Exchange Rate Disconnect Revisited

Ryan Chahrour\textsuperscript{1} Vito Cormun\textsuperscript{2} Pierre De Leo\textsuperscript{3}
Pablo Guerrón Quintana\textsuperscript{4} Rosen Valchev\textsuperscript{4,5}

\textsuperscript{1}Cornell University
\textsuperscript{2}Santa Clara University
\textsuperscript{3}University of Maryland
\textsuperscript{4}Boston College
\textsuperscript{5}NBER
Exchange Rate Disconnect

- In models, real exchange rate $q_t$ tightly linked to macro fundamentals
  - As relative price of consumption, it plays crucial role in clearing markets

- In the data, however, $q_t$ is largely "disconnected" from macro fundamentals, and also an order of magnitude more volatile
  - Empirical dynamics of $q_t$ are roughly a random walk
  - Giving rise to numerous puzzles: Backus-Smith, Fama, Meese-Rogoff, ...  

- Tremendous amount of work on resolving these puzzles, but ...  
  - Many papers address puzzles piecemeal, one at a time
  - Previous focus on theory, but relatively little direct empirical evidence
    - Wedge decomposition finds an important role for exogenous "FX-shocks"

- This paper: identify empirical drivers of $q_t$ using minimal structure
Main Results

1. Real exchange rates are connected with macro fundamentals
   - however, the link runs between current $q_t$ and future $f_{t+k}$
Main Results

1. Real exchange rates are **connected** with macro fundamentals
   - however, the link runs between current $q_t$ and future $f_{t+k}$

2. Noisy news about future TFP explain $\approx 64\%$ of $q_t$ (30\% of $\Delta q_t$)
   - little role for pure “surprise” TFP shocks
   - significant role for fluctuations in **noisy expectations** of TFP
     - decompose into actual, anticipated TFP changes and expectational noise
     - Noise $\Rightarrow$ high frequency excess volatility
     - Anticipated TFP shifts $\Rightarrow$ low-frequency, non-monotonic $q_t$ dynamics
   - **Transmission mechanism**: endogenous, volatile deviations from UIP
   - conditional responses of $q_t$ exhibit many, otherwise disparate, famous exchange rate puzzles
     - puzzles share a common, **fundamental**, origin in **noisy** expectations of TFP
Literature

Empirical: Meese & Rogoff 83, Fama 84, Backus & Smith 93, Eichenbaum & Evans 95, Rogoff 96, Obstfeld and Rogoff (2000), Chari, Kehoe & McGrattan 02, Cheung, Ching & Pascual 02, Engel & West 05, Gourinchas & Rey 07, Engel, Mark & West 08, Chen, Rogoff & Rossi 10, Sarno & Schmelling 14, Nam & Wang 15, Siena 17, Stavrakeva & Tang 20, Alessandria & Choi 21, Miyamoto et al. 21

Theoretica Puzzle “Solutions”:

1. Currency Excess returns:
   - Consumption Risk: Verdelhan 10, Bansal & Shaliastovich 12, Colacito & Croce 13, Farhi & Gabaix 16
   - Segmented Markets Risk: Alvarez, Atkeson & Kehoe 09, Adrian, Etula & Shin 15, Gabaix and Maggiori 15, Camacho, Hau & Rey 18
   - Behavioral biases: Gourinchas & Tornell 04, Bachetta & van Wincoop 06, Burnside et. al 11, Candian & De Leo 21
   - Liquidity premia: Engel 16, Valchev 20, Engel & Wu 20, Bianchi, Bigio & Engel 21

2. Disconnect: Engel & West 05, Bacchetta & Van Wincoop 06, Obstfeld & Rogoff 00, Eichenbaum et. al. 20, Itskhoki & Mukhin 21

3. Backus-Smith Puzzle: Kocherlakota & Pistaferri 07, Corsetti, Dedola & Leduc 08, Benigno & Thoenissen 08, Colacito & Croce 13, Karabarbounis 14, Itskhoki & Mukhin 21

4. Specific FX shocks: Devereux & Engel 02, Jeanne & Rose 02, Kollmann 05, Bacchetta & Van Wincoop 06, Eichenbaum, Johannsen & Rebelo 19, Itskhoki & Mukhin 21

Two semi-structural techniques

1. VAR identification, based on “max-share” approach
   → isolate main comovement patterns associated with surprise $\Delta q$

2. VAR identification, based on “technology/exp. noise” distinction
   → isolate role of TFP and TFP expectations in driving comovement
Data

