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

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Motivation

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- Textbook international macro:
  - Uncovered Interest Parity (UIP) holds
  - The Expectation Hypothesis (EH) holds

- Empirically:
  1. Strong patterns in FX: currency carry trade is profitable $\implies$ deviations from UIP
     [Fama 1984...]
  2. Strong patterns in FI: bond carry trade is profitable $\implies$ deviations from the EH
     [Fama & Bliss 1987, Campbell & Shiller 1991...]
  3. The two risk premia are deeply connected
     [Lustig et al 2019, Lloyd & Marin 2019, Chernov & Creal 2020...]
  4. Quantitative easing not only reduced domestic yields, but also had strong effects on exchange rates and foreign yields
     [Bhattarai & Neely 2018...]

Motivation

- Making sense of these facts is important:
  - To understand what determines exchange rates (volatility, disconnect...)
  - To understand monetary policy transmission, both domestically (along the yield curve)...
  - ...but also via international spillovers, to exchange rates and foreign yields
- This paper: introduce risk averse 'global rate arbitrageur' absorbing supply and demand shocks in bond and currency markets
  - FX and bond markets populated by different investor clienteles (pension funds, importers/exporters)
  - Arbitrageurs (hedge funds, dealer fixed income desk) partly overcome segmentation
- Formally: Two-country version of Vayanos & Vila's (2021) preferred-habitat model
  - More generally, we build on a literature emphasizing the optimization of financial intermediaries and the constraints they face
    [Gabaix & Maggiori 2015, Itskhoki & Mukhin 2019, Koijen & Yogo 2020, Greenwood et al 2023...]
  - Revives an older literature on portfolio-balance
    [Kouri 1982, Jeanne & Rose 2002...]

Findings

1. Can reproduce qualitative and quantitative facts about the joint behavior of bond and currency risk premia

2. Rich transmission of monetary policy shocks via exchange rate and term premia, contrasting with standard models

3. Key mechanisms:
   - Shifts in arbitrageurs' risk exposure lead to changes in required risk compensation
   - Hedging behavior of global arbitrageurs $\implies$ tight linkage between bond term premia and currency risk premia
   - In the presence of market segmentation, policy shocks (particularly unconventional) lead to large shifts in risk exposure

4. General message: floating exchange rates provide limited insulation.
   Failure of Friedman-Obtsfeld-Taylor's Trilemma

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 $y_{jt}^{(\tau)} = -\log P_{jt}^{(\tau)} / \tau$
- Nominal short rate ("monetary policy") $i_{jt} = \lim_{\tau \to 0} y_{jt}^{(\tau)}$ follows (exogenous, stochastic) mean-reverting process

Investors

- Home and foreign preferred-habitat bond investors
  (hold bonds in a specific currency and maturity: $Z_{jt}(\tau)$)
  - Eg, pension funds, money market mutual funds
  - Time-varying demand β_{jt}, downward sloping in terms of bond price (elasticity $\alpha_j(\tau)$)

- Preferred-habitat currency traders
  (hold foreign currency: Z_{et})
  - Eg, importers/exporters
  - Time-varying demand γ_t, downward sloping in terms of exchange rate (elasticity α_e)

- Global rate arbitrageurs
  (can trade in both currencies, in domestic and foreign bonds: $W_{Ft}, X_{Ht}(\tau), X_{Ft}(\tau)$)
  - Eg, global hedge funds
  - Mean-variance preferences (risk aversion a)
  - Engage in currency carry trade, domestic and foreign bond carry trade

Global Rate Arbitrageur: Details

- Mean-variance optimization (limit of OLG model)

$$\max \mathbb{E}_t(\mathrm{d}W_t) - \frac{a}{2}\mathbb{V}\mathrm{ar}_t(\mathrm{d}W_t)$$

$$\text{s.t. } \mathrm{d}W_t = W_t i_{Ht}\,\mathrm{d}t + W_{Ft}\left(\frac{\mathrm{d}e_t}{e_t} + (i_{Ft} - i_{Ht})\,\mathrm{d}t\right) + \int_0^T X_{Ht}^{(\tau)}\left(\frac{\mathrm{d}P_{Ht}^{(\tau)}}{P_{Ht}^{(\tau)}} - i_{Ht}\,\mathrm{d}t\right)\mathrm{d}\tau + \int_0^T X_{Ft}^{(\tau)}\left(\frac{\mathrm{d}(P_{Ft}^{(\tau)}e_t)}{P_{Ft}^{(\tau)}e_t} - \frac{\mathrm{d}e_t}{e_t} - i_{Ft}\,\mathrm{d}t\right)\mathrm{d}\tau$$

- Wealth W_t:
  - W_{Ft} invested in country F short rate (CCT)
  - $X_{jt}^{(\tau)}$ invested in bond of country j and maturity τ (BCT_j)
  - Remainder in country H short rate

Key Insight: Risk averse arbitrageurs' holdings increase with expected return

Preferred-Habitat Bond and FX Investors: Details

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

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

  - $\alpha_j(\tau)$: demand elasticity for τ investor in country j
  - $\theta_j(\tau)$: how variations in factor β_{jt} affect demand for τ investor in country j

- Demand for foreign currency (spot):

$$Z_{et} = -\alpha_e \log e_t - \theta_e \gamma_t$$

  - Can accommodate forward demand. Under CIP, equivalent to spot + H and F bond trades

- Exogenous bond and FX demand risk factors follow (exogenous, stochastic) mean-reverting processes

Key Insight: elastic habitat traders. Price movements require portfolio rebalancing

Dynamics

- Risk factors: short rates ($\mathrm{d}B_{ijt}$), bond demands ($\mathrm{d}B_{\beta jt}$) and currency demand ($\mathrm{d}B_{\gamma t}$)
- State variables collected into vector $\mathbf{q}_t = \begin{bmatrix} i_{Ht} & i_{Ft} & \beta_{Ht} & \beta_{Ft} & \gamma_t \end{bmatrix}^\top$
- Dynamics:

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

- Affine solution:

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

Equilibrium

- Arbitrageurs' optimality conditions imply expected excess returns are given by:

$$\mathbb{E}_t \, \mathrm{d}P_{jt}^{(\tau)} / P_{jt}^{(\tau)} - i_{jt} = \mathbf{A}_j(\tau)^\top \boldsymbol{\Lambda}_t, \quad \mathbb{E}_t \, \mathrm{d}e_t / e_t + i_{Ft} - i_{Ht} = \mathbf{A}_e{}^\top \boldsymbol{\Lambda}_t$$

$$\text{where} \quad \boldsymbol{\Lambda}_t = a\boldsymbol{\Sigma} \left(W_{Ft}\mathbf{A}_e + \sum_{j=H,F} \int_0^T X_{jt}\mathbf{A}_j(\tau) \, \mathrm{d}\tau \right)$$

