Nonlinear pricing with network effects

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Motivation

Some examples of network goods and their drivers of network effects
- **Microsoft Windows**
  - File compatibility
  - Applications software
- **Ability to trade on eBay**
  - Liquidity
  - Supporting marketplace services
- **Oracle Database**
  - Software tools
  - Qualified database administrators

Motivation

• In standard models of network goods
  - Each customer buys one unit
  - Network value depends on adoption = # of customers
  - Network value is constant across customers

• In reality, the usage of many network goods varies across different customers
  - Number of OS licenses (Windows)
  - Trading frequency (eBay)

• Moreover, the network value of these goods
  - Depends on total usage across customers, and not merely the number of customers
  - May also depend on individual usage
  - May vary across customers, even at the same levels of individual and total usage

Research agenda

• Model monopoly nonlinear pricing of network goods
  - Network value depends on total usage
  - Network value for each customer may depend on their individual usage
  - Marginal network value may vary across customers

• Characterize optimal pricing schedules
  - Existence of fulfilled-expectations contract
  - Uniqueness of optimal contract
  - Variation in properties with network value

• Analyze welfare properties of contracts
  - Surplus division between firm/customers
  - Surplus distribution across customers

• Study effects of entry deterrence
  - Changes in pricing
  - Changes in welfare properties

Some related work

• Monopoly models of network goods

• Single-dimensional monopoly price screening

• Empirical estimates of network effects
  - Databases (Gandal 1994, 1995)
  - Spreadsheets (Gandal 1995, Brynjolfsson and Kemerer 1996)
  - Word processing software (Grohn 1999)
  - Networking equipment (Forman 2001)

Model

• Monopoly seller of a network good
  - Continuum of heterogeneous customers, indexed by type \( \theta \)
  - Distributed as \( F(\theta) \) with \( f(\theta) > 0 \), \( F(\theta) \) nondecreasing

• Utility functions of customer type \( \theta \):
  - \( U(q, b, \theta) - p \)
    - \( q \): individual usage of customer
    - \( b \): gross usage across all customers

• Key properties of \( W(q, b, \theta) \)
  - Individual usage: \( W_1(q, b, \theta) < 0 \), \( W_2(q, b, \theta) > 0 \), \( W_3(q, b, \theta) > 0 \)
  - Gross usage: \( W_1(q, b, \theta) < 0 \), \( W_2(q, b, \theta) > 0 \), \( W_3(q, b, \theta) > 0 \)

• Intrinsic value function: \( U(q, \theta) = W(q, b, \theta) \)
• Network value: \( W(q, b, \theta) - U(q, \theta) \)
Model

Contracts: quantity-price pairs $q(\theta)$, $\tau(\theta)$

- Feasible: IC and IR
- Optimal: Given expectation of gross consumption $Q$, maximizes profits among all feasible contracts
- Optimal fulfilled-expectation: Optimal contract for $Q$ under which actual consumption $\int q(\theta)\tau(\theta) = Q$

Sequence of events

- Seller posts contract
- Customers form expectation $Q$ of gross consumption
- Based on type $q$ and expectation $Q$, each customer chooses individual consumption $q$ to maximize surplus
- Seller, customers get payoffs

Base case: $W(q, \theta, Q) = U(q, \theta)$

- Optimal FE contract exists if $w(Q)$ is bounded, is unique if $w_1(Q) < - U_1(q, \theta)$
- Consumption $q(\theta)$ increases for a positive fraction of types, may decrease for lower types
- Surplus distribution is skewed towards higher customer types

Solution: $W(q, \theta, Q) = U(q, \theta) + qw(Q)$

- Trade-off between price discrimination and value creation

Entry deterrence

- Incumbent monopolist
  - Customers get both intrinsic value and network value from incumbent product
- One or more potential entrants
  - Entry cost = 0
  - If entry occurs, customers who purchase get just intrinsic value from product
  - Collapses some 'dynamic' aspects of an incumbent's advantage into a static model
- Monopolist prices to deter entry, by assumption
- Problem reduces to monopoly pricing with type-dependent participation constraints
Entry-deterring solution: 
\[ W(q,\theta, Q) = U(q, \theta) + qw(Q) \]

- With an entry threat, usage \( q'(0) \) is either
  - exactly the same as it was without, or
  - adjusted upwards for a subset of lower types
- Monopolist profits fall, customer surplus increases
- Outcome is not efficient
  - inefficiently low usage by all types
  - but potentially higher total surplus than if entry actually occurs

For constant network effects, entry deterring solution involves fixed price, is socially optimal

Example with entry deterrence

- Individual consumption
- Total price
- Relative customer surplus (lower \( w \))
- Relative customer surplus (higher \( w \))

Summary
- Existence, uniqueness conditions for nonlinear pricing with network effects
- Changes in usage induced by different network effects
  - Just \( Q \): No changes in usage
  - Both \( Q \) and \( q \): Increase in usage across all types
  - \( Q, q \) and customer type: Potential further downward distortion of usage of lower types, below levels in absence of network effects
- Further changes in usage induced a costless entry threat
  - May increases usage for lower types, does not affect usage for a subset of higher types, mitigates downward distortion
- Network effects (and/or an entry threat) generally improve equity in surplus distribution across different customer types
- Threat of entry can result in socially superior outcomes than actual entry, socially efficient outcome in special cases