Search, Design, and Market Structure

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Relationship to network literature

- Take network structure as exogenous
  - not so much shape of network (random matching)
  - instead strength of links (cost of search)

- How does network structure affect behaviour
  - somewhat richer behaviours than typically considered
  - comparative statics

- Key role for heterogeneity
Application: The effect of the Internet

- Lower search costs were expected to lead to harsher competition and lower profits
- What do the empirical studies show? On sales:
- Radical changes to existing industries/new industries?
  - book publishing, eBay stores
Search and Design

- Standard search model, random sequential search to obtain price-quotes and learn match realizations
  - Ceteris paribus, lower search costs lead to lower prices
- Model introduces firm design choices
  - marketing/information
  - type of product ranging from broad (lowest common denominator) to niche (very specialized)
- Search costs affect pricing but also product variety
Niche and Broad Designs

broad design

niche design
Model Ingredients/some related literature

- Costly sequential search: visit to a new firm provides a new price quote as well as a new “match”
  - no match component then Diamond paradox (1971)
  - non-degenerate match a la Wolinsky (1986), or Anderson and Renault (1999)

- Product design
  - Each firm chooses price and a design/information policy
  - monopoly “design” A la Johnson and Myatt (2006)
Results

- Characterization of Equilibrium
  - Prevalence and coexistence of very different design strategies
  - “Low-type” firms specialize, “high-type” firms go mass-market

- Comparative Statics
  - Profits and prices can be non-monotonic in search costs
  - Model delivers coexistence of long-tail and superstar effects
Anecdotal Support

“Both the hits and the tail are doing well,” says Jeff Bewkes, the head of Time Warner, an American media giant. Audiences are at once fragmenting into niches and consolidating around blockbusters. Of course, media consumption has not risen much over the years, so something must be losing out. That something is the almost but not quite popular content that occupies the middle ground between blockbusters and niches. The stuff that people used to watch or listen to largely because there was little else on is increasingly being ignored. The Economist, November 24, 2009
Model

- Continuum of firms of measure 1, endowed with a production technology \( \nu \sim H(\cdot) \) on \( V \).
- Continuum of consumers of measure \( m \).
- Consumer \( l \) when consuming good from firm \( i \) at price \( p_i \) gains utility (not including any search costs)

\[
u_{li}(p_i) = \nu_i + \epsilon_{li} - p_i
\]

where \( \epsilon_{li} \sim F_s(\cdot) \) is the value of the firm-consumer specific match and is i.i.d. across \( l \) and \( i \).

- The cost of visiting an additional firm is \( c > 0 \)
- If consumer \( l \) buys product \( i \) at price \( p_i \) after visiting \( k \) firms she gets

\[
u_{li}(p_i) - kc,
\]
Firm Strategy

- A firm’s strategy: Each \( v \) chooses a price \( p \) and a design \( s \in [B, N] \)
  - \( \sigma : V \rightarrow \Delta(\mathbb{R} \times [B, N]) \)

- Design *a la* Johnson and Myatt (2006):
  - \( F_s(.) \) has support on some interval \((\theta_s, \bar{\theta}_s)\) is continuously differentiable and the distribution has logconcave densities \( f_s(\theta) \)
  - \( \forall s \exists \) a rotation point \( \theta^*_s \) such that \( \frac{\partial F_s(\theta)}{\partial s} < 0 \) for \( \theta > \theta^*_s \) and \( \frac{\partial F_s(\theta)}{\partial s} > 0 \) for \( \theta < \theta^*_s \); further \( \theta^*_s \) is increasing in \( s \)
  - interpretation as physical design or information (then restrict to mean-preserving spread)
Demand Rotations

- Single rotation point
- Differing rotation points

Diagrams showing the rotation points for different designs (N, s, B) and the corresponding functions 1-F_s(ε).
Consumer Strategy

- Consumer strategy: choose whether or not to continue search, choose whether or not to buy
  - Note that with a continuum firms, irrelevant whether or not consumers hold onto previous offers
- Restrict to an optimal stopping rule: a consumer continues searching until he finds an offer such that $v - p + \varepsilon \geq U$
We look for Nash Equilibria \((U, \sigma)\)

- Firms mix in choice of price and product design
  \[ \sigma : V \rightarrow \Delta(\mathbb{R} \times [B, N]) \]

- Consumer strategy \(U\) implicitly defined by
  Cost of next search = the expected extra value of searching when the outside option is to claim \(U\)

\[
c = \int \left( \int \int_{s,p} \left( \int_{U+p-s}^{\infty} (\varepsilon + v - U - p) f_s(\varepsilon) d\varepsilon \right) \sigma(v) dp ds \right) h(v) dv
\]

- Note that given \(U\) and \(\sigma\), the equilibrium implies an unconditional probability \(\rho\) that a consumer buys from a random firm when she visits it

- There is always a class of boring equilibria, firms charging high prices and design irrelevant
Firm’s Problem

- Firm can take $\rho$ and $U$ as given then looks to maximize profits
  \[
  \frac{m}{\rho} p(1 - F_s(p + U - \nu)),
  \]

- **Note** Scale effects are very different from search costs

- Define
  \[
  p_{vs}(U) \doteq \arg \max_p (1 - F_s(p + U - \nu)) = \frac{1 - F_s(p_{vs}(U) + U - \nu)}{f_s(p_{vs}(U) + U - \nu)}
  \]

- Logconcavity ensures that $p_{vs}(U)$ is uniquely-defined, continuous and non-increasing in $U$

- Firm problem reduces to choosing $s$ to maximize profits
Proposition

Firms choose extremal designs, that is every firm chooses either the most niche \((s = N)\) or most broad \((s = B)\) design.

