Dynamics of Networks:
System Dynamics Model for Network Externality and Critical Mass

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Information age comes with networks: broadband networks of telecommunication and cable TV, networks of hardware and software, networks of electronic money services, networks of Internet web sites. Recently, some economists have developed a systematic approach to analyze the characteristics of networks. They introduced the concept of network externality and critical mass as building blocks for explaining the positive loop characteristics of networks (Katz & Shapiro 1985; Economides 1995).

However, their economic model is far from complete and dynamic. Paradoxically enough, the economic model of networks is based on the concept of equilibriums which oppress dynamic behavior of network evolution. In this paper, we developed a system dynamics model for investigating dynamic behavior of network growth and decay. While the economic model of networks focuses on the equilibrium state of networks, the SD model of networks focuses on the historical path toward the evolution of networks.

1. Network externality and the dilemma of telecommunication policy

Network externality can be defined by the existence of positive relationship between the value of product and the size of consumers using the same product. Most of the products in the info-telecommunications industry exhibit network externality. As the number of fax users increases, the value of fax machines to the consumers increases. For system dynamists, network externality can be interpreted as a single positive feedback loop as shown in figure 1.

Figure 1. Network externality as single positive feedback loop

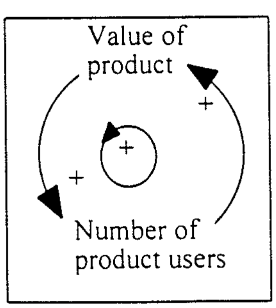


Figure 2. Fundamental dilemma of policy maker in telecommunication industry

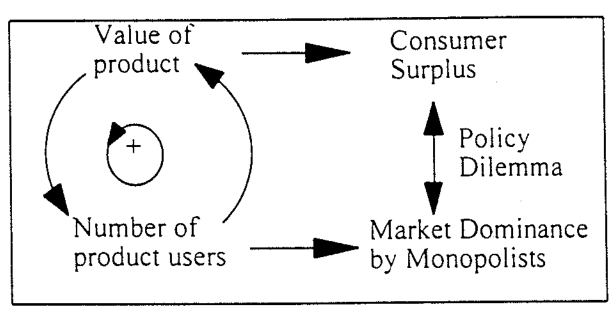
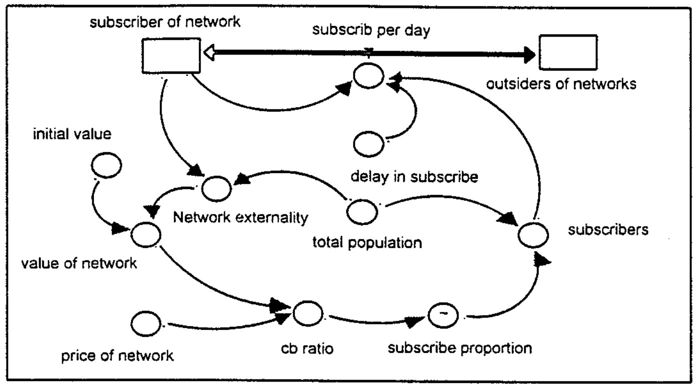


Figure 2 shows that policy makers in the info-telecommunications industry have the fundamental dilemma between maximizing consumer surplus and minimizing market dominance by monopolists. As the priority of policy goals changes, telecommunications policy alternates between separation and integration of telecommunication carriers.

Our goal of building a system dynamics model for network externality is to investigate under what conditions network externality works to the growth of networks and brings the market dominance of monopolists. Figure 3 is our basic model of network externality.

Figure 3. STELLA diagram of network externality



2. Critical mass in the evolution of networks

With the basic model of network externality, we can experiment the conditions under which network externality works to promote the growth of networks. On the process of analyzing the behavior of networks, we found that the concept of critical mass should be re-interpreted as "a threshold demand for the existence of networks." The demand for networks depends on the number of network subscribers and the price of network subscription. Therefore, the concept of critical mass includes the critical number of subscribers and the critical price of networks at the initial stage.

