Network Effects

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Grad IO

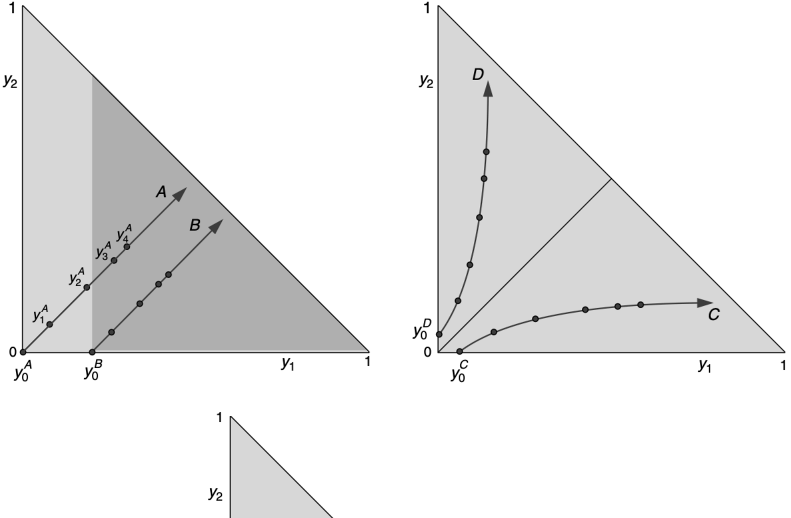
What are Network Effects?

- An important aspect of many digital markets today is *network effects*.
- Main idea is that you value the good more if other people use it.
  - Social Networks: Facebook, Instagram, Twitter, Tindr, etc.
  - Statistical Packages: Stata, R, Matlab, etc.
  - P2P Platforms: Ebay, Etsy, Alibaba, Uber.
  - Software Platforms: iOS, Android, Windows.
  - Game Consoles: PS4, XBox One, etc.
- This creates a lock in effect.
  - You may have an incentive to underprice initially to drive adoption.
  - There may be benefits to being early to market.
  - Markets can tip one way or another.
- Two-sided markets are another important issue (Developers, Developers, Developers!)

- Consumers make adoption decision that is durable (or irreversible) and depends on two things:
  - The share of users on the same platform ρ_{jt}
  - Beliefs about the future of $E[\rho_{j,t}]$
- Because beliefs are important, multiple equilibria can arise
- How do we measure the size/impact of indirect network effects?
- Constructing a counterfactual equilibria in a world without network-effects is hard to do in practice.

What are Network Effects?

Figure 1 **Market Evolution Under Different Scenarios: No Indirect Network Effects (Top Left), Positive Feedback (Top Right), and Multiple Self-Fulfilling Equilibria (Bottom)**



- Start with two firms and $M = 1$ mass of consumers
- Installed base $y_t = [y_{1t}, y_{2t}] \in [0, 1]$ is the state space.
- Assume that demand shock $\xi_{jt} \sim \phi(\xi)$ is private information to the firm (similar to Seim's paper on video stores).
- Timing of the game:
  1. Firms learn ξ_{jt} and set p_{jt}
  2. Consumers adopt $\{1, 2\}$ or delay purchase $= 0$
  3. Software firms supply a given number of titles n_{jt}
  4. Sales are realized and firms receive profits. Consumers receive utility from n_{jt} and in adoption period from platform itself.
- Information structure guarantees a unique best response (conjecture) and a pure-strategy equilibria.
- Hence prices p_{jt} contain a lot of information.
- Titles depend on next period state variable: $n_{jt} = h_j(y_{j,t+1})$. Why?

Need two things:

- Current prices and installed base (p_t, y_t)
- Beliefs about the future $y_{t+1} = f^e(y_t, \xi_t)$ and conjecture about firm policy $p_{jt} = \sigma_j^e(y_t, \xi_t)$.

Utilities

- Flow from software: $u_j(y_{j,t+1}) = \gamma n_{jt} = \gamma h_j(y_{j,t+1})$
- In PDV: $\omega_j(y_{t+1}) = \mathbb{E}[\sum_{k=0}^{\infty} \beta^k u_j(y_{j,t+1+k})|y_{t+1}]$
- This PDV trick is common (and helpful) and solves the recursion:

$$\omega_j(y_{t+1}) \quad = \quad u_j(y_{j,t+1}) + \beta \int \omega_j(f^e(y_t, \xi_t))\phi(\xi)\partial\xi$$

Choose j to maximize choice specific value function (indirect utility) logit error :

$$\begin{aligned} v_j(y_t, \xi_t, p_t) &= \delta_j + \omega_j(f^e(y_t, \xi_t)) - \alpha p_{jt} + \xi_{jt} \\ v_0(y_t, \xi_t) &= \beta \int \max\{v_0(y_{t+1}, \xi) + \varepsilon_0, \\ & \max_j [v_j(y_{t+1}, \xi_t, \sigma^e(y_{t+1}, \xi)) + \varepsilon_j]\} \cdot \phi(\xi)\phi_\varepsilon(\varepsilon) \end{aligned}$$

