Risk Sharing for the Long-Run

A General Equilibrium Approach to International Finance with Recursive Preferences and Long-Run Risks

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Motivation

We would like to explain:

1. The forward premium anomaly: the tendency of high interest rate currencies to appreciate

2. The Backus and Smith anomaly: the lack of correlation between consumption differentials and FX movements
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1. **The forward premium anomaly**: the tendency of high interest rate currencies to appreciate

2. **The Backus and Smith anomaly**: the lack of correlation between consumption differentials and FX movements

A general equilibrium model: quantities (consumption, $NX$, ...) and prices (assets’ returns, $FX$, ...) are outcome of utility maximization problem
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  1. The forward premium anomaly: the tendency of high interest rate currencies to appreciate
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- A general equilibrium model: quantities (consumption, NX,...) and prices (assets’ returns, FX,...) are outcome of utility maximization problem

- The model should be consistent with:
  - low int’l correlation of consumption and output
  - smoothness of exchange rates
  - large int’l equity risk premia
  - large int’l correlation of returns
  - volatility of Net Exports
  - ...
Roadmap of the talk

1. Setup of the model
   - Preferences
   - Endowments

2. Market structures
   - Complete Markets
   - Portfolio Autarky

3. Calibration

4. Results
Preferences

Two countries: home \((h)\) and foreign \((f)\)

Agents have risk-sensitive preferences

\[
U_{i,t} = (1 - \delta) \log C_{i,t} + \delta \theta \log E_t \exp \left\{ \frac{U_{i,t+1}}{\theta} \right\}, \quad \forall i \in \{h, f\}
\]

where \(\theta = 1/(1 - \gamma)\).
Preferences

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\[
U_{i,t} = (1 - \delta) \log C_{i,t} + \delta E_t[U_{i,t+1}], \quad \forall i \in \{h, f\}
\]

where \(\theta = 1 / (1 - \gamma)\). If \(\theta \to -\infty\): time additive case.
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where \(\theta = 1 / (1 - \gamma)\).
Preferences

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\[
U_{i,t} \approx (1 - \delta) \log C_{i,t} + \delta E_t[U_{i,t+1}] + \frac{\delta}{2\theta} V_t[U_{i,t+1}], \quad \forall i \in \{h, f\}
\]

where \(\theta = 1/(1 - \gamma)\). Conditional Variance matters.
Preferences

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\]

where \(\theta = 1/(1 - \gamma)\).

- Preferences are defined over the consumption aggregate

\[
C_{h,t} = (x_{h,t})^\alpha (y_{h,t})^{1-\alpha} \quad \text{and} \quad C_{f,t} = (x_{f,t})^{1-\alpha} (y_{f,t})^\alpha
\]
Preferences

- Two countries: home ($h$) and foreign ($f$)
- Agents have risk-sensitive preferences

$$U_{i,t} = (1 - \delta) \log C_{i,t} + \delta \theta \log E_t \exp \left\{ \frac{U_{i,t+1}}{\theta} \right\}, \quad \forall i \in \{h, f\}$$

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- Preferences are defined over the consumption aggregate

$$C_{h,t} = (x_{h,t})^{\alpha} (y_{h,t})^{1-\alpha} \quad \text{and} \quad C_{f,t} = (x_{f,t})^{1-\alpha} (y_{f,t})^{\alpha}$$

- Consumption bias: $\alpha > 1/2$. 