- Endogenous coefficients $\mathbf{A}_j(\tau), \mathbf{A}_e$ govern sensitivity to market price of risk $\boldsymbol{\Lambda}_t$
- Model is closed through market clearing: $X_{jt}^{(\tau)} + Z_{jt}^{(\tau)} = 0, \; W_{Ft} + Z_{et} = 0$

Key Insight: market price of risk $\boldsymbol{\Lambda}_t$ depends on equilibrium holdings. Bond and currency premia jointly determined

details

Data Generating Process: Assumptions

- In order to derive analytical results, we assume independent short-rate processes, and non-stochastic demand factors:

$$\mathrm{d}i_{Ht} = \kappa_{iH}(\bar{i}_H - i_{Ht})\,\mathrm{d}t + \sigma_{iH}\mathrm{d}B_{iHt}, \quad \mathrm{d}i_{Ft} = \kappa_{iF}(\bar{i}_F - i_{Ft})\,\mathrm{d}t + \sigma_{iF}\mathrm{d}B_{iFt}$$

- For quantitative results, we can allow for rich demand structure embodied in dynamics of risk factors. DGP:

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

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

Risk Neutral Global Arbitrageur

1. Benchmark: Risk Neutral Global Rate Arbitrageur (“Standard Model”)

Consider the benchmark case of a risk neutral global rate arbitrageur: $a = 0$

- Expectation Hypothesis holds:

$$\mathbb{E}_t \, \mathrm{d}P_{Ht}^{(\tau)} / P_{Ht}^{(\tau)} = i_{Ht}, \quad \mathbb{E}_t \, \mathrm{d}P_{Ft}^{(\tau)} / P_{Ft}^{(\tau)} = i_{Ft}$$

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

- Uncovered Interest Parity holds:

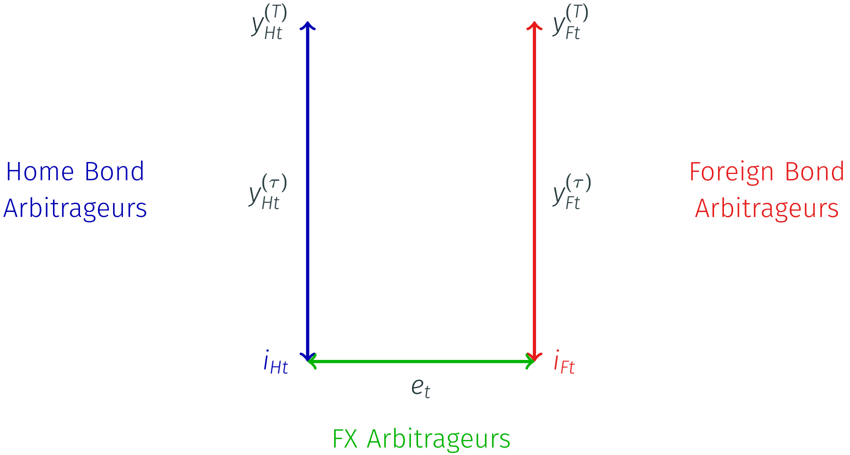
$$\mathbb{E}_t \, \mathrm{d}e_t / e_t = i_{Ht} - i_{Ft}$$

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

Segmented Arbitrage

2. Intermediate Step: Segmented Arbitrage and No Demand Shocks

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



2. Intermediate Step: Segmented Arbitrage and No Demand Shocks

Postulate: $\log P_{jt}^{(\tau)} = -A_{ij}(\tau) i_{jt} - C_j(\tau)$; $\log e_t = A_{iFe} i_{Ft} - A_{iHe} i_{Ht} - C_e$

Proposition (Segmented Arbitrage, Currency Carry Trade CCT 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 $\mathbb{E}_t \, \mathrm{d}e_t / e_t + i_{Ft} - i_{Ht}$ decreases in i_{Ht} and increases in i_{Ft} (UIP deviation)

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

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

2. Intermediate Step: Segmented Arbitrage and No Demand Shocks

Proposition (Segmented Arbitrage and Bond Carry Trade 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 spillover)
- BCT_j expected return $\mathbb{E}_t \, \mathrm{d}P_{jt}^{(\tau)} / P_{jt}^{(\tau)} - i_{jt}$ decreases in i_{jt}

Intuition: Similar to Vayanos & Vila (2021)

- When $i_{jt} \downarrow$, bond 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 their holdings: $Z_{jt}^{(\tau)} \downarrow$
- Bond arbitrageurs increase their holdings $X_{jt}^{(\tau)} \uparrow$, which requires a larger BCT return

Macro Implications of the Segmented Model

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

- Unexpected increase in bond demand in country j (QE_j) reduces yields in country j
- No effect on bond yields in the other country or on the exchange rate
  - QE purchases: $Z_{jt}^{(\tau)} \uparrow$
  - Bond arbitrageurs reduce holdings $X_{jt}^{(\tau)} \downarrow$, reducing risk exposure and pushing down yields
  - Arbitrageurs in other markets are unaffected

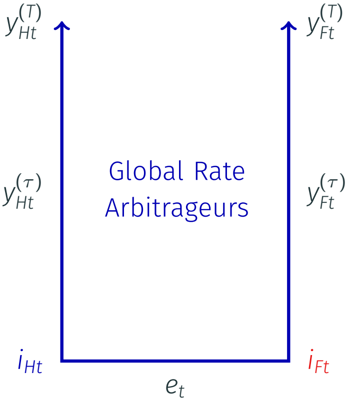
Open Economy Macro Implications:

- 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? As we will see, this result arises because of markets segmentation (limited capital flows), not because of floating exchange rates

Global Arbitrage

3. Global Rate Arbitrageur and No Demand Shocks

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



3. Global Rate Arbitrageur and No Demand Shocks

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

Proposition (Global Arbitrage and Carry Trades CCT, BCT)

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

- The results of the previous propositions obtain: both CCT and BCT_H return decrease with i_{Ht}, and attenuation is stronger than with segmented markets
- ⚠ In addition, BCT_F increases with i_{Ht}
- The effect of i_{jt} on bond yields is smaller in the other country: $A_{jj'}(\tau) < A_{jj}(\tau)$

Intuition: Bond and FX Premia Cross-Linkages

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

Macro Implications of Global Rate Arbitrageur Model

Assume $a > 0$ and $\alpha_e, \alpha_j(\tau) > 0$:

- Unexpected QE_H reduces yields in country H
- ⚠ Also reduces yields in country F, and depreciates the Home currency
  - Arbitrageurs decrease H bond exposure (less exposed to risk of $i_{Ht} \uparrow$)
  - More willing to hold assets exposed to this risk: increase holdings of F bonds and currency, pushing down F yields and depreciating the H currency

Open Economy Macro Implications:

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

The Full Model

The Full Model: Adding Demand Shocks

- Now we allow for richer demand structure of risk factors:

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

  - We assume independent processes for all factors, except shocks to short rates may be correlated, and currency demand γ_t may respond to short rates

$$\mathbf{\Gamma} = \begin{bmatrix} \kappa_{iH} & 0 & 0 & 0 & 0 \\ 0 & \kappa_{iF} & 0 & 0 & 0 \\ 0 & 0 & \kappa_{\beta} & 0 & 0 \\ 0 & 0 & 0 & \kappa_{\beta} & 0 \\ \kappa_{\gamma,iH} & \kappa_{\gamma,iF} & 0 & 0 & \kappa_{\gamma} \end{bmatrix}, \quad \boldsymbol{\sigma} = \begin{bmatrix} \sigma_{iH} & 0 & 0 & 0 & 0 \\ \sigma_{iH,iF} & \sigma_{iF} & 0 & 0 & 0 \\ 0 & 0 & \sigma_{\beta} & 0 & 0 \\ 0 & 0 & 0 & \sigma_{\beta} & 0 \\ 0 & 0 & 0 & 0 & \sigma_{\gamma} \end{bmatrix}$$

- Numerical estimation
  - Data: Zero coupon data: US Treasuries (H) and German Bunds (F); exchange rate data: German mark/euro
  - Time period: 1986-2021 (due to availability of long-term yields)
  - Main estimation strategy: Maximum likelihood (MLE)
  - Alternative: classical minimum distance (CMD) targeting second moments of short/long term rates, exchange rates, and volumes

Maximum Likelihood

- Discretized structural model for time step Δt:

$$\mathrm{d}\mathbf{q}_t = -\boldsymbol{\Gamma}\left(\mathbf{q}_t - \bar{\mathbf{q}}\right)\mathrm{d}t + \boldsymbol{\sigma}\,\mathrm{d}\mathbf{B}_t$$
$$\implies \mathbf{q}_{t+\Delta t} - \bar{\mathbf{q}} = e^{-\boldsymbol{\Gamma}\Delta t}\left(\mathbf{q}_t - \bar{\mathbf{q}}\right) + \boldsymbol{\varepsilon}_{t,t+\Delta t}$$

- Gaussian structural shocks $\boldsymbol{\varepsilon}_{t,t+\Delta t}$: mean zero and variance-covariance matrix solves

$$\boldsymbol{\Gamma}\boldsymbol{\Sigma}_{\Delta t} + \boldsymbol{\Sigma}_{\Delta t}\boldsymbol{\Gamma}^{\top} = \boldsymbol{\Sigma} - e^{-\boldsymbol{\Gamma}\Delta t}\boldsymbol{\Sigma}e^{-\boldsymbol{\Gamma}^{\top}\Delta t}$$

- However, we only have observation data: $\mathbf{p}_t = \mathbf{A}\mathbf{q}_t$
    - Endogenous matrix $\mathbf{A}$ maps structural factors to observation data (yields, exchange rates)
- When $\mathbf{A}$ is full column rank we have

$$\mathbf{B} \equiv \mathbf{A}e^{-\boldsymbol{\Gamma}\Delta t}\mathbf{A}^{+}$$
$$\implies \mathbf{p}_{t+\Delta t} = \mathbf{B}\mathbf{p}_t + \mathbf{A}\boldsymbol{\varepsilon}_{t,t+\Delta t}$$

Maximum Likelihood: Baseline

- Finally, need functional form for habitat demand and elasticity functions:

$$\alpha(\tau) = \alpha_0 e^{-\alpha_1 \tau}, \quad \theta(\tau) = \theta_0 \theta_1^2 \tau e^{-\theta_1 \tau}$$

- Estimate by maximizing likelihood. Baseline MLE choices:
  - Data $\mathbf{p}_t$: 1-year H and F rates, 10-year H and F rates, and exchange rate (so $\mathbf{A}^+ \equiv \mathbf{A}^{-1}$)
  - Quarterly data with $\Delta t = 1$ quarter
  - Technical issue: volume moments do not fit into the MLE framework
    - Thus, we fix shape parameters $\alpha_1 = 0.15, \theta_1 = 0.3$ based on Vayanos-Vila
- Results are robust to:
  - Alternative or additional inclusion of maturities
  - Alternative time frequencies
  - Alternative habitat shape parameters α_1, θ_1
  - Ad-hoc inclusion of volume targets and direct estimation of α_1, θ_1
  - Finally, CMD gives highly similar results

MLE Baseline Estimate

Parameter	Estimate	Standard Error
σ_{iH}	1.163	0.076
σ_{iF}	0.874	0.058
$\sigma_{iH,iF}$	0.338	0.081
κ_{iH}	0.149	0.058
κ_{iF}	0.142	0.047
κ_{β}	0.062	0.055
κ_{γ}	0.161	0.102
$\kappa_{\gamma,iH}$	-0.150	0.118
$\kappa_{\gamma,iF}$	0.185	0.130
$a\theta_0\sigma_{\beta}$	999.532	200.907
$a\theta_e\sigma_{\gamma}$	948.680	461.933
$a\alpha_0$	4.812	2.920
$a\alpha_e$	77.006	37.239

- For policy experiments: CRRA $\gamma = 2$ and arbitrageur wealth $\frac{W}{GDP_H} \approx 5\% \implies a = 40$
- Moment matching estimates: CMD

Return Predictability Regressions

- Compare return predictability regressions in the model vs. data
  - Bond predictability: Fama-Bliss and Campbell-Shiller:

$$\frac{1}{\Delta\tau}\log\left(\frac{P^{(\tau-\Delta\tau)}_{j,t+\Delta\tau}}{P^{(\tau)}_{jt}}\right) - y^{(\Delta\tau)}_{jt} = \alpha_{FB} + \beta_{FB}\left(f^{(\tau-\Delta\tau,\tau)}_{jt} - y^{(\Delta\tau)}_{jt}\right) + e_{t+\Delta\tau}$$

$$y^{(\tau-\Delta\tau)}_{j,t+\Delta\tau} - y^{(\tau)}_{jt} = \alpha_{CS} + \beta_{CS}\frac{\Delta\tau}{\tau-\Delta\tau}\left(y^{(\tau)}_{jt} - y^{(\Delta\tau)}_{jt}\right) + e_{t+\Delta\tau}$$

