DYNAMIC COMPETITION IN THE INDUSTRY WITH RAPID TECHNOLOGICAL CHANGE AND HIGH NETWORK EXTERNALITY

Kyungbae Park • Bowon Kim

KAIST Graduate School of Management, Seoul 130-012, Korea

ABSTRACT

High-tech, such as computer and telecommunications, industries are characterized with the rapid technological innovation and intensive network externality. These industries have shown competitive aspects that are more complex and systemic than those in traditional industries. In order to analyze such industries more properly, we utilize system dynamics simulation approaches. Based on the simulation, we first develop a generic model of competition in the high-tech industry and then a more specific model for the telecommunications industry. Numerical examples and managerial implications are suggested.

KEYWORDS

System Dynamics, Network Externality, High-Tech Industry, Dynamic Competition, Telecommunications

1. Introduction

Fast technology innovation and strong network externality in high-tech industries, like computers, telecommunications and internets, brought new competitive aspects into the business world. Such competitive aspects are very different from those in traditional industries and require new ways of analysis. Many of traditional competitive analyses and strategies are mainly focused on static aspects of competition and impacts of a single or a few variables only, and have many constraints in investigating and analyzing dynamic and complex aspects of high-tech industry competition wholly.

This research is mainly focused on grasping dynamic aspects of competition in high-tech industry through method of system dynamics. System dynamics have used usefully in many areas of management and industrial engineering because of its flexibility of model construction and wideness of applicable area. Recently it has shown great usefulness in learning organization theory (Senge 1990; Wolstenholme 1990).

General model of competition in high-tech industry and the specific model focused on telecommunications industry will be presented. Simulation and analysis through these models present valuable implications on the competitive dynamics of high-tech industry.

2. Literature Review

Competitive aspects of high-tech industries characterized with rapid technological innovation and intensive network externality have been studied in both areas of economics and management. In this chapter, we review streams of existing studies and draw important competitive factors considered in existing studies.

2-1. Studies in Economics

Studies in economics were popular especially in the mid of 1980s and early 1990s. These studies are mainly focused on network externality and solved problem through mathematical approaches like game theory or optimal control theory. These studies deal with competitive strategies like pricing, new product introduction, R&D strategy, and licensing (Katz and Shapiro 1985, 1986, 1992, 1994; Farrel and Saloner 1985, 1986, 1988, 1992; Church and Gandal 1992, 1993; David 1985).

Following competitive factors are frequently referred as important ones in these studies.

First, existence and strength of network externality. It is very natural for industries of high network externality to show different competitive aspects compared to industries of low network externality (Katz and Shapiro 1985, 1992, 1994; Church and Gandal 1992, 1993; David 1985; Kristiansen 1998).

Second, compatibility and standardization. These factors are considered major influencing factors to the competition in most of studies (Katz and Shapiro 1985, 1986, 1994; Farrel and Saloner 1985, 1986, 1988, 1992; David 1985; Kristiansen 1998).

Third, installed base – number of user – is also considered as one of major factors of the competition in many studies (Farrel and Saloner 1986, 1992; David 1985).

Forth, existence of competition. Strategies and results are very much different when direct competitors exist (David and Steinmuller 1994; Katz and Shapiro 1985; 1994).

In addition, factors like timing of entry and superiority of new product to old ones are considered important (Kristiansen 1998; Farrel and Saloner 1986).

Until now, many related studies have been done in economics and much concrete theoretical progress and useful practical implications have been made. But because of characteristics of economic method, economic studies have some limitation in having considered only one or two main factors in their mathematical model.

2-2. Studies in Management

Studies in management that focused on network externality are insufficient in both numbers and depth compared to those of economics. But theories like diffusion theory and dominant design are related and considered important research theme in marketing and technology strategy (Bass 1980; Norton and Bass 1992; Utterback and Abernathy 1975; Anderson and Tushman 1990; Herbig and Cramer 1993).

Diffusion theory has been used as a useful tool for analysis of competition, especially for demand estimation, in marketing and management. But, it has some constraints, because basically it considers only number of adopters and remained non-adopters as influencing factors. This makes it very difficult to include influence of other variables. Dominant design theory gives much insight how different designs compete and how competitive aspects change through emergence of dominant design. But it has limitation because it contains no mathematical process to be tested and used for real business estimation.