United States & G6 aggregates from 1976:Q1 to 2008:Q2
○ results remain virtually unchanged if we extend to 2018:Q4
Data

United States & G6 aggregates from 1976:Q1 to 2008:Q2
  ○ results remain virtually unchanged if we extend to 2018:Q4

Main variables:

1. Nominal exchange rate \( \ln(s_t) \)
2. US consumption \( \ln(C_t) \)
3. G6 consumption \( \ln(C_t^*) \)
4. US investment \( \ln(I_t) \)
5. G6 investment \( \ln(I_t^*) \)
6. Nominal interest rate differential \( \ln(i_t/i_t^*) \)
7. Relative price \( \ln(CPI_t/CPI_t^*) \)
8. US utilization-adj. TFP \( \ln(TFP_t) \)

\[ Y'_t \equiv \begin{bmatrix} \ln(S_t), \ln(TFP_t), \ln(C_t), \ln(C_t^*), \ln(I_t), \ln(I_t^*), \ln \left( \frac{1 + i_t}{1 + i_t^*} \right), \ln \left( \frac{CPI_t}{CPI_t^*} \right) \end{bmatrix} \]
VAR – Max Share Approach

- Estimate a VAR
  \[ Y_t = B(L)Y_{t-1} + u_t \]
  [Bayesian, 4 lags]

- Let
  \[ u_t = A \varepsilon_t, \quad \text{cov}(\varepsilon_t) = I \]
VAR – Max Share Approach

- Estimate a VAR
  \[ Y_t = B(L)Y_{t-1} + u_t \]
  \[ \text{[Bayesian, 4 lags]} \]

- Let
  \[ u_t = A\varepsilon_t, \quad \text{cov}(\varepsilon_t) = I \]
  \[ \varepsilon_t = A^{-1}u_t \]

- Following max-share procedure of Uhlig(2003), Angeletos et.al.(2020):
  - Pick \( A \) to maximize the share of variation in real exchange rate \( q_t \) explained by \( \varepsilon_{1,t} \)

**Objective:** isolate dominant factor behind fluctuations in \( q_t \)
VAR – Max Share Approach

- The real exchange rate is defined as usual (in logs)

\[ q_t = s_t + p_t^* - p_t \]

- Simply a linear combination of VAR variables:

\[ q_t = \phi_q Y_t = \phi_q (I - B(L))^{-1} u_t \]

\[ = \phi_q (I - B(L))^{-1} A \underbrace{\varepsilon_t}_{=A^{-1}u_t} \]

- Variance of \( q_t \) can then be decomposed in contributions of each \( \varepsilon_{i,t} \)

\[ \text{Var}(q_{t+100} - \mathbb{E}_t(q_{t+100})) = \sum_i \text{Var}(q_{t+100} - \mathbb{E}_t(q_{t+100})|\varepsilon_k = 0, \forall k \neq i) \]

- Pick \( A \) to maximize \( \text{Var}(q_{t+k} - \mathbb{E}_t(q_{t+k})|\varepsilon_k = 0, \forall k \neq 1) \)

- Intuition: \( \varepsilon_{1,t} \) gives us the dominant factor behind \( q_t \) fluctuations
CONDITIONAL DYNAMICS – MAX-SHARE ($\varepsilon_1$)
Conditional Dynamics – Max-Share ($\varepsilon_1$)
Conditional Dynamics – Max-Share ($\varepsilon_1$)
First Conclusions

- Strong link between \textit{current} $q$ and \textit{future} $f$

### Forecast Error Variance Decomposition

<table>
<thead>
<tr>
<th></th>
<th>Q1 $\Delta$</th>
<th>Q4 $\Delta$</th>
<th>Q12 $\Delta$</th>
<th>Q24 $\Delta$</th>
<th>Q40 $\Delta$</th>
<th>Q100 $\Delta$</th>
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<tbody>
<tr>
<td>Home TFP</td>
<td>0.03</td>
<td>0.06</td>
<td>0.20</td>
<td>0.37</td>
<td>0.45</td>
<td>0.43</td>
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<tr>
<td><strong>Home Consumption</strong></td>
<td><strong>0.02</strong></td>
<td><strong>0.04</strong></td>
<td><strong>0.21</strong></td>
<td><strong>0.47</strong></td>
<td><strong>0.51</strong></td>
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</tr>
<tr>
<td>Foreign Consumption</td>
<td>0.01</td>
<td>0.04</td>
<td>0.06</td>
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<td>0.30</td>
</tr>
<tr>
<td>Home Output</td>
<td>0.10</td>
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<td>0.22</td>
<td>0.42</td>
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<tr>
<td>Foreign Output</td>
<td>0.10</td>
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<td>0.33</td>
</tr>
<tr>
<td><strong>Home Investment</strong></td>
<td><strong>0.29</strong></td>
<td><strong>0.34</strong></td>
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- Where we define the expected currency return as standard:

$$\mathbb{E}_t(\lambda_{t+1}) = \mathbb{E}_t(q_{t+1} - q_t + r^*_t - r_t)$$
First Conclusions

