Network Markets

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Oxford, 2nd Year MPhil IO

Outline

Motivation

- Networks: value of product depends on who buys it
  - $\Rightarrow$ externalities between users
- Examples with 1 side:
  - if many people have a phone, its more useful to have a phone
  - if many people use Word, it's more useful to have Word
  - if Brad Pitt wears blue shirt, average guy starts wearing blue
    - If Andre Veiga wears a blue shirt, average guy starts wearing red
- Examples with 2 sides:
  - if many shops accept a credit card, buyers will want to carry that card
  - if a newspaper has lots of readers, this will attract advertisers...
    - which will repel readers...
    - which will repel advertisers
    - which will attract readers....
    - ...

- We will refer to firms as “platforms”
- Sometimes connecting users is almost all the platform does
    - Facebook
    - Skype
    - Ebay
- Sometimes externalities are only part of the platform’s value
    - Microsoft Word
    - nightclubs

Several approaches to networks

- We will take a broad-scope "price theory" approach
  - looking at aggregate market measures
  - relate them to consumer types
  - characterize distortions
- Other approaches:
  - Graph theory: users are nodes in a graph
    - Peyton Young, Matt Jackson
  - Detailed view of consumer interactions:
    - consumer bidding on Ebay
    - auction design by search engines
    - user searching & clicking online (White (2008))

Goals

- some math tools
  - differentiating fixed points
  - differentiating arbitrary integrals
- overview of literature
  - where it is, where it's going
  - big gaps? limitations? share your thoughts!

Outline

Overview

- Big theme: multiplicity of equilibria
- Setting: consumers joining a communications network
  - good to join if others join, not otherwise
  - Focus on the consumer game (static platform)

Model

- One platform with fixed price p
- n individuals, indexed by $i \in \{1, \ldots, n\}$

$$x_i = \begin{cases} 0 & \text{, if doesn't adopt} \\ 1 & \text{, if adopts} \end{cases}$$

- Demand $q_i(x_{-i}, p)$, with $x_{-i} \in \mathbb{R}^{n-1}$
  - decreasing in p
  - increasing in every component of x_{-i}: positive network externalities
  - micro-founded by utility $U_i(x_{-i}, p)$ & outside option $U_{i0}(x_{-i})$
  - allows for users to differ in preferences and values
- Reasonable?

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  - allows for users to differ in preferences and values
- Reasonable?
  - no congestion
  - everyone is positively desirable

Equilibrium user sets

- Too general for demand curves
- Equilibrium user sets are solutions to the system of n equations:

$$q_i\left(x_{-i},p\right)=1 \Leftrightarrow U_i\left(x_{-i},p\right)\geq U_{i0}\left(x_{-i}\right),\forall i$$

- Typically no unique solution $\Leftrightarrow$ multiplicity
- maximal equilibrium user set (union of all eql)
  - network is valuable, deviating to not joining is not worthwhile
- minimal equilibrium user set (intersection of all eql)
  - network is low value, deviating to joining is not worthwhile
- bad news: platforms typically start with very few users

More structure

- Assume $U_i = \frac{q}{n} w_i - p$ with $q = \sum_i q_i$
  - additive utility
  - zero outside option
  - constant marginal utility for money
  - users care about only the total demand, $q = \sum_i q_i$
  - join if $U_i \geq 0$
  - types $w_i > 0$ captures interaction benefits to user i
- Reasonable?

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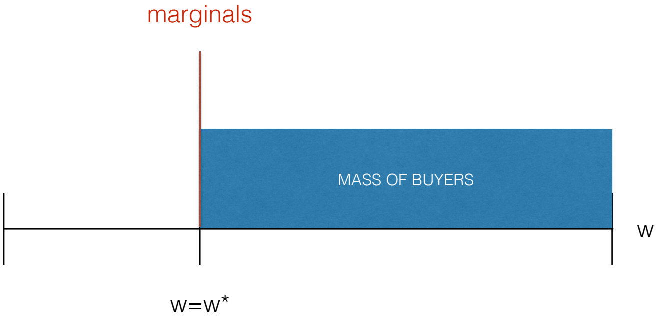
- Reasonable?
  - no intrinsic platform value $\Rightarrow$ null set is an eql for any $p \geq 0$
    - for which platforms is this OK?
  - value of externalities always increases
  - all users have same value to the network
  - requires unidimensional types?

