Asset pricing in the frequency domain: theory and empirics

by Ian Dew-Becker and Stefano Giglio

Discussed by Urban Jermann
Contribution

- Study asset prices in the frequency domain
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- Theoretical results: Frequency domain representation for SDF with applications
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- Theoretical results: Frequency domain representation for SDF with applications
- Empirical results: Estimation of risk prices by frequency from cross-section, find significantly priced low frequency risk
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- Study asset prices in the frequency domain
- Theoretical results: Frequency domain representation for SDF with applications
- Empirical results: Estimation of risk prices by frequency from cross-section, find significantly priced low frequency risk
- Analysis suggests EZ closer to data than Habits
Theory

- Focus on innovations in SDF with time-non-separabilities

\[ \Delta E_{t+1} m_{t+1} = \Delta E_{t+1} \sum_{k=0}^{\infty} z_k \cdot x_{t+1+k} \]

with priced variable \( x_t \)
Theory

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- Assume a vector MA process for state variables

\[
x_t = B_1 X_t = B_1 \Gamma (L) \varepsilon_t
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- Assume a vector MA process for state variables

\[ x_t = B_1 X_t = B_1 \Gamma (L) \varepsilon_t \]

\[ \Delta E_{t+1} m_{t+1} = - \sum_j \left( \sum_{k=0}^{\infty} z_k \cdot g_{j,k} \right) \varepsilon_{j,t+1} \]

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Result 1

\[
\Delta E_{t+1} m_{t+1} = - \sum_j \left( \sum_{k=0}^{\infty} z_k g_{j,k} \right) \varepsilon_{j,t+1}
\]

\[
= - \sum_j \left( \frac{1}{2\pi} \int_{-\pi}^{\pi} Z(\omega) G_j(\omega) \, d\omega \right) \varepsilon_{j,t+1}
\]

with

\[
Z(\omega) \equiv z_0 + 2 \sum_{k=1}^{\infty} z_k \cos(\omega k)
\]

\[
G_j(\omega) \equiv \sum_{k=1}^{\infty} g_{j,k} \cos(\omega k)
\]

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Derivation

- #1: Discrete-time Fourier Transform, and Inverse

\[
\tilde{G}_j(\omega) \equiv \sum_{k=0}^{\infty} e^{-i\omega k} g_{j,k}, \text{ and } g_{j,k} = \frac{1}{2\pi} \int_{-\pi}^{\pi} \tilde{G}_j(\omega) e^{-i\omega k} d\omega
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Derivation

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#2: Using fact that \( g_{j,k} = 0, \) for \( k < 0, \) and algebra

\[ \sum_{k=0}^{\infty} z_k \left( \frac{1}{2\pi} \int_{-\pi}^{\pi} \tilde{G}_j(\omega) 2\cos(\omega k) d\omega \right) \]
\[ \sum_{k=0}^{\infty} z_k g_{j,k} = \frac{1}{2\pi} \int_{-\pi}^{\pi} \tilde{G}_j(\omega) \left[ z_0 + \sum_{k=1}^{\infty} z_k 2 \cos(\omega k) \right] d\omega, \]

\[ \equiv Z(\omega) \]

\[ Z(\omega) \equiv \text{‘weighting function’} \]
• #3: A lot more algebra

\[ \sum_{k=0}^{\infty} z_{k} g_{j,k} = \frac{1}{2\pi} \int_{-\pi}^{\pi} G_j(\omega) \left[ z_0 + \sum_{k=1}^{\infty} z_k 2 \cos(\omega k) \right] d\omega \]

with

\[ G_j(\omega) = \text{re} (\tilde{G}_j(\omega)) = \sum_{k=1}^{\infty} g_{j,k} \cos(\omega k) \]
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- \( G_j(\omega) \) and \( Z(\omega) \) are real
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- \(G_j(\omega)\) and \(Z(\omega)\) are real
- Frequency response function: \(H(\omega) = |H(w)| \cdot e^{-i\psi(\omega)}\)

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3: A lot more algebra

\[ \sum_{k=0}^{\infty} z_k g_{j,k} = \frac{1}{2\pi} \int_{-\pi}^{\pi} G_j(\omega) \left[ z_0 + \sum_{k=1}^{\infty} z_k 2 \cos(\omega k) \right] d\omega \]