This gives us logit shares $s_j(y_t, \xi_t, p_t)$ and a law of motion for y_t:

$$y_{j,t+1} = y_{jt} + (1 - \sum_{k=1}^{J} y_{kt}) s_j(y_t, \xi_t, p_t) = f_j(y_t, \xi_t, p_t)$$

Firms

- Constant marginal cost c_j and royalty rate r_j per unit of software $q_j(y_{t+1})$.
- Get $q_j(y_t)$ directly from the data.
- only integrate over your opponent's ξ_{-j}

$$\pi_j(y,\xi,p_j) = (p_j - c_j)\cdot(1-\sum_k^J y_{kt})\cdot\int s_j(y,\xi_j,\xi_{-j},p_j,\sigma_{-j}(y,\xi_{-j}))\phi_j(\xi_{-j})$$
$$+r_j\int q_j(f_j(y,\xi_j,\xi_{-j},p_j,\sigma_{-j}(y,\xi_{-j})))\phi_j(\xi_{-j})$$

Solve Bellman:

$$V_j(y,\xi_j) \quad = \quad \sup_{p_j\geq 0}\left[\pi_j(y,\xi,p_j)+\beta_f\int V_j(f_j(y,\xi_j,\xi_{-j},p_j,\sigma_{-j}(y,\xi_{-j})))\phi(\xi_{-j})\phi(\xi_j')\right]$$

Equilibrium

Define an MPE such that:

1. Choice specific value functions v_j and v_0 waiting value satisfy the Belmman Equation.
2. Firm's Value functions satisfy the Bellman equation
3. $p_j = \sigma_j(y, \xi_j)$ maximizes the RHS of the Bellman for each j in firm problem. (Tricky since econometrician doesn't see ξ directly).
4. Consumers have rational expectations $\sigma_j^e = \sigma_j$ and $f^e(y,\ \xi) = f(y, \xi, \sigma(y, \xi))$
5. Everyone acts rationally given expectations about the future, and those expecatations are consistent with what actually happens.

- 32/64-bit console market , no backwards-compatibility, first to use CDROM
- 3DO had $\$700 - 1000$ console prices and failed to launch
- Sony Playstation was big winner: $9 royalty, low production cost.
- Sega Saturn was a failure. They exit console market completely afterwards
- N64 had lower console price but higher royalty $18. (and cartridge based)
- By Christmas of 1996 Nintendo had 8 games compared to PS 200.
- No must-buy title on PS.

Data and Estimates

Table 1 Descriptive Statistics

	Console	Mean	Std. dev.	Min	Max
Sales	PlayStation	275,409	288,675	26,938	1,608,967
	Nintendo	192,488	201,669	1,795	1,005,166
Price	PlayStation	119.9	30.3	55.7	200.6
	Nintendo	117.6	33.9	50.3	199.9
Game titles	PlayStation	594.2	381.1	3	1,095
	Nintendo	151.2	109.9	1	281

Table 2 Second-Stage Parameter Estimates

	Model 3		Model 7	
	Estimate	Std. error	Estimate	Std. error
δ_{Sony}	−1.21	0.89	−1.119	0.971
δ_{N64}	−1.34	0.87	−1.119	1.093
α	−1.94	0.52	−1.923	0.460
Time (<60)	−0.04	0.01	−0.049	0.028
γ ($n_{jt}/1{,}000$)	0.09	0.04	0.090	0.040
ψ (std. dev. of ξ_{jt})	0.05	0.09	0.028	1.950

Notes. Model 7 uses PPIs and exchange rates as instruments in first stage. $\beta = 0.9$; number of simulations $= 60$.

Counterfactual

Suppose we got rid of network effects, how much lower would the concentration of the market be?

Results

Table 3 Predicted One-Firm Concentration Ratios

Model predictions: Symmetric case (parameter estimates for Sony)				
Scale factor for γ	0.25	0.50	0.75	1.00
C_1	0.501	0.503	0.508	0.845
Discount factor (β)	0.600	0.700	0.800	0.900
C_1^a	0.501	0.502	0.508	0.845
C_1^b	0.501	0.501	0.508	0.845
Model predictions: Estimated parameter values				
Scale factor for γ	0.250	0.500	0.750	1.000
C_1	0.600	0.593	0.562	0.843
Discount factor (β)	0.600	0.700	0.800	0.900
C_1^a	0.602	0.601	0.599	0.843
C_1^b	0.571	0.572	0.562	0.843

Table 5 Profit Increase for Installed Base Advantage

Installed base adv. of Sony	Discount factor (β) 0.6	0.7	0.8	0.9
0.025	70	134	370	808
0.050	139	271	732	1,142
0.075	207	410	1,052	1,271
0.100	274	547	1,317	1,381
0.125	339	680	1,529	1,470
0.150	403	807	1,711	1,541
0.175	464	922	1,857	1,589
0.200	523	1,030	1,985	1,617

Notes. This table shows the increase in the expected present discounted value of Sony's profits, measured in millions of dollars, for a given initial installed base advantage. The results are based on 5,000 simulations, and the present discounted value of profits is calculated for a time horizon of 48 months after the competitor (Nintendo) enters the market.