- Strong link between current $q$ and future $f$

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- Specifically, we see a link with future TFP

$\Rightarrow$ Next: directly identify disturbances to TFP and TFP expectations
**Shocks to TFP and its expectations**

Allow for general time series process for TFP $a_t$:

$$a_t = \sum_{k=0}^{\infty} \alpha_k \varepsilon_{t-k}$$

**Basic idea:** Agents have noisy information about future TFP innovations:

$$\mathbb{E}_t(\varepsilon_{t+k}^a) \neq 0$$

WLOG represent information as an arbitrary signal $\eta_t$ of future $\varepsilon_{t+k}^a$:

$$\eta_t = \sum_{k=1}^{\infty} \zeta_k \varepsilon_{t+k}^a + \nu_t \quad \nu_t = \sum_{k=0}^{\infty} \nu_k \varepsilon_{t-k}^v$$

where $\varepsilon_t^a \perp \varepsilon_t^v$

**Goal:** separately identify disturbances to TFP $\varepsilon_t^a$ and expectations $\varepsilon_t^v$
We follow the method of Chahrour and Jurado (2021). Some intuition:

- Imagine we have data on both $a_t$ and $\eta_t$.
- Then we could represent their time series dynamics as

$$\begin{bmatrix} a_t \\ \eta_t \end{bmatrix} = A(L) \begin{bmatrix} \varepsilon^a_t \\ \varepsilon^v_t \end{bmatrix}$$

where $A(L) = \sum_{-\infty}^{\infty} A_k L^k$ is a \textit{two-sided} lag polynomial.

- Under our null hypothesis we can impose following zero restrictions

$$\begin{bmatrix} a_t \\ \eta_t \end{bmatrix} = \cdots + \begin{bmatrix} 0 & 0 \\ * & 0 \end{bmatrix} \begin{bmatrix} \varepsilon^{a+1}_t \\ \varepsilon^v_{t+1} \end{bmatrix} + \begin{bmatrix} * & 0 \\ * & * \end{bmatrix} \begin{bmatrix} \varepsilon^{a}_t \\ \varepsilon^v_{t} \end{bmatrix} + \begin{bmatrix} * & 0 \\ * & * \end{bmatrix} \begin{bmatrix} \varepsilon^{a-1}_t \\ \varepsilon^v_{t-1} \end{bmatrix} + \cdots$$

to separately identify $\varepsilon^a_t$ and $\varepsilon^v_t$. 

Shocks to TFP and its expectations
In practice we do not have direct observations of $\eta_t$.

This is where we can use the broader information set of our VAR.

Assuming information is reflected in agent decisions, then endogenous variables $y_t$ are a function of future expected TFP innovations

$$y_t = \sum_{k=0}^{\infty} \gamma_k \varepsilon_{t-k}^a + \sum_{k=1}^{\infty} \chi_k \mathbb{E}_t(\varepsilon_{t+k}^a)$$

So the VAR, by including sufficient endogenous forward looking variables, will give us an estimate of the agent’s forecast of future TFP innovations $\mathbb{E}_t(\varepsilon_{t+k}^a)$

We can then basically identify $\varepsilon_t^a$ and $\varepsilon_t^v$ from

$$\begin{bmatrix} \hat{a}_t \\ \hat{\mathbb{E}}_t(\varepsilon_{t+k}^a) \end{bmatrix} = \cdots + \begin{bmatrix} 0 & 0 \\ * & 0 \end{bmatrix} \begin{bmatrix} \varepsilon_{t+1}^a \\ \varepsilon_{t+1}^v \end{bmatrix} + \begin{bmatrix} * & 0 \\ * & * \end{bmatrix} \begin{bmatrix} \varepsilon_{t}^a \\ \varepsilon_{t}^v \end{bmatrix} + \begin{bmatrix} * & 0 \\ * & * \end{bmatrix} \begin{bmatrix} \varepsilon_{t-1}^a \\ \varepsilon_{t-1}^v \end{bmatrix} + \cdots$$
**Shocks to TFP and its expectations**

