Market Structure and Productivity: A Concrete Example.

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Hotelling's Circular City

- Consumers are located uniformly with density D along a unit circumference circular city.
- Consumer buys a unit good.
- Consumer transportation cost t.
- Firm entry cost f. Firms are evenly placed in the circle.

2 Stage Model

- 1st Stage: firms decide whether to enter or not. Free entry with entry cost f.
  Entrant firms are evenly placed in the circle.
- 2nd stage: After entry, firms charge prices given prices of other firms and the number of firms.

Symmetric Equilibrium in the 2nd Stage

Since all firms are the same, in equilibrium they charge the same price p. Let the equilibrium number of firms be n.
A consumer located at the distance $x \in (0, \frac{1}{n})$ from firm i is indifferent between firm i and its closest neighbor if the cost of purchase from firm i and the other firm are the same. That is,

$$p_i + tx = p + t(\frac{1}{n} - x)$$

$$2tx = p - p_i + \frac{t}{n}$$

Consumer closer to firm i than the above x will choose firm i.
Since consumers are located at both sides, the demand of firm i is

$$D_i(p_i, p) = 2Dx = D\frac{p - p_i + t/n}{t}$$

Firm i maximizes the profit

$$\pi_i = (p_i - c)\, D_i(p_i, p) - f = (p_i - c)\, D \frac{p - p_i + t/n}{t} - f$$

First Order Condition with respect to p_i

$$\frac{p - p_i + t/n}{t} - \frac{p_i - c}{t} = 0$$

$$p_i = \frac{p + t/n + c}{2}$$

Because all firms are the same, in equilibrium, $p_i = p$. Therefore,

$$p = c + t/n$$

Substituting into the profit function, we get

$$\pi = \frac{t}{n}\frac{D}{n} - f$$

1st Stage: Entry

With free entry, zero profit holds, and thus

$$\pi = \frac{t}{n}\frac{D}{n} - f = 0$$

hence

$$\frac{Dt}{n^2} = f$$

Hence, the equilibrium number of firms and price is

$$n = \sqrt{\frac{Dt}{f}}$$

$$p = c + \frac{t}{n} = c + \sqrt{\frac{tf}{D}}$$

- Higher transportation cost (more product differentiation), higher price and more number of firms.
- Higher fixed cost, less number of firms and higher price.
- Higher market density, higher number of firms and lower price.

Circular city model with uncertainty in marginal cost

- Stage 1: After paying entry cost s, individuals receive marginal cost draw $c_i \sim g(c_i)$. They learn their own cost of production, but not those of others.
- Stage 2: Firms decide whether to produce or not. f is the fixed cost of production.
  Producing firms are placed evenly on the circle.

2nd Stage

Indifferent consumer location. Firm i knows own price but does not know other firm's prices, because it does not know their cost. Therefore, it also does not know the number of firms n.

$$p_i = tx_{i,j} = p_j + t(\frac{1}{n} - x_{i,j})$$

$$2tx_{i,j} = p_j - p_i + \frac{t}{n}$$

Expected demand

$$E\left(x_{i,j}\right) = \frac{E(p_j) - p_i}{2t} + \frac{1}{2}E(\frac{1}{n})$$

Instead of maximizing the profit, the firm maximizes the expected profit.

$$\begin{aligned} E\left(\pi_i\right) &= 2E\left(x_i\right)\left(p_i - c_i\right)D - f \\ &= E\left[\frac{E(p_j) - p_i}{2t} + \frac{1}{2}E(\frac{1}{n})\right]\left(p_i - c_i\right)D - f \end{aligned}$$

First Order Condition

$$\left[\frac{E(p) - p_i}{t} + E(\frac{1}{n}) - \frac{1}{t}\left(p_i - c_i\right)\right]D = 0$$

$$p_i = \frac{1}{2}\left[c_i + E(p) + tE(\frac{1}{n})\right]$$

Taking expectations on both sides,

$$E(p) = \frac{1}{2}\left[E(c) + E(p) + tE(\frac{1}{n})\right]$$

$$E(p) = E(c) + tE\left[\frac{1}{n}\right]$$

which is very similar to the deterministic model.
Substituting in the price equation,

$$p_i = \frac{1}{2}c_i + \frac{1}{2}\left[Ec) + tE\left(\frac{1}{n}\right)\right]$$

price-cost margin:

$$p_i - c_i = -\frac{1}{2}c_i + \frac{1}{2}\left[Ec) + tE\left(\frac{1}{n}\right)\right]$$