Proof.

Recall design chosen to optimize
\[
\frac{m}{\rho} p v_s(U) (1 - F_s(p v_s(U) + U - \nu)) \quad \text{or equivalently}
\]
\[
p(1 - F_s(p + U - \nu))
\]
with respect to both \(p\) and \(s\): affine transforms of demand rotations are still rotations, and the firm is a monopolist on this residual demand curve so that Proposition 1 of Johnson and Myatt (2006) can be applied.
Graphical Intuition

optimal price is above the point of rotation: more “nichey” design

optimal price is below the point of rotation: more “broad” design
Quality and Design Choice

Define $V$ implicitly (Indifferent firm between going broad or niche)

$$p_{VB}(U)(1 - F_B(p_{VB}(U) + U - V)) = p_{VN}(U)(1 - F_N(p_{VN}(U) + U - V)).$$

**Proposition**

*Given a consumer search rule, $U$, there is a threshold type of firm $V(U)$ such that all firms with lower quality than this threshold type, $v < V(U)$, choose a niche design, and all firms with $v > V(U)$ choose a broad one. Moreover $V(U)$ is increasing in $U$ (in fact, $\frac{dV(U)}{dU} = 1$); that is, as consumers search more intensively, more firms choose niche designs.*
Equilibrium (Summary)

Nash Equilibria in consumer and firm strategies

- There is always a class of boring equilibria, firms charging high prices and design irrelevant
- Optimal for firm to choose either a broad ($s = B$) or niche ($s = N$)
- Can characterize firm behaviour by an indifferent firm $V$ between the two design strategies
  - firms with $v < V$ choose niche and $v > V$ choose broad
Equilibria with degenerate design

- Can characterize $c_B$ such that if $c > c_B$ then all firms choose broad design.
- Can characterize $c_N$ such that if $c < c_N$ then all firms choose niche design.
- In case of all-niche or all-broad, then when $c$ goes down:
  - Consumer surplus $U$ goes up
  - Prices and profits go down
- When $c_N < c_B$ then there must be co-existence of different designs in equilibrium.
Superstars and Longtails

**Definition**

We say that a *superstar effect* is present if the firm with the highest sales captures an increasing market share as search costs fall.

**Definition**

We say that a *long tail effect* is present if the firm with the lowest sales captures an increasing market share as search costs fall.

**Remarks**

1. With fixed designs no long tail effect.
2. In any stable equilibrium, lower search cost increases $U$ and so, also, $V$. 
Uniformly Distributed Firms and Linear Demands

- Niche and Broad demand curves are linear
  - $\varepsilon_N \sim U[\theta_N, \bar{\theta}_N].$
  - $\varepsilon_B \sim U[\underline{\theta}_B, \bar{\theta}_B].$
- Uniformly distributed firm types $\nu \sim U[L, H].$
Comparative Statics

Proposition

Under the assumptions above, when all firms are active then

1. There is a unique equilibrium \((U, V)\) for each search cost \(c\). When different firms choose different design strategies then as the search cost decreases

2. Consumer surplus \((U)\) increases

3. There are more niche firms \((V\) increases);

4. Profits of the highest and lowest quality firms increase if and only if \(\bar{\theta}_N - \bar{\theta}_B > H - L\);

5. The superstar effect arises; and,

6. The long tail effect can, but need not, arise; a sufficient condition for the long tail effect to arise is \(\bar{\theta}_N - \bar{\theta}_B > H - L\).
Example

- Linear demands
  - niche distribution uniform on $[-12, 4]$
  - broad distribution uniform on $[-3, 3]$
- Types uniformly distributed on $[0, 0.75]$
Prices against search costs

For a given firm at $\nu = 0.5$
Note: We consider a fixed number of firms. We could allow free entry, then average profits would be zero and the number of firms would vary non-monotonically in search costs.
Sales against quality (\(v\)) at two different search costs (\(c = 0.05\) and \(c = 0.06\)).

