The theory of Industrial Organization

Ph. D. Program in Law and Economics

Session 10: Network externalities

J.L. Moraga

Network Effects

Network: Set of individuals and set of links between them.

– Physical: Telephone, Fax, ATM networks, Internet, etc.
– Virtual: networks of users of compatible and complementary goods; videorecorders and videotapes, hardware and software, cars and repair parts, etc.

Network Externalities: the value to a user of connecting to a network (or acquiring a product) is increasing in the # of other persons who are (will be) in the network.

– Physical: direct  Virtual: indirect
**Systems**

*System*: 2 or more goods with little (or no) value in isolation but generating a large value when consumed together.

- *Consumers shop for systems, not for individual products (strong complementarities)*
  - *Examples*: Nuts and bolts, razors and blades, cameras and lenses, hardware and software, music players and cassettes

---

**Multiplicity of equilibria**

Network externalities and system products generally lead to multiple equilibria.

↓

In such settings expectations play an important role in selecting among equilibria.

The question that arises is how *private* and *public* institutions can influence expectations.
The role of expectations: example 1

2 products $a$, $b$ offered competitively at price $p$

2 consumers.

consumer’s utility:
- $u_a(A)$ if he acquires product $a$ with network size $A$
- $u_b(B)$ if she acquires product $b$ with network size $B$

Assume:
- Network externalities: $u_a(A_2) > u_a(A_1)$ when $A_2 > A_1$; and $u_b(B_2) > u_b(B_1)$ when $B_2 > B_1$.
- Network effects more important than product features: $u_a(2) > u_b(1)$ and $u_b(2) > u_a(1)$

Game: All consumers decide simultaneously which product to acquire.

Result

Assume $p > u_a(1)$ and $p > u_b(1)$

<table>
<thead>
<tr>
<th>Strategy</th>
<th>$a$</th>
<th>$b$</th>
<th>no adoption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buyer 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a$</td>
<td>$u_a(2)-p$, $u_a(2)-p$, $u_a(1)-p$, $u_b(1)-p$, $u_a(1)-p$, $0$</td>
<td>$u_a(1)-p$, $0$</td>
<td></td>
</tr>
<tr>
<td>$b$</td>
<td>$u_b(1)-p$, $u_a(1)-p$, $u_b(2)-p$, $u_b(2)-p$, $u_b(1)-p$, $0$</td>
<td>$u_b(1)-p$, $0$</td>
<td></td>
</tr>
</tbody>
</table>

Buyer 2

<table>
<thead>
<tr>
<th>Strategy</th>
<th>$a$</th>
<th>$b$</th>
<th>no adoption</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$</td>
<td>$u_a(2)-p$, $u_a(2)-p$, $u_a(1)-p$, $u_b(1)-p$, $u_a(1)-p$, $0$</td>
<td>$u_a(1)-p$, $0$</td>
<td></td>
</tr>
<tr>
<td>$b$</td>
<td>$u_b(1)-p$, $u_a(1)-p$, $u_b(2)-p$, $u_b(2)-p$, $u_b(1)-p$, $0$</td>
<td>$u_b(1)-p$, $0$</td>
<td></td>
</tr>
</tbody>
</table>

Then, there are 3 pure strategy Nash-equilibria:
- no one adopts the product
- everyone chooses product $a$
- everyone chooses product $b$
Coordination problem

*How can consumers coordinate at a particular equilibrium? Formation of expectations is not a trivial task.*

**Implications for firm behavior and for social welfare**

- how private (firms) and public institutions (government) can influence consumer expectations?

Firms’ perspective

*Investment in new technologies:* Firms’ incentives to invest are clearly sensitive to the pattern of adoption.

- Who is going to invest ‘lots of money’ in something that perhaps is not adopted?
- How can firms *sponsor* new technologies?
  - Create an installed base (innovate faster)
  - Introductory Pricing
  - Drastic innovation (sufficient quality leapfrogging)
Welfare perspective

From the point of view of the society welfare, two problems can arise:

- Since \( p = c < \{ u_a(2), u_b(2) \} \), there is a potential for under-utilization of the network (no adoption equilibrium).
- If, for instance, \( u_a(2) > u_b(2) \), there is a potential for proliferation of inefficient technologies (\( b \) equilibrium rather than \( a \)).

These two reasons explain why public institutions are interested in participating in these markets.