Simulation results of our basic model show that the critical mass can be exploited by policy makers. This result justifies the importance of governmental initiatives in expanding the number of network subscribers and the regulation of telecommunications tariff at the initial stage.

In addition to the basic model of network externality and critical mass, a heuristic rule for finding the boundary of the critical mass is developed into the model. One can find out the critical number of subscribers and the critical price of networks by increasing one of them incrementally until the network start to grow by itself.

3. Critical mass in the path-dependent evolution of networks

Path-dependent evolution of networks says that an inferior product with network externality will defeat a product which has better quality and lower price but has no network externality (Arthur 1990). Previous studies on the evolution of networks paid little attention to the conditions of path-dependent evolution of networks. Do all kinds of network externality produce path-dependancy? For investigating the condition of path-dependancy, we developed our second model that depicts competitive dynamics between pair of networks.

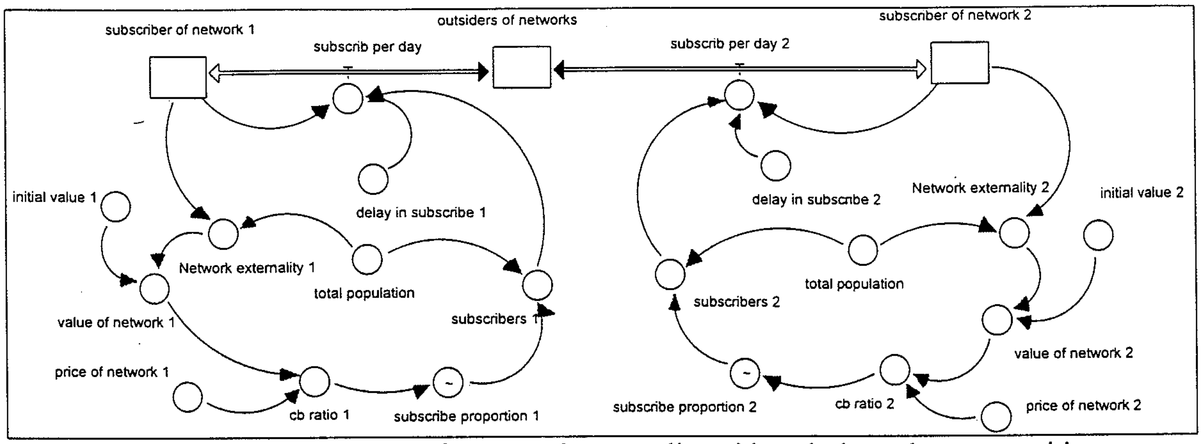
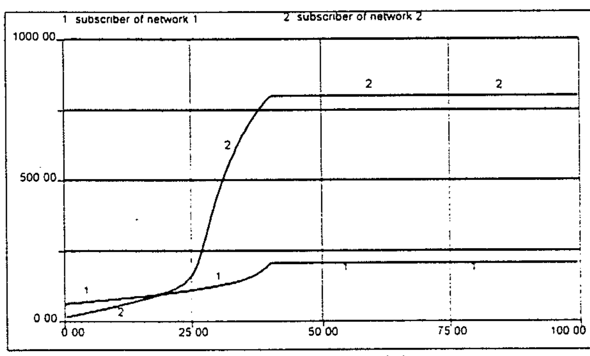


Figure 4. STELLA diagram for network externality with path-dependant competition

In figure 4, subscription price of network 1 is set as 3.3 and subscription price of network 2 as 3.1. However, the number of initial subscribers in the first network is set as 50 and that of the second network is set as 10 in the first experiment. And they are set as 100 and 10, respectively, in the second experiment. Figure 5 and figure 6 shows our simulation results.