- long tail and superstar effects; disappearing middle
Market share against search costs for highest and lowest firms

- superstar effects everywhere but at a single point
- longtail effects at intermediate range
Related Literature

- Search models (design exogenous)

- Product design and demand rotations (monopoly models)
  - Johnson and Myatt (2006); Lewis and Sappington (1994); Bar-Isaac, Caruana and Cuñat (2009)

- Search and product design / Endogenous differentiation
  - Larson (2008); Kuksov (2004); Cachon, Tewiesch and Xu (forthcoming); Watson (2007)

- Long tail and superstar effects
Conclusions

- Simple and tractable model that integrates consumer search and firms’ strategic price and product design choices.
- Search costs affect product design
- Prevalence and coexistence of very different design strategies, with rich price and sale distributions
- Firms with better technologies will tend to adopt broader strategies
- Prices and profits may be non-monotonic in search costs
- Long tail and superstar effects
- Paper also provides a full characterization and shows similar results when all firms are ex-ante homogeneous
As it becomes easier for consumers to find quirky stuff that they will love, more firms will provide such quirky stuff. This has equilibrium effects on profits and sales distributions.
Homogeneous Firms

(Degenerate distribution of \( v \)'s: \( v = 0 \) for all firms)

- Three possibilities:
  - All firms choose a broad design
  - All firms choose a niche design
  - All indifferent: a proportion \( \lambda \) go niche, \( (1 - \lambda) \) go broad

- An equilibrium can be summarized as a pair \((U, \lambda)\)
Mixed Strategy Equilibrium

- Firm condition:
  \[ p_B(\bar{U})(1 - F_B(p_B(\bar{U}) + \bar{U})) = p_N(\bar{U})(1 - F_N(p_N(\bar{U}) + \bar{U})) \]

- Consumer’s condition:
  \[ c = (1 - \lambda)c_B + \lambda c_N \]

- \[ p_N(\bar{U}) > p_B(\bar{U}) \]
- Sales: \[ \frac{m}{\rho} (1 - F_B(p_B(\bar{U}) + \bar{U})) > \frac{m}{\rho} (1 - F_N(p_N(\bar{U}) + \bar{U})) \]
- Consumer surplus is constant \( \bar{U} \)
Multiplicty and Uniqueness

- \( c_B > c_N \) unique (stable) equilibria throughout
- \( c_B < c_N \) multiplicity and mixed equilib is unstable
- when demands are linear (or equivalently \( f_s(\cdot) \) is uniform) then the ratio of consumer surplus to firm profits for a monopolist is constant at \( \frac{1}{2} \)
  - when two firms facing linear demands (regardless of their slopes) who earn the same profits must generate the same consumer surplus.
  - So \( c_N = c_B \) in this case

- easy to find cases where either uniqueness (and stability) or multiplicity (and instability) can arise.
  - if demand is convex then the ratio of consumer surplus to profits is always higher than it would be in the linear case.
  - if \( F_B \) is linear and \( F_N \) is concave then \( c_N > c_B \) and multiplicity arises whereas in the opposite case,
  - if \( F_B \) concave and \( F_N \) linear then \( c_B > c_N \).
Comparative Statics Summary

<table>
<thead>
<tr>
<th>Proposition</th>
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<tr>
<td>As search costs fall within the region, ( c \in (c_N, c_B) ), where both designs are offered</td>
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<tr>
<td>1. Consumer surplus (( U )) is constant;</td>
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<td>2. There are more niche firms (( \lambda ) increases);</td>
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<tr>
<td>3. Consumers search more (( \rho ) decreases);</td>
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<td>4. Every firm’s profits increase; and</td>
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<td>5. Both long tail and superstar effects arise.</td>
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Comparative Statics: Mixed Region

- $\bar{U}$ constant throughout mixed region
- price of niche (broad) firm does not change $p_N(\bar{U})$ (or $p_B(\bar{U})$) through mixed region
- Probability of selling to a visiting consumer does not change for niche (broad) firm: it is $1 - F_N(p_N(\bar{U}) + \bar{U})$ (or $1 - F_B(p_B(\bar{U}) + \bar{U})$) throughout mixed region
- BUT number of customers who visit changes:
  - mix of firms and so also $\rho$ (ex-ante expected probability of buying from a random firm) changes, in particular $\rho$ decreases as $c$ falls
  - $c$ falls then more niche firms, more consumers end up going on for second, third, fourth visits etc ...
Comparative Statics: Mixed Region II

- Total sales stay constant (by set up of model) but
  - sales for niche firm is \( \frac{m}{\rho} \left[ 1 - F_N(p_N(U) + U) \right] \) which increases as \( \rho \) falls (as \( c \) falls)
  - sales for broad firm is \( \frac{m}{\rho} \left[ 1 - F_B(p_B(U) + U) \right] \) which increases as \( \rho \) falls (as \( c \) falls)
  - some broad switching to niche compensates for the fact that BOTH niche and broad types sells more

- mix of firms and \( \rho \) change so average (sales weighted) prices/profits change
Comparative Statics: Price against Search Cost

- Price and profit (for a given firm) non-monotonic in search costs
- Average/Total industry profits and prices also non-monotonic
Comparative Statics: Sales distributions at different search costs

- long-tail effects (niche firms have higher sales)
- superstar effects (broad firms have higher sales)
- coexistence of “superstar” and “long tail” effects