Endowments’ growth is *almost* i.i.d.

\[
\Delta \log X_t = \mu_x + z_{1,t-1} + \varepsilon_{x,t}
\]
\[
\Delta \log Y_t = \mu_y + z_{2,t-1} + \varepsilon_{y,t}
\]

where \( z_{1,t} \) and \( z_{2,t} \) are small, predictable components

\[
z_{1,t} = \rho_1 z_{1,t-1} + \varepsilon_{1,t}
\]
\[
z_{2,t} = \rho_2 z_{2,t-1} + \varepsilon_{2,t}
\]

- Shocks are homoskedastic.
Markets

- *Home* is endowed with good $X$;
- *Foreign* is endowed with good $Y$;
- Complete set of one period ahead state contingent securities;
- Budget constraints:

  $$x_{h,t} + p_t y_{h,t} + \sum_{s_{t+1}} Q_{t+1}(s_{t+1}) A_{t+1}(s_{t+1}) \leq X_t + A_t \quad [\text{Home}]$$

  $$x_{f,t} + p_t y_{f,t} - \sum_{s_{t+1}} Q_{t+1}(s_{t+1}) A_{t+1}(s_{t+1}) \leq p_t Y_t - p_t A_t \quad [\text{Foreign}]$$
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$$x_{f,t} + p_t y_{f,t} - \sum_{s_{t+1}} Q_{t+1}(s_{t+1})A_{t+1}(s_{t+1}) \leq p_t Y_t - p_t A_t \quad [\text{Foreign}]$$

- We shall solve the Pareto problem first...
Planner’s problem

Efficient allocations are the solution to the planner’s problem

choose \( \{x_{h,t}, x_{f,t}, y_{h,t}, y_{f,t}\}_{t=0}^{+\infty} \)

to max \( Q = \mu_h U_{h,0} + \mu_f U_{f,0} \)

s.t. \( x_{h,t} + x_{f,t} = X_t \)

\( y_{h,t} + y_{f,t} = Y_t, \quad \forall t \geq 0 \)
Planner’s problem

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\[
y_{h,t} + y_{f,t} = Y_t, \quad \forall t \geq 0
\]

- \(\mu_h\) and \(\mu_f\) correspond to an initial distribution of assets.
- Notation: \(S = \mu_h / \mu_f\).
Allocations

**Time Additive Preferences**

Let $k = \frac{\alpha}{1-\alpha}$:

\[
\begin{align*}
  x_t^h &= \frac{kS}{1 + kS} X_t, \\
  y_t^h &= \frac{S}{k + S} Y_t,
\end{align*}
\[
\begin{align*}
  x_t^f &= \frac{1}{1 + kS} X_t, \\
  y_t^f &= \frac{k}{k + S} Y_t
\end{align*}
\]

where

\[
S = \frac{\mu_h}{\mu_f}
\]
Risk Sensitive Preferences

Let \( k = \frac{\alpha}{1 - \alpha} \):

\[
\begin{align*}
  x^h_t &= \frac{kS_t}{1 + kS_t} X_t, & x^f_t &= \frac{1}{1 + kS_t} X_t \\
  y^h_t &= \frac{S_t}{k + S_t} Y_t, & y^f_t &= \frac{k}{k + S_t} Y_t
\end{align*}
\]

where

\[
S_t = S_{t-1} \cdot \frac{\delta \exp \{ U_{h,t}/\theta \}}{E_{t-1} \exp \{ U_{h,t}/\theta \}} \bigg/ \frac{\delta \exp \{ U_{f,t}/\theta \}}{E_{t-1} \exp \{ U_{f,t}/\theta \}}
\]
Economic Interpretation

1. What is $S_t$?

2. How does $S_t$ move?

3. Why does $S_t$ move?
Economic Interpretation

1. What is $S_t$?
   - $S_t$ indexes the relative share of consumption at date $t$.

2. How does $S_t$ move?

3. Why does $S_t$ move?
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   - $S_t$ indexes the relative share of consumption at date $t$.
   - I.e. when $S_t \downarrow$, home is decreasing its share of world consumption.

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   - $S_t$ indexes the relative share of consumption at date $t$.
   - I.e. when $S_t \downarrow$, home is decreasing its share of world consumption.
   - $S_t \downarrow$ means that the home country is exporting more.

2. How does $S_t$ move?

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How does $S_t$ move?
- $S_t \downarrow$, when home receives good (short- or long-run) news.

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- $S_t \downarrow$, when home receives good (short- or long-run) news.
- Equivalently, countries export more in good times.