3. Model for Competition between Systems

3-1. Basic Model

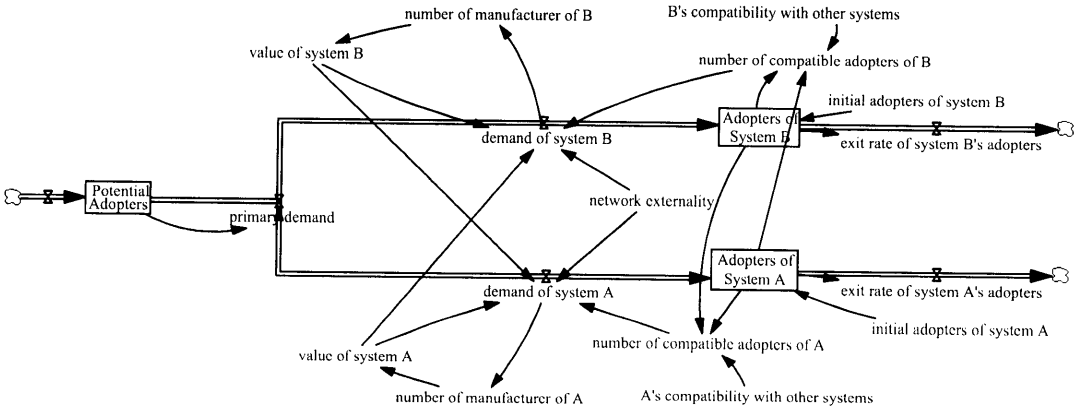
Basic model includes most of competitive factors presented above. It shows the situation in which two different system providers compete to get its own user from constrained number of potential user pool. In each period,

some of adopters of each system go back to potential user.

Major competitive factors included are like following: number of potential adopters, number of adopters of each system, number of initial adopters of each system, the strength of network externality, value of each system (value = performance/price), number of manufacturer which sells each system and depth of compatibility of each system with other one.

The concrete system dynamics model is Figure 1.

Figure 1. Basic Model



In each period, part of potential adopters become primary demand to entire industry, and the number of total adopters of each period (primary demand) is determined by diffusion model according to the total number of adopters and number of remained potential adopters. Exit users of each system go back to potential adopter.

Primary Demand = p(N-n) + q(N-n)n + demand for substitution

p : coefficient of innovation; q : coefficient of imitation; n : total number of adopter

N : initial number of potential adopter ; N-n = number of potential adopter

After primary demand determined by diffusion model, demand for each competing system is determined by attraction model, that is one of market share models. Attraction of each system is determined by number of compatible adopters of each system and value (performance/price) of each one. Attraction is influenced more by number of adopters when strength of network externality is greater. Compatibility of each system influences the number of compatible adopters of each one.

Number of manufacturer of each system is determined by demand for each system and minimum efficient

scale and it increases according to demand increases. As each system gets more manufacturers, there are more R&D and competition for the system. It causes the value (performance/price) of the system goes up, and it attracts more demand to the system. Finally, there is a strong reinforcing loop among demand of each system, value, and number of manufacturer of the system.

In entire model, because primary demand increases according to increase of total number of adopters, there is one more reinforcing loop also.

These two reinforcing loop and the fact that attraction of each system goes up when number of adopters of the system increases properly models the effect of network externality.

3-2. Simulation Result

We simulated the base model first, and then performed sensitivity analysis. Sensitivity analysis was performed by altering the value of each major variable. Finally, we got implications by comparing the results of base model and those of each sensitivity analysis model.

The major variables we altered are the strength of network externality, number of initial adopters of each system and compatibility.

Results from Base Simulation

A. The number of adopters of each system shows S-shaped growth, and after peak, it declines. Finally, it remains stable at some level when demand equals to exit rate of the system.

B. The system with more compatibility finally wins the competition.

C. Demand of loser declines first, and then demand of winner declines also. It is because of market saturation.

Results from Sensitivity Simulation

A. When network externality is strong, compatibility has greater influence than the number of initial adopters.

B. When other conditions are equal, just a little difference in compatibility brings much difference in long-term demand and determines the competition.