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with

\[ G_j(\omega) = \text{re} \left( \tilde{G}_j(\omega) \right) = \sum_{k=1}^{\infty} g_{j,k} \cos(\omega k) \]

- \(G_j(\omega)\) and \(Z(\omega)\) are real
- Frequency response function: \(H(\omega) = |H(\omega)| \cdot e^{-i\psi(\omega)}\)
- Need Inverse "Dew-Becker-Giglio" Transform

\[ z_k = \begin{cases} \frac{1}{2\pi} \int_{-\pi}^{\pi} Z(\omega) d\omega & \text{for } k = 0 \\ \frac{1}{\pi} \int_{-\pi}^{\pi} Z(\omega) \cos(\omega k) d\omega & \text{for } k > 0 \end{cases} \]

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Alternative derivation

#1: Parseval’s theorem

\[ \sum_{k=-\infty}^{\infty} z_k g_k = \int_{-\pi}^{\pi} Z(\omega) \overline{G(\omega)} \, d\omega \]

\[ Z(\omega) = \sum_{k=-\infty}^{\infty} z_k e^{-i\omega k}, \quad G(\omega) = \sum_{k=-\infty}^{\infty} g_k e^{-i\omega k} \]
Alternative derivation

- **#1: Parseval’s theorem**

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\sum_{k=-\infty}^{\infty} z_k g_k = \int_{-\pi}^{\pi} Z(\omega) \overline{G(\omega)} d\omega
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\[
Z(\omega) = \sum_{k=-\infty}^{\infty} z_k e^{-i\omega k}, \quad G(\omega) = \sum_{k=-\infty}^{\infty} g_k e^{-i\omega k}
\]

- \(Z(\omega)\) is complex, because \(\sum_{k=0}^{\infty} z_k L^{-k}\)

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#2: Make \{z_k\} into a two-sided symmetric filter, z_{-k} = z_k
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\sum_{k=-\infty}^{\infty} z_k g_k = \sum_{k=-\infty}^{\infty} z_k^{[2Sym]} g_k, \text{because } g_k = 0, \text{ for } k < 0
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Frequency response function

\[
Z(\omega) = \sum_{k=-\infty}^{\infty} z_k^{[2Sym]} e^{-i\omega k} = z_0 + \sum_{k=1}^{\infty} z_k 2 \cos(\omega k)
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This is the "Dew-Becker-Giglio" Weighting Function!
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This is the "Dew-Becker-Giglio" Weighting Function!

Need Inverse D-B-G Transform, split weights
Habits versus Epstein-Zin

- CRRA

\[ E_{t+1}m_{t+1} = -\alpha E_{t+1}\Delta c_{t+1} \]

\[ Z(\omega) = \alpha \]
Habits versus Epstein-Zin

- CRRA

\[ E_{t+1} m_{t+1} = -\alpha E_{t+1} \Delta c_{t+1} \]

\[ Z(\omega) = \alpha \]

- Habits

\[ u(\cdot) = \frac{1}{1-\alpha} (C_t - bC_{t-1})^{1-\alpha} \]
Habits versus Epstein-Zin

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\[ u(.) = \frac{1}{1 - \alpha} (C_t - bC_{t-1})^{1-\alpha} \]

\[ \exp (m_{t+1}) = \beta \frac{(C_{t+1} - bC_t)^{-\alpha} - E_{t+1} b(C_{t+2} - bC_{t+1})^{-\alpha}}{(C_t - bC_{t-1})^{-\alpha} - E_t b(C_{t+1} - bC_t)^{-\alpha}} \]
Habits versus Epstein-Zin

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\[ \exp(m_{t+1}) = \beta \frac{(C_{t+1} - bC_t)^{-\alpha}}{(C_t - bC_{t-1})^{-\alpha}} - E_{t+1} b (C_{t+2} - bC_{t+1})^{-\alpha} \]

\[ E_{t+1} m_{t+1} \approx -\alpha \left[ \left( b (1-b)^{-2} + 1 \right) E_{t+1} \Delta c_{t+1} \right] \]

\[ -b (1-b)^{-2} E_{t+1} \Delta c_{t+2} \]

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Figure 2. Theoretical spectral weighting functions
Internal Habit

- If $E_{t+1}\Delta c_{t+2} = E_{t+1}\Delta c_{t+1}$: very persistent shock
Internal Habit

