Deflation in Durable Goods Markets: an Empirical Model of the Tokyo Condominium Market

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¹The views expressed in this presentation are those of the author and do not necessarily reflect the official views of the Bank of Japan.
Introduction

- Durable goods market and market power
  - limited market power – Coase Conjecture (1972)
  - the role of a secondary market
  - cost structure and market power – Kahn (1986)
- The Tokyo condominium market in the 1990s
  - expansion & price deflation
  - divergence of land prices (cost) & condo prices ⇒ market structure?
    - 10 firm concentration ratio is about 40%
    - about 15% of market participants are small firms

This paper:
- Develops a durable goods oligopoly model that accommodates the secondary market and time varying cost.
Key variables in the Tokyo Condominium Market 1985-2000

- Annual Supply of New Condominiums
- Building Construction Cost Index
- Land Price Index (residential)
- New Condominium Price Index
Existing Literature

Empirical Works on Durable Goods

Housing Supply
- Most literature assumes perfectly competitive market.
Model

- Goods (condominiums):
  - $\delta = 1$ - physical depreciation rate (annual).
  - Differentiated by the vintage ($d = 0, 1, 2, \cdots, D$).
  - Homogenous within the vintage.

- Firms:
  - $J$ oligopolistic firms with infinite life in the market
  - Firm $j (= 1, \ldots, J)$ produces $q_{jt}$ units at time $t$.
  - They are subject to macro cost shock $\tilde{c}_t$, that evolves in AR(1) process.
  - Small firms (fringe competitors) collectively produce $x_t$ units at time $t$, that evolves in AR(1) process.
  - No entry.
  - The state variables for the firms are $\tilde{c}_t$, $x_t$ and $s_t^d$, total stock of age $d$ product at time $t$.

- $\beta = \text{common discount factor for both consumers and producers}$
Consumers

- Consumer’s problem is in MNL framework.
- Consumer’s choice set:
  \{\text{new(age 0), age 1, \cdots, age } D, n(=\text{outside alt.})\}.
- Consumer receives \(g(d)\) from one year ownership of a unit of age \(d\).
- The owner of condominium can sell the unit in the secondary market after a year.
- No transactions cost.
  \(\Rightarrow\) consumers’ optimal policy is rental-like policy.
- Resulting inverse demand function for new condo, \(p^0_t\) is a non-linear function of past, current and future production.

\[
p^0_t = \frac{1}{\alpha} E \left[ \sum_{d=0}^{D} \beta^d \left( \ln \mu^n_{t+d} - \ln \mu^d_{t+d} + g(d) \right) \right] + \beta^{D+1} \bar{p}_{t+D+1},
\]

\[
= EP^0(\tilde{s}_t, x_t, x_{t+1}, \ldots, x_{t+D}, \tilde{q}_t, \tilde{q}_{t+1}, \ldots \tilde{q}_{t+D}).
\]
Markov Perfect Nash Equilibrium

Firms maximize the PDV of profit stream given the law of motion for state variables $[\tilde{c}_t, x_t, s^d_t]$. Only consider the time consistent symmetric solution $\Rightarrow$ Symmetric Markov Perfect Nash Equilibrium

In recursive form,

$$V_j(\vec{S}_t) = \max_{q_{jt}} E \left[ \pi_{jt}(\vec{S}_t, q_{jt}, \vec{q}_{-jt}, \{\vec{q}_\tau\}_{\tau=t+1}^D) + \beta E V_j(\vec{S}_{t+1}|\vec{q}_t) \right]$$  \hspace{1cm} (1)

subject to the law of motion and

$$q_{jt} = h_j(\vec{S}_t),$$

$$q_{jt} \leq M - \sum_{d'=1}^D s^d_t - x_t - \sum_{j' \neq j} q_{j't}, \hspace{1cm} (\ast)$$

given $q_{j't} = h_{j'}(\vec{S}_t)$, $j' = 1, 2, ..., j-1, j+1, ..., J,$

where $h_l(\cdot)$ is stationary policy function for firm $l$.

