AN ANALYSIS OF NETWORK COMPETITION WITH CHANGES OF NETWORK TOPOLOGY THROUGH "OPEN API"

Completed Research Paper

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Abstract

A social network service (SNS) is the most prospering business in Web 2.0 regime. In May 2007, Facebook implemented "Open API" which allows third-parties to create applications in SNSs. This innovation led to a rapid growth of Facebook and made surpass Myspace, the leading SNS at that time. Based on the laws of the network value, we hypothesize "Open API" policy revolutionized Facebook's topology from one defined by Metcalfe's law to that by Reed's law. We model the duopoly competition of SNSs and show that the growth of SNS adoption is a polynomial function of time under both laws, but the marginal growth under Reed's law is greater than that under Metcalfe's law. We also empirically test the effect of "Open API" to user growth by using panel analysis on the traffic data of five SNSs. The result implies "Open API" makes a SNS turn into a group forming network.

Keywords: Social networks, open innovation, online communities, network topologies, network value

Introduction

From the inception of Web 2.0, the focus of internet use has shifted to social interactions in the internet and social network services (SNS) have become prevailing, especially online platforms enabling such interactions. Morgan Stanley reported that social networking usage surpassed that of e-mail since November 2010 (Morgan Stanley 2010). According to eBizMBA Rank[1], the top 10 SNSs such as Facebook, Myspace, Twitter, and Linkedin each have millions of regular visitors each month.

Myspace and Facebook are known as the pioneer examples that characterized features of Web 2.0, and are maintaining SNSs listed in the "Alexa Top 10 Global Sites[2]." Both boast over tens of millions users nowadays. Myspace was launched in August 2003, and over 80 million users had subscribed to Myspace by 2007 (Ahn et. al. 2007). Facebook started its business about six months later, and had to catch up to Myspace.

In 2007, Facebook announced an "Open API[3]" platform model and brought in a new trend to social networking services. Similar to the "open source software development" policy in the software industry, this new "Open API" platform allowed third-parties to create applications on the Facebook platform (Arrington 2007). Due to the impact of this open innovation, lots of APIs were created and used by individual users in Facebook. According to the recent statistics in "Facebook Press Room[4]," over 550,000 applications have been developed by this time, and users of Facebook installed 20 million of them every day.

After this open innovation, there brought a huge changeover in competition between Facebook and Myspace. In October 2007, after 4 months following the innovation, the Alexa Traffic Rank[5] of Facebook arose by almost 10 steps from 16th. In contrast to this, Myspace's rank gradually fell off. Eventually, Myspace lost it No. 1 title to Facebook in 2009 (MSNMoney 2009). This reverse in ranking defies the open frequently cited law in network, the network externalities. According to the positive network externalities, the larger (leader) network has competitive advantage over the follower. This startling outcome of network growth in Facebook raises the question of how "Open API" innovation affects social network characteristics than in turn result in the growth of networks.

One remarkable change after open innovation is that "Open API" affected user interactions in Facebook. For this issue, the media commented that adoption of "Open API" somehow seems to bring proliferation of new activities for users, who were previously limited to just making online connections (Stone 2008). Social network games were the most popular case of newly emerged activities which were available as APIs in Facebook. Such new activities were usually based on group interactions, not just on peer-to-peer interactions. In case of "Farmville (http://www.farmville.com)," one of the most installed API in Facebook, a group of people can harvest crops together in the same virtual place. Due to the characteristic of openness, "Open API" brought a huge increase in the number of APIs in Facebook. The explosive growth in the number of APIs may change the fundamental rule of interaction in Facebook.

Relating to the rule of interactions, there are three well-known statements of the network value – Sarnoff's, Metcalfe's, and Reed's law. Each of them assumes different topology of the network (Dohler et. al. 2008; Westland 2010). For example, Sarnoff's law assumes a one-to-many broadcasting network such as radio or traditional TV's. Metcalfe's law is applied to one-to-one communication networks, in which users interact by link-formations. On the other hand, in a network under Reed's law, each new group that is formed contributes to the value. Therefore, we hypothesize that "Open API" may have changed the characteristics of networks, that is, network topology. The network topology is related to the logical and

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[1] http://www.ebizmba.com/articles/social-networking-websites

[2] http://www.alexa.com/topsites, the above ranking was recorded on April 10th 2010.