C. The stronger network externality, the less maximum level of number of adopters of loser is.

D. The stronger network externality, the timing of declining in loser's demand comes faster.

4. Model for Mobile Phone Market.

Based on above basic model, we apply it to cellular phone market. To analyze financial status, financial module is added to the model.

4-1. Model Construction

The model includes two groups of variables, Decision variables and environmental variables.

Decision variables are those company can choose. Decision variables consist of five groups of variables: price variables, investment variables, financial variables, marketing variables and strategic variables.

A. Price variables: unit usage fee, access fee

B. Investment variables: investment to connection base, subsidy per customer

C. Financial variables: external financing, equity

D. Marketing variables: Ad & promotion expenses

E. Strategic variables: priority of investment (subsidy, connection base), priority of financing method (debt, equity)

Company can not choose environment, but environment influences the company and the competition. In this model, environmental variables are composed of three parts.

A. Macroeconomic variables: population, GNP, market potential

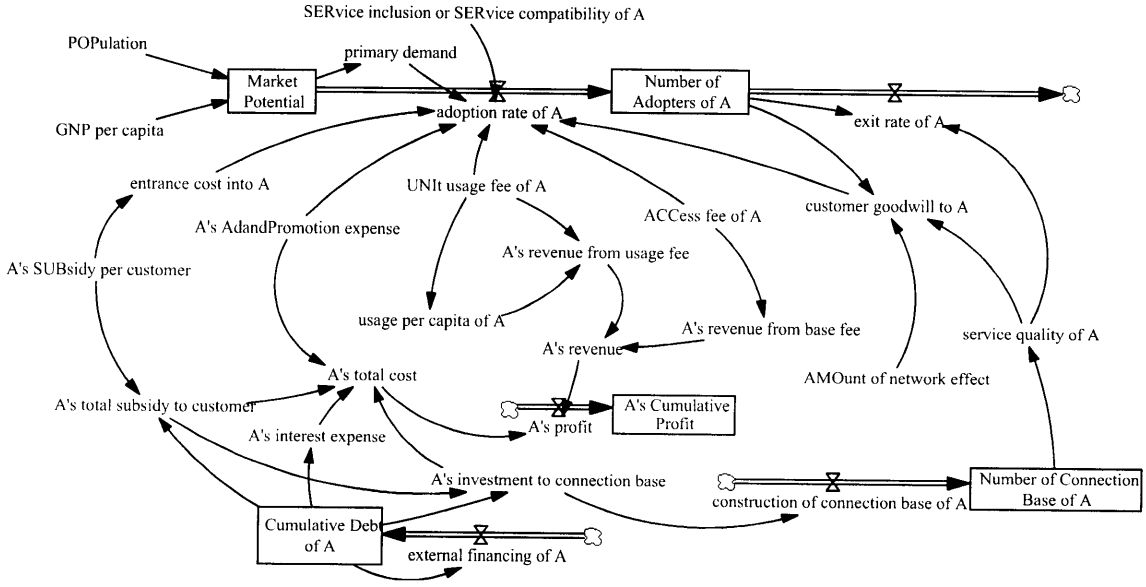
B. Market characteristic: parameters in adoption rate and exit rate, portion of the never-come-back

C. Industry characteristic: amount of network effect, service inclusion or service compatibility, price of handset,

price of connection base

Concrete system dynamics model for mobile phone market is Figure 2.

Figure 2. System dynamics model for mobile phone market



4-2. Simulation Results

Simulation is performed in both of monopoly situation and two competing company situation. In each of situation, base model and sensitive model was performed and compared. Results are as followings.

A. Small difference in exit rate brings big difference in long-term performance. The company with lower exit rate, i.e., higher loyalty, wins the competition.

B. Penetration pricing is superior: low access fee and low unit usage fee wins the competition.

C. Dynamic pricing: initial lower price over competitor is more important than the later one.

D. Initial Equity is very crucial for competition. It allows more debt, faster improvement of service quality, more subsidy and faster establishment of installed base.

E. Investment to service quality (connection base) is more superior to subsidy and gives more basic and long-term performance.

F. Although everything is equal, just a random demand difference brings significant difference in long-term performance. It is because of network externality.

5. Conclusions and Implications

The competitive dynamics of high-tech industries with high network externality is very different from that of traditional ones. In these industries, dynamic aspects are very important and many factors influence the competition. We applied system dynamics method to analyze the competitive dynamics of such industries.