Note that $\pi_{jt}(\cdot)$ is not quadratic. $\Rightarrow$ cannot use a linear quadratic trick.
Data

Primary Market Data: "National Condominium Market Trends"
1985-2000, Real Estate Economic Institute Co., Ltd

Secondary Market Data: "Weekly Housing Information"
1991-2002, Recruit Co., Ltd

Issues with the data

1. The prices are likely to be higher than transaction prices.
   ⇒ Less problematic if the bias in two sources are similar.

2. Not all secondary market prices are observable.
   - there are no data source containing all transactions
   - most properties are not transacted each periods.
   ⇒ The secondary market price for each observation in the first dataset is **imputed** from the second data.
Three Step Estimation

- Estimate parameters: \([\vartheta, \sigma^2_\xi, \alpha, g(0), g(1), \rho, \bar{c}_2, \sigma^2_\lambda]\)
- Sequential Estimation – Three Steps
- Nested Fixed Point Algorithm: Rust(1987)

**Step 1:** Estimation of the process of \(x_t (\vartheta, \sigma^2_\xi)\) - OLS, ML

**Step 2:** Estimation of demand parameters \((\alpha, g(0), g(1))\) - GMM

**Step 3:** Estimation of supply parameters \((\rho, \bar{c}_2, \sigma^2_\lambda)\)
- GMM with nested algorithm
  - outer loop: optimizing the objective function
  - inner loop1: solving the dynamic programming problem
  - inner loop2: integrating unobservable state \(\tilde{c}\).

- Alternative methods: Indirect methods [Hotz et.al. (1994), Bajari et.al. (2007)]
The process of $x_t$:
- The process of $x_t$ is gradually converging toward the positive steady state value.

The demand parameters:
- Negative marginal utility for money.
- Consumers value new condo more than older ones but less than the outside alternative.

The supply parameters:
- The macro cost shock $\tilde{c}$ is stationary process.
- $\bar{c}_2$ is positive and significant $\Rightarrow$ The technology in this industry is DRS.
**Table:** Parameter Estimates for the process of $x_t$: the first step estimation

$$x_t = \bar{x} + \vartheta x_{t-1} + \xi_t; \xi_t \sim (0, \sigma_\xi^2)$$

<table>
<thead>
<tr>
<th></th>
<th>Model I</th>
<th>Model II</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 firms</td>
<td>10 firms</td>
<td></td>
</tr>
<tr>
<td>$\vartheta$</td>
<td>0.878</td>
<td>0.897</td>
</tr>
<tr>
<td>(0.203)***</td>
<td>(0.1829)***</td>
<td></td>
</tr>
<tr>
<td>$\bar{x}$</td>
<td>3.846</td>
<td>3.200</td>
</tr>
<tr>
<td>(3.189)</td>
<td>(2.228)</td>
<td></td>
</tr>
<tr>
<td>$\sigma_\xi^2$</td>
<td>3.363</td>
<td>2.631</td>
</tr>
<tr>
<td>$x_{ss}^a$</td>
<td>32.20</td>
<td>31.16</td>
</tr>
<tr>
<td>(63.30)</td>
<td>(75.46)</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.7692</td>
<td>0.7748</td>
</tr>
<tr>
<td>$N$</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>
## Table: Demand Parameter Estimates: the second step estimation

\[
\ln \mu^d_t - \ln \mu^n_t = g(d) - \alpha p_t^d + \alpha \beta p_{t+1}^d \\
= \bar{X}_{j,t} \Gamma - \alpha C_{jt}^d + \omega_{jt+1}^{d+1}
\]

<table>
<thead>
<tr>
<th></th>
<th>OLS</th>
<th>GMM</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-\alpha$ (coefficient for ECC)</td>
<td>-0.016</td>
<td>-0.328</td>
</tr>
<tr>
<td></td>
<td>(0.002)**</td>
<td>(0.043)**</td>
</tr>
<tr>
<td>1(age==0)</td>
<td>-11.067</td>
<td>-22.007</td>
</tr>
<tr>
<td></td>
<td>(0.160)**</td>
<td>(1.691)**</td>
</tr>
<tr>
<td>1(age==1)</td>
<td>-11.089</td>
<td>-22.636</td>
</tr>
<tr>
<td></td>
<td>(0.161)**</td>
<td>(1.758)**</td>
</tr>
<tr>
<td>log(size)</td>
<td>-0.2194</td>
<td>2.7389</td>
</tr>
<tr>
<td></td>
<td>(0.039)**</td>
<td>(0.446)**</td>
</tr>
<tr>
<td>$g(0)$</td>
<td>-11.978</td>
<td>-10.605</td>
</tr>
<tr>
<td></td>
<td>(0.012)**</td>
<td>(0.181)**</td>
</tr>
<tr>
<td>$g(1)$</td>
<td>-11.998</td>
<td>-11.233</td>
</tr>
<tr>
<td></td>
<td>(0.012)**</td>
<td>(0.102)**</td>
</tr>
</tbody>
</table>