Why does $S_t$ move?
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Reducing Expected Utility

Reducing Volatility

$\gamma = 25$
Why does $S_t$ move?

Reducing Expected Utility

Reducing Volatility

$\gamma = 25$
Why does $S_t$ move?

Trade-off between Expected Utility and Utility Variance
Why does $S_t$ move?

\[
\sigma[U_{h,t+1}(s_{t+1}|s_t)]
\]

$\gamma=1$ (Time Additive Case – No Tradeoff)

$\gamma=25$
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   - Agents are willing to trade-off lower consumption today for smoother future utility profiles.
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3. Why does $S_t$ move?
   - Agents are willing to trade-off lower consumption today for smoother future utility profiles.
   - Volatilities are high in bad times and low in good time.
Consumption growth

Time Additive Preferences

\[
\Delta c_t^h = \alpha \Delta x_t + (1 - \alpha) \Delta y_t
\]

\[
\Delta c_t^f = (1 - \alpha) \Delta x_t + \alpha \Delta y_t
\]
**Consumption growth**

**Risk Sensitive Preferences**

\[
\Delta c^h_t = \Delta c^{h, TA}_t + \lambda^h c s_{t-1} + \sigma^h_t \varepsilon_t \\
\Delta c^f_t = \Delta c^{f, TA}_t + \lambda^f c s_{t-1} + \sigma^f_t \varepsilon_t
\]
Consumption growth

Risk Sensitive Preferences

\[ \Delta c_h^t = \Delta c_h^{t, TA} + \lambda^h c_s t-1 + \sigma^h_1 g(\varepsilon_1, t, \varepsilon_2, t, \varepsilon_x, t, \varepsilon_y, t) \]

\[ \Delta c_f^t = \Delta c_f^{t, TA} + \lambda^f c_s t-1 + \sigma^f t g(\varepsilon_1, t, \varepsilon_2, t, \varepsilon_x, t, \varepsilon_y, t) \]

Additional endogenous predictive component
Consumption growth

Risk Sensitive Preferences

\[
\Delta c^h_t = \Delta c^{h,TA}_t + \lambda^h c_{s-1} + \sigma^h_t g(\varepsilon_1, t, \varepsilon_2, t, \varepsilon_x, t, \varepsilon_y, t)
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\Delta c^f_t = \Delta c^{f,TA}_t + \lambda^f c_{s-1} + \sigma^f_t g(\varepsilon_1, t, \varepsilon_2, t, \varepsilon_x, t, \varepsilon_y, t)
\]

1. Additional endogenous predictive component
2. Contemporaneous response to long-run shocks
Consumption growth

Risk Sensitive Preferences

\[ \Delta c^h_t = \Delta c^h_{t,TA} + \lambda^h_c s_{t-1} + \sigma^h_1 g(\varepsilon_{1,t}, \varepsilon_{2,t}, \varepsilon_{x,t}, \varepsilon_{y,t}) \]

\[ \Delta c^f_t = \Delta c^f_{t,TA} + \lambda^f_c s_{t-1} + \sigma^f_1 g(\varepsilon_{1,t}, \varepsilon_{2,t}, \varepsilon_{x,t}, \varepsilon_{y,t}) \]

1. Additional endogenous predictive component
2. Contemporaneous response to long-run shocks
3. Endogenous time-varying volatility
Exchange rates are functions of relative supplies of the two goods.
Exchange rates are functions of relative supplies of the two goods

- Both current

\[ \Delta e_t = f \left( \begin{pmatrix} \varepsilon_{x,t} - \varepsilon_{y,t} \\ <0 \end{pmatrix} \right) \]
Exchange rates are functions of relative supplies of the two goods

- Both current and future

\[ \Delta e_t = f \left( \varepsilon_{x,t} - \varepsilon_{y,t}, \varepsilon_{1,t} - \varepsilon_{2,t} \right) \]

where \( \varepsilon_{x,t} \) and \( \varepsilon_{y,t} \) are the supplies of goods X and Y respectively at time t, and \( \varepsilon_{1,t} \) and \( \varepsilon_{2,t} \) are the supplies of goods 1 and 2 respectively at time t. The function f indicates that the exchange rate \( \Delta e_t \) depends on the differences in these supplies.
Exchange rates are functions of relative supplies of the two goods