  - FX predictability: Fama and Chinn-Meredith:

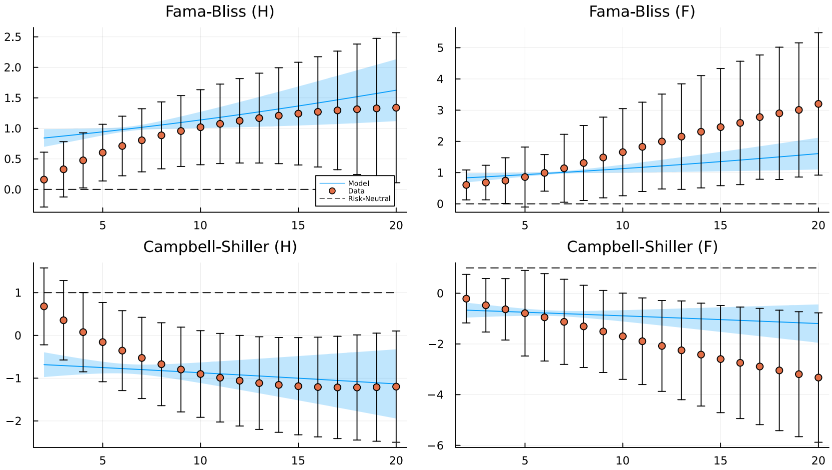
$$\frac{1}{\Delta\tau}\log\left(\frac{e_t}{e_{t+\Delta\tau}}\right) = \alpha_{UIP} + \beta_{UIP}\left(y^{(\Delta\tau)}_{Ft} - y^{(\Delta\tau)}_{Ht}\right) + e_{t+\Delta\tau}$$

  - FX-Bond predictability: Lustig-Stathopoulos-Verdelhan, Chernov-Creal, Lloyd-Marin

$$\frac{1}{\Delta\tau}\log\left(\frac{P^{(\tau-\Delta\tau)}_{F,t+\Delta\tau}e_{t+\Delta\tau}}{P^{(\tau)}_{Ft}e_t}\right) - \frac{1}{\Delta\tau}\log\left(\frac{P^{(\tau-\Delta\tau)}_{H,t+\Delta\tau}}{P^{(\tau)}_{Ht}}\right) = \alpha_{LSV} + \beta_{LSV}\left(y^{(\Delta\tau)}_{Ft} - y^{(\Delta\tau)}_{Ht}\right) + e_{t+\Delta\tau}$$

$$\frac{1}{\Delta\tau}\log\left(\frac{e_t}{e_{t+\Delta\tau}}\right) = \alpha_{UIP-LS} + \beta_L\left(y^{(\Delta\tau)}_{Ft} - y^{(\Delta\tau)}_{Ht}\right) + \beta_S\left[\left(y^{(\tau_2)}_{Ft} - y^{(\tau_1)}_{Ft}\right) - \left(y^{(\tau_2)}_{Ht} - y^{(\tau_1)}_{Ht}\right)\right] + e_{t+\Delta\tau}$$

MLE Regression Coefficients: Term Structure

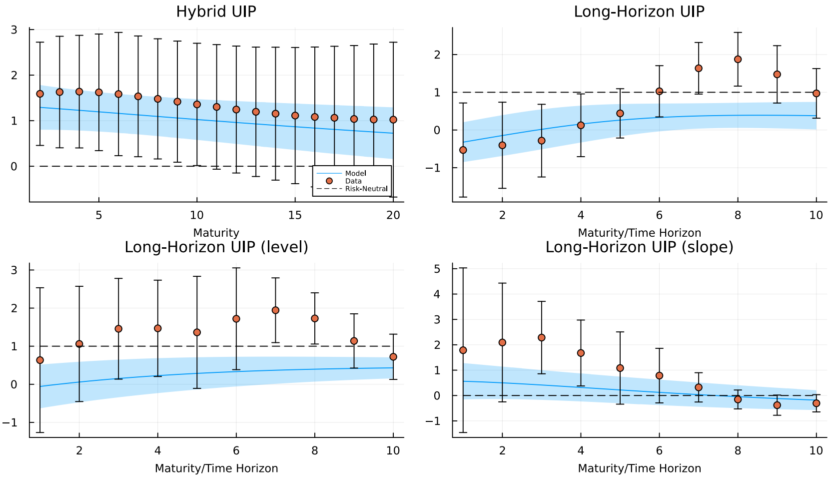


Moment-matching results: CMD

Term Structure Predictability

- Implications: Positive slope-premia relationship
- Intuition: positive slope predicts higher bond returns for two main reasons:
- Due to elastic bond habitat traders, an increase in the short rate implies long-term yields under-react and arbitrageurs require less risk compensation
- When habitat demand is low, long-term yields are high and arbitrageurs require more risk compensation

MLE Regression Coefficients: UIP



Moment-matching results: CMD

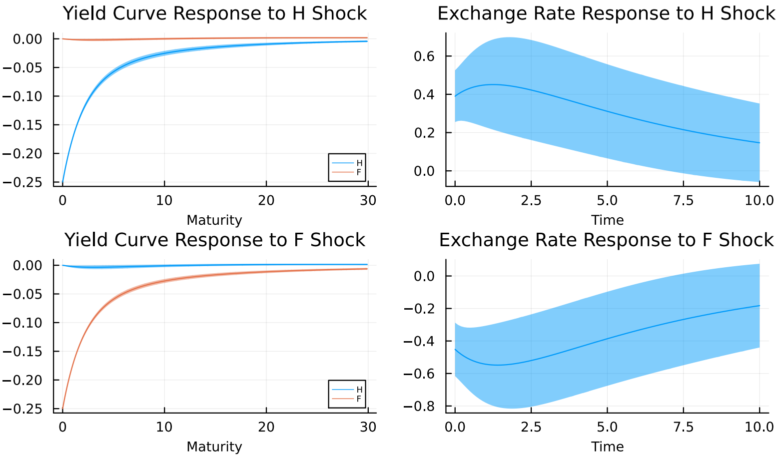
FX Predictability

- Implications: CCT is profitable, but profitability goes to zero if CCT is done with long-term bonds
- Intuition: Due to elastic currency traders, an increase in the foreign short rate implies foreign currency appreciates and arbitrageurs require more risk compensation
- However, long-maturity bond returns underperform in high short-rate countries, hence the CCT is most profitable when conducted with short-term bonds
- Implications: Slope differential predicts CCT return
- Intuition: when habitat demand is low for foreign bonds, long-term foreign yields are high
- Moreover, foreign yield curve is steeper than home yield curve
- Additionally, the low demand causes appreciation of foreign currency today and an expected depreciation, implying low expected returns for the CCT