Installed base and critical mass

Firms’ viewpoint

- Market with large benefits from network externalities (e.g., telecom)
- Assume there is a continuum of consumers of size \( M \).
- Each buyer has a demand for one connection
- A buyer is represented by parameter \( v \).
  - Assume \( v \) uniformly distributed in \([0,1]\)
  - The willingness-to-pay for a connection increases as \( v \) increases.
- Buyer’s utility is \( U = n v - p \) where \( n \) is (expectation) of the # of buyers subscribing to the (telecom.) network.
- Assume network product is offered at price \( p \)
Given $p$ and network size expectation $n^e$, a consumer $v$ connects to the network if and only if he/she obtains a non-negative utility.

Define $v_0$, consumer indifferent between buying and not buying

$$v_0 n^e - p = 0. \text{ Then } v_0 = p / n^e.$$  

Consumers with $v \geq v_0$ will connect.

For given $n^e$, the actual # of buyers is then $Q = M n^e (1 - v_0)$.

Assume consumers’ perfect foresight.

$$n^e = Q = M n^e (1 - p / n^e).$$

Demand is $p = Q (1 - Q / M)$.
The demand for telecom. services

Low adoption equilibrium is unstable. $Q^L_0$ is the critical mass:
- If # users > critical mass, convergence towards high-adoption equi.
- Otherwise convergence towards no adoption equi.

Installed base and critical mass

- How to cross critical mass threshold?
  - Introductory pricing
  - Take care of installed base:
    - build a new network upon an existing one
    - Provide compatibility
Installed base and critical mass
Welfare viewpoint

Farrel-Saloner (AER, 1986) compare private and social incentives for the adoption of a new technology that is incompatible with the installed base.

2 models:
- Network builds with new users
- Network builds through switching of old users

In their models ‘excess inertia’ and ‘excess momentum’ can arise in equilibrium.
- Excess inertia: private reluctance to switch to a new socially more desirable technology due to the existing network effects of the old technology (installed base).
- Excess momentum: The inefficient adoption of a new technology

Example: a model with New Users

The set-up:
- There is an Old network, at time T* a new better technology arrives.
- The new network must be built up by new users
- Users are infinitesimal and arrive continuously over time to the market.
- Each new user decides which technology to adopt given what the others have done.

The determining variables:
- The size of the installed base (network size of the old technology)
- The relative superiority of the new technology (superior technical features / higher network benefits)
- How fast network benefits of the new technology are realised
Nash equilibrium

- A Nash equilibrium is a collection of users’ strategies such that no user wants to change its strategy given the choices of the other users.
- A user adopts the new technology if the present value of the flow of benefits obtained is greater than when adopting the old technology.
- A user is more inclined to adopt New when
  - is technically better
  - is subject to larger network externalities
  - arrives fast in the market (old has small installed base)
  - Future benefits are important (low interest rate)

Welfare point of view

- There are positive and negative welfare effects from the adoption (or not) of a new technology $N$.
- Positive: Late users gain because $N$ is adopted.
- Negative:
  - Early adopters of N may have preferred not to adopt and lose
  - The $O$ network stops growing; there are people stuck with the old technology, they suffer a loss.
Alignment of private and social incentives

Factors leading to excess inertia (or less excess momentum)
- Large installed base (slow innovation)
- Moderate innovativeness
- High interest rates

Product pre-announcements increase the extent to which the new technology is adopted. It can mitigate excess inertia but accentuate excess momentum.

Compatibility and standardization

- A solution to excess inertia and excess momentum is provision of compatibility.

- Compatibility can be achieved via
  - *Industry Standards*: all firms that choose compatibility must agree to make their networks compatible.
  - *Adapters*: in this case any firm can unilaterally choose to be compatible with another firm
Incentives for Compatibility may be too low

- But do firms have the proper incentives to produce compatible products?
  - Private incentives to achieve compatibility may be too low

- Private incentives:
  - \( \alpha - \lambda = \lambda ' - \lambda ' \) in the case of an adapter,
  - Or by \( \alpha - \lambda = \lambda ' \alpha - \lambda \) in the industry-standard case (allowing for syde payments)

- Social incentives:
  - \( \alpha W = \alpha - + \alpha CS \)

Since compatibility increases aggregate output, private incentives are not be excessive.

Too low incentives

*Large* firms will tend to be against compatibility, while *small* firms will tend to favor product compatibility.

In dynamic contexts:
- backward compatibility often provided
- but not so much forward compatibility
Caveats with compatibility

- Product variety is reduced.
- Competition