

Network Effects

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INTRODUCTION

From the 1980s, *network effects* attracted a lot of interest in economics and management sciences. This was mainly due to the work of Arthur (e.g., 1988, 1989, 1990). While the subject of increasing returns to scale in companies had a long tradition in economics, network effects (i.e., increasing returns in markets) had hardly been addressed.

In economics, it is typically assumed that the behavior of economic agents is not directly influenced by the behavior of others. Of course, in economic terms the agents do influence each other, but always indirectly, namely through the price mechanism in the market. With network effects, there is *direct economic interaction* between economic agents.¹

While relatively new to economics, mechanisms of direct interaction between agents had been studied for a long time in sociology. It had been known under the label theory of collective action (e.g., Granovetter, 1978; Marwell, Oliver, & Prahl, 1988; Oliver, Marwell, & Teixeira, 1985), bandwagon effects (Granovetter & Soong, 1986), information cascades (e.g., Bikhchandani, Hirschleifer, & Welch, 1992), or network analysis (e.g., Burt, 1987, 1992). Gradually this work has penetrated into economics and into the management sciences (e.g., through Granovetter, 1985; Gulati, 1995, 1998; Westphal, Gulati, & Shortell, 1997).

The phenomenon of network effects has therefore attracted a lot of attention in recent years, both in economics and in management science (e.g., Arthur, 1989; Farrell & Saloner, 1985, 1986, 1992; Katz & Shapiro, 1985, 1986, 1994; Liebowitz & Margolis, 1994, 1999; Rosenberg, 1982; Shapiro & Varian, 1998, 1999). Network effects are sometimes also referred to as network externalities, increasing returns to adoption, or demand-side increasing returns (to scale).² Here, we use the term network effects.

BACKGROUND

Network effects occur when the economic utility of using a product or technology becomes larger as its network grows in size (Farrell et al., 1985; Katz et al., 1985). Network size is determined by the number of suppliers and users of products based on a common technological standard. Two different types of technological networks can be distinguished (Liebowitz et al., 1994; Katz et al., 1994): (1) literal networks, in which participants are literally, physically connected to each other (e.g., the telephone network, the cable television network) and (2) metaphorical or virtual networks, in which there are no physical connections (e.g., the network of Apple computers users or the network of Ford motorcar owners).

Network size appears to be very important in modern information and knowledge intensive markets, such as the markets for software programs, cellular phones, and Internet applications. More classical examples of products where network effects played an important part are the telegraph, telex, and telephone. The fax machine also belongs to this category. To cite Kelly (1997, p. 142): "Consider the first modern fax machine that rolled off the conveyor belt around 1965. Despite millions of dollars spent on its R&D, it was worth nothing. Zero. The second fax machine to roll off immediately made the first one worth something. There was someone to fax to. Because fax machines are linked into a network, each additional fax machine sliding down the chute increases the value of all the fax machines operating before it."

MAIN FOCUS OF THE ARTICLE

When the economic utility of a product or technology increases as more customers start using it, this is referred to as *direct network effects* (Farrell et al., 1985; Katz et al., 1985). Because the standardized product

provides access to the larger network for all customers, both existing and new ones, utility for every customer rises as the network grows in size.

For example, consider a utility function in which the utility (U) of a product to a user (i) is dependent on the number of other users of this product:

$$U_i = a + b \times (\text{number of other users}) \quad (b > 0)$$

Here, a is the constant term (i.e., the fraction of the utility of the product that is *not* dependent on the number of other users), and b is the coefficient (i.e., the fraction of the utility of the product that is dependent on the number of other users).

The utility of the first user is:

$$U_1 = a + b \times (0 \text{ other users})$$

The utility of the second user is:

$$U_2 = a + b \times (1 \text{ other user})$$

Or, in general:

$$U_i = a + b \times (i-1)$$

Now, because of the network effect, the total utility after two adopters is not $U_1 + U_2$, but rather $2 \times U_2$.

Therefore:

$$U_{\text{total}} = i \times (a + b \times (i-1)) = ai + bi^2 - bi$$

Here, the i^2 term represents the positive feedback effect. As the utility of every customer in the network continues to rise, it becomes more attractive for prospective customers to join this network. This means that the network grows in size, thereby further increasing the utility for every customer. Therefore, network effects may easily cause positive feedback in the market.

The same mechanism makes it unattractive for customers to leave the network. Apart from financial investments made in the product or the technology and apart from the investments made in learning to use the product or technology, a move to a newer, smaller network would simply mean a reduction of the network benefits.

It can even be shown that customers who have a negative autonomous valuation of the product, in the

previous example that would mean that $a < 0$, or who have a higher autonomous valuation of a competing product, may eventually be persuaded to buy into the network, simply because the network benefits outweigh the negative autonomous valuation (Arthur, 1989). For example, many people complain about the quality of *Microsoft* software, justly or unjustly. Some people even have a negative autonomous valuation of it and would probably be inclined not to buy it if the decision depended purely on their own judgment. However, as the network around *Microsoft* software is very large, the network benefits are also huge, and often easily outweigh any negative autonomous valuation.

Indirect Network Effects

Network effects are also present when products are used in combination with complementary products based on the same technological standard. The increase in a product's economic utility as more customers start using complementary products or as more suppliers start offering complementary products, is referred to as *indirect or market-mediated network effects* (Farrell et al., 1985; Katz et al., 1985).³ Sometimes it is called the *hardware-software paradigm* (Katz et al., 1985), after the markets where the most typical examples of indirect network effects can be found. The market for computer hardware and the software for it or the market for DVD players and the DVD movies available for them (cf., Katz et al., 1994) provide good examples.

With a growing number of customers who have bought hardware, it becomes more attractive for other customers to do the same (i.e., direct network effects). As the market extends, it therefore becomes more attractive for suppliers to start selling complementary products such as software and peripheral equipment (i.e., indirect network effects) and because they extend the original hardware's functionality, it becomes more appealing for potential customers to buy these complementary products, which in turn increases the demand for the original hardware. Assuming positive network effects, no matter where we step in to this line of reasoning, we always end up with the positive feedback loop of extending markets for hardware and software. This is a reason why, in the market for personal computers, a very large and dominant network emerged around *Microsoft* and *Intel* products, which became known as the "*Wintel*" standard.

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