# Lecture 22 - Network Externalities

14.03 Spring 2003

## 1 Network Externalities

- We have mostly discussed games where one player triumphs at the expense of another. But another important class of games are so called "coordination" games. Here, all players are better off if they make complementary decisions.
- Classic coordination problem examples are:
  - Which side of the street to drive on
  - Spoken language
  - Calendar system (lunar, solar)
  - 120 vs. 240 volts
- These are *pure coordination problems* in that there is (probably) no best standard. But it's very important that people adhere to the same standard. Moreover, the benefits to adhering to the standard often increase with the number of others doing likewise (i.e., what makes English a particularly useful language to know is that many other people throughout the world speak it).
- An economic entity with the property that the benefits to using it increase with the number of users is said to exhibit network externalities.

**Definition 1** *Network: A virtual community of others with whom you interact if you are adhering to the same standard.*

**Definition 2** *Nework Externality: When the utility of what one person does (chooses, consumes) depends positively on how many other people are doing the same thing. ("Scale economies in consumption.")*

- Examples of networks:
  - Language
  - Religion

- Computer operating systems
- The Internet (of course)

- There may arise a trade-off between the gains from coordinating versus the gains from choosing a superior standard.
- Why would there be a trade-off? There would not be if all standards (good and bad) were made available simultaneously. People would make the globally best choice in a coordinated manner.
- But it's the nature of technologies to improve and so people/networks/countries will often face a choice of adhering to an old, settled standard and moving to a superior one.
- And this is not simply a private decision – there are externalities as the name implies. So the decisions are interdependent.
- I might be delighted to move to the Italian workday model: drink red wine with lunch and nap for an hour. But I don't want to make this move alone.
- There may be many examples where the market has settled into an inferior equilibrium:
  - Roman versus Aramaic numerals
  - Hieroglyphics versus phonetic alphabets
  - SAE versus Metric in the U.S.
  - QWERTY versus DVORAK
  - Windows versus Linux
  - Visual Basic versus Java
- What are the factors that affect the cost of moving from one network standard to another?
  - Sunk capital costs (throw out the old equipment)
  - Difficulty of learning a new standard
  - Foregone productivity using the old standard (i.e., might eventually get faster with a DVORAK keyboard, but not right away).
  - Inconvenience of two standards temporarily coexisting (e.g., gas stations offered both leaded and unleaded fuel for 20 years to accommodate old and new cars).
  - Risk: What if I adopt and others do not?
- Early adopters: less averse to risking a new standard. Put up with the inconveniences for the thrill of the bleeding edge. (Closets filled with Betamaxes and Apple 'Lisas'; speak Esperanto.)

- Network externalities particularly relevant to information technology markets because:

    1. "Wetware" is one of the largest costs of using a new technology. Irreversible investment. Limited attention and learning capacity.
    2. Commercial/social networks critically important for intercommunication, support, complementary products development (e.g., software, hardware).
    3. Production costs are declining over an almost infinite range. So "consumption side" scale economies augmented by "production side" scale economies.

- Do companies consider networks when introducing products?

    - Acrobat Reader and Acrobat Writer.
    - Loss leaders like eBook reader.
    - TiVo – Large fixed cost to develop and maintain, small marginal cost to produce the boxes. Must attract critical mass of buyers or the system will crumble.
    - Microsoft: brilliant at supporting anyone who develops software for Microsoft products.