We were able to derive several implications from basic model and simulation results. The number of adopters shows S-shaped growth and declines, but there is a stable level. Compatibility is most important factor of competition.

Applying the model to mobile phone market also gives us useful implications.

To keep the service quality, hence to keep the user loyalty is crucial. Penetration pricing is superior and it is better when it is earlier. Initial equity and financing ability are important. Just a random and eventual demand fluctuation can be important to the competition

Although our research gives many useful implications and shows great usefulness of system dynamics for analysis of high-tech industries, there are several further works to be done.

First, if the simulation results can be fitted to real data, it will add more reliability to the model.

Second, other industries other than telecommunications, like internet business, can be used to expand basic model. By comparing results from different industries, we would get more valuable implications and insights.

REFERENCES

1. Anderson, Philps and Michael L. Tushman (1990), "Technologicla Discontiuities and Dominant Designs : A Cyclical Model of Technological Change", *Administrative Science Quarterly*, Vol. 35
2. Bass, Frank M. (1980), " The Relationship between Diffusion Rates, Experience Curves, and Demand Elasticities for Consumer Durable Technological Innovations", *Journal of Business*, Vol.53, No. 3
3. Church, Jeffrey and Neil Gandal (1992), "Network Effects, Software Provision, and Standardization", *Journal of Industrial Economics*, Vol. 40, No.1
4. Church, Jeffrey and Neil Gandal (1993), "Complementary network externalities and technological adoption", *International Journal of Industrial Organization*, Vol. 11, No.2
5. David, Paul A. (1985), "Clio and the Economics of QWERTY", *American Economic Review*, Vol. 75, No.2
6. David, Paul A. and Wedward Steinmueller (1994), "Economics of compatibility standards and competition in telecommunication networks", *Information Economics and Policy*, Vol. 6, No.3-4
7. Farrel, Joseph and Garth Saloner (1985), "Standardization, Compatibility, and Innovation", *Rand Journal of Economics*, Vol. 16, No. 1
8. Farrel, Joseph and Garth Saloner (1986), "Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation", *American Economic Review*, Vol. 76, No. 5
9. Farrel, Joseph and Garth Saloner (1988), "Coordination through committees and markets", *Rand Journal of Economics*, Vol. 76, No. 5
10. Farrel, Joseph and Garth Saloner (1992), "Converters, Compatibility, and the Control of Interfaces", Journal of Industrial Economics, Vol. 40, No. 1
11. Herbig, Paul A. and Hugh Kramer (1993), "Innovation Inertia: the Power of the Installed Base", *Journal of Business & Industrial Marketing*, Vol.8, No. 8
12. Katz, Michael L. and Carl Shapiro (1985), "Network Externalities, Competition, and Compatibility", *American Review*, Vol. 75, No. 3
13. Katz, Michael L. and Carl Shapiro (1986), "Product Compatibility Choice in a Market with Technological Progress", *Oxford Economic Papers*, Vol. 38, November
14. Katz, Michael L. and Carl Shapiro (1992), "Product Introduction with Network Externalities", *Journal of Industrial Economics*, Vol. 40, No. 1
15. Katz, Michael L. and Carl Shapiro (1994), "System Competition and Network Effects", *Journal of Economic Perspectives*, Vol. 8, No. 2
16. Kristiansen, Erik Gaard (1998), "R&D in the presence of network externalities: timing and compatibility", *Rand Journal of Economics*, Vol.29, No. 3
17. Norton, John A. and Frank M. Bass (1992), "Evolution of Technological Generations: The Law of Capture", *Sloan Management Review*, Winter
18. Senge, M. Peter (1990), *The Fifth Discipline: The Art and Practice of the Learning Organization*, Currency

and Doubleday, New York

19. Wolstenholme, F. Eric (1990), System Enquiry: A System Dynamics Approach, John Wiley & Sons, West Sussex, England

20. Utterbak, James M. and Willam J. Abernathy (1975), "A Dynamic model of Process and Product Innovation", Omega, Vol.3, No.6

APPENDIX

: An example of simulation result for telecommunications market model

(unit usage fee of A = 110, unit usage fee of B=120, every other factor is same among 2 players)