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Conference Paper

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28th European Regional Conference of the International Telecommunications Society (ITS):
"Competition and Regulation in the Information Age", Passau, Germany, 30th July - 2nd
August, 2017

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Mitomo, Hitoshi (2017) : Data Network Effects: Implications for Data Business,
28th European Regional Conference of the International Telecommunications Society (ITS):
"Competition and Regulation in the Information Age", Passau, Germany, 30th July - 2nd August,
2017, International Telecommunications Society (ITS), Calgary

This Version is available at:

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Data Network Effects: Implications for Data Business

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Abstract:

This paper aims to investigate the existence of “data network effects” in data platform services such as Big Data, Internet-of-Things (IoT) and Artificial Intelligence (AI) and their influence on the diffusion of the services. It intends to present a preliminary formal analysis of the effects of data network externalities. Policy implications will be discussed in terms of the diffusion of services.

1. Introduction

This paper aims to investigate the existence of “data network effects” in data platform services such as Big Data, Internet-of-Things (IoT) and Artificial Intelligence (AI) and their influence on the diffusion of the services.

The existence of dependencies of the demand for and the benefit from interactive telecommunications services on the number of the users, which is defined as the demand externalities or consumption externalities, was first pointed out by Squire (1973), Rohlfs (1974) and Littlechild (1975), and has been repeatedly investigated by many scholars. Katz and Shapiro (1985) termed it “network effects” without a rigorous definition. Since then, the concept has been extensively applied to explain similar dependencies. The theory of two-sided markets is an extension of the concept that deals with interdependencies between two or more interrelated markets on a platform.

Beside the proliferation of human-centric data services, recent advancement of sensor and network technologies has enabled non-human-centric use of the Internet, i.e., IoT. In addition, the advancement of data processing technologies has reached a level where they are more intelligent than humans and, subsequently, are called AI. Big Data, IoT and AI are expected to increase efficiencies, reduce costs, improve convenience, and make the impossible possible in our society. However, it seems that, despite the technological advances, their economic investigation has lagged behind as data platform services have been dealt with as being one and the same.

It is obvious that the accumulation of data enhances the advantage in providing data

platform services. As compared to the dependency on the number of users, this dependency can be defined as “data network effects”. Matt Turk (2016) defined it in such a way that “data network effects occur when your product, generally powered by machine learning, becomes smarter as it gets more data from your users. In other words: the more users use your product, the more data they contribute; and the more data they contribute, the smarter your product becomes”. That market dominance originates from data dominance is widely recognized in the data industry. As suggested by Parker et al. (2016), for rapid diffusion of data platform services, it is efficient to make the most of data network effects.

This paper intends to present a contrastive demonstration and preliminary formal analysis of the effects of data network externalities. Policy implications will be discussed in terms of competition and the diffusion of services. Data network effects are formulated after a brief review of network effects. Various types of data network effects exist, but the analysis will focus on a type of data service whereby data are collected from users such as Google and Amazon. It is obvious that the existence of data network effects will result from the dependency of users’ demand on the scale of data, namely the number of users. A formal approach is proposed to represent the impact of data network effects on the diffusion of the service and dominance in the market. In the same way as the network effects of telecommunication services, the critical mass phenomenon will occur. The ultimate diffusion level would be lower than the socially optimal level due to the existence of positive externalities. The necessity of taking policy measures arises to fill the gap between a lower realized diffusion level and the social optimum when data network effects exist. However, this would not be compatible with creation of a platform competition and may result in market concentration.

There is another type of data service that data do not depend on users and are collected from alternative data sources, such as physical sensors or people other than users; here, demand externality is less likely to occur. Although the supply side will benefit from the scale effect of data created by a large number of data sources, this may have a limited effect on users. In this case, the competitive advantage of the antecessor relies on the dependency between demand and supply. If the dependency is low, competition is more likely to occur. Parker et al. (2016) investigated how online platforms work and what they mean for business and economics and suggested the theory of two-sided markets (see, for example, Parker, 2005) will be able to explain the dependency to a certain extent.