**Instruments**: log(height) log(distance)

**Observations**: 10,113
Table: Cost Parameter Estimates: the third step estimation

\[ C(q_{j,t}, \tilde{c}_t) = (\bar{c}_1 + \tilde{c}_t)q_{j,t} + \bar{c}_2 q_{j,t}^2 \]
\[ \tilde{c}_{t+1} = \rho \tilde{c}_t + \eta_{t+1}, \eta_{t+1} \sim (0, \sigma^2_\eta) \]
\[ q_{jt} = h(\mathbf{S}_t) + \lambda_{jt} \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Explanation</th>
<th>Model I 5 firms</th>
<th>Model II 10 firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho$</td>
<td>AR(1) Coefficient</td>
<td>0.9443***</td>
<td>0.9552***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0044)</td>
<td>(0.0012)</td>
</tr>
<tr>
<td>$\bar{c}_2$</td>
<td>Cost Parameter</td>
<td>3.5812***</td>
<td>5.8332***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0159)</td>
<td>(0.0045)</td>
</tr>
<tr>
<td>$\sigma_\lambda$</td>
<td>Standard Deviation of</td>
<td>0.1664</td>
<td>0.096</td>
</tr>
<tr>
<td></td>
<td>Idiosyncratic Production Shock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tilde{c}^d_{2000}$</td>
<td>terminal value of $\tilde{c}$</td>
<td>14.5151</td>
<td>10.4544</td>
</tr>
<tr>
<td>$N$</td>
<td></td>
<td>35</td>
<td>70</td>
</tr>
</tbody>
</table>
Simulations

Table: The Model’s Performance—the Benchmark Simulation

<table>
<thead>
<tr>
<th></th>
<th>5 firms</th>
<th></th>
<th>10 firms</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\sum q_{jt})</td>
<td>(P_0^t)</td>
<td>(\sum q_{jt})</td>
<td>(P_0^t)</td>
</tr>
<tr>
<td>Mean Observation</td>
<td>7.4</td>
<td>49.4</td>
<td>10.3</td>
<td>49.4</td>
</tr>
<tr>
<td>(Standard Deviation)</td>
<td>(1.9)</td>
<td>(1.9)</td>
<td>(2.1)</td>
<td>(1.9)</td>
</tr>
<tr>
<td>Mean Prediction</td>
<td>5.4</td>
<td>49.5</td>
<td>10.3</td>
<td>49.0</td>
</tr>
<tr>
<td>Mean Deviation from Observations (^b)</td>
<td>3.5</td>
<td>7.3</td>
<td>3.3</td>
<td>7.8</td>
</tr>
<tr>
<td>Mean % of times that prediction falls in 15% interval</td>
<td>24</td>
<td>100</td>
<td>38</td>
<td>100</td>
</tr>
<tr>
<td>Markup (s.d.)</td>
<td>0.56% (0.0005)</td>
<td>0.48% (0.0007)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Market Power and Profits

- The mean prediction of markup—around 0.5% in both model.
  ⇒ It indicates that firms may not possess substantial market power.
- Nevertheless, it does not imply that firms have no profit given the decreasing return to scale specification.
Role of Cost Variations

The comparison of markups under different cost phases shows:

- The markup in cost inflation phase is significantly higher than that in deflationary phase.
- The markup under inflation is 31% higher than that under deflation.
- It is consistent with the intuition of Kahn(1986).
Conclusion

- This paper investigates
  - the market power of condominium developers in Tokyo in the 1990s.
  - the implication of cost variation across time to the market power.
- A dynamic oligopoly model of durable goods producer is developed and its parameters are estimated.