This buys us: nice equilibrium structure

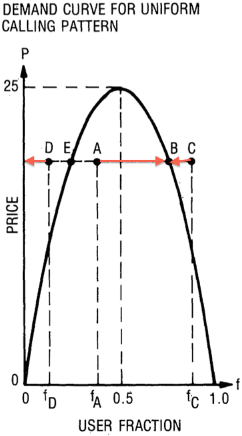
- Equilibrium joiners are the q people with the highest w_i:



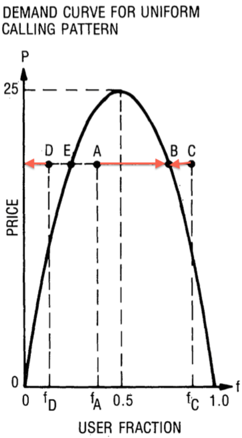
- There is still multiplicity! Multiple q's can be equilibria.

Demand with "uniform calling"

- We can order users $\Rightarrow$ we can build a demand curve
- Continuum of users with mass $n = 1$, distribution $w_i \sim \mathscr{U}\,[0, 100]$
  - if q users join, marginal user is $w^\star = 100\,(1 - q)$
  - marginal user has $U_i = w^\star q - p = 0 \Rightarrow p = 100q\,(1 - q)$: a parabola
    - demand is not downward sloping in $q \Rightarrow$ multiplicity



Stability



- Stability
  - upward sloping demand ⇒unstable equilibria
  - downward sloping demand ⇒ stable equilibria
  - more in this next

One last issue: startup problem

- Viability: is there some equilibrium with positive profits?
- Start-up: can we achieve a viable equilibrium from a small initial set?
  - "chicken-and-egg" problem of Caillaud and Jullien (2003)
  - "failure to launch" of Evans and Schmalensee (2010)
- Rohlfs (1974) has a few thoughts:
  - half measures are worst, because then the whole effort might be lost
    - platforms business are risky?
  - best to give the service for free until the right user base is reached
    - Dhebar and Oren (1985): optimal dynamic path of prices
    - Veiga (2014): $p\,|_{t=0} < 0$ optimal because cost of subsidy increases with q

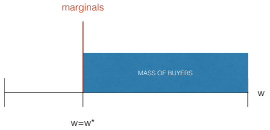
Outline

- Now some real IO: platform pricing
  - platform game, not consumer game
  - exposition follows White (2012)
- Unit mass of consumers with utility $u_i = v_i + \beta N - P$
  - $v_i \in \mathbb{R}$ heterogeneous participation benefits, with smooth PDF $f(v)$
    - reasonable for Word? Facebook?
  - $\beta > 0$ homogeneous interaction benefits
  - $N \in [0,1]$ is the expected measure of buyers
  - price P
- Zero outside option
- Timing:
  - first platform chooses P
  - then each consumer decides whether or not to join
- Assume expectation N correct in equilibrium
  - Fulfilled Expectation Cournot Equilibrium (Katz and Shapiro (1985))

Solving

- Consumer joins if $u_i \geq 0$
  - that is, $v_i \geq P - \beta N = v^\star$
  - $v^\star$ is the marginal/indifferent type
- Demand is

$$N = \mathcal{N}(P, N) = \int_{v^\star}^{\infty} f(v)\, dv$$



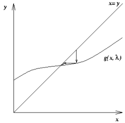
- $\mathcal{N}$ function = ignoring multiplicity: effectively, platform chooses N
- $N = \mathcal{N}(P, N)$ is a fixed point
  - N feedbacks on itself: $\mathcal{N}(P, \mathcal{N}(P, \mathcal{N}(P, \mathcal{N}(P, \ldots))))$

Partial (∂) vs Total (d) effects

- Profit is $\pi = PN - c(N)$
- For FOC we will need $\frac{dN}{dP}$. Differentiate $N = \mathcal{N}(P, N)$:

$$\underbrace{\frac{dN}{dP}}_{\text{total effect}} = \underbrace{\frac{\partial \mathcal{N}}{\partial P}}_{\text{direct partial effect}} + \underbrace{\frac{\partial \mathcal{N}}{\partial N}\frac{dN}{dP}}_{\text{indirect partial effect}} \Rightarrow \frac{dN}{dP} = \frac{\frac{\partial \mathcal{N}}{\partial P}}{1 - \frac{\partial \mathcal{N}}{\partial N}}$$

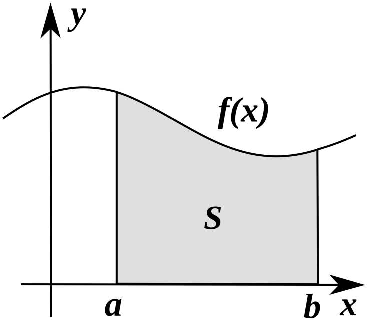
- Denominator captures the feedback/multiplier effect
  - stability if $\frac{\partial \mathcal{N}}{\partial N} < 1$ (Filistrucchi and Klein (2013))
    - network externalities are weak $\Rightarrow$ system is not explosive
    - can interpret as $\frac{1}{1-\frac{\partial \mathcal{N}}{\partial \boldsymbol{N}}} = 1 + \frac{\partial \mathcal{N}}{\partial N} + \frac{\partial \mathcal{N}}{\partial N}^2 + \ldots$
    - $\Rightarrow \mathcal{N}$ is a contraction $\Rightarrow$ has a unique fixed point