Finally, the impact of data network effects on government policies is discussed. In most countries, government policies are implemented to support further diffusion and utilization of data. The analysis suggests that the role of the government should be limited. Inappropriate government intervention may skew the market because the advancement of data services is sometimes not compatible with the promotion of a competitive market environment. A reduction of the negative social effects of data services, such as ethical problems or privacy concerns, will be one of the preferred policy directions.

2. Data Network Effects

(1) Network effects

The existence of externalities was first pointed out in the use of traditional telephone service. Interactive communication has demand or consumption externalities in that the benefit to a subscriber depends on the number of subscribers. Squire (1973) and Littlechild (1975) recognized that the externalities must affect the optimal pricing per call and per phone, and examined corresponding optimal usage and network size.

(2) Existence of Data Network Effects

As ICT advances, the traditional network effects in telecommunication no longer have a significant implication in the markets. However, a different type of externality effect has emerged. Table 1 lists the top ten companies in the size of current market capitalization in the world. Many of them are providing platform services in digital markets.

Table 1

This suggests that by attracting more users, the value of data services will increase dramatically and exceed the value of manufacturing. As Matt Turck (2016) pointed out, the value of data is enhanced by the dependencies on the number of users.

3. Formal Approach to Data Network Effects: A Case of User-Generated Data

One of the most typical data businesses is that a company collects data from its users and create a data platform (see Fig. 1). Users in return get useful information from the data platform. They can access not only information about a service or a product but also additional information such as user evaluations. The abundance and reliability of information rely on how many users are contributing to the data platform. This type of service is expected to have demand externalities in that the benefit to a user depends on the total number of users. As the number of users increases, benefit that each user can obtain from the service also increases.

Fig. 1

Suppose there is a data platform service which is composed of a set of users. The number of the total users is denoted by y where y is a subset of the total potential users N . Each user acquires information from the platform. In return, he/she provides a variety of data including personal information to the service. We assume that a benefit to a user does not depend directly on the information provided but simply on the number of users. It is because both the quality and quantity of the service depends on how many people use the service.

Following Oren and Smith (1981) and Mitomo (1992), let us assume that each individual

user is indexed by a unique index i , and without loss of generality that it distributes uniformly between 0 and N such that $i \in [0, N]$.

Assumption 1. Users are distributed in the order of the size of their potential demand.

Let the index of the user who has the minimum potential demand be N and that of the user who has the maximum be 0 .

The potential demand for the service can be defined as $v_p = D(p, i, y)$, where p is the unit price for the service. This demand function explicitly defines the existence of dependencies of each individual user's demand on the number of users. Recently, most platform services are provided for free or users do not pay for the service directly. Alternatively, some services are provided with a flat rate. A two-part tariff can deal with both usage sensitive and non-sensitive price settings. The total charge C that the user i should pay for the service $C(v_p)$ is represented by a combination of the usage and the flat fees:

$$C(v_p) \equiv C(D(p, i, y)) = pD(p, i, y) + F \quad (1)$$

Assumption 2. The demand for the service is finite even in the case where the service is provided free of charge. Namely,

$$D(0, i, y) = V(i, y) \quad (2)$$

where $V(i, y)$ denotes the potential demand of user i for the service for the user set y .

The gross benefit for user i from consuming the service depends on the unit price and the potential demand defined as:

$$B(p, V(i, y)) = \int_0^{v_p} D^{-1} dv \text{ where } v_p = D(p, i, y). \quad (3)$$

Therefore, the net benefit from this service is

$$\begin{aligned} NB(p, i, y) &\equiv NB(p, V(i, y)) = B(p, V(i, y)) - C(v_p) \\ &= S(p, i, y) - F. \end{aligned} \quad (4)$$

Since the gross benefit can be illustrated by the area under the relevant demand curve, the net benefit is formulated as the consumer surplus $S(p, i, y)$ net of the fixed charge, F .

For a user set to be feasible, the net benefit for the smallest user $i = y$ should be non-negative:

$$NB(p, i, y) \geq 0 \text{ for } i = y.$$

According to Mitomo (1992), stable and unstable equilibria can be defined in terms of the user set. For an equilibrium point $y=y^*$, if $dNB(p, y, y)/dy$ is negative, the user set $[0, y^*]$ is a stable equilibrium, and if positive, it is an unstable equilibrium. An unstable equilibrium defines a "critical mass", a well-known concept in the diffusion theory.