- Both current and future

\[
\Delta e_t = f \left( \begin{array}{c}
\varepsilon_{x,t} - \varepsilon_{y,t}, \\
<0
\end{array} \right) \left( \begin{array}{c}
\varepsilon_{1,t} - \varepsilon_{2,t}, \\
<<0
\end{array} \right)
\]

- Agents are extremely sensitive to long-run news
Exchange rates are functions of relative supplies of the two goods

- Both current and future

\[ \Delta e_t = f \left( \varepsilon_{x,t} - \varepsilon_{y,t}, \varepsilon_{1,t} - \varepsilon_{2,t} \right) \]

- Agents are extremely sensitive to long-run news
- Long-run risks should be very correlated to replicate FX volatility
The Backus and Smith Anomaly
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The quest for $corr(\Delta c^h - \Delta c^f, \Delta e) \approx 0$
The Backus and Smith Anomaly

The quest for \( \text{corr}(\Delta c^h - \Delta c^f, \Delta e) \approx 0 \)
The Backus and Smith Anomaly

The quest for \( \text{corr}(\Delta c^h - \Delta c^f, \Delta e) \approx 0 \)

→ Short-run shock to \( X \): home country is happy!
The Backus and Smith Anomaly

The quest for $\text{corr}(\Delta c^h - \Delta c^f, \Delta e) \approx 0$

→ Home increases consumption more than foreign.
The Backus and Smith Anomaly

The quest for $corr(\Delta c^h - \Delta c^f, \Delta e) \approx 0$

$\rightarrow$ Home increases consumption more than foreign.
The quest for $\text{corr}(\Delta c^h - \Delta c^f, \Delta e) \approx 0$

→ Home increases consumption more than foreign.
The Backus and Smith Anomaly

The quest for \( \text{corr}(\Delta c^h - \Delta c^f, \Delta e) \approx 0 \)

→ Home currency depreciates
The Backus and Smith Anomaly

The quest for $\text{corr}(\Delta c^h - \Delta c^f, \Delta e) \approx 0$

$\rightarrow$ Home currency depreciates: $\text{corr}(\Delta c^h - \Delta c^f, \Delta e)$ is positive
The Backus and Smith Anomaly

The quest for \( \text{corr}(\Delta c^h - \Delta c^f, \Delta e) \approx 0 \)

→ Long-run shock to \( X \): home country is very happy!
The Backus and Smith Anomaly

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→ Long-run shock to $X$: home country is very happy!
The Backus and Smith Anomaly

The quest for \( \text{corr}(\Delta c^h - \Delta c^f, \Delta e) \approx 0 \)

→ Home consumption falls to restore equilibrium.
The Backus and Smith Anomaly

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The quest for \( corr(\Delta c^h - \Delta c^f, \Delta e) \approx 0 \)

\[ \Delta c^h - \Delta c^f \rightarrow \text{Home currency depreciates} \]
The quest for $\text{corr}(\Delta c^h - \Delta c^f, \Delta e) \approx 0$

→ Home currency depreciates: $\text{corr}(\Delta c^h - \Delta c^f, \Delta e)$ is negative
The Backus and Smith Anomaly

The quest for $\text{corr}(\Delta c^h - \Delta c^f, \Delta e) \approx 0$

Short–Run Shock

Long–Run Shock

$\Delta c^h - \Delta c^f$

$\Delta c^h - \Delta c^f$
The quest for $corr(\Delta c^h - \Delta c^f, \Delta e) \approx 0$
Forward Premium Anomaly
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Why do high interest rate currency have the tendency to appreciate?
Forward Premium Anomaly

Why do high interest rate currency have the tendency to appreciate?

