International R&D Spillovers and Asset Prices

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1The views of this presentation are my own and do not represent the views of the Federal Reserve Bank of St. Louis or the Federal Reserve System.
## Motivation: The Facts

<table>
<thead>
<tr>
<th>Corr. with the U.S.</th>
<th>Consumption Growth</th>
<th>Stock market</th>
<th>FX Depr. Volatility</th>
<th>FX Carry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>0.39</td>
<td>0.72</td>
<td>9.58</td>
<td>3.52</td>
</tr>
<tr>
<td>Canada</td>
<td>0.44</td>
<td>0.77</td>
<td>4.81</td>
<td>0.41</td>
</tr>
<tr>
<td>Germany</td>
<td>0.12</td>
<td>0.76</td>
<td>9.14</td>
<td>-3.60</td>
</tr>
<tr>
<td>Japan</td>
<td>0.15</td>
<td>0.55</td>
<td>9.95</td>
<td>-6.46</td>
</tr>
<tr>
<td>New Zealand</td>
<td>0.14</td>
<td>0.60</td>
<td>10.01</td>
<td>6.30</td>
</tr>
<tr>
<td>Norway</td>
<td>0.08</td>
<td>0.48</td>
<td>8.81</td>
<td>0.75</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.32</td>
<td>0.46</td>
<td>9.39</td>
<td>1.24</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.09</td>
<td>0.63</td>
<td>9.37</td>
<td>-4.96</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.49</td>
<td>0.86</td>
<td>8.33</td>
<td>3.86</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>0.25</strong></td>
<td><strong>0.65</strong></td>
<td><strong>8.82</strong></td>
<td><strong>0.12</strong></td>
</tr>
<tr>
<td><strong>Volatility</strong></td>
<td><strong>0.16</strong></td>
<td><strong>0.14</strong></td>
<td><strong>1.59</strong></td>
<td><strong>4.31</strong></td>
</tr>
</tbody>
</table>
Motivation

- With complete financial markets (in logs)

\[ \Delta q_{t+1} = m^*_{t+1} - m_{t+1} \]

- FX depreciation rate = Foreign SDF - Home SDF

- Puzzle: Take variance of both sides
  - Data says \( \sigma(\Delta q) \approx 10\% \), \( \sigma(m^*) \approx 50\% \), \( \sigma(m) \approx 50\% \)
  - It must be that \( corr(m^*, m) \) is positive and large

- With standard time additive CRRA preferences \( m^i \propto \Delta c^i \), but consumption growth has low correlation across countries (Brandt, Cochrane and Santa-Clara (2004))
Finance Literature

- Colacito-Croce (2011): ∃ a common component \( x \) in SDF that drives up \( \text{corr}(m^*, m) \)
  - It has to be:
    - Highly autocorrelated within the country (Bansal and Yaron (2004))
    - Highly correlated across countries (Colacito and Croce (2011))
  - Must matter a lot for assets prices and little for quantities

\[ \implies \text{Must move away from standard preferences} \]
What is \( x \)?

- Kung-Schmidt (2013) ➞ In a **closed economy**, \( x \) is driven by endogenous R&D (Romer (1990), Comin and Gertler (2006), Comin, Gertler and Santacreu (2011))

- Gavazzoni-Santacreu (2015) ➞ Endogenous growth through innovation (R&D) and its international spillovers (**through trade in varieties**) with recursive preferences affects the joint dynamics of asset prices and quantities
  
  **Idea:**
  
  - Asset prices reflect anticipation of future growth within countries
  - Joint dynamics of international asset prices depend on how future growth spreads worldwide
R&D Spillovers Literature


- R&D Spillovers and multinationals (Ramondo (2009), Guadalupe, Kuzmina, and Thomas (2010), Monge-Naranjo (2012))

- R&D Spillovers and networks (Cai and Li (2012))
International Trade and Stock Market Correlation

Stock Market Returns Correlations with Trade Variables

- Trade Intensity (1985-2009)
- Intensive Margin of Trade (1985-2009)
- Extensive Margin of Trade (1985-2009)
International Trade and FX Volatility

Exchange Rate Volatility with Trade Variables

![Graphs showing exchange rate volatility with trade variables.](image)
Our Paper

- **Theoretical:** Build a general equilibrium model that captures the relation between asset prices and international R&D spillovers

- **Empirical:**
  - Show in the data the relationship between asset prices, R&D and international trade
  - Empirical validity of our mechanisms: Predictability regressions
THE MODEL
The Model

- Two-country \( \{d, f\} \), symmetric production economy
- One representative consumer per country, recursive preferences
- Endogenous growth through R&D
- International R&D spillovers through trade in varieties: international adoption
- Complete financial markets
Preferences