[3] http://en.wikipedia.org/wiki/Open_API

[4] http://www.facebook.com/press.php

[5] http://www.alexa.com

physical structure of the network[6]. Interactions over a network can be view as logical structure of the network. Hence, a fundamental change in this logical structure (topology) may alters the mechanism of interactions, and values of networks are determined by the number of interactions that may be governed by newly introduced interaction mechanisms. Based on this context and the unexpected outgrowth of Facebook over then-leader Myspace, it is important to find out whether Facebook's open innovation has really changed the fundamentals of its network topology and the rule of game.

To address this question, the main objective of our research is to find the relationship between the growth of SNS adoption and the network topology which is linked to the value of a social network. Finding the relationship between the growth and topology of social network is important in an academic perspective. From Sarnoff's to Reed's law, so-called network laws are yet to be analytically or empirically verified (Metcalfe 1995; Reed 1999) while industry often cites them. As a result, verification of these network value functions and application to our analysis is one of the important issues of this study. Previous studies in social networks were mainly focused on the behavioral issues in social networks (Boyd & Ellision 2008).

From the relationship between the network growth and its topology, our research also tries to analyze the effect of network value to the adoption of SNSs in a duopoly situation. The growth of social network is practically important indicator for social network business, because most of these services (SNSs) rely on advertising for their profits. After the announcement of "Open API", Facebook experienced a radical increase of users, and erased its gap with Myspace. The analysis of the impact of "Open API" may suggest insights to newly entered SNS about how to take over the leading SNS. Competition of two technologies under the existence of network effect has been intensively studied in economics and MIS literature (Arthur 1989). However, to the best of our knowledge, they assume the constant and mostly homogeneous network topologies (Swann 2002). In this study, we focus on the changes of network topologies and their impact on SNS competition.

For these ends, our research employs two approaches. First, we use well-known laws of the network value – Metcalfe's and Reed's law - and model the duopoly competition of dynamic social network adoption using a simulation method in multi-periods. Using daily web traffic data from Facebook and Myspace including the date Facebook adopted an "Open API" policy, we empirically test the difference of growth patterns between, before and after "Open API." We try to generalize our findings with data from 5 famous online social networking sites to perform panel data analysis on the effect of "Open API" to the growth of SNS.

The rest of the paper is organized as follows. In section 2, we review research on social network adoption and network value. In section 3, we suggest our model and simulation. The result of simulation is discussed in Section 4. Section 5 is for the empirical analysis to enhance the result of the analytical model. Section 6 discusses the implication of our findings both from the analytical model and the empirical test. Finally, we discuss the managerial implications, future research directions, and contributions.

Literature Review

A social network has been widely studied in IS research, especially since the term "Web 2.0" emerged. Prior studies on social networks (or social network analysis) were usually centered on patterns of human interactions (Everett 1962; Milgram 1967; Granovetter 1973), structures of human relations (Laumann & Pappi 1976; Dunbar 1992), or development of tools to explain human behavior in the network (Wellman 1988; Anderson & Jay 1985). However, these studies mostly focused on technical issues about social topics (Boissevain 1979). Research on social networking sites (SNSs) mainly discussed purposes of SNS uses (Boyd 2004; Marwick 2005), relationship with offline social networks (Ellison et al. 2006; Choi 2006), and privacy concerns of SNS uses (Acquisti & Gross 2006). In a broad perspective, our research is also about human interactions in social networking sites, but we more focus on the economic impact according to the change in rules of human interaction.

"Open API" in Facebook is somewhat similar concept with open innovation. Open innovation is a paradigm that firms use external ideas to advance their technology (Chesbrough 2003). Open innovation

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[6] http://en.wikipedia.org/wiki/Network_topology

have been usually adopted in the area of R&D department – the case of “Proctor & Gamble” (Chesbrough 2006) – or software development like the case of “Linux” (Godfrey 2000). Our research aims that “Open API” brought enormous increase in diversity of user activities, and assumes that “Open API” changed the rule of interactions in Facebook.

Relating to the rule of interactions in networks, the three network value law – Sarnoff’s, Metcalfe’s, and Reed’s law – assumed different underlying network structures and network externalities. Sarnoff’s law stated that the network value is proportional to the network size, which assumed that the network effect is constant. Metcalfe’s law states that the value of a network is proportional to the square of the network size (Metcalfe 1995). It is generally applied to a telecommunication network such as telephones. In a telecommunication network, the main interaction is one-to-one communication. Under Metcalfe’s law, the marginal network effect is equal to the network size. Reed’s law states that the value of a network is proportional to the exponential of the network size (Reed 1999). It is generally applied to “Group Forming Networks (GFNs).” In GFNs, people consider collaboration and group facilitation as an important value. News groups or chat groups in the internet are examples of GFNs. In a GFN, the number of possible subgroups determines the value of a network. These three laws are widely-accepted statements, but there is lack of theoretical and empirical validation about these laws so far. Adopting the network value laws, we develop the model of two SNSs competing user adoptions.