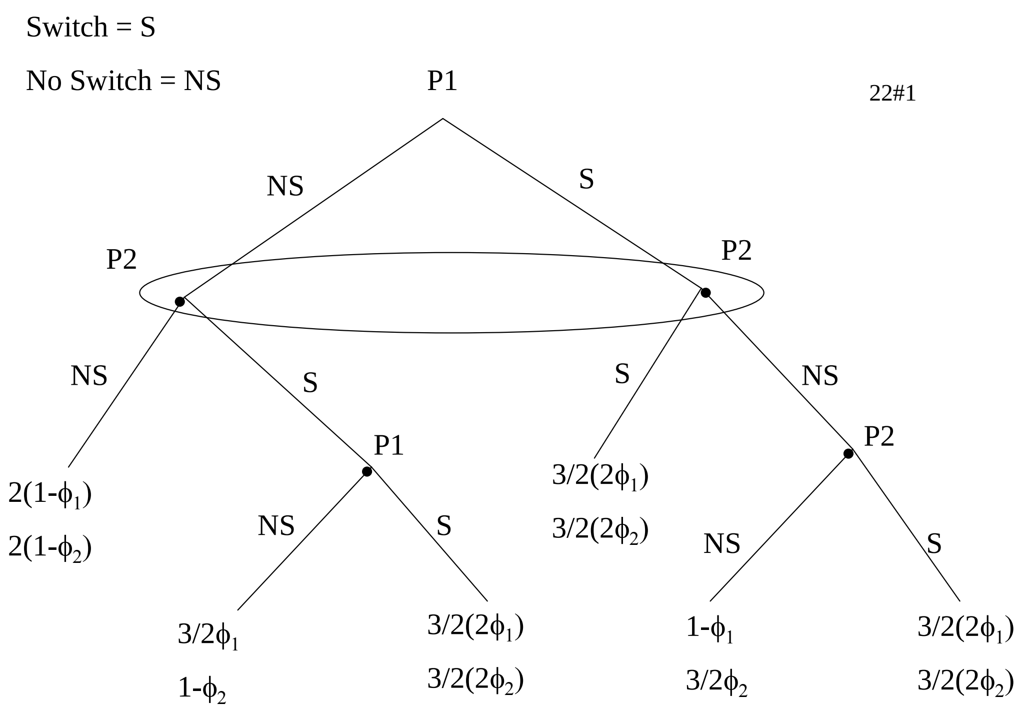
- Do consumers consider network externalities in purchase or learning decisions?

    - Don't want to buy technological orphans, such as incompatible music players, Commodore Amigas, etc.
    - Don't buy a Peugeot.
    - Are you waiting to buy a digital camera? An electric car?
    - Not much use for Swahili in Cambridge.
    - GSM cell phone technology: superior to Sprint, AT&T, Verizon. Many people won't use it until the physical GSM network is available in most cities. And that won't happen until more people are using it. So late adopters free-ride on the early adopters.

- All of these factors suggest that network externalities could be especially important in an information age economy.

## 1.1 A simple game theory model

Consider the simple technology choice model by Jean Tirole. This 2-player game captures a surprising amount of the richness of the conundrum posed by network externalities.




- Two players are currently using the status quo technology, $A$.
- Each can make an irreversible decision to switch to the new technology, $B$, which is better on average.
- However, the benefits to switching to $B$ are greater if both players switch.
- Each player is uncertain about the other's preferences for the two technologies.
- Each player knows his own taste $\phi_i$ and knows that the other player's taste is uniform on $[0, 1]$.
- The payoffs to each technology are a function of $\phi$, the preference parameter and $n$, the number of users.

$$\begin{aligned} V_A(\phi, n) &= (1-\phi)n_A, \\ V_B(\phi, n) &= \frac{3}{2}\phi n_B. \end{aligned}$$

- The timing of the game is as follows:
  1. In the first period, players decide simultaneously whether or not to switch to $B$.

2. If they both stay on $A$ or both switch to $B$, the game ends (payoffs as above).
3. Otherwise, the player who did not switch in the first period gets another chance to switch.

- Each player has three possible strategies:

1. Never switch
2. Wait to the 2nd period and switch if the other players switches first
3. Switch right away

- What is the equilibrium of this model?
- Use backward induction.