In a nutshell

1. We use the estimated VAR to recover the Wold representation of TFP

\[ a_t = \sum_{k=0}^{\infty} \alpha_k \varepsilon_{t-k}^a \]

this gives us an estimate of the TFP shocks \( \varepsilon_t^a \)

2. Given \( \{\varepsilon_t^a\} \) we use the VAR-implied \( \widehat{\mathbb{E}}_t(\varepsilon_{t+k}^a) \) to extract \( \{\varepsilon_t^v\} \)

\[ \{\varepsilon_t^v\} \equiv \{\widehat{\mathbb{E}}_t(\varepsilon_{t+k}^a)\}_{t=0}^{T-k} \perp \{\varepsilon_t^a\}_{t=0}^T \]

- Essentially, \( \varepsilon_t^v \) represents fluctuations in \( \mathbb{E}_t(\varepsilon_{t+k}^a) \) unrelated to any actual innovations to TFP past, current or future.
- For implementation, we choose \( k = 20 \) but results robust to choice of \( k \)
Conditional Dynamics – Technology ($\varepsilon^a$)
Conditional Dynamics — Expectation noise ($\varepsilon^v$)
Broader Impact – Technology ($\varepsilon^a$)
Conditional Dynamics – Expectation noise ($\varepsilon^v$)


**Variance Decomposition**

- The rare shocks that drive both FX and international business cycles
  - A fundamental link between the exchange rate and the macroeconomy

Variance Decomposition (2-100Q frequency)

<table>
<thead>
<tr>
<th></th>
<th>Both</th>
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</tr>
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<tbody>
<tr>
<td>Home TFP</td>
<td>1.00</td>
<td></td>
<td></td>
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<tr>
<td><strong>Home Consumption</strong></td>
<td>0.70</td>
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<tr>
<td><strong>Foreign Consumption</strong></td>
<td>0.63</td>
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<td></td>
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<tr>
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<tr>
<td>Expected Excess Returns</td>
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<tr>
<td>Quarterly $\Delta q_t$</td>
<td>0.30</td>
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## Variance Decomposition

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<td>0.30</td>
<td>0.11</td>
<td>0.18</td>
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More on Role of Expectations
Noise Dominates at Higher Frequencies

Variance Decomposition of Real Exchange Rate

Pericodities (Quarters)

2-32 33-100 2-100

20 40 60

Percent

Technology Noise
A natural hypothesis is that the news transmit to exchange rate through current and expected future interest rate differentials.

Denote the excess currency return as

\[ \lambda_{t+1} \equiv q_{t+1} - q_t + r_t^* - r_t \]

Then, a standard decomposition of the real exchange rate gives us:

\[ q_t = - \sum_{k=0}^{\infty} \mathbb{E}_t(r_{t+k} - r_{t+k}^*) - \sum_{k=0}^{\infty} \mathbb{E}_t(\lambda_{t+k+1}) \]

\[ \equiv q_t^{\text{UIP}} \quad \equiv q_t^\lambda \]
Transmission Mechanism

\[ q_t = q_t^{UIP} + q_t^\lambda \]

- We want to know whether \( q_t^\lambda \) plays an important role in the transmission of the noisy news shocks we have identified.
  - This would be informative about underlying equilibrium model.

- This is not an orthogonal decomposition, but still

\[ \text{Var}(q_t) = \text{Cov}(q_t, q_t^{UIP}) + \text{Cov}(q_t, q_t^\lambda) \]

<table>
<thead>
<tr>
<th></th>
<th>Both shocks</th>
<th>Tech shocks</th>
<th>Noise shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>( q_t^{UIP} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( q_t^\lambda )</td>
<td>-0.02</td>
<td>-0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>( \text{Var}(q_t) )</td>
<td>1.02</td>
<td>1.02</td>
<td>0.95</td>
</tr>
<tr>
<td>( \text{Cov}(\Delta q_t, \Delta q^i) ) / ( \text{Var}(\Delta q_t) )</td>
<td>0.14</td>
<td>-0.16</td>
<td>0.43</td>
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<tr>
<td></td>
<td>0.86</td>
<td>1.16</td>
<td>0.57</td>
</tr>
</tbody>
</table>
Impulse responses: $q_t^{UIP}$ vs $q_t^\lambda$
Common driver to FX puzzles

- Conditional dynamics also exhibit all famous exchange rate puzzles, suggesting a **common fundamental origin**
- Let us delve into the puzzles one at a time.
- Consider first deviations from Uncovered Interest Parity

\[
\mathbb{E}_t(q_{t+1} - q_t + r^*_t - r_t) = 0
\]

\[= \lambda_{t+1}\]

1. On the one hand, \(\varepsilon^a_t\) and \(\varepsilon^v_t\) account for 50% of \(\text{Var}(\mathbb{E}_t(\lambda_{t+1}))\).