Interest rate differential

\[ \uparrow r_{t-1}^h - r_{t-1}^f \approx \uparrow E_{t-1} \left[ \Delta c_t^h - \Delta c_t^f \right] + \frac{1}{2} \left( V_{t-1} \left[ \Delta c_t^f \right] - V_{t-1} \left[ \Delta c_t^h \right] \right) \]
Forward Premium Anomaly

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**Interest rate differential**

\[ \uparrow r^h_{t-1} - r^f_{t-1} \approx \uparrow E_{t-1} [\Delta c^h_t - \Delta c^f_t] + \frac{1}{2} (V_{t-1} [\Delta c^f_t] - V_{t-1} [\Delta c^h_t]) \uparrow \]

**Expected FX growth**

\[ \uparrow \downarrow E_{t-1} [\Delta e_t] = \uparrow E_{t-1} [\Delta c^h_t - \Delta c^f_t] + \frac{1}{2\theta^2} (Var_{t-1} [U^h_t] - Var_{t-1} [U^f_t]) \downarrow \]
Forward Premium Anomaly

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### Interest rate differential

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### Expected FX growth

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→ Assume that Home has good long-run news (\(\varepsilon_{1,t} \uparrow\))
Forward Premium Anomaly

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→ Assume that Home has good long-run news ($\epsilon_{1,t} \uparrow$)
Forward Premium Anomaly

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**Expected FX growth**

\[ \uparrow \downarrow E_{t-1} \left[ \Delta e_t \right] = \uparrow E_{t-1} \left[ \Delta c_t^h - \Delta c_t^f \right] + \frac{1}{2 \theta^2} \left( Var_{t-1} \left[ U_t^h \right] - Var_{t-1} \left[ U_t^f \right] \right) \downarrow \]

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Expected FX growth

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→ Assume that Home has good long-run news (\(\varepsilon_{1,t} \uparrow\))
Why do high interest rate currency have the tendency to appreciate?

**Interest rate differential**

\[ \uparrow r^h_{t-1} - r^f_{t-1} \approx \uparrow E_{t-1} [\Delta c^h_t - \Delta c^f_t] + \frac{1}{2} \left( V_{t-1} [\Delta c^f_t] - V_{t-1} [\Delta c^h_t] \right) \uparrow \]

**Expected FX growth**

\[ \uparrow\downarrow E_{t-1} [\Delta e_t] = \uparrow E_{t-1} [\Delta c^h_t - \Delta c^f_t] + \frac{1}{2\theta^2} \left( \text{Var}_{t-1} [U^h_t] - \text{Var}_{t-1} [U^f_t] \right) \downarrow \]

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→ Assume that Home has good long-run news \((\epsilon_{1,t} \uparrow)\)
Forward Premium Anomaly

Why do high interest rate currency have the tendency to appreciate?

**Interest rate differential**

\[ \uparrow r^h_{t-1} - r^f_{t-1} \approx \uparrow E_{t-1} [ \Delta c^h_t - \Delta c^f_t ] + \frac{1}{2} \left( V_{t-1} [ \Delta c^f_t ] - V_{t-1} [ \Delta c^h_t ] \right) \uparrow \]

**Expected FX growth**

\[ \downarrow \uparrow E_{t-1} [ \Delta e_t ] = \uparrow E_{t-1} [ \Delta c^h_t - \Delta c^f_t ] + \frac{1}{2 \theta^2} \left( Var_{t-1} [ U^h_t ] - Var_{t-1} [ U^f_t ] \right) \downarrow \]

\[ \rightarrow \text{Assume that Home has good long-run news (} \varepsilon_{1,t} \uparrow \) \]
Why do high interest rate currency have the tendency to appreciate?