Recursive Preferences:

\[ U_{d,t} = \left\{ (1 - \beta)C_{d,t}^{\theta} + \beta \left( E_t \left( U_{d,t+1}^{1-\gamma} \right) \right)^{\frac{\theta}{1-\gamma}} \right\}^{\frac{1}{\theta}} \]

\( \gamma \) is CRRA, \( \psi \equiv \frac{1}{1-\theta} \) is IES (when \( \psi > 1/\gamma \), agents fear variation in \( U_{t+1} \))

\[ M_{d,t+1} = \beta \left( \frac{C_{d,t+1}}{C_{d,t}} \right)^{\theta - 1} \left( \frac{U_{d,t+1}}{E_t(U_{d,t+1})^{1-\gamma}} \right)^{1-\gamma-\theta} \]
Final Producers

\[ Y_{d,t} = \left( K_{d,t}^\alpha (\Omega_{d,t} L_{d,t})^{(1-\alpha)} \right)^{(1-\xi)} G_{d,t}^\xi \]

\[ G_{d,t} = \left[ N_{d,t}^d (X_{d,t})^\nu + N_{f,t}^d (X_{f,t})^\nu \right]^{\frac{1}{\nu}} \]

with \( \alpha \in (0, 1), \xi \in (0, 1), \) and \( \nu > 1. \) The shock \( \log(\Omega_{d,t}) \) is AR(1)
Intermediate Producers

- Monopolistic competitive firms
- Use final output with a CRS technology
- Iceberg transport costs: $\tau$
- Set prices as a constant mark-up over the marginal cost
Innovation

- Innovators invest resources (final output) to introduce new prototypes of a product
- Value of a prototype to innovator:

\[ V_{d,t} = \Pi_{d,t} + (1 - \phi) E_t[M_{d,t+1} V_{d,t+1}] \]

where \( \phi \) is the exogenous probability that a new variety becomes obsolete
- Law of motion:

\[ N_{d,t+1}^d = \vartheta_{d,t} S_{d,t} + (1 - \phi) N_{d,t}^d \]

R&D expenditure

with \( \vartheta_{d,t} = \frac{\chi N_{d,t}^d}{S_{d,t}^{1-\eta} (N_{d,t}^d)^\eta} \)
- Free entry: \( 1/\vartheta_{d,t} = E_t(M_{d,t+1} V_{d,t+1}) \)
International R&D Spillovers

\[ N_{f,t+1}^d = \theta_f^d (1 - \phi)(N_{f,t}^d - N_{f,t}^d) + (1 - \phi)N_{f,t}^d \]
Quantities: Aggregate Productivity

- We can write the production function as:

\[ Y_{d,t} = K_{d,t}^\alpha (Z_{d,t} L_{d,t})^{1-\alpha} \]

where

\[ \log Z_{d,t} = \log \Omega_{d,t} + \log \left\{ (\bar{A})^{\frac{1}{1-\alpha}} \left[ N_{d,t}^d + (\tau Q_t)^{\frac{v}{v-1}} N_{f,t}^d \right] \right\} . \]

- TFP comes from:
  - Exogenous growth: \( \log \Omega_{d,t} \)
  - Endogenous growth:
    - Domestic R&D
    - Adoption of foreign R&D
Asset prices: Stock Market

\[ Q_{d,t} = \text{Value of installed capital (} K_{d,t} \text{)} + \]
\[ \text{Value of already invented technologies (used or not used abroad)} + \]
\[ \text{Value of future domestic R&D} + \]
\[ \text{Value of future domestic R&D (potentially sold abroad)} \]

- Last two terms are highly correlated across countries:
  international long run risk through adoption
NUMERICAL EXERCISE
## Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Lower Spillover</th>
<th>Higher Spillover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Aversion</td>
<td>$\gamma$</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>IES</td>
<td>$\psi$</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Subjective Discount Factor</td>
<td>$\beta$</td>
<td>$0.984^{1/4}$</td>
<td></td>
</tr>
<tr>
<td>Capital Share</td>
<td>$\alpha$</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>Share of Materials</td>
<td>$\zeta$</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Autocorrelation of $\Omega$</td>
<td>$\rho_a$</td>
<td>$0.95^{1/4}$</td>
<td></td>
</tr>
<tr>
<td>Depreciation of capital stock</td>
<td>$\delta$</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Scale Parameter</td>
<td>$\chi$</td>
<td>0.4240</td>
<td></td>
</tr>
<tr>
<td>Innovation Obsolescence Rate</td>
<td>$\phi$</td>
<td>0.0375</td>
<td></td>
</tr>
<tr>
<td>Elasticity of Innovation wrt R&amp;D</td>
<td>$\eta$</td>
<td>0.83</td>
<td></td>
</tr>
<tr>
<td>Volatility of exogenous shock</td>
<td>$\sigma$</td>
<td>1.00%</td>
<td></td>
</tr>
<tr>
<td>Inverse Markup</td>
<td>$\nu$</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Shipping Cost</td>
<td>$\tau$</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>International Adoption Parameter</td>
<td>$\vartheta_d$</td>
<td>0.015</td>
<td>0.025</td>
</tr>
</tbody>
</table>
## Numerical exercise: Results