2. On the other, we can also consider traditional UIP tests

\[
\lambda_{t+1} = \alpha_{\text{UIP}} + \beta_{\text{UIP}}(r_t - r^*_t) + \varepsilon_{t+1}
\]

\[
\sum_{k=0}^{\infty} \mathbb{E}_t(\lambda_{t+k+1}) = \alpha_\Lambda + \beta_\Lambda(r_t - r^*_t) + \varepsilon_t
\]
## UIP deviations

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<td>$\beta_{UIP}$</td>
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<tr>
<td>$\text{Cov}(\lambda_{t+1}, r_t - r^*_t)$</td>
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<td>$\beta_\Lambda$</td>
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</tr>
<tr>
<td>$\text{Cov}(\sum_{k=0}^{\infty} \lambda_{t+k+1}, r_t - r^*_t)$</td>
<td>1.08</td>
<td>0.60</td>
<td></td>
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</table>
# UIP Deviations

<table>
<thead>
<tr>
<th></th>
<th>Unconditional</th>
<th>Both</th>
<th>Technology</th>
<th>Exp. Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_{UIP}$</td>
<td>-2.46</td>
<td>-2.20</td>
<td>-2.08</td>
<td>-2.96</td>
</tr>
<tr>
<td>$\text{Cov}(\lambda_{t+1}, r_t - r_t^*)$</td>
<td>-1.26</td>
<td>-0.82</td>
<td>-0.68</td>
<td>-0.14</td>
</tr>
<tr>
<td>$\beta_\Lambda$</td>
<td>2.53</td>
<td>2.62</td>
<td>2.33</td>
<td>1.72</td>
</tr>
<tr>
<td>$\text{Cov}(\sum_{k=0}^{\infty} \lambda_{t+k+1}, r_t - r_t^*)$</td>
<td>1.08</td>
<td>0.60</td>
<td>0.54</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Risk-sharing (Backus-Smith 93)

- An enduring puzzle is the mildly negative $corr(\Delta q_t, \Delta c_t - \Delta c_t^*)$
  - Debate in the literature if it is driven by “supply” or “demand” shocks
  - Our results can shed light on likely mechanism

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</tr>
</thead>
<tbody>
<tr>
<td>$corr(\Delta q_t, \Delta (c_t - c_t^*))$</td>
<td>-0.27</td>
<td>-0.35</td>
<td>-0.31</td>
<td>-0.38</td>
</tr>
<tr>
<td>$Cov(\Delta q_t, \Delta (c_t - c_t^*))$</td>
<td>-0.7</td>
<td>-0.28</td>
<td>-0.10</td>
<td>-0.18</td>
</tr>
<tr>
<td>$Cov(\Delta q_t^\lambda, \Delta (c_t - c_t^*))$</td>
<td>-0.49</td>
<td>-0.24</td>
<td>-0.13</td>
<td>-0.11</td>
</tr>
</tbody>
</table>

- We can decompose our effects based on fluctuations driven by expectations $\mathbb{E}_t(\varepsilon_{t+k}^a)$ and those on realized (current and past) $\varepsilon_{t-k}^a$
  - $Cov(\Delta q_t, \Delta (c_t - c_t^*)|\mathbb{E}_t(\varepsilon_{t+k}^a)) = -0.22$
  - 80% of effects of our two shocks in “anticipation” phase, hence akin to “demand” shocks
**Excess Volatility and Persistence**

- The response of $q_t$ is highly persistent in response to both shocks.
- Excess volatility of exchange rate largely due to expectational noise.