    - $\Rightarrow \frac{dN}{dP} < 0$: demand is overall downward sloping
    - $\frac{\partial \mathcal{N}}{\partial N} < 1$ is joint condition on u_i and $f(v)$

Computing partial effects by the Leibniz Rule

- For $\frac{\partial \mathscr{N}}{\partial P}$ and $\frac{\partial \mathscr{N}}{\partial N}$, differentiate $\mathscr{N}(P, N)$ by Leibniz Rule:



$$\frac{dS}{dz} = \left[\int_a^b \frac{df}{dz} dx \right] + \frac{db}{dz} f(b) - \frac{da}{dz} f(a)$$

Partial effects

$$\mathcal{N}(P,N) = \int_{v^\star = P - \beta N}^{\infty} f(v)\, dv$$

$$\downarrow$$

$$\frac{\partial \mathcal{N}}{\partial P} = -\frac{\partial v^\star}{\partial P} f(v^\star) = -f(v^\star) < 0$$

$$\frac{\partial \mathcal{N}}{\partial N} = -\frac{\partial v^\star}{\partial N} f(v^\star) = \beta f(v^\star) > 0$$

- Signs are intuitive
- Stability if $\beta f(v^\star) < 1$: types are dispersed & β small

Profit Maximization

- FOC is $N + (P - c') \frac{dN}{dP} = 0$, or

$$P - c' = -\frac{N}{\frac{dN}{dP}} = -\frac{N}{\frac{\frac{\partial \mathcal{N}}{\partial P}}{1 - \frac{\partial \mathcal{N}}{\partial N}}} = \underbrace{\frac{N}{f(v^\star)}}_{\text{Markup}} - \underbrace{\beta N}_{\text{Externality}}$$

- $\frac{N}{f(v^\star)} > 0$ is the Cournot markup over marginal cost
  - $f(v^\star)$ is density of marginal users
- $-\beta N$ captures the effect of externalities:
  - $\beta > 0 \Rightarrow$ downward pressure on price
  - Lowering price has two effects:
    - directly increases N (as usual)
    - extra feedback of N on itself, proportional to β

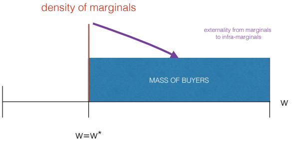
Welfare Maximization

- Welfare is $W = -c(N) + \int_{v^\star}^{\infty} (v + \beta N) f(v)\, dv$, since u_i quasi-linear

$$\pi_{max} \Rightarrow P - c' = \frac{N}{f(v^\star)} - \beta N$$

$$W_{max} \Rightarrow P - c' = 0 - \beta N < 0$$

- no markup
- price < marginal cost: Pigouvian subsidy to participation. Why?
  - externality from a marginal user to all infra-marginals is βN:

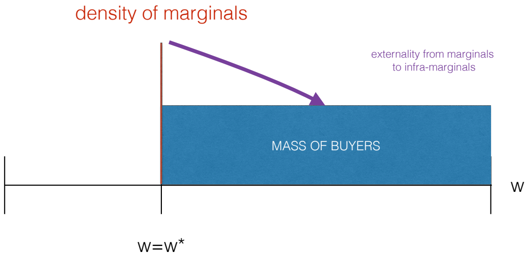


- Externality fully internalized by the profit maximizer
  - not true if β heterogeneous (next lecture)

Outline

Ideas

- Externalities: actions are public goods
- Problems:
  - Multiplicity
  - Insufficient participation



- Solution: contingent payments

Contingent payments

- Assume $U_i = w_i(N) - p$, with $N = \sum_{j \neq i} x_j$
  - people care only about the total number of adopters
- Gov gives adopters $S(N)$ and charges non-adopters $T(N)$
- Intuition: to implement $N = N^\star$, choose $S^\star(N, N^\star)$ such that
  - N low $\Rightarrow$ large payment $\Rightarrow$ good to join
  - N large $\Rightarrow$ small payment $\Rightarrow$ still good to join
  - $S^\star(N, N^\star)$ compensates, at each N, the $N^\star$-th user
  - always obtain $N^\star$ in equilibrium
- Similar to insurance scheme
  - cheap: no transfers in equilibrium
    - recall: startup pricing in Rohlfs (1974) was costly
  - Budget balances: raising S and T by ε preserves incentives