In the case of user-generated data, each user receives the benefit from the service depending on the number of users. Thus, interdependencies among users will create a mass effect. This will result in the advantage of a service attracting a larger number of users. If the services provided by competitive suppliers are homogeneous, such as online information retrieval system, the antecessor can take this advantage.

Fig. 2 illustrates a case of a single modal net benefit function. $NB(p, y, y)$ has a single modal parabolic curve at each unit price level. The fixed price is shown as F , which is a cutting plane parallel to the bottom plane. At the price p^* , the curve has two points of intersection with F . The lower intersection, y_0^* , is defined as a “critical mass” and the upper one, y_1^* , as an ultimate expansion level of the user set. The supplier once can attain a user set exceeding y_0^* , it will expand autonomously to y_1^* . This suggests the existence of the first-mover advantage due to the existence of data network effects. If an antecessor can overcome difficulties associated with the start-up stage of business and reach a critical mass level, the business can acquire a dominant position.

Although the revenue from the business is not reflected in this figure, the combination of a unit price and a fixed charge can cover a variety of tariff settings and the supplier can select an appropriate setting as a strategic tool for attracting users. Early adopters are usually those who have a larger demand for the service. In an early stage of service delivery, it is less attractive because they do not know how it is useful. In order to facilitate the subscription, the supplier can apply a low introductory price, namely, a very low price or even zero price. In the case of a flat rate ($F > 0, p = 0$), the net benefit is depicted by the nearest parabola. It is shown that a critical mass is lower than in the case of a positive unit usage charge. As an extreme case, the advantage of freemium or an advertising model can also be illustrated in the figure.

Fig. 2

4. Competition in the Presence of Data Network Effects

As shown in the previous section, the antecessor has an advantage in the provision of the service over potential entrants and can occupy a dominant position. Suppose there exists an entrant that seeks to provide a service identical with the antecessor’s service. From a marketing point of view, the entrant will employ a strategy of product differentiation to avoid fierce competition with the antecessor. If the service is homogeneous, a successful entry will be a cream-skimming entry. Namely, the entrant would focus on large-scale users.

From the assumption, the consumer surplus or the net benefit is monotone decreasing with respect to user index i as shown in Fig. 3. At $i = y$, it should be equal to zero since the net benefit for the smallest user must be equal to zero at an equilibrium.

Fig. 3

The success or failure of a new entry totally depends on the shape of the net benefit function. Fig. 3 illustrates the consumer surplus function, which is defined as the gross benefit net of the total unit usage charge. Assume p^0 and p^1 are the prices for the services provided by the antecessor and the entrant, respectively. If the services from the two suppliers are substantially homogeneous, the entrant cannot set the price higher than the antecessor's. Thus, $p^0 \geq p^1$. Since

$$\frac{\partial S(p,i,y)}{\partial p} = -D(p,i,y) \quad (5)$$

and the demand is monotone decreasing with respect to i , we obtain, for $p^0 \geq p^1$, that

$$\left. \frac{\partial S(p,i,y)}{\partial p} \right|_{p=p^0} \geq \left. \frac{\partial S(p,i,y)}{\partial p} \right|_{p=p^1}. \quad (6)$$

This means that the consumer surplus curve for the antecessor is less steep than that for the entrant. Depending on the setting of the fixed charges, F^0 and F^1 , an intersection can be found, as shown in Fig. 4(a). This implies that the entrant can obtain the users $0 \leq i \leq e$ and the antecessor's share is $e \leq i \leq y$. However, there is a case where the benefit from the antecessor's service exceeds that from the entrant's for all users, as depicted in Fig. 4(b). The success or failure of the entrant depends on the shape of the benefit function and the tariff setting. If the antecessor's service is provided for free or at a very low price by utilizing other revenue sources such as advertisement, it would be difficult for the entrant to get a share in the market.