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<tbody>
<tr>
<td>$\text{autocorr}(\Delta q_t)$</td>
<td>0.29</td>
<td>0.58</td>
<td>0.90</td>
<td>0.33</td>
</tr>
<tr>
<td>$\text{autocorr}(\Delta q^\lambda_t)$</td>
<td>0.73</td>
<td>0.60</td>
<td>0.80</td>
<td>0.42</td>
</tr>
<tr>
<td>$\frac{\sigma(\Delta q_t)}{\sigma(r_t - r^*_t)}$</td>
<td>5.88</td>
<td>4.00</td>
<td>2.70</td>
<td>7.69</td>
</tr>
<tr>
<td>$\frac{\sigma(\Delta q_t)}{\sigma(\Delta c_t)}$</td>
<td>6.05</td>
<td>5.65</td>
<td>3.99</td>
<td>8.14</td>
</tr>
<tr>
<td>$\frac{\sigma(\Delta q^\lambda_t)}{\sigma(\Delta c_t)}$</td>
<td>7.30</td>
<td>6.58</td>
<td>5.82</td>
<td>7.74</td>
</tr>
</tbody>
</table>
Common fundamental origin to FX Puzzles

Noisy news to TFP are primarily transmitted to $q_t$ via UIP deviations

- In turn, the resulting volatile dynamics in $E_t(\lambda_{t+1})$ also generate other famous puzzles such as Backus-Smith and excess volatility

$\Rightarrow$ common, fundamental origin of FX puzzles as modulated by fluctuations in currency excess returns due to noisy news about TFP

Echoes theoretical results emphasizing UIP wedge (Itskhoki&Mukhin 22)

However, our results are more specific and imply that

- UIP wedge fluctuations endogenous to noisy news about future TFP

Important about models, shifts focus back to TFP-driven mechanisms

- But driven by medium-to-long-run news, not surprises
- Lends support for “long-run risk” models a-la Colacito-Croce (2013)
What is the key empirical regularity underlying our results?

- In practice, TFP is virtually a random walk. Hence,
  \[ \varepsilon_t^a \approx \ln(a_t) - \ln(a_{t-1}) \]

- A simple, partial version of our VAR exercise is
  \[ \Delta q_t = \alpha + \beta_0 \Delta TFP_t + \sum_{k=1}^{h} \beta_{-k}^{\text{lag}} (\Delta TFP_{t-k}) + \sum_{k=1}^{h} \beta_{k}^{\text{lead}} (\Delta TFP_{t+k}) + \varepsilon_t \]
○ Cholesky-identified TFP shock assumed $\varepsilon_t^a$ is complete surprise
  ▶ Surprise-TFP shocks have no impact on $q_t$
Discussion – other shocks

- Our basic result shows $q_t$ is strongly related to fluctuations in TFP expectations.
- Assuming TFP innovations are exogenous, we can interpret our results as driven by noisy-news about TFP.
- A potential concern: endogenous TFP growth, driven by confounding shock which has its own, direct and separate impact on $q_t$.
  - R&D productivity shocks – essentially a type of “news” shock anyways.
  - Monetary policy shocks – possible only if *contractionary* monetary shocks spur R&D activity and future TFP growth.

Correlation between Technology, Noise and Other Economic Shocks

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<tr>
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<th>Technology</th>
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<tbody>
<tr>
<td>U.S. Monetary Policy Shocks</td>
<td>0.09</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>$p$-value = 0.46</td>
<td>$p$-value = 0.62</td>
</tr>
</tbody>
</table>
Discussion – noise shocks in $q_t$

- A related concern is that we are picking up Itskhoki-Mukhin(2021) style currency-specific shocks, since $q_t$ is part of the forecast $E_t(\varepsilon_{t+k}^a)$

- We redo our analysis dropping $q_t$ from the VAR set
  - Extracted shocks correlation is 0.99
**Discussion – $q_t$ and Stock Prices**

- If we are truly capturing news about future TFP, then those should be reflected in other asset prices, such as stock prices.
- Indeed, they are

![Graphs showing the relationship between Technology and Noise](image-url)
Robustness

- Results in extended sample (1976-2018)
- Results across G7 countries
  - Canada
  - France
  - Germany
  - Italy
  - Japan
  - United Kingdom
- Results using VECM (assumes $q$ and $r - r^*$ are stationary)
- Responses of other variables
- R&D Expenditures
- Correlation with monetary shocks
- Results without FX in VAR
CONCLUSION

○ Exchange rates are connected to macro fundamentals!
  ▶ Noisy news about future TFP are the rare structural shocks that drive all of $q_t$, macro aggregates and stock prices

○ Exchange rate puzzles have a common, fundamental origin
  ▶ puzzles connected with each other via volatile, endogenous UIP wedge

○ Moving forward: how do we model all of this?
  ▶ Rich and precise set of results that sharply discriminate across models
  ▶ Intuitively consistent with long-run risk style of models. Shifts focus back to fundamental mechanisms, deeply connected to macroeconomy
  ▶ But more work remains to be done
    ★ e.g. excess currency returns fluctuate significantly after TFP improvement, not just before
## Variance Decomposition (Reduced-form Approach)