Substituting into the expected demand,

$$2E(x_i) = \frac{1}{2t}E(c) + E\left(\frac{1}{n}\right) - \frac{1}{2t}c_i$$

Therefore,

$$E\left(\pi_i\right) = \frac{D}{4t}\left[E(c) - c_i + 2tE\left(\frac{1}{n}\right)\right] - f$$

price-cost margin, expected market share decline both in c_i.

Equilibrium Marginal Cost Distribution

Cutoff cost c^*: marginal cost that makes zero profit. Firms produce zero output if $c > c^*$.

$$E(\pi_i) = \frac{D}{4t}\left[E(c) - c^* + 2tE\left(\frac{1}{n}\right)\right] - f = 0$$

$$c^* = E(c) + 2tE\left(\frac{1}{n}\right) - \sqrt{\frac{4tf}{D}}$$

And the expected profit of the non-zero producer is

$$E(\pi_i | c_i \leq c^*) = \frac{D}{4t}\left(c^* - c_i + \sqrt{\frac{4tf}{D}}\right)^2 - f$$

Hence, expected profit before entry is

$$V^e = \int_0^{c^*} \frac{D}{4t}\left[\left(c^* - c + \sqrt{\frac{4tf}{D}}\right)^2 - f\right] g(c)dc - s$$

and the free entry condition is

$$V^e = 0$$

Comparative Statics

Higher market density reduces cutoff cost c^*.

$$\frac{dc^*}{dD} = -\left[\frac{\partial V^e/\partial D}{\partial V^e/\partial c^*}\right] < 0$$

Empirical Implication

Higher demand density

- higher minimum productivity level (lower maximum marginal cost c^*)
- less productivity dispersion among local producers.
- higher average productivity level (lower average marginal cost)
- larger average plant size. (smaller number of entrants per consumer)

Data

- Data on ready mix concrete plants from Census of Manufacturers.
- Local market: Bureau of Economic Analysis's component economic area (CEA): collection of counties. that are economically intertwined. 348 markets that are mutually exclusive and exhaustive.
- Ready mix concrete industry: ideal for defining the local market because ready mix concrete hardens and becomes useless within fixed short period of transportation time.

Empirical Model

it: CEA-year market.

$$y_{it} = \beta_0 + \beta_d dens_{it} + X_{c,it} B_c + \epsilon_{it}$$

y_{it}: TFP dispersion, Median TFP, Average TFP, etc.
$dens_{it}$: demand density: log of the number of construction sector workers per square mile in the CEA-year market.
$X_{c,it}$: other controls.
TFP: total factor productivity of a plant

$$TFP_{it} = q_{it} - \alpha_{lt} l_{it} - \alpha_{kt} k_{it} - \alpha_{nt} m_{it} - \alpha_{et} e_{it}$$

All variables are in logs. l_{it}: log labor input
k_{it}: log capital input.
m_{it}: log materials
e_{it}: log energy input.
α: Cobb- Douglass production function coefficients.

Estimation Results

Dependent Variable	density coef.	std. error
TFP dispersion (interquartile range)	−0.029	(0.008**)
Median TFP	0.012	(0.005**)
Average TFP	0.016	(0.008**)
10th percentile TFP	0.065	(0.019**)
Producer-demand ratio	−0.313	(0.022**)
Average Plant Output	0.184	(0.017**)

All the coefficients are consistent with the model predictions.

- Higher demand density reduces productivity dispersion. Only high productivity firms survive.
- Higher demand density increases productivity (median, average, 10th percentile).
- Higher demand density reduces producer demand ratio. Less number of firms per consumer. Larger plant size.