Main findings:

1. The data suggests that firms in the Tokyo primary market do not have substantial market power.
2. The inflation in production costs strengthens the market power of condominium developers while its deflation exacerbates the erosion of their market power from condominiums’ durability.
Future research agenda:

- Relaxing the assumption regarding transaction cost,
- Allowing asymmetric equilibrium, and
- Allowing for differentiated product within a cohort.
Three Step Estimation

- Estimate parameters: \([\vartheta, \sigma^2_\xi, \alpha, g(0), g(1), \rho, \bar{c}_2, \sigma^2_\lambda]\)
- Sequential Estimation – Three Steps
- Nested Algorithm: Rust (1987)
  - outer loop: optimizing the objective function
  - inner loop 1: solving the dynamic programming problem
  - inner loop 2: integrating unobservable state \(\tilde{c}\)

**Step 1:** Estimation of the process of \(x_t\)

\[ x_t = \bar{x} + \vartheta x_{t-1} + \xi_t \]  

(2)

where \(\xi_t \sim N(0, \sigma^2_\xi)\).

- \(\bar{x}\) and \(\vartheta\) are recovered by OLS.
Step 2: Estimation of Demand Parameters ($\alpha, g(0), g(1)$)

Assume consumer’s rational expectation $\Rightarrow \nu_{t,t+1}$: the aggregated forecast error.

$$p_{t+1} = E_t(p_{t+1} | \Omega_t) + \nu_{t,t+1}$$

where $\Omega_t$ is the information available at time $t$

- Use firm level data to take advantage of richness of the dataset.

$$\ln \mu^d_{jt} - \ln \mu^n_t = \bar{X}^d_{j,t} \Gamma - \alpha p^d_t + \alpha \beta p^{d+1}_{t+1} + \omega^{d+1}_{jt+1}$$

- $\bar{X}^d_{j,t}$ = a vector of characteristic variables for firm $j$ at time $t$.
- $CC^d_{jt}$ = realized capital cost of product by $j$, in age $d$ at time $t$.
- $\omega^{d+1}_{jt+1}$ = $\alpha \beta \nu^{d+1}_{jt+1}$

$$E(\omega^{d+1}_{jt+1} | \Omega_t) = 0$$
$$E(y_{jt} \cdot \omega^{d+1}_{jt+1}) = 0$$

- $y_{jt} = [\log(height), \log(distance)]$, can be estimated by GMM.
Step 3: Estimation of Cost Parameters ($\rho, \bar{c}_2, \sigma^2_\lambda$)

$$q_{jt} = h(\tilde{S}_t) + \lambda_{jt}, j = 1, ..., J$$  \hfill (3)

- $\lambda_{jt}$ is unobserved by any firm at the time of production decision.
- $\lambda_{jt} \sim \text{iid } N(0, \sigma^2_\lambda)$ across firms and time.

**Instruments:** $\tilde{z}_{jt}$ is independent of the structural error $\lambda_{jt}$.

$$E(\tilde{z}'_{jt} \cdot \lambda_{jt}) = 0.$$ \hfill (4)

$$E\tilde{z}'_{jt}[(q_{jt} - h(\tilde{S}_t))^2 - \sigma^2_\lambda] = 0.$$ \hfill (5)

Stacking conditions (4) and (5) together... $E(Z_{jt} \ast \Lambda_{jt}) = 0$.

Its sample analogue:

$$\gamma_s = \frac{1}{TJ} \sum_{t=1}^T \sum_{j=1}^J Z_{jt} \ast \Lambda_{jt}.$$ 

The instruments: $z_{jt} = [1, q_{j,t-1}, q_{j,t-2}, x_t]$.  

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Step 3: Estimation of Cost Parameters ($\rho, c_2, \sigma^2_\chi$) (cont.)

The Initial Condition Problem: unobservable $\tilde{c}$

- $\tilde{c}$ is integrated out from the condition and
- The terminal value has to be found for $\tilde{c}$ as it is serially correlated.