<table>
<thead>
<tr>
<th></th>
<th>Q1 Δ</th>
<th>Q4 Δ</th>
<th>Q12 Δ</th>
<th>Q24 Δ</th>
<th>Q40 Δ</th>
<th>Q100 Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home TFP</td>
<td>0.03</td>
<td>0.06</td>
<td>0.20</td>
<td>0.37</td>
<td>0.45</td>
<td>0.43</td>
</tr>
<tr>
<td>Home Consumption</td>
<td>0.02</td>
<td>0.04</td>
<td>0.21</td>
<td>0.47</td>
<td>0.51</td>
<td>0.40</td>
</tr>
<tr>
<td>Foreign Consumption</td>
<td>0.01</td>
<td>0.04</td>
<td>0.06</td>
<td>0.21</td>
<td>0.36</td>
<td>0.30</td>
</tr>
<tr>
<td>Home Investment</td>
<td>0.29</td>
<td>0.34</td>
<td>0.32</td>
<td>0.40</td>
<td>0.42</td>
<td>0.41</td>
</tr>
<tr>
<td>Foreign Investment</td>
<td>0.06</td>
<td>0.08</td>
<td>0.15</td>
<td>0.22</td>
<td>0.34</td>
<td>0.33</td>
</tr>
<tr>
<td>Interest Rate Differential</td>
<td>0.40</td>
<td>0.39</td>
<td>0.30</td>
<td>0.34</td>
<td>0.35</td>
<td>0.39</td>
</tr>
<tr>
<td>Real Exchange Rate</td>
<td>0.50</td>
<td>0.69</td>
<td>0.82</td>
<td>0.73</td>
<td>0.70</td>
<td>0.68</td>
</tr>
<tr>
<td>Expected Excess Returns</td>
<td>0.47</td>
<td>0.33</td>
<td>0.34</td>
<td>0.44</td>
<td>0.45</td>
<td>0.47</td>
</tr>
<tr>
<td>Real Exchange Rate Changes</td>
<td>0.50</td>
<td>0.49</td>
<td>0.47</td>
<td>0.49</td>
<td>0.49</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Share of forecast error variance explained by the Main FX shock ($\varepsilon_1$)
FX Decomposition

Using the definition of expected excess returns:

\[ E_t \lambda_{t+1} = E_t(q_{t+1}) - q_t - (r_t - r_t^*) \]

We can rearrange:

\[ q_t = E(q_{t+1}) - (r_t - r_t^*) - E_t \lambda_{t+1} \]

And solve forward:

\[ q_t = - \sum_{k=0}^{\infty} E_t(r_{t+k} - r_{t+k}^*) - \sum_{k=0}^{\infty} E_t \lambda_{t+k+1} \]

\[ = q_t^{UIP} \]

\[ = q_t^\lambda \]
Anticipated vs surprise in fundamentals

- Our empirical procedure allows us to identify the following representation of the exchange rate

\[
q_t \mid \{\varepsilon^a_t, \varepsilon^v_t\} = \sum_{k=-\infty}^{\infty} \zeta^a_k \varepsilon^a_{t+k} + \sum_{k=0}^{\infty} \zeta^v_k \varepsilon^v_{t-k}
\]

\[
= \sum_{k=1}^{\infty} \zeta^a_k \varepsilon^a_{t+k} + \sum_{k=0}^{\infty} \zeta^v_k \varepsilon^v_{t-k} + \sum_{k=0}^{\infty} \zeta^q_k \varepsilon^a_{t-k}
\]

<table>
<thead>
<tr>
<th></th>
<th>Fwd-looking</th>
<th>Bkwd-looking</th>
</tr>
</thead>
<tbody>
<tr>
<td>(q_t)</td>
<td>0.29</td>
<td>0.71</td>
</tr>
<tr>
<td>(\Delta q_t)</td>
<td>0.69</td>
<td>0.0031</td>
</tr>
</tbody>
</table>

Var Decomposition: Forward-looking vs backward-looking components
Identifying Expectations

Problem:
- Noise information structures are generically non-causal and non-invertible
- Common view: “VAR methods not applicable”
- Barsky & Sims 2012; Blanchard et al, 2013; etc.