Assumptions & Limitations

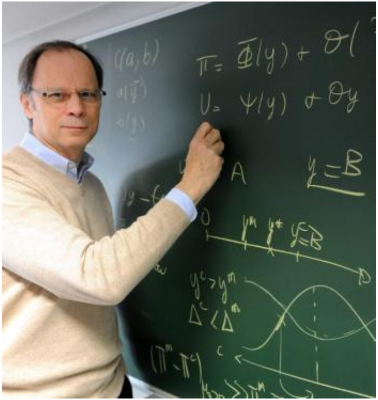
- Assume:
  - Gov knows (only) statistical distribution of preferences
    - Sakovics and Steiner (2012) use personalized subsidies
  - cannot use Groves mechanism
  - Gov can commit
  - payment can depend on the N
  - Binary choices
- Limitations?

Assumptions & Limitations

- Assume:
  - Gov knows (only) statistical distribution of preferences
    - Sakovics and Steiner (2012) use personalized subsidies
  - cannot use Groves mechanism
  - Gov can commit
  - payment can depend on the N
  - Binary choices
- Limitations?
  - what if agents have heterogeneous values? subsidy might attract the wrong users (Veiga and Weyl (2012))
  - what if there is an intensive margin? does it matter how much time people spend on Facebook?
  - reversible decisions? with switching costs?

Outline

Two sided markets



- Examples
  - video games: gamers & developers
  - newspapers: readers & advertisers
  - straight dating websites: men & women
  - job search engines: jobs & workers
  - credit cards: shops & buyers

Definition & Issues

- Definition
  - multiple groups of users
  - can be discriminated in some way
    - different prices
    - different qualities
  - transactions/activity depend on
    - price level
    - price structure
  - externalities
    - across sides
    - maybe also within sides (as in the 1-sided models we saw)
- Issues:
  - What kind of pricing? entry fee? per transaction?
  - Competition: single vs multi-homing? does it increase welfare?
  - Regulation: when is there collusion, predation, etc?

Outline

Weyl (2010) and Spence (1975)

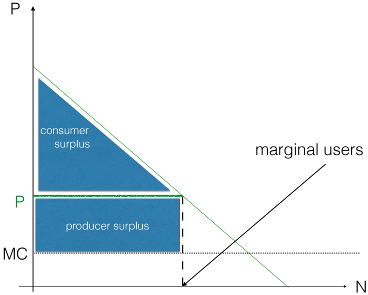
- Main idea of Weyl (2010): N is the quality of the platform
  - number of games = console quality for gamers
  - number of gamers = console quality for game developers
- The platform can choose the quality on each side through price on the other side
- If there are 2 sides, A and B:
  - P^A can be used to change N^A, which is quality towards side B
  - P^A has two functions:
    - collect revenues from side A
    - set quality for side B
  - this was also true with 1SM we saw
    - changing price directly affected revenues
    - changed N (quality), which had a further effect on revenues
    - 2SM are not that different!
  - Also: great intuition from the Spence (1975) paper about quality-choosing monopoly...

Spence (1975) profit and welfare

- Monopoly chooses quantity N, quality x.
  - Inverse demand is $P(N,x)$, x can have any effect on demand
  - cost is $c(x)N$, marginal cost of quality is $N^{\star}c'$

$$\pi = \left(P\left(N^{\star},x\right) - c(x)\right) N^{\star}$$

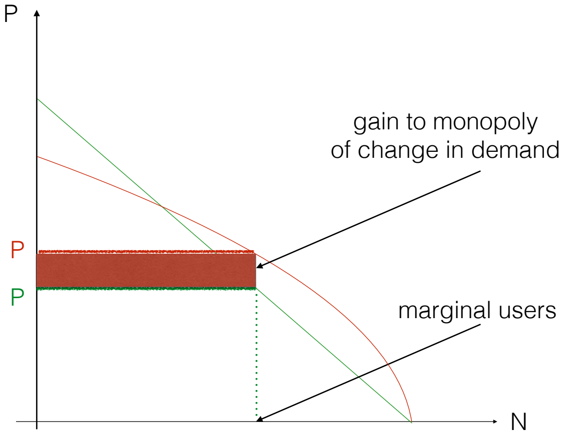
$$W = \int_0^{N^{\star}} P(N,x)\, dN - c(x)\, N^{\star} = N^{\star}\left(\mathbb{E}\left[P(N,x)\right] - c(x)\right)$$