Various studies examined the network effect and its implementation. The network effect rises when the value of a product to one user depends on how many other users exist. Technologies that are generally subjected to strong network effects tend to exhibit long lead times following by explosive growth with the result of positive feedbacks. Kats and Shapiro (1986) examined the technology adoption in the presence of network externalities. They argued that the pattern of adoption depends on whether technologies are sponsored and they suggested strategic advantages in a two firm competition situation. Saloner and Shepard (1995) econometrically tested the existence of the network effect through the empirical examination of adoption of automated teller machines. Farrell and Saloner (1986) examined the dynamics of installed base competition. Arthur(1989) also has emphasized the role of positive feedback in the economy. Network effects were more recently popularized by Robert Metcalfe. In our research, we mainly incorporate Arthur’s model of technology adoption to the analytical model.

While prior studies argue the important role of interaction and group forming activity in SNS, their analyses are based on mostly static social network service in terms of network topology. In early studies, behavior of impression management (Skog 2005), the network structure of SNSs (Kumar et. al. 2010), and privacy issues (Acquisti & Gross 2006; George 2006) were examined. While Facebook’s phenomenal success has been frequently mentioned (even by a Hollywood movie, “The Social Network”), theoretical explanation has not been provided. Facebook was originally a follower in the SNS market and outpaced Myspace later. It is a unique case that defies the first move advantage from positive network externalities. This study is to fill such void.

Model

The main purpose of the model is to show growth patterns of social network adoption by different mechanisms of user interactions in a social network. For this issue, our study models two social network services that are in a competition with the purpose of adopting potential users. Our analysis basically employs a basic structure of Arthur’s (1989) model. Arthur’s model handled the adoption of two competing technologies under the pre-existence of the network effect that occurred by previous adoptions. Instead of technology, we consider “social network” to be an online social network site (SNS), such as Facebook or Myspace. We also regard the network effect in the model as the value which is induced by interactions among existing members of the network. The main difference between our model and previous studies is the functional form of the network value. We apply two different rules of interactions – Metcalfe’s and Reed’s law – and derive how growth patterns of SNSs change by different functional forms of the network value.

Social Network Services

Our model assumes two different online social network services – A and B. In each period, users in each SNS make interactions with each other and the amount of interactions among users leads to an increase in the network value of each SNS. In our model, it is assumed that interactions in a SNS are sharing information with other users in that SNS. Finding out trends or getting information is one of the important reasons that people use social network services on the internet (Ellison et. al. 2006; Weaver & Morrison 2008; Shi et. al. 2010). Therefore, the network value of a SNS j at time t (NV_{jt}) is assumed to be the total amount information which is created at time t in SNS j. The network value of a SNS is determined by the total number of existing users at the previous period, and the network value law (law_j) that decides the rules of interactions in SNS j. There are two types of network value laws, Metcalfe's and Reed's law. The main difference between these two laws is the unit of interaction. If a SNS follows Metcalfe's law (law_j=M), the rule of interaction is based on one-to-one communication, which implies that the unit of interaction is a node / a user in the network. On the other hand, if SNS j follows Reed's law (law_j=R), users interact by group communication. This implies the unit of interaction under Reed's law is a group. We will describe the details of how users interact with each other in the other section.

Potential Users

There are N potential users in the model. At every turn, potential users observe expected utilities of adopting each SNS and choose the one that provides the most benefit to the user. Similar with the Arthur (1989), the model assumes a preferred SNS for each user (f_i=A or B). This implies that each user is initially given one SNS that he prefers over the other one. Therefore, if the expected utilities of adopting A and B are the same, a user chooses to adopt the preferred one. User i's expected utility of adopting SNS j at time t is as follows

$$U_{ijt} = wtp_{ij} + \alpha NV_{jt-1} \qquad (1)$$

U_{ijt} consists of user i's willingness to pay for adopting SNS j (wtp_{ij}) and the network value of j at time (t-1) (NV_{jt-1}). wtp_{ij} means each user i's perceptive value to SNS j. For the preferred SNS, user i's willingness to pay for adoption (wtp_{if_i}) is normally distributed with mean of μ [7] variance of σ^2. For the non-preferred one, willingness to pay for adoption is ($wtp_{if_i} - \Delta$). Our model does not assume switching cost of SNS adoption.