Solution: Chahrou & Jurado (RESTUD, 21)
- Relax these assumptions
  - Past and future symmetric to econometrician
- Focus on “recoverability”
- Expand the scope of VAR methods to...exactly cases like this
MA Representation

**MA representation:**

\[
\begin{bmatrix}
    a_t \\
    \eta_t
\end{bmatrix} = \cdots + \begin{bmatrix}
    0 & 0 \\
    * & 0
\end{bmatrix} \begin{bmatrix}
    \epsilon_{t+1}^a \\
    \epsilon_{t+1}^v
\end{bmatrix} + \begin{bmatrix}
    * & 0 \\
    * & *
\end{bmatrix} \begin{bmatrix}
    \epsilon_t^a \\
    \epsilon_t^v
\end{bmatrix} + \begin{bmatrix}
    * & 0 \\
    * & *
\end{bmatrix} \begin{bmatrix}
    \epsilon_{t-1}^a \\
    \epsilon_{t-1}^v
\end{bmatrix} + \cdots
\]

**Compare to Cholesky:**

\[
\begin{bmatrix}
    a_t \\
    \eta_t
\end{bmatrix} = \cdots + \begin{bmatrix}
    0 & 0 \\
    0 & 0
\end{bmatrix} \begin{bmatrix}
    \epsilon_{t+1}^a \\
    \epsilon_{t+1}^v
\end{bmatrix} + \begin{bmatrix}
    * & 0 \\
    * & *
\end{bmatrix} \begin{bmatrix}
    \epsilon_t^a \\
    \epsilon_t^v
\end{bmatrix} + \begin{bmatrix}
    * & 0 \\
    * & *
\end{bmatrix} \begin{bmatrix}
    \epsilon_{t-1}^a \\
    \epsilon_{t-1}^v
\end{bmatrix} + \cdots
\]
Trade Balance and Exchange Rate

Technology

Noise

Real Exchange Rate

-20 -10 0 10 20
-20 -10 0 10 20
-2 -1 0 1 2
-2 -1 0 1

-0.3 -0.2 -0.1 0 0.1
0.05 0.1

0 0.05 0.1
Conditional Dynamics – Technology ($\varepsilon^a$) – Extended Sample

- Home TFP
- Interest Rate Differential
- Home Consumption
- Real Exchange Rate
- Foreign Consumption
- Expected Excess Returns
Conditional Dynamics – Expectational noise ($\varepsilon^v$) – Extended Sample
Conditional Dynamics – Technology ($\varepsilon^a$) – Canada
Conditional Dynamics – Expectational noise ($\varepsilon^y$) – Canada

- Home TFP
- Interest Rate Differential
- Home Consumption
- Real Exchange Rate
- Foreign Consumption
- Expected Excess Returns
Conditional Dynamics – Technology ($\varepsilon^a$) – France
Conditional Dynamics – Expectational noise ($\varepsilon^y$)– France
Conditional Dynamics – Technology ($\varepsilon^a$) – Germany
Conditional Dynamics – Expectational noise ($\varepsilon^v$) – Germany
Conditional Dynamics – Technology ($\varepsilon^a$) – Italy

- Home TFP
- Interest Rate Differential
- Home Consumption
- Real Exchange Rate
- Foreign Consumption
- Expected Excess Returns
Conditional Dynamics – Expectational noise ($\varepsilon^v$) – Italy
Conditional Dynamics – Technology ($\varepsilon^a$) – Japan
Conditional Dynamics – Expectational noise ($\varepsilon^y$) – Japan
Conditional Dynamics – Technology ($\varepsilon^a$) – United Kingdom

- **Home TFP**
- **Interest Rate Differential**
- **Home Consumption**
- **Real Exchange Rate**
- **Foreign Consumption**
- **Expected Excess Returns**
Conditional Dynamics – Expectational noise ($\varepsilon^y$) – United Kingdom

- Home TFP
- Interest Rate Differential
- Home Consumption
- Real Exchange Rate
- Foreign Consumption
- Expected Excess Returns
Conditional Dynamics – Technology ($\varepsilon^a$) – VECM
Conditional Dynamics – Expectational noise ($\varepsilon^v$) – VECM

Home TFP

Interest Rate Differential

Home Consumption

Real Exchange Rate

Foreign Consumption

Expected Excess Returns
Conditional Dynamics – R&D Expenditure

- Technology
- Noise
- Home TFP
- Home R&D expenditure

Graphs showing the dynamics of R&D expenditure and TFP over time.
Correlation with monetary policy shocks

Correlation between Technology, Noise and Other Economic Shocks

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Conditional Dynamics – no FX in VAR