1. Start at 2nd period and calculate the payoffs if this period occurs.
2. Go back to 1st period and calculate optimal choices given payoffs in period 2.
3. Bear in mind that this is a symmetric game, so ultimately players will follow identical decision rules. (This does not mean they will take the same action since it will not normally be the case that $\phi_1 = \phi_2$.)

### 1.1.1 Starting in 2nd period

- This period only occurs if one player has switched but not the other. So assume player 1 has switched and not player 2. What will player 2 do?

$$\begin{aligned} V_B^2 &= \frac{3}{2} \cdot \phi_2 \cdot 2, \\ V_A^2 &= (1 - \phi_2) \end{aligned}$$

- Hence, player 2 switches if

$$\begin{aligned} 1.5 \cdot \phi_2 \cdot 2 &> (1 - \phi_2), \\ 4\phi_2 &> 1 \\ \phi_2 &> \frac{1}{4}. \end{aligned}$$

- What is the probability that player 2 will switch if player 1 switches first? Given uniform distribution of $\phi_B$, this probability is $\Pr\left(\phi_2 > \frac{1}{4}\right) = \frac{3}{4}$.
- So, for player 1, the expected value of switching in 1 is:

$$\begin{aligned} E(V|\text{Switch in 1}) &= \frac{3}{4} \cdot \frac{3}{2} \cdot \phi_1 \cdot 2 + \frac{1}{4} \cdot \frac{3}{2} \cdot \phi_1 \\ &= \frac{9}{4}\phi_1 + \frac{3}{8}\phi_1 \\ &= \frac{21}{8}\phi_1 \end{aligned}$$

### 1.1.2 Working backward

- The advantage to switching first is that you may cause the other player to switch to your preferred standard, though she would not do this on her own. The disadvantage is that you might switch and regret it.
- What are the benefits of not switching in period 1? Get the benefit of observing the other player's action. Can make your best choice based on their choice. But the other player is making the same calculations. Could easily result in both players waiting to see what the other does.
- Clearly, it must be the case that for $\phi_i$ sufficiently high, a person would always want to switch. (For example, for $\phi_i = 1$, technology $B$ dominates regardless of what the other player does.)
- We can look for this critical $\phi^*$ using the fact that this is a symmetric game, so both players will have the same cutoff value.
- So the equilibrium strategy will have to look something like:

  1. If $\phi_i > \phi^*$, switch in period 1.
  2. As we have already established: if $\frac{1}{4} < \phi_i \leq \phi^*$, don't switch in period 1 but switch in period 2 if the other player has switched.
  3. If $\phi_i \leq \frac{1}{4}$, never switch.

- What's $\phi^*$?
- Given the uniform distribution, the probability that the other player does not switch in period 1 must be equal to $\phi^*$, and the probability that she does switch in period 1 must be equal to $1 - \phi^*$.
- Note that for a player with $\phi_i = \phi^*$, this player will switch in period 2 if she has not done so in period 1 and the other player has switched. So, $\phi_i = \phi^*$ always yields a coordinated equilibrium.
- So now we can write the main equilibrium condition as:

$$\begin{aligned}
V_i(\text{Switch in } 1|\phi_i &= \phi^*) = V_i(\text{Wait}|\phi_i = \phi^*), \\
\frac{21}{8}\phi^* &= \phi^*(1-\phi^*) \cdot 2 + (1-\phi^*) \cdot \frac{3}{2} \cdot \phi^* \cdot 2, \\
\frac{21}{8} &= (1-\phi^*) \cdot 2 + (1-\phi^*)\frac{3}{2} \cdot 2, \\
\phi^* &= \frac{19}{40}.
\end{aligned}$$

- So the strategy of each player will be:

  1. Switch in 1 if $\phi_i > \frac{19}{40}$

2. Switch if 2 if player 1 switches and $\frac{1}{4} < \phi_i \leq \frac{19}{40}$ player has switched.
3. Never switch if $\phi_i \leq \frac{1}{4}$

| | | Player 2 | | |
|---|---|---|---|---|
| | | $0 - \frac{1}{4}$ | $\frac{1}{4} - \frac{19}{40}$ | $\frac{19}{40} - 1$ |
| | $0 - \frac{1}{4}$ | $A, A$ | $A, A$ | $A, B$ |
| Player 1 | $\frac{1}{4} - \frac{19}{40}$ | $A, A$ | $A, A$ | $B, B$ |
| | $\frac{19}{40} - 1$ | $B, A$ | $B, B$ | $B, B$ |

- Are we done? Not quite. We now want to analyze the efficiency properties of this model. There are two sources of inefficiency:

  1. Missed chances to coordinate on $B$ when both would have been better off. When does this occur?

  $$\frac{3}{2} \cdot 2 \cdot \phi > 2(1 - \phi),$$
  $$\phi > \frac{2}{5} = \frac{16}{40}.$$

  So for $\phi_1, \phi_2 \in \left[\frac{16}{40}, \frac{19}{40}\right]$, there were missed chances to coordinate. "Excess inertia."

  2. One person switches to $B$ and then regrets it because the other does not switch. When does this occur?

  $$\frac{3}{2}\phi_i \cdot 1 < 2(1 - \phi_i),$$
  $$\phi_i < \frac{4}{7}.$$

  So, for $\phi \in \left[\frac{19}{40}, \frac{4}{7}\right] = \left[\frac{133}{280}, \frac{160}{280}\right]$, a player will regret switching if the other player does not either switch simultaneously or switch in the second period (which will happen $\frac{1}{4}$ of the time). This case is "Excess momentum."

- So to summarize, this deceptively simple model captures 4 possible outcomes of a network externality problem:

  1. Optimal coordination on the old technology: both players have $\phi_1, \phi_2 < \frac{16}{40}$ or for 1 player $\phi_i < \frac{1}{4}$ and for the 2nd player, $\phi_i < \frac{4}{7}$).
  2. Optimal coordination on the new technology: both players have $\phi_1 > \frac{1}{4}$ and one player has $\phi_i > \frac{19}{40}$ ).
  3. Excess inertia. $\phi_1, \phi_2 \in \left[\frac{16}{40}, \frac{19}{40}\right]$ .
  4. Excess momentum. One player has $\phi_i \in \left[\frac{19}{40}, \frac{4}{7}\right]$ and the other has $\phi_i < \frac{1}{4}$.

## 1.2 Conclusions

- Increasing returns on the demand side (network externalities) generate:
  - Path dependence
  - Sub-optimal outcomes ex post
  - Excess inertia *and* excess momentum
- Policy responses
  - This line of argument makes it clear that standards are a public good
  - Generally no simple solution since "optimal choices" depend on unknown variables: Future technologies; distribution of preferences
- Standards body: Suggest public policy responses to coordinate society on best standards:
  - Internet standards
  - Daylight savings time
  - SAE versus Metric
  - Mobile phones (a failure of coordination)
- Governments may have difficulty choosing standards because economics provides little guidance. Tells us what goes wrong (positive economics) but does not tell us how to fix it (normative economics).
- Also suggests there will be vigorous competition in marketplace to set and control standards.
- Example: 1887- 1892 Battle between Edison and Westinghouse over standards for power (Edison: Direct Current, Westinghouse: Alternating Current). Both had advantages: DC was more efficient to generate; AC could be transmitted over longer ranges. Edison's response: invent the AC electric chair, and persuade the State of New York to execute condemned criminals "by administration of an alternating current," naming the process of electrocution "Westinghousing."
- Race to create standards and lock-in users. Get there first, get the bandwagon rolling.
- Try to make products sufficiently superior and easy/low cost to switch that they upset the bandwagon. Backward compatibility is key.
- Lock in an advantage by deliberately being incompatible: Windows Media Player, Microsoft extensions to Java, EBCIDIC versus ASCII.