Fig. 4(a) and 4(b)

5. Policy and Business Implications

The previous section overviewed the possibility of competition in the market. In reality, it seems difficult to enhance competition in dominant platform business even when a potential entrant seeks to start a competitive service as far as there is no substantial product differentiation. On the other hand, a policymaker intends to realize a liberalized market. Although it is difficult to intervene in the private business directly, it can seek to promote further diffusion of the service.

In the presence of positive externalities, it is known that the equilibrium diffusion level tends to be lower than the socially optimal level (See Mitomo and Jitsuzumi, 1999). The existence of data network effects can apply to this case. Suppose there exists a potential user who is willing to use the service. He will perceive the benefit from using the system with the total number of users $y+1$. His perceived benefit is simply given by $NB(y+1)$. The whole users

are also benefited from his participation. The increase in the social benefit is

$$(y + 1)NB(y + 1) - yNB(y) = y[NB(y + 1) - NB(y)] + NB(y + 1). \quad (7)$$

In addition to his own benefit, $NB(y+1)$, the new user will create an additional benefit to all other users, $y[NB(y+1)-NB(y)]$. He will not perceive this additional benefit created by his own participation. Thus, the private benefit is lower than the social benefit created by him by this amount. The equilibrium point where the marginal private benefit is equal to the marginal (private) cost is lower than the social optimal point where the social marginal benefit is equal to the marginal (social) cost. If it is left to the market mechanism, a lower diffusion level will be attained. The existence of the gap will justify a policy support to fill it and attain the socially optimal level of diffusion.

6. Conclusion

There are two types of data network effects. This paper focused on the service based on the data collected from users such as Google and Amazon. The existence of data network effects results from the dependency of users' demand on the scale of data, most simply, on the number of users. This type of data network effects can be analyzed analogous to the traditional network effects. This paper analyzed the effect of the effect based on the framework developed by Mitomo (1992). It was shown that, once the antecessor could attract a certain scale of users, the user set grew automatically to the ultimate expansion level. However, the level attained is lower than the social optimum due to the existence of positive data network effects.

An up-to-date data service will be more complicated. Data do not depend on users and are collected from alternative data sources, such as physical sensors or many unspecified users. In this case, the competitive advantage of the antecessor relies on the interdependencies among multi-sided markets. The theory of two-sided (or multi-sided) markets will shed the light on the dependencies. In order to identify the consequence and impact of such interdependencies, a more suitable framework should be developed, which is left to the future work.

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Table 1: Top 10 companies ranked by Current Market Capitalization (U.S.\$ millions)

1	Apple Inc.	\$775,458	UNITED STATES
2	Alphabet Inc.	\$657,696	UNITED STATES
3	Microsoft Corporation	\$532,887	UNITED STATES
4	Amazon.com, Inc.	\$446,524	UNITED STATES
5	Facebook Incorporation	\$435,396	UNITED STATES
6	Berkshire Hathaway Inc.	\$411,102	UNITED STATES
7	Exxon Mobil Corporation	\$347,519	UNITED STATES
8	Johnson & Johnson	\$334,822	UNITED STATES
9	JPMorgan Chase & Co.	\$309,094	UNITED STATES
10	Tencent Holdings Limited	\$296,819	CHINA

Corporate Information (2017)