Rules of Interactions in a Social Network

Generally, social networks are considered as either a one-to-one communication network or a group forming network (Reed 2001). A social network usually contains various functions such as instant messaging or online chatting. To identify the topology of a social network, it is important to focus on what kinds of functions the network has. In that sense, our analysis assumed a typical social network that focuses on functions that facilitates one-to-one communication such as messaging. Our analysis also considers that each application (API) in a social network can be a trigger for making subgroups in the network. In that sense, we only focus on the rules under Metcalfe's and Reed's law. The rule under Sarnoff's law is not considered because Sarnoff's law assumed the network effect is constant regardless of the network size.

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[7] μ generally gets negative value, which means that most people are reluctant to adopt a new product or technology (Lee and Lee 2006)

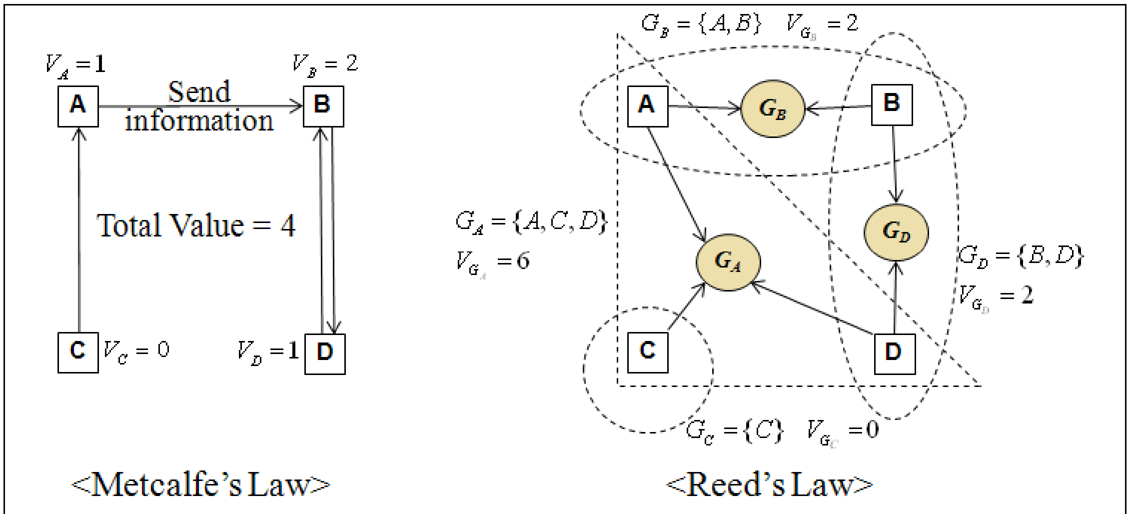

Figure 1. Rules of Interactions and the network value of a SNS

Under Metcalfe' law, users make interactions by sending information to other users. Sending information under Metcalfe's law includes interactions such as writing comments on other users' Myspace profile pages or posting on walls in Facebook. At every period, each user of SNS j can send information to other users up to p_j times. Hence, if the number of users in SNS j at time t is n_{jt}, the network value NV_{jt} is $n_{jt}p_j$. Metcalfe's law states that the network value is proportional to square of the network size, but this holds only when all links in the network are activated. Prior studies criticized over-estimation of network value under Metcalfe's law (Odlyzko and Tilly 2005; Yoshikai 2005; Briscoe et. al. 2006). Considering the cost of sending information[8], our model complies with the method of interactions under Metcalfe's law but limits the amount of interaction per user to p_j. The number of interactions in SNS j (p_j) is assumed to be equivalent to all users in the same SNS. Users spend all possible number of interactions, because they have to maximize their benefit.

Under Reed's law, on the other hand, users interact by group communication. In a SNS following Reed's law ($law_j=R$), each user joins several groups in the SNS and send information to the affiliated group. A group in our model is like an API in Facebook. In Facebook, people play games with other users through API. Considering active uses of APIs and cost of API uses[9], our model limits that the total number of groups in a SNS is same as the number of existing users. Moreover, we assumed that a user in SNS j can join q_j number of groups at one period. If a SNS follow Reed's law, each user in the SNS creates an API when he/she adopts the SNS. G_A in Figure 1 represents the group created by user A. Before the joining process occurs, each group has only one member. After joining groups, each user stocks information to the groups he/she belongs to. A user can send one unit of information to each group. The value of each group in a SNS is defined as the multiplication of the size of group and the amount of information in the group. The network value of SNS under Reed's law is the sum of total value of groups in the SNS. Figure 1 shows the graphical representation of interactions in a SNS by its network value law.

