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1. Questions

- What are the asset pricing implications of housing?

- DSGE Models

- Can we simultaneously explain asset pricing, business cycle, and housing market facts?
Literature

• Davis and Heathcote (2005)

• Piazzesi, Schneider and Tuzel (2007)

• Many other papers
Outline

1. Questions and literature
2. Baseline Model
3. Habit Formation
4. Results
2. Baseline Model

\[ U = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma} [C_t \nu(L_t)]^{1-\sigma} \right\} \]

\[ C_t = c_M^\kappa h_t^{1-\kappa} \]

\[ N_{Tt} = N_{Mt} + N_{Ht} \]

\[ L_t + N_{Tt} = 1 \]
Housing Parameter

- In the case $\kappa=1$, the model reduces to a standard one-sector business cycle model

- The stock of housing cannot be adjusted instantaneously
Market Sector

\[ y_{Mt} = A_t k_{Mt}^\alpha N_{Mt}^{1-\alpha} \]

\[ y_{Mt} = c_{Mt} + i_{Mt} + i_{Ht} \]
Capital Accumulation

\[(1 - \delta_k) k_t + \Phi \left( \frac{i}{k} \right) k_t = \gamma k_{t+1}\]

\[(1 - \delta_k) k_t + \Phi \left( \frac{i}{k} \right) k_t = \gamma k_{t+1}\]

Same degree of adjustment costs:

\[\epsilon = \frac{\Phi'' \left( \frac{i}{k} \right) \frac{i}{k}}{\Phi' \left( \frac{i}{k} \right)}\]
Housing Sector

\[ y_{Ht} = k_{Ht}^{\phi} N_{Ht}^{1-\phi} \]

\[ \gamma h_{t+1} - (1 - \delta_H) h_t = y_{Ht} \]
Asset Pricing Implications

- Equivalence between the competitive equilibrium and the centralized problem
- Aggregate sector which produces the final output good and new homes
- Bonds in zero net supply
Risk-free Rate

\[ \frac{1}{1+r_{ft}} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \]

\[ \lambda_t = U_{c_M}(c_{M_t}, h_t, L_t) \]
Equity Prices

In a competitive equilibrium where:

\[ d_t = y_{Mt} + p_{Ht}y_{Ht} - W_{Mt}N_{Mt} - W_{Ht}N_{Ht} - i_{Mt} - i_{Ht} \]

Equity prices:

\[ p_{Et} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[ d_{t+1} + p_{Et+1} \right] \]
House Prices

\[ p_{Ht} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[ r_{Ht+1} + (1 - \delta_H) p_{Ht+1} \right] \]

Where:

\[ r_{Ht} = \frac{U_h(c_{Mt}, h_t, L_t)}{U_{cM}(c_{Mt}, h_t, L_t)} \]
Driving Process

Technology shocks:

\[ A_t = \rho A_{t-1} + \varepsilon_t \]

Where:

\[ \rho = 0.979 \quad \sigma_\varepsilon = 0.0072 \]
Loss Function

2 free parameters:

\[ \kappa, \epsilon \]

Where:

\[ \kappa = [0.01 : 1], \epsilon = [0.0 : 6.25] \]

2 moments of interest:

Mean risk-free rate and the equity premium
Results

Parameter estimates:

\[ \kappa = 1, \ \epsilon = 6.25 \]

Theoretical Moments vs Data

<table>
<thead>
<tr>
<th></th>
<th>( E(r_M - r_f) )</th>
<th>( E(r_f) )</th>
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</thead>
<tbody>
<tr>
<td>Data</td>
<td>6.50</td>
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<tr>
<td>Model</td>
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<td>12.75</td>
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</table>
Discussion I

- Wide rejection

- Loss function is minimized when the housing sector is removed

- Adjustment costs parameter is implausible
Impact of $\kappa$ on the Model's Performance

Loss Function

$\kappa$

2. Model 14/15
Discussion II

- In this model agents can too easily protect their consumption against shocks.

- Introducing housing increases the potential for diversification.