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\[
E_{t+1}m_{t+1} \approx -\alpha \left[ \left( b (1 - b)^{-2} + 1 \right) E_{t+1}\Delta c_{t+1} - b (1 - b)^{-2} E_{t+1}\Delta c_{t+2} \right] = -\alpha E_{t+1}\Delta c_{t+1}
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\left. -b(1-b)^2 E_{t+1}\Delta c_{t+2} \right]
\]

\[
= -\alpha E_{t+1}\Delta c_{t+1}
\]

- If $E_{t+1}\Delta c_{t+2} = -E_{t+1}\Delta c_{t+1}$: shock reversed immediately
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- if $E_{t+1}\Delta c_{t+2} = -E_{t+1}\Delta c_{t+1}$: shock reversed immediately

\[
E_{t+1}m_{t+1} \approx -\alpha \left[ \frac{2b}{(1 - b)^2} \right] E_{t+1}\Delta c_{t+1} = -\alpha \left[ 40 \right] E_{t+1}\Delta c_{t+1} \quad \text{for } b = .8
\]
Consumption durability $b < 0$
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Consumption durability $b < 0$

If $E_{t+1} \Delta c_{t+2} = E_{t+1} \Delta c_{t+1}$: very persistent shock

$$E_{t+1} m_{t+1} \approx -\alpha \left[ \begin{array}{c} \left( b (1 - b)^{-2} + 1 \right) E_{t+1} \Delta c_{t+1} \\ -b (1 - b)^{-2} E_{t+1} \Delta c_{t+2} \end{array} \right]$$

$$= -\alpha E_{t+1} \Delta c_{t+1}$$
Consumption durability $b < 0$

If $E_{t+1}\Delta c_{t+2} = E_{t+1}\Delta c_{t+1}$: very persistent shock

\[ E_{t+1}m_{t+1} \approx -\alpha \left[ \left( b (1 - b)^{-2} + 1 \right) E_{t+1}\Delta c_{t+1} \right. \]
\[ \left. - b (1 - b)^{-2} E_{t+1}\Delta c_{t+2} \right] = -\alpha E_{t+1}\Delta c_{t+1} \]

if $E_{t+1}\Delta c_{t+2} = -E_{t+1}\Delta c_{t+1}$: shock reversed immediately
Consumption durability \( b < 0 \)

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If \( E_{t+1} \Delta c_{t+2} = -E_{t+1} \Delta c_{t+1} \): shock reversed immediately

\[
E_{t+1} m_{t+1} \approx \alpha \left[ \frac{2b}{(1 - b)^2} \right] = -\alpha \left[ \frac{1.6}{(1.8)^2} \right] E_{t+1} \Delta c_{t+1} \\
= -\alpha [0.5] E_{t+1} \Delta c_{t+1}
\]
Consumption durability \( b < 0 \)

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= -\alpha \left[ 0.5 \right] E_{t+1} \Delta c_{t+1}
\]

External habits, only innovations in \( \Delta c_{t+1} \), spectrum is flat

\[
\exp(m_{t+1}) = \beta \frac{(C_{t+1} - b \bar{C}_t)^{-\alpha}}{(C_t - b \bar{C}_{t-1})^{-\alpha}}
\]

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Epstein-Zin

- If $E_{t+1} \Delta c_{t+1+j} = E_{t+1} \Delta c_{t+1}$: very persistent shock
Epstein-Zin

- If $E_{t+1} \Delta c_{t+1+j} = E_{t+1} \Delta c_{t+1}$: very persistent shock

\[
\Delta E_{t+1} m_{t+1} \approx - \left( \rho \Delta E_{t+1} c_{t+1} + (a - \rho) \Delta E_{t+1} \Delta c_{t+1} \sum_{j=0}^{\infty} \theta^j \right)
\]

\[
= - \left( \rho + (a - \rho) \frac{1}{1 - \theta} \right) \Delta E_{t+1} c_{t+1}
\]

\[
= - \left( .5 + (5 - .5) \frac{1}{.025} \right) \Delta E_{t+1} c_{t+1}
\]

\[
= - [180] \Delta E_{t+1} c_{t+1}
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Epstein-Zin

- If $E_{t+1} \Delta c_{t+1+j} = E_{t+1} \Delta c_{t+1}$: very persistent shock

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$$
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- if $E_{t+1} \Delta c_{t+2} = -E_{t+1} \Delta c_{t+1}$: shock reversed immediately
Epstein-Zin