**Interest rate differential**

\[ \uparrow r_{t-1}^h - r_{t-1}^f \approx \uparrow E_{t-1} \left[ \Delta c_t^h - \Delta c_t^f \right] + \frac{1}{2} \left( V_{t-1} \left[ \Delta c_t^f \right] - V_{t-1} \left[ \Delta c_t^h \right] \right) \uparrow \]

**Expected FX growth**

\[ \uparrow \downarrow E_{t-1} \left[ \Delta e_t \right] = \uparrow E_{t-1} \left[ \Delta c_t^h - \Delta c_t^f \right] + \frac{1}{2 \theta^2} \left( Var_{t-1} \left[ U_t^h \right] - Var_{t-1} \left[ U_t^f \right] \right) \downarrow \]

→ Assume that Home has good long-run news (\( \varepsilon_{1,t} \uparrow \))
## Calibration

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Methodology:

- Define GDP as sum of consumption and Net Export
- For each country: regress $\Delta GDP$ on lagged $\Delta c$, $pd$, $cy$
- Use projection as measure of long-run risks
- Apply to US and UK
Using all NX

\[ \rho_{12} = 0.46 \]

\[ \rho_{12} = 0.70 \]
Long-Run Risks

Using all NX

\[ \rho_{12} = 0.46 \]

\[ \rho_{12} = 0.70 \]

\[ \rho_{12} = 0.89 \]
Long-Run Risks

Using only bilateral NX

\( \rho_{12} = 0.49 \)

\( \rho_{12} = 0.63 \)
Long-Run Risks

→ Using only bilateral NX

\[
\begin{align*}
\rho_{12} &= 0.49 \\
\rho_{12} &= 0.63 \\
\rho_{12} &= 0.83
\end{align*}
\]
## Results: quantities

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- $Std[m^h]$
- $Std[\Delta e]$
- $E[r^h_i]$
- $Std[r^h_i]$
- $corr[r^h_{fi,t}, r^f_{fi,t}]$
- $corr[\Delta c^h_i - \Delta c^f_i, \Delta e_t]$
- $\beta_{UIP}$
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<td><code>Std[r^h_i]</code></td>
<td>1.210</td>
<td>0.884</td>
</tr>
<tr>
<td><code>corr[r^h_i, r^f_i]</code></td>
<td>0.500</td>
<td>0.512</td>
</tr>
<tr>
<td><code>corr[Δc^h_i - Δc^f_i, Δe_i]</code></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><code>β_{UIP}</code></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Epstein and Zin Preferences

- Risk Sensitive preferences are a special case of Epstein and Zin preferences.
- What happens when the elasticity of intertemporal substitution is different from 1?
- Main results are confirmed, larger equity risk premium...
### Epstein and Zin Preferences: Results

<table>
<thead>
<tr>
<th>$\psi$</th>
<th>1.5</th>
<th>1</th>
<th>0.66</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma$</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>$Std(\Delta e)$</td>
<td>18.02</td>
<td>18.14</td>
<td>27.57</td>
</tr>
<tr>
<td>$E[r_c - r_f]$</td>
<td>3.24</td>
<td>0.28</td>
<td>-1.27</td>
</tr>
<tr>
<td>$E[r_f]$</td>
<td>1.48</td>
<td>3.6</td>
<td>5.27</td>
</tr>
<tr>
<td>$Std(r_f)$</td>
<td>0.85</td>
<td>1.47</td>
<td>2.06</td>
</tr>
<tr>
<td>$corr(r_f^h, r_f^f)$</td>
<td>0.86</td>
<td>0.93</td>
<td>0.95</td>
</tr>
<tr>
<td>$corr(\Delta c^h - \Delta c^f, \Delta e)$</td>
<td>-0.13</td>
<td>0</td>
<td>0.63</td>
</tr>
<tr>
<td>$\beta_{UIP}$</td>
<td>-2.56</td>
<td>-2.65</td>
<td>-3.29</td>
</tr>
</tbody>
</table>
Concluding Remarks

A two-countries model with:

- complete markets
- two goods
- long-run risks in the endowments
- recursive preferences

1. generates
   - dynamic risk-sharing scheme
   - endogenously time varying second moments

2. replicates a number of international finance facts

3. introduce frictions and investments