Thus available condition is

$$\Upsilon_{si} = \frac{1}{j} \sum_{j=1}^{J} \int \cdots \int Z_{jt} \Lambda_{jt}(\tilde{c}) f(\tilde{c} | c_T) d\tilde{c}. \quad (6)$$

- From the informal information about the cost break down, I conjectured the latest value of $\tilde{c}_{2000} = 10.454$.
- Evaluation of (6) involves solving the Bellman equation of a firm for each candidate set of parameters.
**Table: Number of Firms**

<table>
<thead>
<tr>
<th>year</th>
<th>(A) number of active firms</th>
<th>(B) number of single appearance</th>
<th>(C) ((B)/(A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>89</td>
<td>35</td>
<td>0.393</td>
</tr>
<tr>
<td>1993</td>
<td>111</td>
<td>26</td>
<td>0.234</td>
</tr>
<tr>
<td>1994</td>
<td>205</td>
<td>56</td>
<td>0.273</td>
</tr>
<tr>
<td>1995</td>
<td>228</td>
<td>48</td>
<td>0.211</td>
</tr>
<tr>
<td>1996</td>
<td>227</td>
<td>29</td>
<td>0.128</td>
</tr>
<tr>
<td>1997</td>
<td>231</td>
<td>35</td>
<td>0.152</td>
</tr>
<tr>
<td>1998</td>
<td>221</td>
<td>32</td>
<td>0.145</td>
</tr>
<tr>
<td>1999</td>
<td>230</td>
<td>33</td>
<td>0.143</td>
</tr>
<tr>
<td>2000</td>
<td>231</td>
<td>44</td>
<td>0.190</td>
</tr>
<tr>
<td>Total</td>
<td>1,773</td>
<td>338</td>
<td>0.191</td>
</tr>
</tbody>
</table>

**Table: Concentration Measures**

<table>
<thead>
<tr>
<th>Year</th>
<th>5-firm (^a)</th>
<th>10-firm (^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>0.383</td>
<td>0.523</td>
</tr>
<tr>
<td>1993</td>
<td>0.402</td>
<td>0.538</td>
</tr>
<tr>
<td>1994</td>
<td>0.309</td>
<td>0.442</td>
</tr>
<tr>
<td>1995</td>
<td>0.293</td>
<td>0.416</td>
</tr>
<tr>
<td>1996</td>
<td>0.297</td>
<td>0.412</td>
</tr>
<tr>
<td>1997</td>
<td>0.306</td>
<td>0.443</td>
</tr>
<tr>
<td>1998</td>
<td>0.259</td>
<td>0.385</td>
</tr>
<tr>
<td>1999</td>
<td>0.312</td>
<td>0.417</td>
</tr>
<tr>
<td>2000</td>
<td>0.317</td>
<td>0.433</td>
</tr>
<tr>
<td>Average</td>
<td>0.310</td>
<td>0.433</td>
</tr>
</tbody>
</table>
The market share is expressed as:

\[
\mu_d^t = \begin{cases} 
\frac{\exp(g(d) - \alpha ECC_t^d)}{1 + \sum_{d'=0}^D \exp(g(d) - \alpha ECC_t^{d'})} & \text{for } d = 0, 1, \ldots, D \\
\frac{1}{1 + \sum_{d'=0}^D \exp(g(d) - \alpha ECC_t^{d'})} & \text{for } d = n.
\end{cases}
\]  

The market share of each type is defined by:

\[
\mu_t^d = \begin{cases} 
\frac{(x_t + \sum_j q_{jt})/M}{s_t^d/M} & \text{if } d = 0, \\
\frac{1}{M} & \text{if } d = 1, 2, \ldots, D \\
\frac{1 - \left(\sum_j q_{jt} + \sum_d s_t^d + x_t\right)/M}{M} & \text{if } d = n.
\end{cases}
\]
Without transactions cost, well-known that consumers’ optimal policy is rental-like policy. Consumer $i$’s problem:

$$d_{it} = \arg\max\{\{g(d) - \alpha ECC_t^d + e_{it}^d, d = 0, 1, ...D\}, e_{it}^n\}$$

- $ECC_t^d =$ Expected capital cost of owning age $d$ unit for a year at time $t$.

$$ECC_t^d = \begin{cases} p_t^d - \beta p_{t+1}^{d+1} & \text{if } d = 0, ...D - 1, \\ p_t^d - \beta \bar{p} & \text{if } d = D, \end{cases}$$

- $\bar{p} = p^{D+1}$, the terminal/scrappage value of the condo when it reaches age $D + 1$ in period $t + 1$.

