Digital Convergence, Product Architecture and Market Structure

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Digital Convergence: Overview

Examples of converging products and services
- **Mobile devices**: Wireless telephony, mobile Internet and handheld computers (Palm, Symbian)
- **Consumer electronics**: Home entertainment systems, video game consoles, and home computers (X-Box, Digeo, Sony)
- **Residential communications**: Broadcast video, Internet access and wireline telephony (cable moderns, DSL)
- **Networking equipment**: Layer-3 switches (routers)

Key technological drivers of convergence
- Widespread digitization of product technologies and content
- Increasing power and miniaturization of semiconductor components
- Shift to platform-based architectures (hardware->OS->applications)

Digital Convergence: Overview

Primary economic trade-off
- Products become more valuable
  - Fulfill larger set of consumer needs
  - Sometimes fulfill them better
- Products become closer substitutes
  - Increased flexibility – adding applications
  - Overlap in delivered functionalities

Research Agenda

- Explore the trade-off between value and substitutability in converging technology markets
- Characterize the nature of outcomes as distinct technology markets overlap
  - Structure of equilibrium configurations
  - Prices and consumption patterns
  - Profits and surplus distribution
  - Investment levels in platform scope
- Study the impact of changes in
  - Breadth of consumer requirements
  - Cost structure (variable, fixed)

Snapshot of Results

As technology markets converge:
- Higher prices and profits possible, despite reduced product differentiation
- Strategic choices of product scope prevent commoditization and Bertrand outcomes
- Distortions in investment incentives are positive when markets are fully covered
- Consumption patterns may be altered
  - Multiple products \(\rightarrow\) fewer products \(\rightarrow\) multiple products.
Modeling Framework
Model needs to be able to:
- Represent set of relevant functionalities
- Allow variable and possibly endogenous fulfillment of functionalities by products
- Admit varying sets of consumer requirements
- Allow consumers to make either discrete or multiple purchases to fulfill requirements

Modeling Framework: Products
- Feasible functionalities distributed around unit circle
- Product defined by location of core functionality
- Level of platform scope \(1/t\), exogenous loss function \(g(x)\)
- Products provide functionalities with varying effectiveness

Modeling Framework: Consumers
- Continuum of heterogeneous consumers
- Require different sets of functionalities
- Have same breadth of functionality requirements \(r\)
- Uniformly distributed around unit circle

Duopoly: Model Specification
- Two single-product firms – diametrically opposite locations
- Linear loss function \(g(x)=x\)
- Game structure
  a. Symmetric exogenous scope, simultaneously choose prices
  b. Two-stage game – endogenous scope, then prices

Duopoly: Inverse Demand Curve
- Distinct ‘monopoly’ and ‘competitive’ regions
- Demand is less elastic in the competitive region
- Location of kink driven by opponent’s price

Duopoly: Some analytical details
1. Utility functions
   \(U(q,t) = \max \left( \frac{q}{\kappa(t) + \rho}, q, \frac{q}{\kappa(t) + \rho} \right)\) for \(q > 0\)
   \(U(q,t) = \max \left( \frac{q}{\kappa(t) + \rho}, q, \frac{q}{\kappa(t) + \rho} \right)\) for \(q < 0\)

2. Inverse demand curves
   \(P(q,t) = U(q, t)\)
   \(P(q,t) = U(q, t) - U(1-q, t)\)

3. Second-stage payoff functions
   \(W(q_i, t, p_j) = u(q_i, t, p_j) - u(q_i, t, p_j)\) or \(W(q_i, t, p_j) = u(q_i, t, p_j) - u(q_i, t, p_j)\)

4. Interior local maxima
   \(Q(t) = q: q = \frac{U(q, t) - U(1-q, t)}{U(1-q, t) - U(q, t)}\)
   \(Q(t) = q: q < \frac{U(q, t) - U(1-q, t)}{U(1-q, t) - U(q, t)}\)

5. Equilibrium configurations
   Local Monopoly: \(Q(t_i) = Q(t_j) > \frac{1}{2}\) and \(Q(t_i) = Q(t_j) < \frac{1}{2}\)
   Competitive: \(Q(t_i) = Q(t_j) < \frac{1}{2}\) and \(Q(t_i) = Q(t_j) > \frac{1}{2}\)
   Kinked: \(Q(t_i) = Q(t_j) > \frac{1}{2}\)
### Duopoly: Equilibrium Structure

- Competitive (Non-exclusive)
- Kinked
- Local monopoly

### Duopoly: Equilibrium Prices

- Initially, prices increase despite decreasing differentiation
- Prices higher than corresponding monopoly price
- Endogenous-scope price = highest possible duopoly price

### Duopoly: Profits

- Profits increase initially even after market is fully covered
- When platform scope is very high, competition → Bertrand
- Endogenous-scope profits = highest possible duopoly profits

### Duopoly: Surplus

- Total surplus always higher under duopoly than monopoly
- Consumer surplus declines in kinked region, rises otherwise
- Endogenous-scope CS = lowest duopoly CS with full coverage

### Summary of Key Results

- In the earlier stages of convergence (kinked)
  - Prices increase even as products become less differentiated
  - Prices are higher than corresponding monopoly prices
  - Firms can therefore appropriate surplus created by increased platform scope and product value
- In later-stage convergence (competitive)
  - Prices, profits fall rapidly as platform scope increases
  - Consumers realize all the surplus (and more) created by increased platform scope and product value
- Therefore, in the trade-off central to converging markets:
  - Value increases dominate initially (kinked configuration)
  - Substitutability dominates subsequently (competitive configuration)
- If scope can be chosen strategically, all sub-game perfect equilibria preserve high prices and profits.

### Further Results

- As the breadth of consumer requirements increases, prices and profits increase for all values of scope
  - Highlights the importance of separating consumer parameters from product variables
- As variable costs fall, exogenous-scope prices
  - decrease under local monopoly and competitive equilibria
  - remain constant under kinked equilibria
- Kinked equilibrium outcome is subgame perfect, 'standard' competitive outcome is not.
- Relative to social optimum, in both monopoly and duopoly.
  - Firms under-invest in scope when market is partially covered
  - Firms over-invest in scope when market is fully covered
- For broad consumer requirements, permitting non-exclusive choice leads to a new kind of outcome
  - Multiple products → one product → multiple products
Ongoing Work

- Endogenize choice of effectiveness on core functionality in addition to scope
- Incorporate intra-industry competition by having more than one firm at a single location
- Generalization to multi-dimensional functionality spaces

Questions?