Policy Spillovers

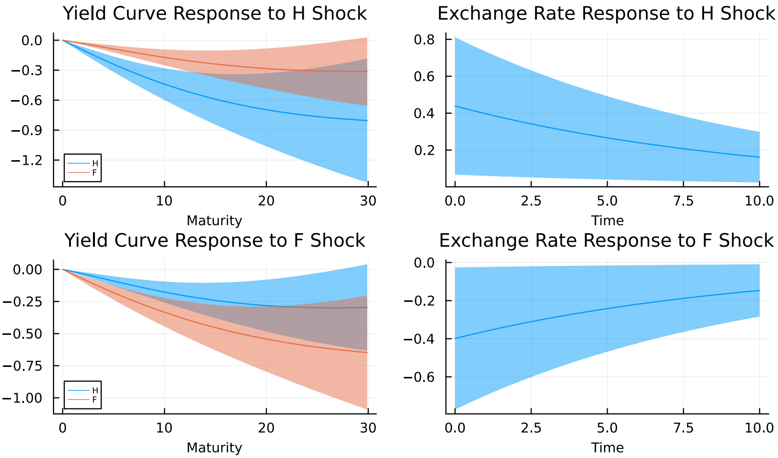
- Monetary policy shock: unanticipated and idiosyncratic 25bp decrease in policy rate
    - Zero-probability shock
    - Half-life $\approx$ 1 year
- QE shock: unanticipated and idiosyncratic positive demand shock $= 10\%$ of GDP
    - Zero-probability shock
    - Half-life $\approx$ 7 years
- Use the model to examine spillovers:
    - Across the yield curves (short and long rates; and across countries)
    - To the exchange rate

Monetary Shock Spillovers



Moment-matching results: CMD

QE Shock Spillovers

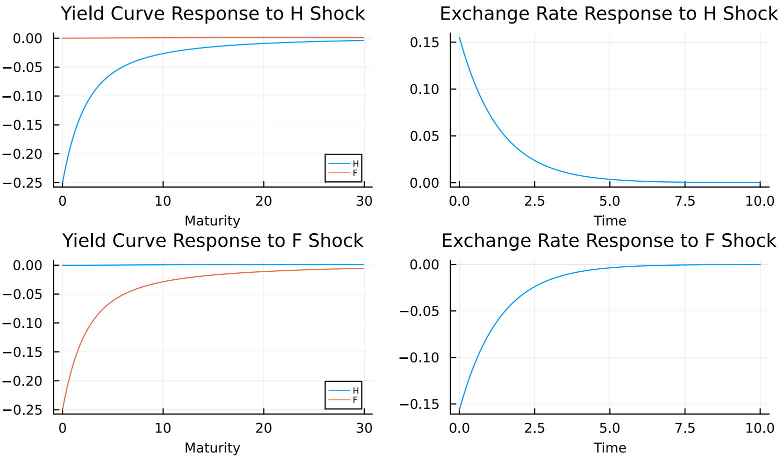


Moment-matching results: CMD

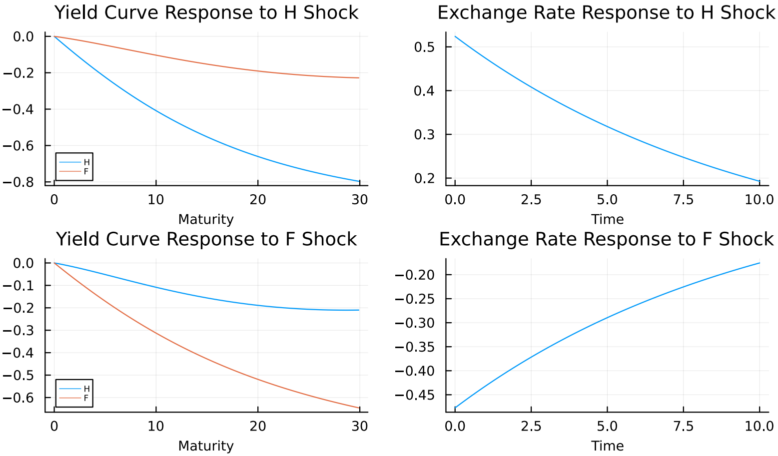
Policy Spillovers

- Implications: small cross-country yield spillovers of conventional policy; exchange rate “delayed overshooting”
- Implications: large yield spillovers of QE; relatively large exchange rate depreciation
- Intuition: “delayed overshooting” due to estimated currency demand response
- Intuition: small MP yield spillovers and large QE yield spillovers due to correlated short rates, estimated currency elasticity

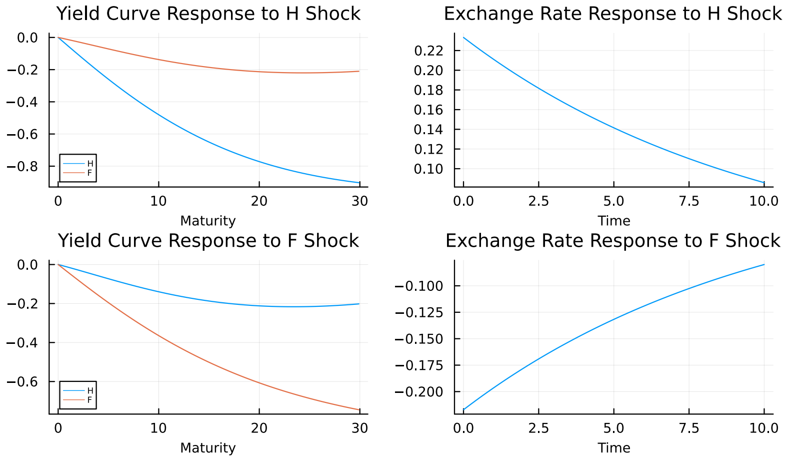
Monetary Shock Spillovers: No Currency Demand Response