The Procedure of Simulation

Based on the set up for SNSs, potential users, and the rules of interactions, we perform a simulation to derive the growth patterns of SNS adoption in a duopoly competition. The procedure of simulation organizes with three major parts. In the initialization part, the network value law is assigned to SNS A and

[8] Generally, it is impossible to interact millions of Facebook users at a given time.

[9] In fact, Facebook has over millions of API, but only tens of them occupy the most interaction (active uses of API).

B, and wtp_{ij} and f_i are assigned to potential users. After the initialization, the model iterates adoption and interaction procedures. The iteration performs 50 times but stops when there is no more new adoption (including switch to the other SNS) in this period. In the adoption process, each potential user observes the network values of SNS *A* and *B* at the previous period and chooses one that gives the most benefit. In the interactions process, adopted users make interaction with others in each SNS. The amount of interaction affects the network value of a SNS.

Results and Discussion

For the simulation, several variables in the model are set by certain values. The number of potential adopters in the market is set by 1000 (*N*=1000). wtp_{ij} is assumed to follow normal distribution with mean value -50 and a variance of 30 ($\mu = -50, \sigma^2 = 30$). The gap of willingness to pay for adoption between a preferred and a non-preferred SNS is 55 ($\Delta = 55$). Under Metcalfe's law, the default value of the amount of interaction per user is 5 ($p_j = p_{j'} = 5$). Under Reed's law, the number of groups that a user can join at one period is also set to 5 ($q_j = q_{j'} = 5$). As mentioned in section 3, these values are assigned in the initialization process. Adoption and interaction processes are iterated until 50 periods or until no more new adoptions occur. The results are obtained by 1000 times of simulation. In this section, we mainly discuss the growth patterns of SNS adoption and marginal growth under Metcalfe's and Reed's law.

Growth Patterns of SNS Adoption

The growth patterns of SNS adoption under Metcalfe's and Reed's law can be mathematically derived to an approximate functional form. Assuming two firms are symmetric[10], user *i* will adopt SNS *j* at time *t* only if wtp_{ij} is lower than $-NV_{jt-1}$. This implies that SNS *j*'s number of users at time *t* (n_{t-1}^j) is affected by the standard normal cumulative distribution function of wtp_{ij}. Therefore, it can be expected that the number of users is $\frac{1}{2}\Phi(\frac{NV_{jt-1} - \mu}{\alpha_j \sigma})$. Therefore, by Taylor approximation of the normal cumulative distribution function (Marsaglia 2004), it can be speculated that the growth of SNS adoption is an odd degree polynomial function of time *t* with a given number of initial adopters (n_0^j). We empirically test the relationship between the number of adopters and time using the data of the simulation[11]. Assuming two SNSs are symmetric, the result verifies that the growth of SNS adoption takes the form of an odd degree polynomial function of time *t* (Under Metcalfe's law β_1=11.88, β_2:-0.003, all $ps<0.01$; Under Reed's law β_1=29.01, β_2:-0.027, all $ps<0.01$).

Proposition 1. *If the number of interactions per user is far lower than the network size, the growth of SNS adoption under both Metcalfe's and Reed's law is approximately an odd polynomial function of time with a given number of initial adopters.*

Figure 2 shows the growth patterns of SNS adoption under Metcalfe's and Reed's law. Both growth patterns can be explained with three parts – the number of adopters in the equilibrium, the critical mass that converts marginal growth into an increasing trend, and the time that it takes to reach the equilibrium. It can be observed that the number of adopters in the equilibrium under Reed's law is higher than the one

[10] This means that *A* and *B* follow the same network value law with the same number of initial adopters and interactions per user.

[11] Considering the rest terms as an error, we set up the model to $n_t^j = C + \beta_1 t + \beta_2 t^3 + \varepsilon_t$ for regression analysis.

under Metcalfe's law, and the equilibrium also reaches faster. This shows that the network value per unit of interaction under Reed's law is greater than the one under Metcalfe's law.