Spence FOCs for quality

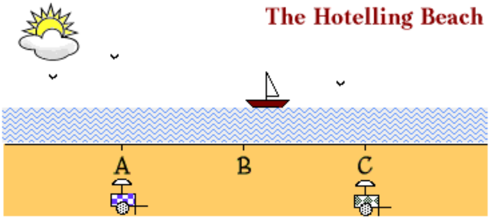
$$w_{max} \Rightarrow N^{\star} c' = N^{\star} \mathbb{E}\left[\frac{\partial P(N,x)}{\partial x}\right]$$

$$\pi_{max} \Rightarrow N^{\star} c' = N^{\star} \frac{\partial P(N^{\star},x)}{\partial x}$$



Examples

- City shops cater to tourists
- Film studios cater to kids
- Median voter theorem
  - who votes?
- Cell phone companies send you SIM card for free
  - but customer service is often bad
- Location on the Hotelling beach



Outline

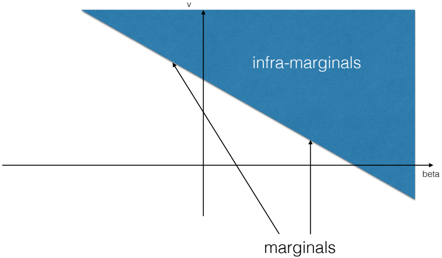
Broad picture

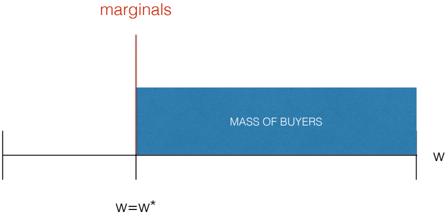
- Generalization of Rochet and Tirole (2006), Armstrong (2006) and other papers
- N is quality (following Spence (1975))
- Insulating tariffs for uniqueness (following Dybvig and Spatt (1983))
- Multidimensional types
- Exposition follows White (2012)

Model

- two sides $i \in \{A, B\}$, $j \neq i$
- platform chooses prices P^i
- consumer utility $u^i = v^i + \beta^i N^j - P^i$
  - types $\theta^i = \left(v^i, \beta^i\right) \in \mathbb{R}^2$ has PDF $f^i\left(\theta^i\right)$
  - N^i is number of consumers on side i
  - only cross-side effects
  - outside option zero
  - NEW: 2 sides, β heterogeneous!
- Buyers/infra-marginals are $\left\{v^i \geq P^i - \beta^i N^j\right\} = \left\{v^i \geq v^{i\star}\right\}$
- Marginals are $\left\{v^i = v^{i\star}\right\}$
  - margin is defined by the function $v^{i\star}\left(\beta^i, P^i, N^j\right)$
  - there are several types on the margin

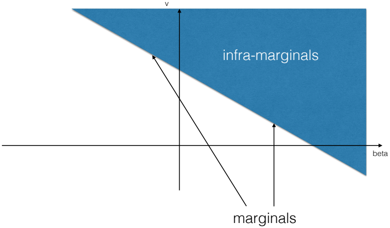
- Margin is defined by $v^i = v^{i\star}\left(\beta^i, P^i, N^j\right)$: high $v^i \Leftrightarrow$ low β^i
- in 1D models, there is a unique type on the margin





- Mass of buyers is

$$N^i = \mathscr{N}^i\left(P^i, N^j\right) = \int_{-\infty}^{\infty}\left[\int_{v^{i\star}}^{\infty} f\left(v^i, \beta^i\right) dv^i\right] d\beta^i$$



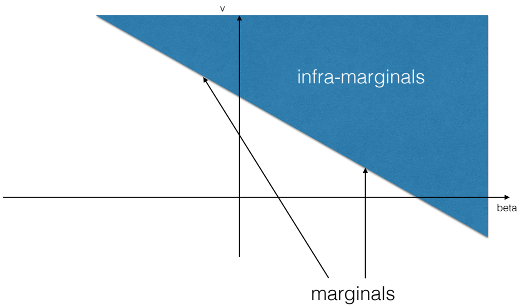
- Profit is $\pi = \sum_i N^i P^i - C\left(N^i, N^j\right)$.
- We want $\frac{dN^i}{dP^i}$; we will need $\frac{\partial \mathscr{N}^i}{\partial P^i}$ & $\frac{\partial \mathscr{N}^i}{\partial N^j}$ as before

Partial effect of price

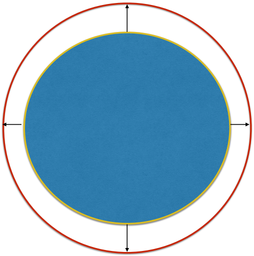
- $\mathcal{N}^i\left(P^i, N^j\right) = \int_{-\infty}^{\infty}\left[\int_{v^{i\star}}^{\infty} f\left(v^i, \beta^i\right) dv^i\right] d\beta^i$ and $v^{i\star} = P^i - \beta^i N^j$