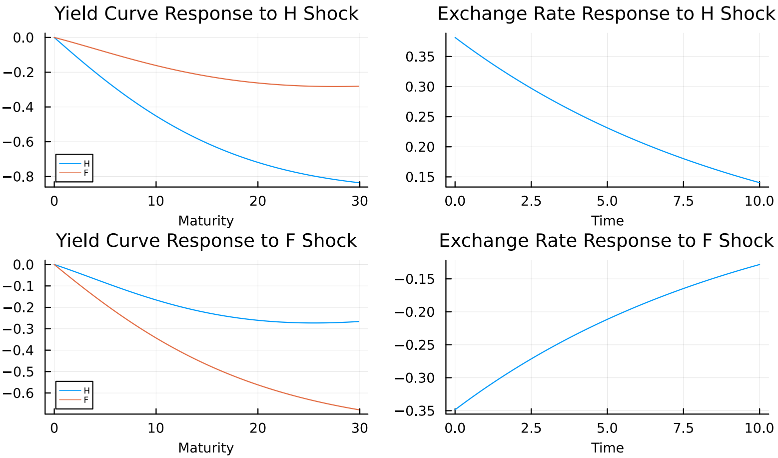
QE Shock Spillovers: Uncorrelated Short Rates



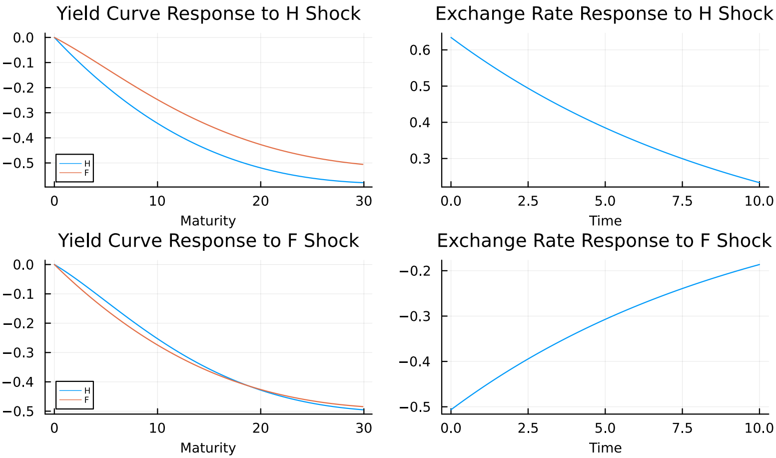
QE Shock Spillovers: Low to High Currency Elasticity



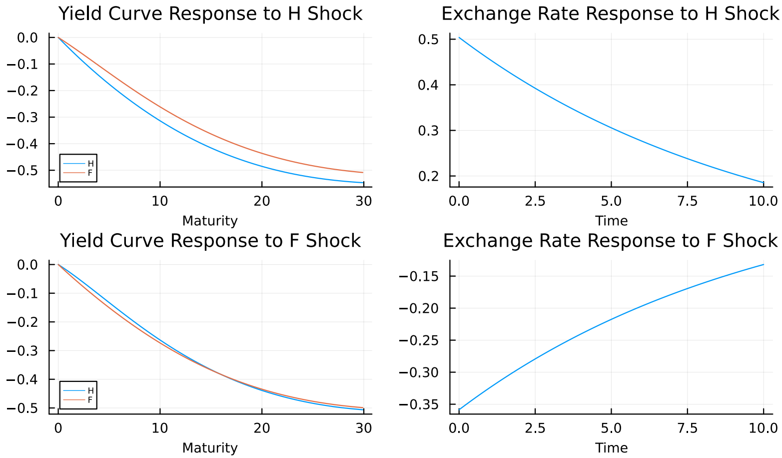
QE Shock Spillovers: Low to High Currency Elasticity



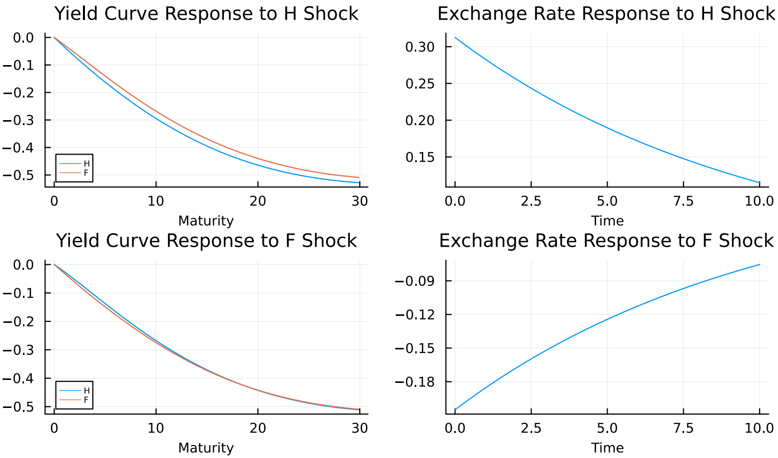
QE Shock Spillovers: Low to High Currency Elasticity



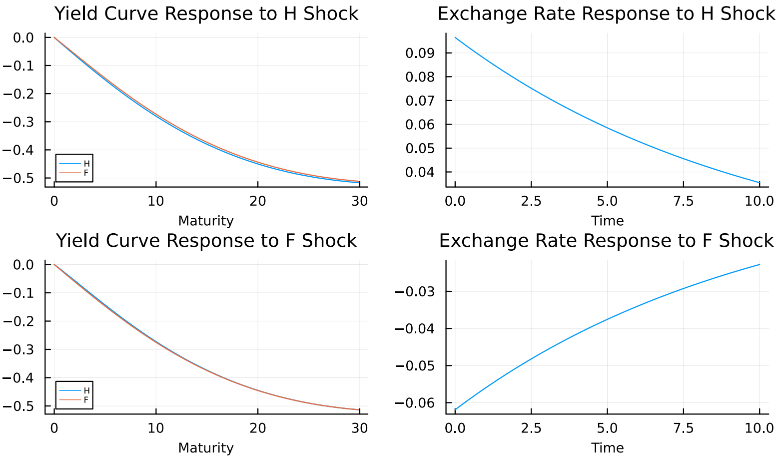
QE Shock Spillovers: Low to High Currency Elasticity



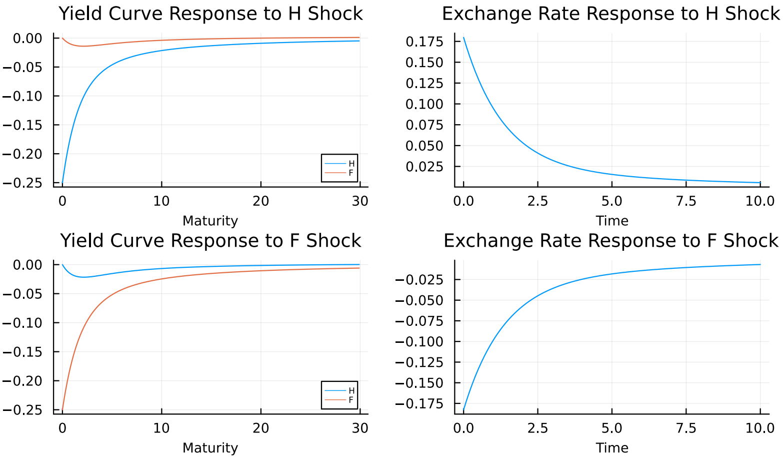
QE Shock Spillovers: Low to High Currency Elasticity