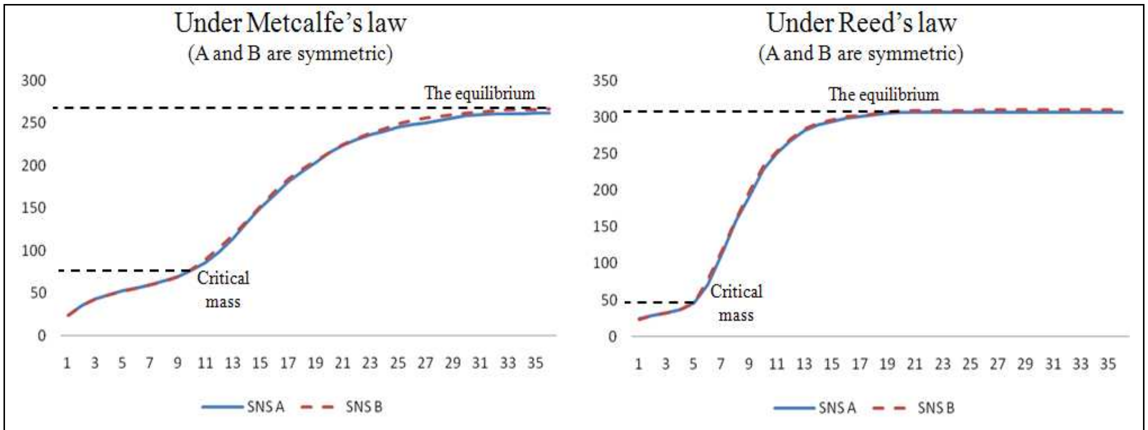

Figure 2. Growth of SNS adoption under Metcalfe's and Reed's law

The Marginal Growth of SNS

There are three main factors affecting the marginal growth of SNS adoption – the initial adopters (n_0^j), the number of interactions per user (p_j, q_j), and the mechanism of interaction (Metcalfe's or Reed's law). The number of initial adopters means whether the SNS has a first-mover advantage. The number of interactions per user refers to the question of how many interactions are activated in the SNS. The mechanism of interaction determines if the SNS is facilitated to one-to-one communications or group communications. Generally, these three factors affect the amount of interaction and eventually increase the growth of SNS adoption.

In perspective of the marginal growth, the number of interactions per user has more effect on the growth of SNS adoption than the initial adopters. In the model, we perform simulations by altering SNS *A*'s number of interactions per user or the number of initial adopters. Regardless of the network value law, it can be shown that adoption of SNS *A* grows more rapidly as p_A increases, even when *B*'s initial adopters are higher than *A*'s. This implies that the first-mover advantage can be overcome by facilitating interactions in a SNS, which leads to increase in the marginal network value.

Proposition 2. *Under both Metcalfe's and Reed's law, the marginal growth to the number of interactions per user is higher than that of the initial adopters if other conditions are hold.*

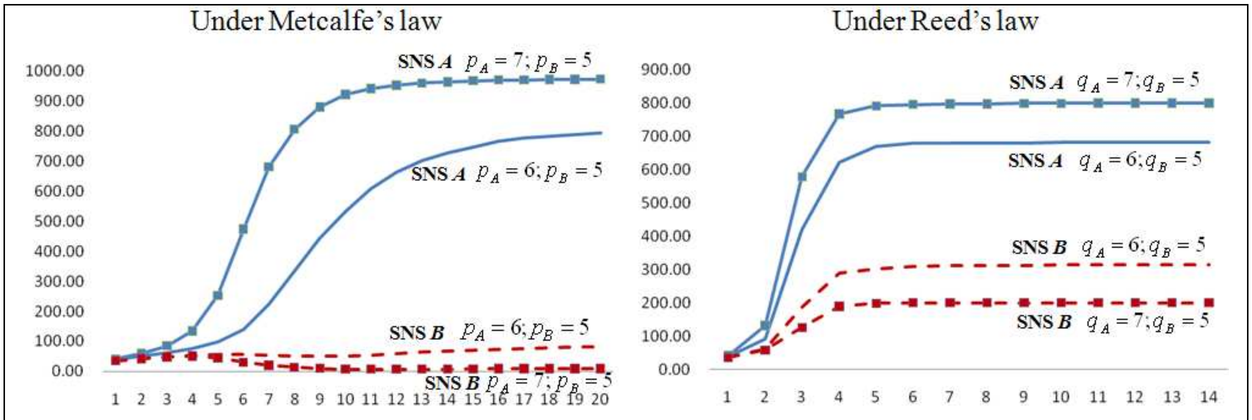

Figure 3. Growth of SNS adoption under Metcalfe's and Reed's law (the variables except p_A and p_B get the same values as those that were set up in the beginning of Section 4)

The result shows that the most effective factor that increases the marginal growth of SNS adoption is a change in the mechanism of interaction – from one-to-one communication to group communication. The change of interaction mechanism, from one-to-one to group communications, transforms the network value per unit of interactions. Even when *A* has higher initial adopters and higher number of interactions per users, the SNS adoption under Reed's law outgrows that under Metcalfe's law. This means that the change of interaction mechanism in a SNS is the most effective way to increase the number of its adoption.