- $e_{it}^d =$ Consumer taste shock.
Derivation of Inverse Demand Function

- Assumption of dist’n of $e_{it}^d$ (iid type I extreme value across $i$, $t$ and $d$) leads to the market share expression. ▶ detail
- $\mu_t^d =$ market share of age $d$ product at time $t$.
- With the inversion technique of Berry(1994),

$$\ln \mu_t^d - \ln \mu_t^n = g(d) - \alpha ECC_t^d,$$

$$= g(d) - \alpha p_t^d + \alpha \beta p_{t+1}^{d+1},$$

Arranging market share equations yields

$$p_0^t = \frac{1}{\alpha} E \left[ \sum_{d=0}^{D} \beta^d (\ln \mu_{t+d}^n - \ln \mu_{t+d}^d + g(d)) \right] + \beta^{D+1} \bar{p}_{t+D+1},$$

$$= EP^0(\bar{s}_t, x_t, x_{t+1}, \ldots, x_{t+D}, \bar{q}_t, \bar{q}_{t+1}, \ldots \bar{q}_{t+D}).$$

- $p_0^t$ is a non-linear function of past, current and future production.
Firms - Environment

The state of the world: \( \tilde{S}_t = [\tilde{c}_t, x_t, s_t^1, \ldots, s_t^D] \).

- Firm \( j \)'s cost function to produce \( q_{jt} \) units:

\[
C(q_{j,t}, \tilde{c}_t) = (\bar{c}_1 + \tilde{c}_t)q_{j,t} + \bar{c}_2q_{j,t}^2,
\]

where
- \( \bar{c}_1 \) and \( \bar{c}_2 \): constant.
- \( \tilde{c}_t \)=the macro shock to the market: \( AR(1) \)

\[
\tilde{c}_{t+1} = \rho \tilde{c}_t + \eta_{t+1},
\]

where \( \rho \in (0, 1) \) and \( \eta_t \sim N(0, \sigma^2_\eta) \).
• $x_t =$ aggregate production by fringe competitors: AR(1)

\[ x_t = \bar{x} + \vartheta x_{t-1} + \xi_t \]

where $\xi_t \sim N(0, \sigma^2_\xi)$.

• The stock of condominiums with age $d$ at time $t$ is given by:

\[ s_t^d = \delta^d \left( \sum_{j=1}^{J} q_{j,t-d} + x_{t-d} \right) \]

\[ = \delta s_{t-1}^{d-1}, \quad d = 2 \ldots D \]
For individual firm: $\forall t, \forall j$, period-$t$ production $q_{jt}$ maximizes

$$
\sum_{\tau=t}^{\infty} \beta^{\tau-t} E_t \left[ p_{j\tau}^0 q_{j\tau} - C(q_{j\tau}, \tilde{c}_{\tau}) \right],
$$

subject to the law of motion and

$$
q_{jt} \leq M - \sum_{d'=1}^{D} s_{d'}^t - x_t - \sum_{j' \neq j} q_{j't}, (*)
$$

Note the usual formulation leads to time inconsistency.

$$
\max_{\{q_{j\tau}\}_{\tau=t}^{\infty}} E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[ p_{j\tau}^0 q_{j\tau} - C(q_{j\tau}, c_{\tau}) \right],
$$

subject to law of motion and $(*)$. 
Identification

Source of identification

- Demand parameters: cross sectional and time series variations of $\mu$ and $\rho$.
- Supply parameters: not trivial – especially $\rho$ and $\bar{c}_2$
  $\Rightarrow$ Simulations of simplified model will give intuition.