QE Shock Spillovers: Low to High Currency Elasticity



Monetary Shock Spillovers: High Currency Elasticity and Uncorrelated Short Rates



Shock Spillovers: Counterfactual Parameters

- Implications: QE yield spillovers increase and conventional policy spillovers decrease as short rate correlation increases
- Intuition: higher short rate correlation implies deterioration of hedging properties of international bonds
- Implications: QE and conventional policy yield spillovers increase as currency demand elasticity increases
- However, exchange rate response to QE is non-monotonic function of currency demand elasticity
- Intuition: higher currency demand elasticity increases hedging properties of international bonds
- Eventually, large enough values of currency elasticity imply small equilibrium exchange rate movements

Concluding Remarks

- Present an integrated framework to understand term premia and currency risk
- Resulting model ties together
  - Deviations from Uncovered Interest Parity
  - Deviations from Expectation Hypothesis
  - Joint behavior of currency/bond return predictabillity
- Rich transmission of monetary policy domestically and abroad via FX and term premia
- Extensions:
  - Embed into a standard open-economy NK model
  - $\implies$ endogenizing policy rates as in Ray, Droste, & Gorodnichenko (2023), Ray (2019)
  - Allow for deviations from LOP as in Hebert, Du & Wang (2019)
  - $\implies$ introducing holding costs into the preferred habitat framework

Thank You!

Equilibrium Details: Solution Characterization

- Substitute market clearing into arbitrageur optimality conditions, collect $\mathbf{q}_t$ terms:

$$\mathbf{A}_j'(\tau) + \mathbf{M}\mathbf{A}_j(\tau) - \mathbf{e}_j = \mathbf{0}, \quad \mathbf{M}\mathbf{A}_e - (\mathbf{e}_H - \mathbf{e}_F) = \mathbf{0} \quad (\text{where } \mathbf{e}_j^\top \mathbf{q}_t = i_{jt})$$

- The matrix $\mathbf{M}$ is defined as

$$\begin{aligned} \mathbf{M} = \mathbf{\Gamma}^\top - a\Big\{ & \int_0^T \left[-\alpha_H(\tau)\mathbf{A}_H(\tau) + \mathbf{\Theta}_H(\tau)\right] \mathbf{A}_H(\tau)^\top \,\mathrm{d}\tau \\ & + \int_0^T \left[-\alpha_F(\tau)\mathbf{A}_F(\tau) + \mathbf{\Theta}_F(\tau)\right] \mathbf{A}_F(\tau)^\top \,\mathrm{d}\tau \\ & + \left[-\alpha_e \mathbf{A}_e + \mathbf{\Theta}_e\right] \mathbf{A}_e^\top \Big\} \mathbf{\Sigma} \end{aligned} \tag{1}$$

- Initial conditions $\mathbf{A}_j(0) = \mathbf{0}$. Hence

$$\mathbf{A}_j(\tau) = \left[\mathbf{I} - e^{-\mathbf{M}\tau}\right] \mathbf{M}^{-1}\mathbf{e}_j \tag{2}$$

$$\mathbf{A}_e = \mathbf{M}^{-1}(\mathbf{e}_H - \mathbf{e}_F) \tag{3}$$

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Equilibrium Details: Existence and Uniqueness

- Note: $\mathbf{M}$ appears on both sides of equation (1), through the solution of the affine coefficients (2), (3)
    - Interpretation: risk-adjusted dynamics of the risk factors
- In general: system of J^2 nonlinear equations in J^2 unknowns, where $J = \dim \mathbf{q}_t$
- Under risk neutrality ($a = 0$), the solution is simple: $\mathbf{M} = \boldsymbol{\Gamma}^\top$
- When $a > 0$, the solution may not exist, or there may be multiple equilibria
- Can show (using IFT) that in a neighborhood of $a = 0$, the solution exists and is (locally) unique. Beyond that, very difficult to prove anything analytically in the fully general version of the model
- Numerically: solve via continuation as $\uparrow a$ (more stable, and serves as equilibrium selection device)

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Moment-Matching Results

Parameter	Estimate	Standard Error
σ_{iH}	1.429	0.148
σ_{iF}	0.751	0.140
$\sigma_{iH,iF}$	1.054	0.083
κ_{iH}	0.126	0.030
κ_{iF}	0.090	0.020
κ_{β}	0.050	0.009
κ_{γ}	0.134	0.102
$\kappa_{\gamma,iH}$	-0.267	0.550
$\kappa_{\gamma,iF}$	0.252	0.528
$a\theta_0\sigma_{\beta}$	648.905	80.268
$a\theta_e\sigma_{\gamma}$	762.715	1067.005
$a\alpha_0$	4.740	3.302
$a\alpha_e$	73.378	106.339
α_1	0.144	0.031
θ_1	0.374	0.014

- CMD point estimates very similar to MLE point estimates (but wider SEs) back

Moment-Matching Model Fit: Short Rates and Exchange Rates

Moment	Data	Model	Moment	Data	Model
$\sigma\left(y_{Ht}^{(1)}\right)$	2.622	2.614	$\rho\left(\Delta \log e_t, (y_{Ht}^{(1)} - y_{Ft}^{(1)})\right)$	-0.105	-0.096
$\sigma\left(\Delta y_{Ht}^{(1)}\right)$	1.273	1.254	$\rho\left(\Delta \log e_t, \Delta y_{Ht}^{(1)}\right)$	-0.095	-0.214
$\sigma\left(y_{Ft}^{(1)}\right)$	2.822	2.853	$\rho\left(\Delta \log e_t, \Delta y_{Ft}^{(1)}\right)$	0.048	0.071
$\sigma\left(\Delta y_{Ft}^{(1)}\right)$	1.09	1.174	$\rho\left(\Delta^{(5)} \log e_t, (y_{Ht}^{(5)} - y_{Ft}^{(5)})\right)$	0.12	0.06
$\sigma\left((y_{Ht}^{(1)} - y_{Ft}^{(1)})\right)$	1.816	1.717	$\tilde{V}_H(0 \leq \tau \leq 3)$	0.361	0.378
$\sigma\left(\Delta \log e_t\right)$	10.186	10.183	$\tilde{V}_H(11 \leq \tau \leq 30)$	0.08	0.116