Proposition 3. *The effect of the network value induced by group communications dominates that of one-to-one communications in perspective of marginal growth of SNS adoption.*

The Impact of Open Innovation to the Growth of SNS

Considering that Facebook adopted open innovation in 2007, we put the similar circumstance in our model. This is to analyze the impact of open innovation to the growth of SNS adoption in the model. We regard SNS A and B as Myspace and Facebook respectively, and bring the real case of "Open API" in Facebook to our model. For the simulation, it is assumed that SNS A has more initial adopters (150 initial adopters) to let A take first-mover advantage – just like Myspace took in the real case. Both *A* and *B* are assumed to follow Metcalfe's law at the start of the simulation, but *B* changes to follow Reed's law after the 10^{th} period. Assuming that "Open API" triggered group interactions in Facebook, this change in the simulation eventually shows how open innovation affect the growth of SNS adoption. Figure 4 shows the result. As mentioned in the propositions, the change of interaction mechanism dramatically increases the network value of SNS *B*. The number of adopters of *B* eventually overgrows that of *A* after 14^{th} period. This result seems consistent with the case of "Open API" in Facebook.

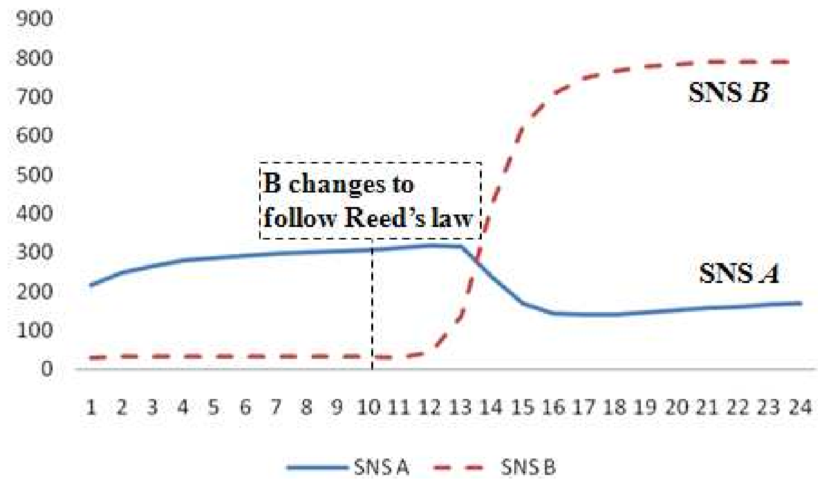

Figure 4. The change of interaction mechanism (from Metcalfe's to Reed's law) in SNS B (α_A=0.03, α_B=0.002)

Empirical Analysis

In this section, we empirically validate our finding in the simulation model. The main finding of our model shows that the number of SNS adoption show different growth patterns in accordance with the network value law. In case of Facebook, it can be said that "Open API" triggered group interactions and changed the network value. For this issue, we first empirically test the effect of "Open API" policy to the competition between Myspace and Facebook. We use traffic data of Facebook and Myspace to verify whether the "Open API" policy increased group interactions in Facebook and the marginal growth of its users. After that, we also test the effect of "Open API" policy on the growth of social networking services. We collect the traffic data of 5 famous online social networking sites (SNSs) including Facebook and Myspace to verify the effect of group interactions to the value of the social network.

For the empirical analysis, we collect the traffic data from "Alexa Web Information Services (http://aws.amazon.com/awis)." It provides two types of traffic data – Reach and Pageviews. Reach measures the number of users out of million samples. Reach data usually represent the percentage of all internet users who visit a given site. Pageviews measures how many times page was viewed by site visitors. In our analysis, we collected both types of daily traffic data over a period of November 11th 2006 to October 31st 2007 (365 daily samples). For the second test associating with 5 online SNSs, we collect the monthly traffic data from August 2007 to December 2010 (41 monthly samples).