<http://www.corporateinformation.com/Top-100.aspx?topcase=b>

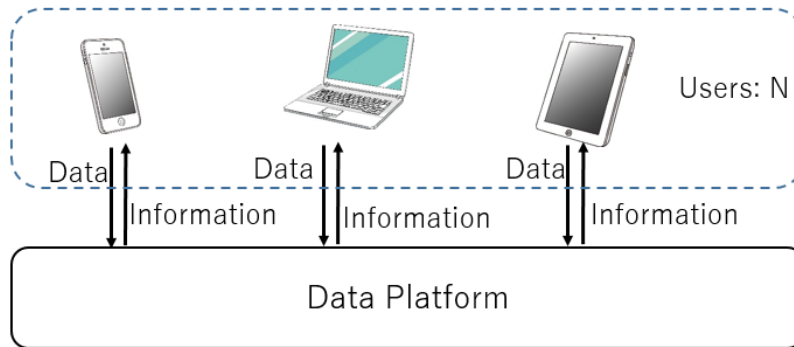


Fig. 1: Data Service Based on Data Collected from Users

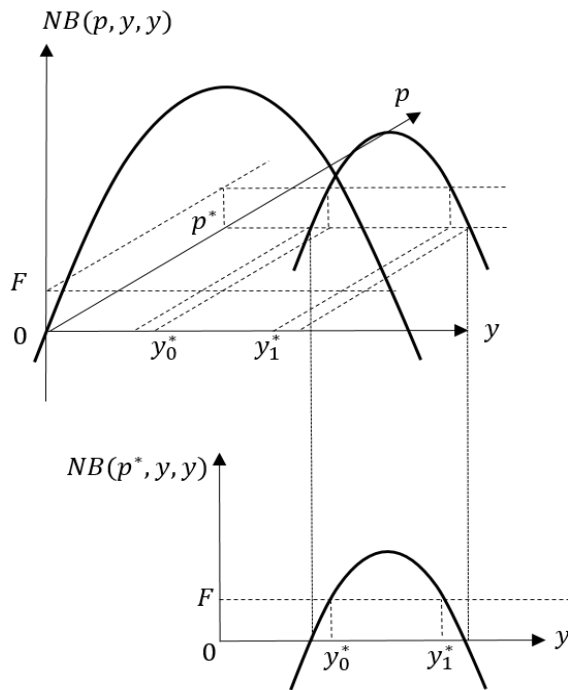


Fig. 2: The Net Benefit for the Smallest Subscriber: Existence of Equilibria

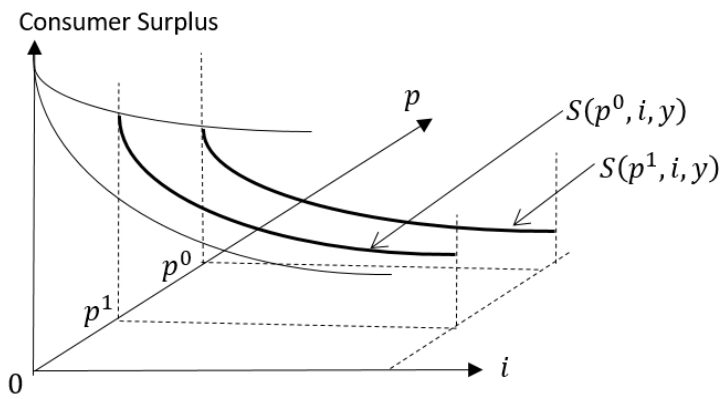


Fig. 3: The Consumer Surplus Function

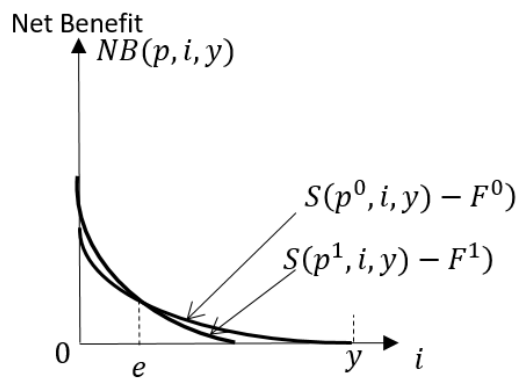


Fig.4(a): Cream-Skimming Entry

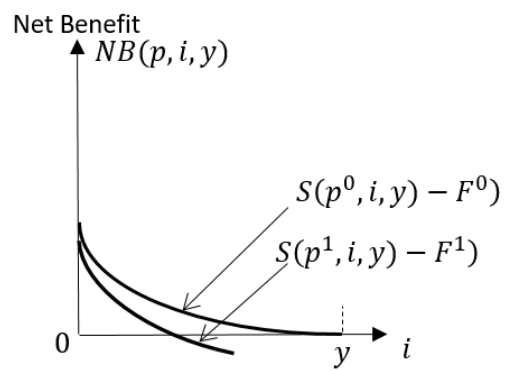


Fig.4(b): Failure of Entry