- If $E_{t+1}\Delta c_{t+1} + j = E_{t+1}\Delta c_{t+1}$: very persistent shock

$$\Delta E_{t+1}m_{t+1} \approx -\left(\rho \Delta E_{t+1}c_{t+1} + (a - \rho) \Delta E_{t+1}\Delta c_{t+1} \sum_{j=0}^{\infty} \theta^j\right)$$

$$= -\left(\rho + (a - \rho) \frac{1}{1 - \theta}\right) \Delta E_{t+1}c_{t+1}$$

$$= -\left(.5 + (5 - .5) \frac{1}{.025}\right) \Delta E_{t+1}c_{t+1}$$

$$= -[180] \Delta E_{t+1}c_{t+1}$$

- if $E_{t+1}\Delta c_{t+2} = -E_{t+1}\Delta c_{t+1}$: shock reversed immediately

$$\Delta E_{t+1}m_{t+1} \approx -\rho \Delta E_{t+1}c_{t+1}$$

$$= -0.5\Delta E_{t+1}c_{t+1}$$

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Estimates of spectral weighting functions

- Parameterize spectral functions
Estimates of spectral weighting functions

- Parameterize spectral functions
- Utility basis

\[ Z^U(\omega) = q_1 \sum_{j=1}^{\infty} \theta^j \cos(\omega j) + q_2 + q_3 \cos(\omega) \]

EZ : \( q_1, q_2 > 0, \) \( q_3 = 0 \)

Internal Habit : \( q_3 < 0, \) \( q_2 > 0, \) \( q_3 = 0 \)
Estimates of spectral weighting functions

- Parameterize spectral functions
- Utility basis

\[ Z^U(\omega) = q_1 \sum_{j=1}^{\infty} \theta^j \cos(\omega j) + q_2 + q_3 \cos(\omega) \]

**EZ** : \( q_1, q_2 > 0, q_3 = 0 \)

**Internal Habit** : \( q_3 < 0, q_2 > 0, q_3 = 0 \)

- Bandpass basis

\[ Z^{BP}(\omega) = q_1 Z^{(\infty,32\text{quarters})} + q_2 Z^{(32,6)} + q_3 Z^{(6,2)} \]
Apply Inverse Transform

\[ \Delta E_{t+1} m_{t+1} = -q' \left( \sum_{j=0}^{\infty} H_j^{U,BP} B_1 \Phi^j \right) \left( X_{t+1} - \Phi X_t \right) \]

\[ = -q' u_{t+1} \]
Apply Inverse Transform

\[ \Delta E_{t+1} m_{t+1} = -\bar{q}' \left( \sum_{j=0}^{\infty} H_{j}^{U,BP} B_{1} \Phi^{j} \right) \left( X_{t+1} - \Phi X_{t} \right) \]

= \bar{q}' u_{t+1}

Moment conditions

\[ E \left( R_{i,t} - R_{t-1}^{f} \right) = -E \left( -\bar{q}' u_{t+1}, r_{i,t} - r_{t-1}^{f} \right) \]
Results

<table>
<thead>
<tr>
<th>Portfolios: Basis:</th>
<th>FF25</th>
<th>Bandpass</th>
<th>t-stat</th>
<th>Utility (0.975)</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption growth</td>
<td>q1</td>
<td>269</td>
<td>2.47 **</td>
<td>555.47</td>
<td>1.66 *</td>
</tr>
<tr>
<td></td>
<td>q2</td>
<td>-431</td>
<td>-1.17</td>
<td>-442.65</td>
<td>-0.44</td>
</tr>
<tr>
<td></td>
<td>q3</td>
<td>138</td>
<td>0.33</td>
<td>616.12</td>
<td>0.32</td>
</tr>
</tbody>
</table>
Results

Epstein-Zin Risk Aversion coefficient implied by Utility basis

\[ q_1 = (\alpha - \rho)^2 \]

Risk Aversion: \[ \alpha = \frac{555.47}{2} + \rho > 277.7 \]
Other comments

- Comparison with Yu (2012)
Other comments

- Comparison with Yu (2012)
- Cross-section: Drivers of results, and literature (ex: Parker and Julliard (2005), Hansen, Heaton, Lee & Roussanov (2007))
Conclusion

Nice paper!