- Only contributes to worsen the problem.
3. Habit Formation

- Jermann (1998)
- Adopt a particular specification of internal habit formation
- Increase the uncertainty generated by business cycle fluctuations
Internal Specification

\[ U = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma} \left[ C_t v(L_t) - x_t \right]^{1-\sigma} \right\} \]

Where:

\[ \gamma x_{t+1} = mx_t + (1-m)[C_t v(L_t)] \]
Asset Pricing and Business Cycle Implications

- Smooth the consumption bundle and market consumption alone is irrelevant

- Internal habit formation and coefficient of relative risk aversion

- Labor supply not used to decrease output volatility
Loss Function

1 more free parameter:

\[ \kappa, m, \varepsilon \]

3 moments of interest:

mean-risk free rate, equity premium, and SD of house prices
Parameter Estimates

\[ \kappa = 0.80, \ m = 0.05, \ \epsilon = 1.45 \]

Role for housing

Plausible adjustment costs parameter
Results I

Financial Market Implications

<table>
<thead>
<tr>
<th></th>
<th>$E(r_M - r_f)$</th>
<th>$E(r_f)$</th>
<th>$\sigma(r_f)$</th>
<th>$\frac{E(r_M - r_f)}{\sigma(r_M)}$</th>
<th>$E(r_H - r_f)$</th>
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<tbody>
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<td>1.77</td>
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<td>5.15</td>
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</table>

Business Cycle Variables, Volatility

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<thead>
<tr>
<th></th>
<th>$\sigma_{y_T}$</th>
<th>$\sigma_{c_M}/\sigma_{y_T}$</th>
<th>$\sigma_{i_M}/\sigma_{y_T}$</th>
<th>$\sigma_{N_T}/\sigma_{y_T}$</th>
<th>$\sigma_{i_H}/\sigma_{y_T}$</th>
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</thead>
<tbody>
<tr>
<td>Data</td>
<td>1.65</td>
<td>0.47</td>
<td>3.31</td>
<td>0.98</td>
<td>6.0</td>
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<tr>
<td>Model</td>
<td>1.28</td>
<td>0.54</td>
<td>2.36</td>
<td>0.65</td>
<td>8.92</td>
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## Results II

### Relative Prices, Volatility

<table>
<thead>
<tr>
<th></th>
<th>$\sigma_{pH}$</th>
<th>$\sigma_{pH}/\sigma_{yT}$</th>
<th>$\sigma_{wT}/\sigma_{yT}$</th>
<th>$\sigma_{pH/zH}/\sigma_{yT}$</th>
<th>$\sigma_{pE}/\sigma_{yT}$</th>
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</thead>
<tbody>
<tr>
<td>Data</td>
<td>2.43</td>
<td>1.63</td>
<td>0.42</td>
<td>1.52</td>
<td>5.67</td>
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<tr>
<td>Model</td>
<td>2.88</td>
<td>2.25</td>
<td>0.16</td>
<td>1.70</td>
<td>3.65</td>
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### Relative Prices, Correlations with Output

<table>
<thead>
<tr>
<th></th>
<th>$\rho(w_{Tt}, y_{Tt})$</th>
<th>$\rho(p_{Ht}, y_{Tt})$</th>
<th>$\rho(p_{Et}, y_{Tt})$</th>
<th>$\rho(r_{ft}, y_{Tt})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
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<td>0.59</td>
<td>0.44</td>
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<tr>
<td>Model</td>
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<td>0.99</td>
<td>0.99</td>
<td>-0.99</td>
</tr>
</tbody>
</table>
Impact of $\kappa$ on the Model's Performance

Habit Formation 8/9
Discussion

• Difference between housing and equity returns

• Introducing housing reduces the uncertainty generated by business cycle fluctuations

• With this specification of habit formation, housing has important asset pricing implications
4. Conclusion

- Asset pricing implications of introducing housing into business cycle models
- Asset pricing puzzles in DSGE business cycle models
- Lead-lag correlation of business vs. residential investment