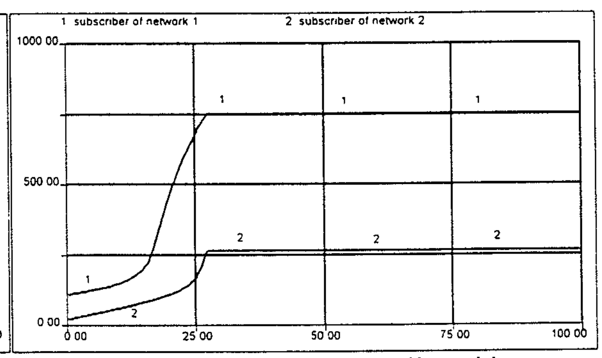


Figure 5. Network externality with no path-dependent evolution (Initial number of subscriber in network 1 = 50)

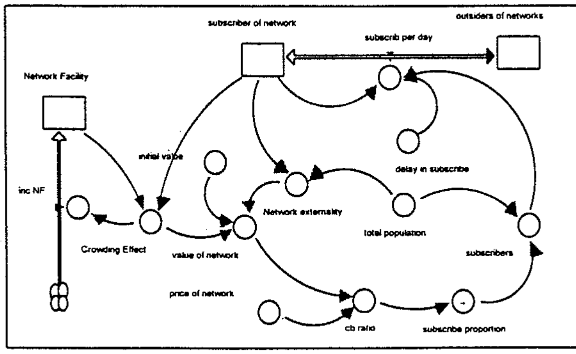
Figure 6. Network externality with path-dependent evolution (Initial number of subscriber in network 1 = 100)

Note that in the first experiment the system displayed network externality but not path-dependancy. With the increase of initial number of subscriber in network 1 to 100, it showed path-dependent behavior. That is, in spite of higher price for subscribtion, network 1 dominates the network market and defeats the second network.

From these results, we can conclude that the critical mass for the path-dependent evolution is higher than the critical mass for the simple growth of networks. Even if there exists network externality in the market, the path-dependancy phenomena will not appear unless the number of subscribers at the initial stage exceeds the critical mass for the path-dependancy.

4. Crowding effects for competitive evolution of networks

Does path-dependent evolution with network externality dictate that governmental measures must guard against the birth of inferior monopolists? As the multimedia use of networks increases, network externality becomes counter balanced by the crowding effects (Kim & Ha 1996).



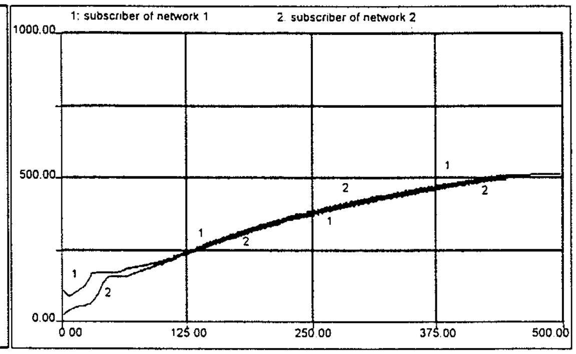


Figure 7. Part of STELLA diagram of Network externality with erowding effects

Figure 8. Increase of competition with crowding effects

As the number of subscribers increases, the magnitude of crowding effects begins to exceed that of network externality. That is, a dominant feedback loop shifts from the positive loop of network externality to the negative loop of crowding effects (Figure 7).

We simulated the competitive evolution of networks with interactions of network externality and crowding effects. Figure 8 shows that crowding effects will produce a higher level of competition in the market. Even if network externality is strong, the introduction of crowding effects will keep the information market from shifting into the path-dependent evolution of inferior monopolists.

5. Future research

Dynamic games on the interconnected networks are very complicated areas for public policy makers as well as business strategy makers. We plan to expand our model to incorporate many more economic and social issues, such as oligopolistic network games, interconnectivity among networks, and chaotic evolution of networks.

[Reference]

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