<table>
<thead>
<tr>
<th>Moment</th>
<th>Lower Spillover</th>
<th>Higher Spillover</th>
<th>CRRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma(\Delta c)$</td>
<td>1.67</td>
<td>1.62</td>
<td>1.97</td>
</tr>
<tr>
<td>$ACF_1(\mathbb{E}<em>t \Delta z</em>{t+1})$</td>
<td>0.9832</td>
<td>0.9838</td>
<td>0.963</td>
</tr>
<tr>
<td>$ACF_1(\mathbb{E}<em>t \Delta c</em>{t+1})$</td>
<td>0.9865</td>
<td>0.9869</td>
<td>0.914</td>
</tr>
<tr>
<td>$\text{Corr}(\Delta c, \Delta c^*)$</td>
<td><strong>0.2030</strong></td>
<td><strong>0.2800</strong></td>
<td><strong>0.980</strong></td>
</tr>
<tr>
<td>$E(r_f)$</td>
<td>1.45</td>
<td>1.46</td>
<td>5.38</td>
</tr>
<tr>
<td>$E(r_m - r_f)$</td>
<td>2.80</td>
<td>2.91</td>
<td>6.00</td>
</tr>
<tr>
<td>$\sigma(r_m - r_f)$</td>
<td>11.0</td>
<td>12.0</td>
<td>8.20</td>
</tr>
<tr>
<td>$\text{Corr}(r_f, r_f^*)$</td>
<td>0.708</td>
<td>0.850</td>
<td>0.850</td>
</tr>
<tr>
<td>$\text{Corr}(r_m - r_f, r_m^* - r_f^*)$</td>
<td><strong>0.823</strong></td>
<td><strong>0.859</strong></td>
<td>$-0.786$</td>
</tr>
<tr>
<td>$\sigma(\Delta q)$</td>
<td><strong>7.00</strong></td>
<td>5.88</td>
<td>12.0</td>
</tr>
</tbody>
</table>
Numerical exercise: The importance of the mechanism

<table>
<thead>
<tr>
<th>Moment</th>
<th>Exo R&amp;D (no adopt.)</th>
<th>Endo R&amp;D (no adopt.)</th>
<th>Exo R&amp;D (no adopt.)</th>
<th>CRRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Corr}(\Delta c, \Delta c^*)$</td>
<td>0.043</td>
<td>-0.008</td>
<td>-0.008</td>
<td>0.980</td>
</tr>
<tr>
<td>$\text{Corr}(r_m - r_f, r_m^* - r_f^*)$</td>
<td>0.014</td>
<td>0.779</td>
<td>0.011</td>
<td>-0.786</td>
</tr>
<tr>
<td>$\sigma(\Delta q)$</td>
<td>9.62</td>
<td>26.2</td>
<td>11.2</td>
<td>12.0</td>
</tr>
</tbody>
</table>
Conclusion

- Hard to reconcile dynamics of quantities and asset prices

- New empirical findings:
  - **Positive** correlation between stock market returns correlation and:
    - bilateral R&D intensity
    - the extensive margin of trade
  - **Negative** correlation between FX volatility:
    - and bilateral R&D intensity
    - the extensive margin of trade

- An endogenous growth model with international R&D spillovers rationalizes these findings

- Next:
  - Empirical validity of the mechanism through predictability tests
The Mechanism

\[ \Omega_{d,t} \uparrow \Rightarrow TFP_{d,t}^{EXO} \uparrow \]

- Domestic final good producers demand:
  - 1. More domestic varieties: \( TFP_{d,t}^{ENDO} \uparrow \). With international adoption, \( TFP_{f,t+1}^{ENDO} \uparrow \).
  - 2. More foreign varieties: \( TFP_{f,t}^{ENDO} \uparrow \). With international adoption, \( TFP_{d,t+1}^{ENDO} \uparrow \).

- **Result:** Expected TFP’s are positively autocorrelated (endogenous growth) and positively correlated across countries (international adoption):
  - Mild effect on quantities.
  - Strong effect on asset prices (through EZ preferences).