- An increase in $\bar{c}_2$ decreases the level of production.
- An increase in $\rho$ shifts the peak of the hump by making it reach steady state slower. It can match with observed data series.
Discussions about Some Assumptions

- Dimension reduction for tractability
  - No differentiation among newly produced products.
  - Homogenous (oligopolistic) firms
  - Fixed scrap value
  - Symmetric MPNE
  - No transaction cost

- No liquidity constraint
<table>
<thead>
<tr>
<th>Variable</th>
<th>Notation</th>
<th>Obs</th>
<th>Mean</th>
<th>Weighted Mean&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from NTS&lt;sup&gt;c&lt;/sup&gt; (m)</td>
<td>dist</td>
<td>5,522</td>
<td>701.31</td>
<td>734.44</td>
<td>913.61</td>
<td>0</td>
<td>13,880</td>
</tr>
<tr>
<td>Height of the building</td>
<td>height</td>
<td>5,522</td>
<td>8.72</td>
<td>9.61</td>
<td>4.39</td>
<td>2</td>
<td>54</td>
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<tr>
<td>Total units for sale in a given phase</td>
<td>qt</td>
<td>5,522</td>
<td>26.33</td>
<td>--</td>
<td>20.54</td>
<td>1</td>
<td>319</td>
</tr>
<tr>
<td>Average size of the units ( m&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>size</td>
<td>5,522</td>
<td>66.59</td>
<td>65.35</td>
<td>34.92</td>
<td>20</td>
<td>807</td>
</tr>
<tr>
<td>Number of developers</td>
<td></td>
<td>5,522</td>
<td>1.21</td>
<td>1.13</td>
<td>0.45</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Whether secondary market data is available</td>
<td></td>
<td>5,522</td>
<td>0.27</td>
<td>--</td>
<td>0.45</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Unit Price (0,000 yen)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary market (age0)</td>
<td>p&lt;sub&gt;t&lt;/sub&gt;&lt;sup&gt;0&lt;/sup&gt;</td>
<td>5,522</td>
<td>5,209</td>
<td>4,905</td>
<td>3,221</td>
<td>1,559</td>
<td>73,706</td>
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<tr>
<td>Secondary market (age1)</td>
<td>p&lt;sub&gt;t&lt;/sub&gt;&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>4,749</td>
<td>4,548</td>
<td>2,810</td>
<td>1,316</td>
<td>70,086</td>
</tr>
<tr>
<td>Secondary market (age2)</td>
<td>p&lt;sub&gt;t&lt;/sub&gt;&lt;sup&gt;2&lt;/sup&gt;</td>
<td>5,522</td>
<td>4,583</td>
<td>4,380</td>
<td>2,740</td>
<td>1,179</td>
<td>66,686</td>
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<td>Production by an oligopolistic firm</td>
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<td></td>
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</tr>
<tr>
<td>5 firms</td>
<td>q&lt;sub&gt;j&lt;/sub&gt;t</td>
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<td>1,475</td>
<td>1,033</td>
<td>443</td>
<td>43</td>
<td>4,054</td>
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<td>10 firms</td>
<td>q&lt;sub&gt;j&lt;/sub&gt;t</td>
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<td>1,025</td>
<td>871</td>
<td>0</td>
<td>43</td>
<td>4,054</td>
</tr>
</tbody>
</table>

<sup>a</sup> Data

<sup>b</sup> Summary Statistics
The Market

**Definition:**
- A condominium is multi-unit housing consisting of 5 units or more, with three stories or more, and with a steel-reinforced concrete structure.
- The market under study is the central districts within Tokyo metropolitan area. (3.5 million households, 240 square miles)

**Durability:**
- Condominiums generally require either large scale repair or the complete replacement in 25 to 30 years.
- Residential buildings in Japan are not as durable as those in other countries. (average age of demolished housing units is 26 years as of 1997.)
Fixed Parameters

For computational convenience, some parameters are predetermined.

**Market size** \( (M) \): 3.514 million (households)
   \[ \text{Number of hh as of 1995} \]

**Lifespan of a condominium** \( (D + 1) \): 2

**Scrappage price** \( (\bar{p}) \): 42.3 million (yen)
   \[ \text{Average price of 2 year-old condominiums} \]

**Time invariant cost parameter** \( (\bar{c}_1) \): 24.71 million (yen)
   \[ \text{The range of macro cost shock} \]

**Variance of macro cost shock** \( (\sigma^2_{\eta}) \): 1
The model is solved using the collocation methods.

- The solution & price at $s_t = 31.16$

- Both policy and value functions are decreasing in all state variables $(s_t, x_t, \tilde{c}_t)$.

- Measured in elasticities, the policy is more sensitive to production by the fringe competitors $(x_t)$ than one year old stock $(s_t)$.