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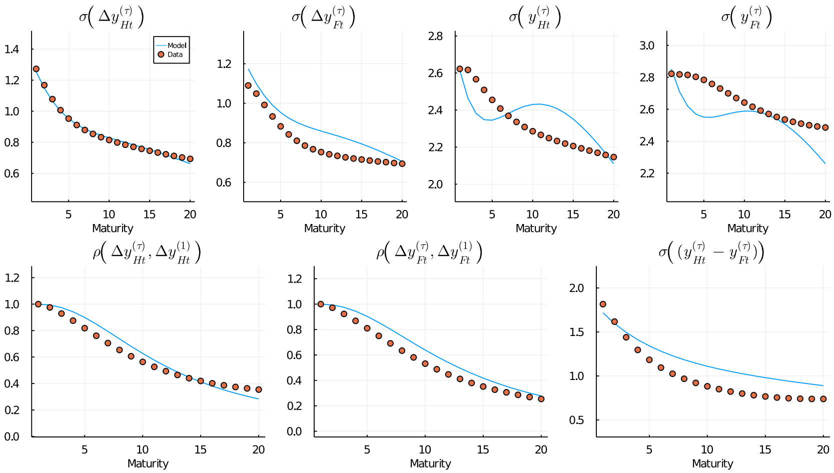
Moment-Matching Model Fit: Long Rates



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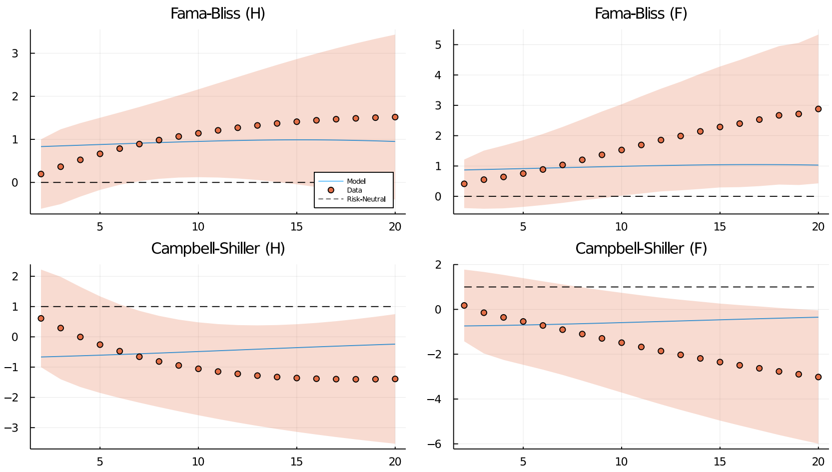
Moment-Matching Regression Coefficients: Term Structure



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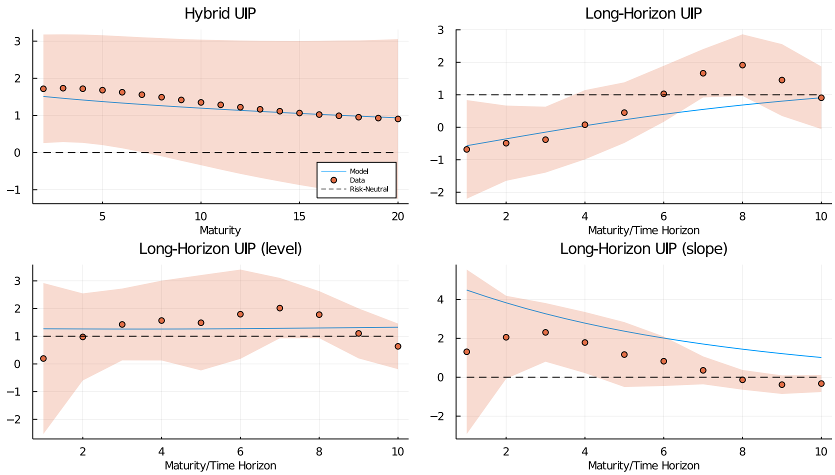
Moment-Matching Regression Coefficients: UIP



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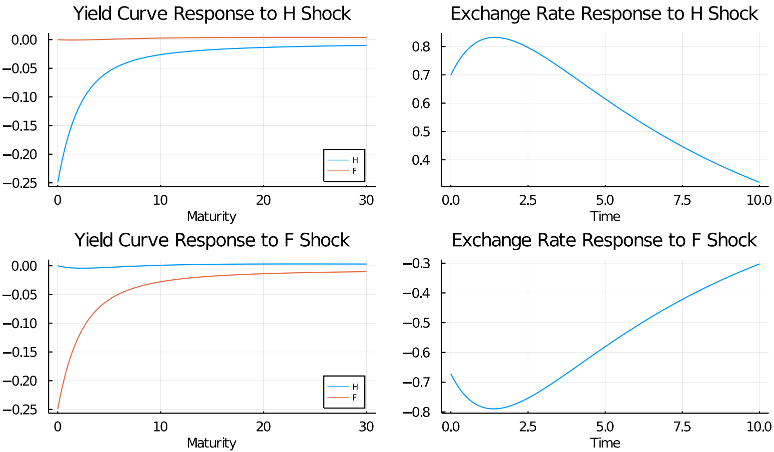
Moment-Matching Monetary Shock Spillovers



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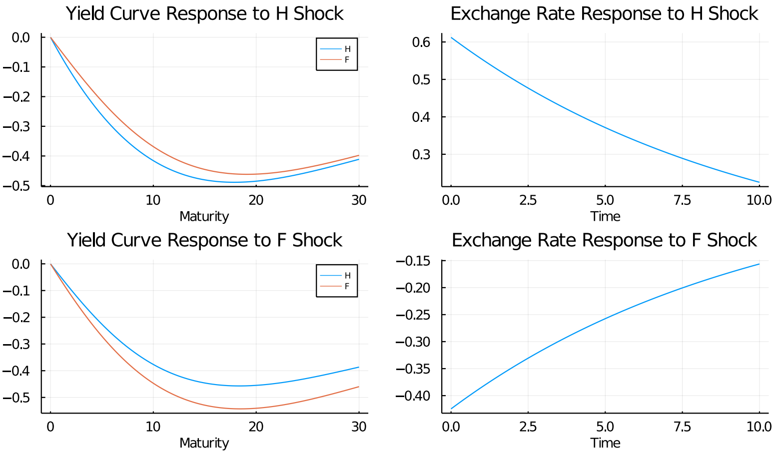
Moment-Matching QE Shock Spillovers



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