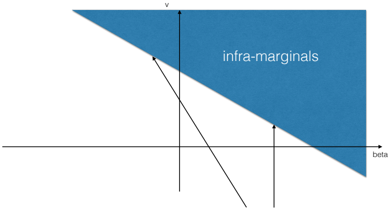
$$\frac{\partial \mathcal{N}^i}{\partial P^i} = \int_{-\infty}^{\infty}\left[-\frac{\partial v^{i\star}}{\partial P^i} f\left(v^{i\star}, \beta^i\right)\right] d\beta^i = -\int_{-\infty}^{\infty} f\left(v^{i\star}, \beta^i\right) d\beta^i = -M^i$$

- This is the density of marginal buyers
  - before: $N = \int_{v^\star}^{\infty} f(v)\, dv$ and $M = f(v^\star)$
  - now: N is a double integral and M is a line integral



Example: circle in 2D





- Area: $N = \pi r^2$. Then $\frac{dN}{dr} = 2\pi r = M$
- Price is similar: shrinks set of buyers everywhere by the same amount because preferences are quasilinear

Partial effect of quality (N^j)

- $\mathcal{N}^i\left(P^i, N^j\right) = \int_{-\infty}^{\infty}\left[\int_{v^{i\star}}^{\infty} f\left(v^i, \beta^i\right) dv^i\right] d\beta^i$ and $v^{i\star} = P^i - \beta^i N^j$

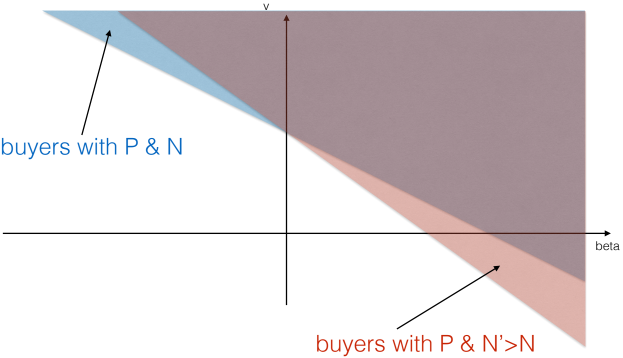
$$
\begin{aligned}
\frac{\partial \mathcal{N}^i}{\partial N^j} &= \int_{-\infty}^{\infty}\left[-\frac{\partial v^\star}{\partial N^j} f\left(v^{i\star}, \beta^i\right)\right] d\beta^i = \int_{-\infty}^{\infty} \beta^i f\left(v^{i\star}, \beta^i\right) d\beta^i \\
&= M^i \frac{\int_{-\infty}^{\infty} \beta^i f\left(v^{i\star}, \beta^i\right) d\beta^i}{\int_{-\infty}^{\infty} f\left(v^{i\star}, \beta^i\right) d\beta^i} \\
&= M^i \mathbb{E}\left[\beta^i \mid v^i = v^{i\star}\right]
\end{aligned}
$$

- The change in users on side i, when users on side j changes:
  - depends on density of margin
  - depends on average preferences (marginal WTP) for N^j among marginal on side i
  - marginals are the only ones affected by a small change in N^j

Visual intuition

- Homogeneous prefs over P^i: $\frac{\partial \mathcal{N}^i}{\partial P^i} = M^i \mathbb{E}\left[\frac{\partial u^i}{\partial P^i} \mid v^i = v^{i\star}\right] = -M^i$
- Heterogeneous preferences over N^j:

$$\frac{\partial \mathcal{N}^i}{\partial N^j} = M^i \mathbb{E}\left[\frac{\partial u^i}{\partial N^j} \mid v^i = v^{i\star}\right] = M^i \mathbb{E}\left[\beta^i \mid v^i = v^{i\star}\right]$$



Total effect

- Here too we compute the total effect from $N^i = \mathscr{N}^i\left(P^i, N^j\right)$

$$\frac{dN^i}{dP^i} = \underbrace{\frac{\partial \mathscr{N}^i}{\partial P^i}}_{\text{direct effect}} + \underbrace{\frac{\partial \mathscr{N}^i}{\partial N^j}\frac{\partial \mathscr{N}^j}{\partial N^i}\frac{d\mathscr{N}^i}{dP^i}}_{\text{indirect effect through } N^j} \Leftrightarrow \frac{dN^i}{dP^i} = \frac{\frac{\partial \mathscr{N}^i}{\partial P^i}}{1 - \frac{\partial \mathscr{N}^i}{\partial N^j}\frac{\partial \mathscr{N}^j}{\partial N^i}}$$

