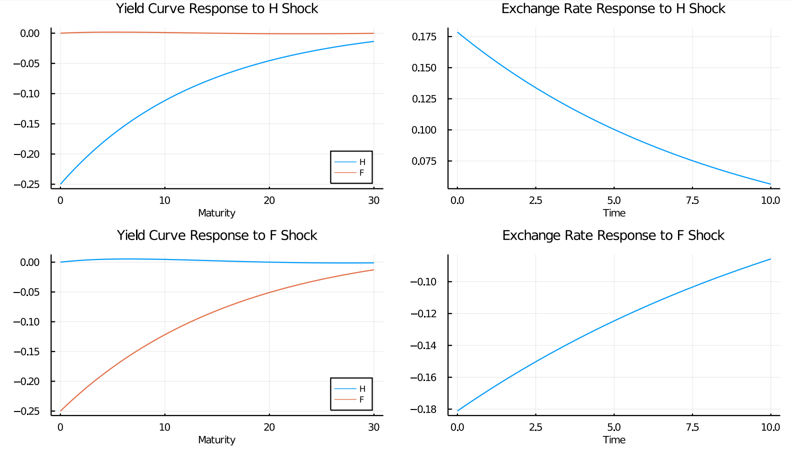
Conduct policy experiments:

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

Examine spillovers:

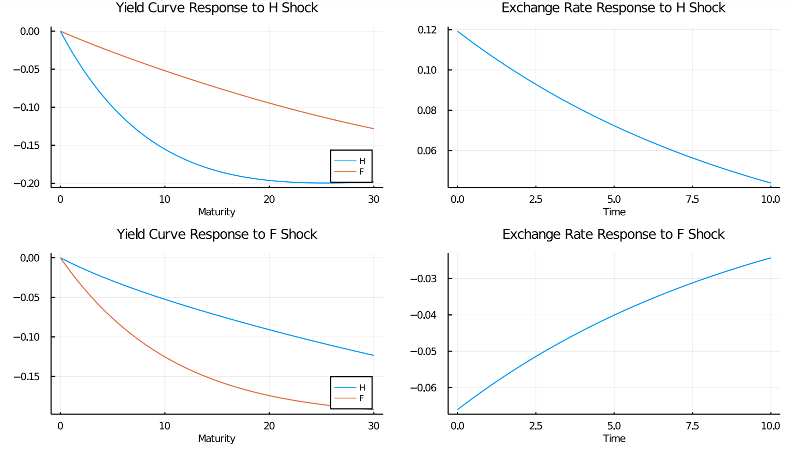
- Across the yield curves (short and long rates; and across countries)
- To the exchange rate

Monetary Shock Spillovers - Baseline Model



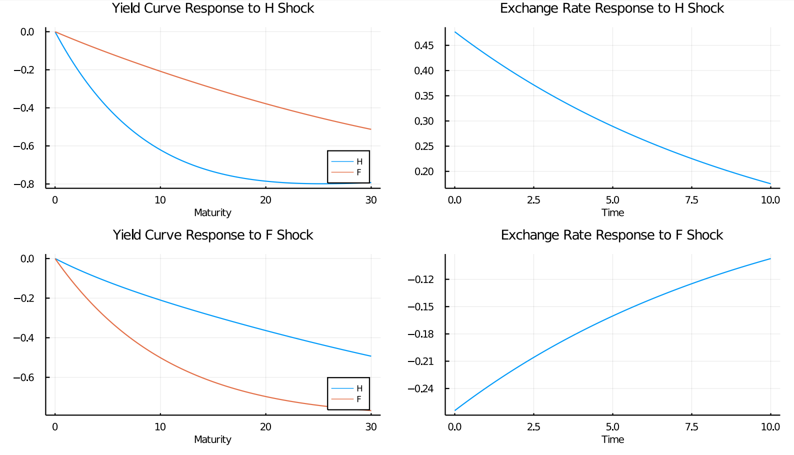
Finding: Tiny cross-country spillover of conventional MP. Intuition: small α_j implies little change in arb's portfolios and small hedging demands.

QE Shock Spillovers, $a = 10$



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.

Conclusion

- Present an integrated framework to understand term premia and currency risk
- Extend Vayanos & Vila (2021) to a two-country environment
- Resulting model ties together
    - Violations of UIP.
    - Violations of EH.
- Allow rich demand specification.
- Break the 'Friedman-Obstfeld-Taylor' Trilemma: monetary policy transmits to other countries via exchange rates and term premia.
- Extensions: (a) endogenize policy rates as in Ray (2019); (b) consider deviations from LOP as in Hebert Du & Wang (2019); (c) embed into New Keynesian open-economy model.