- $\frac{\partial \mathscr{N}^j}{\partial N^i}$ is symmetric to $\frac{\partial \mathscr{N}^i}{\partial N^j}$
- Now stability requires $\frac{\partial \mathscr{N}^i}{\partial N^j}\frac{\partial \mathscr{N}^j}{\partial N^i} < 1$
  - feedback depends on the interaction of the two sides
  - interpretation as infinite feedback loop
  - overall downward sloping demand
- This is special to 2SM

FOCs

- $W = \sum_i \left\{ \int_{\beta^i} \int_{v^{i\star}}^{\infty} \left(v^i + \beta^i N^j \right) f^i dv^i d\beta^i \right\} - C\left(N^i, N^j\right)$
- $\pi = \sum_i \left\{ P^i N^i \right\} - C\left(N^i, N^j\right)$

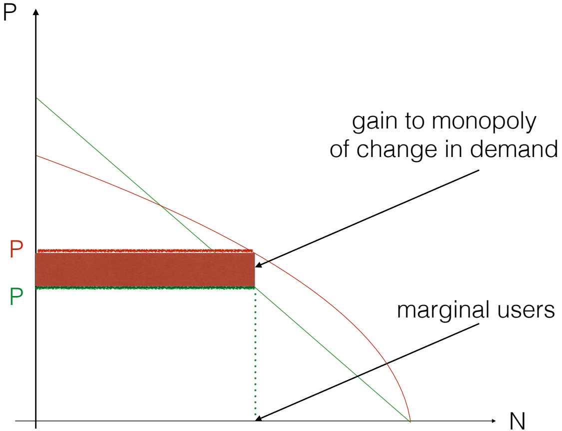
$$W_{max} \Rightarrow P^i - \frac{\partial C}{\partial N^i} = 0 - N^j \mathbb{E}\left[\beta^j \mid v^j \geq v^{j\star}\right]$$

$$\pi_{max} \Rightarrow P^i - \frac{\partial C}{\partial N^i} = \underbrace{\frac{N^i}{M^i}}_{\text{markup}} - N^j \underbrace{\mathbb{E}\left[\beta^j \mid v^j = v^{j\star}\right]}_{\text{Spence term}}$$

- Positive markup as before
- Spence distortion: Platform considers marginal users

Spence distortion

- Spence distortion: Platform considers marginal users
  - when N^i increases, platform captures from all N^j users, the surplus of marginal j users
  - absent before because β homogeneous (demand just shifts vertically)
  - not special to 2SM



Spence distortion

- Sign of the Spence distortion depends on

$$\mathbb{E}\left[\beta^i \mid v^i = v^{i\star}\right] \gtrless \mathbb{E}\left[\beta^i \mid v^i \geq v^{i\star}\right]$$

  - If β homogeneous, no distortion
  - Spence can mitigate or exacerbate Cournot (true also in 1SM)
  - consequence of inability to price discriminate (Simon Cowan's lectures)
- profit maximizing P^j might be negative if $\mathbb{E}\left[\frac{\partial u^i}{\partial N^j} \mid v^i = v^{i\star}\right]$ large
  - would not occur in a 1-sided setting
  - regulation: zero price does not necessarily mean predation
  - often there are technical reasons why negative prices don't work
    - users create fake accounts, etc
  - lots of examples of zero pricing in 2SM:
    - Google's searchers
    - Facebook's users

Price levels

$$\pi_{max} \Rightarrow P^i - \frac{\partial C}{\partial N^i} = \frac{N^i}{M^i} - N^j \mathbb{E}\left[\beta^j \mid v^j = v^{j\star}\right]$$

- Which side is charged more?
  - depends on elasticity of demand
  - depends on how much you matter to the other side
    - as judged by their marginal users
- If you opened a nightclub, would you charge more to women or men?
  - "divide and conquer" of Jullien (2011)

Insulation

- platform can implement any $\left(\hat{N}^i, \hat{N}^j\right)$ by committing to $P^i\left(N^j\right)$
  - contingent prices, aka "insulating tariff"
  - "smooth" version of Dybvig and Spatt (1983)
- Then $P^i\left(N^j\right)$ defined by the differential equation

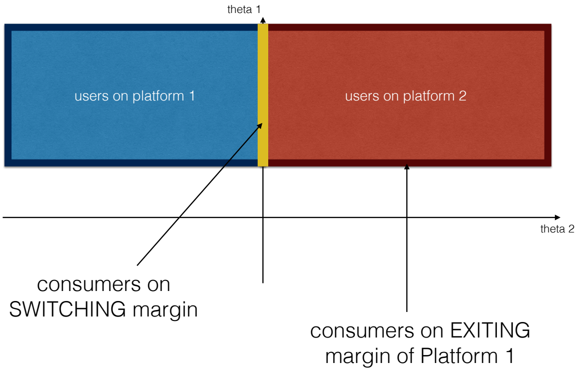
$$\frac{dN^i}{dN^j} = 0 \Rightarrow \frac{\partial N^i}{\partial N^j} + \frac{\partial N^i}{\partial P^i}\frac{\partial P^i}{\partial N^j} = 0 \Rightarrow -\frac{\frac{\partial N^i}{\partial N^j}}{\frac{\partial N^i}{\partial P^i}} = \frac{\partial P^i}{\partial N^j}$$

- boundary condition: $\hat{N}^i = N^i\left(\hat{N}^j, P^i\left(\hat{N}^j\right)\right)$
- Intuition:
  - for any N^j, adjust P^i enough to obtain desired N^i
  - requires $\frac{\partial N^i}{\partial P^i} < 0$ for all N^j (true under regularity conditions on f^i)
  - prices might be negative
  - composition of buyers might change
  - monopolist only needs to insulate 1 side
- Same limitations as before

Outline

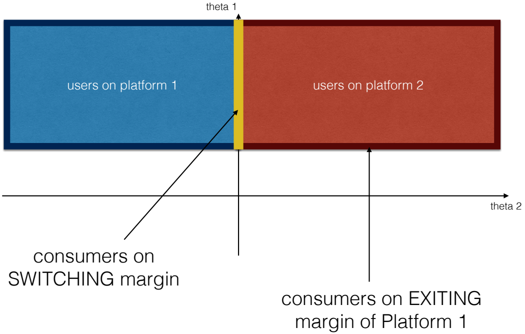
Model

- Adding competition to Weyl (2010)
- Consider a market with 2 (1-sided) platforms, 1 and 2
  - for instance θ_2 is the Hotelling location
- There are two sets of "marginal users"
  - exiting margin: densities M_1^X and M_2^X
  - common switching margin with density M^S

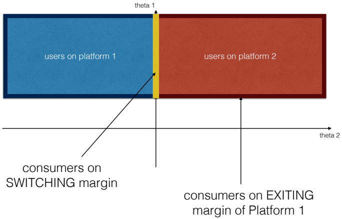


FOCs

- Profit maximizer considers $M = M^X + M^S$
- Welfare maximizer ignores S margin
  - S margin: same utility on either platform
  - increasing price $\Rightarrow$ "lose" switching users
  - $\Rightarrow$ no loss in surplus (by envelope theorem)



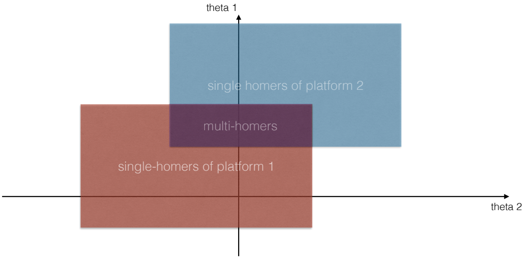
Effect of Competition



- increasing competition $\approx$ increasing M^S
  - true in a symmetric Hotelling model
- Markup decreases: $\frac{N}{M^S+M^X} \to 0$
- Spence distortion: importance of S increases, relative to X
  - if S users are representative $\Rightarrow$ distortion decreases
  - if X users are representative $\Rightarrow$ distortion increases
  - might be non-monotonic
  - perfect competition + symmetric equilibrium $\Rightarrow$ everyone in S
    - no Spence distortion

Competition and Multi-homing

- Users can "multi-home": be on both platforms at once
  - platform demands are independent
  - $\Rightarrow$ Firms are monopolies



- What if time spent on each network matters? multi-homers are less valuable than single-homers.

Outline

- Katz and Shapiro (1985)
  - static Cournot oligopoly with positive externalities
  - firms choose wether their products are compatible
  - large networks $\Rightarrow$ oppose compatibility
  - as a whole, firms have lower incentives for compatibility than society
  - Fulfilled Expectation Cournot Equilibrium
    - consumer expectations about network size are realized in equilibrium
- Farrell and Saloner (1985)
  - firms make sequential decision about whether to adopt a new standard or not
  - payoff to adoption increases in number of adopters
  - agents are better off moving earlier than later
  - there can be excess inertia or excess momentum

- Biglaiser, Cremer and Veiga (2013)
    - explicit dynamics
    - consumers receive stochastic opportunities to switch
    - free riding incentive
    - there can be too much or too little switching
    - welfare loss from too much segregation
- Sakovics and Steiner (2012)
    - platform/gov knows consumers types and can solve coordination by giving personalized subsidies
- Jullien and Pavan (2013)
    - uniqueness in consumer game due to global games framework

Thank you!

For questions, please email me at

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