The Competition between Myspace and Facebook

In this section, we first construct the regression model to test the relationship between the amount of interaction in a SNS and its adoption. Based on the model, we perform the Chow breakpoint test (Chow 1960) on data that lies between the period of before and after "Open API." This test is for verification of a structural change in the relationship between the network value and the new adoption after introducing "Open API."

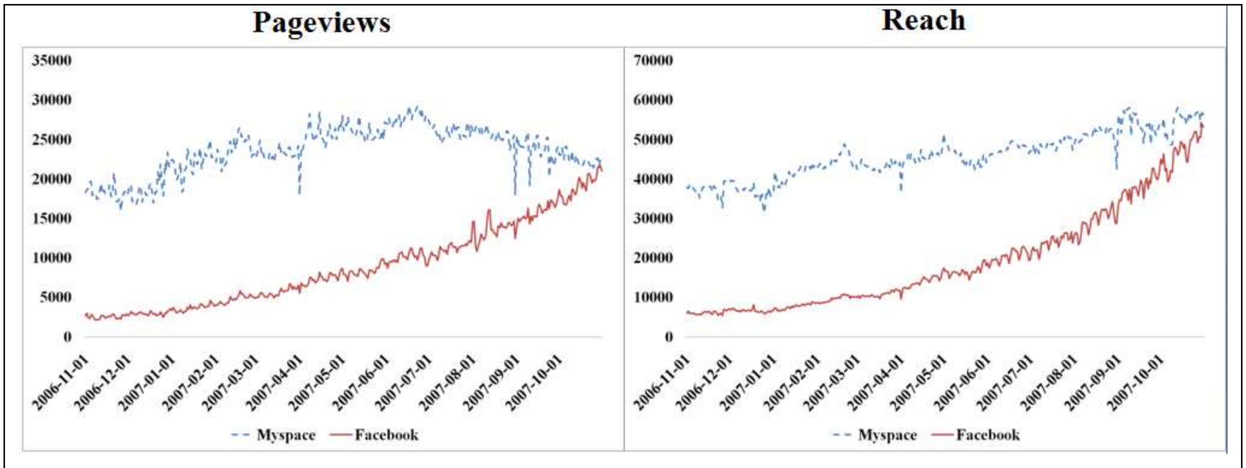

Figure 5. Reach and Pageviews data of Facebook and Myspace (2006.11.01 ~ 2007.10.31; "Open API" announcement: 2007.05.24)

According to the definitions of traffic data in prior studies, we use Reach data as a proxy for the number of users (adoption), and Pageviews data as the amount of interaction in a SNS. The reason using Reach instead of the direct measurement – the number of users – is because the statistics published by SNSs themselves usually include the data of fake or inactive accounts[12]. Therefore, using Reach data reflects the active number of users in a SNS, more than the total number of users. Additionally, Reach data is used to measure the market share in e-business (Kozberg 2001). Actually, the number of users of Facebook and Myspace (self-published data) increased 125% and 19% respectively during the period of our data sample[13]. The Reach data of Facebook and Myspace show similar trends of growth in the number of users. Pageviews data is a measurement of how many times a particular web property has been seen (Demers and Lev 2001). Therefore, it can be interpreted that Pageviews data is the amount of interactions that occur in a SNS.

Regression models for the empirical analysis are based on the growth patterns in the results of the simulations. We hypothesize that the amount of interactions at a previous period positively affects the new adoption in a SNS. In the regression model, we use Reach data ($R_{f,t}$) as a dependent variable and Pageviews ($PV_{j,t}$) as an independent variable as shown in equation (2). We observe whether there are changes in β_i before and after "Open API (2007.05.24)." However, we discover that all Reach and Pageviews data have unit roots. For that reason, Durbin-Watson statistics is a value of 2.018 when using equation (2). Moreover, there are high correlations between Reach and Pageviews data in both Facebook and Myspace. Instead of applying equation (2), we use I(1) series of each variable and use equation (3). Because daily data was used in this case, the day of the week effect must be considered (Trusov et. al. 2009). Therefore, Monday, Saturday, and Sunday are used as control variables.

$$\begin{pmatrix} R_{f,t} \\ R_{m,t} \end{pmatrix} = \begin{pmatrix} C_1 \\ C_2 \end{pmatrix} + \begin{pmatrix} \beta_1 & \beta_2 \\ \beta_3 & \beta_4 \end{pmatrix} \begin{pmatrix} PV_{f,t-1} \\ PV_{m,t-1} \end{pmatrix} + \begin{pmatrix} \beta_5 & \beta_6 \\ \beta_7 & \beta_8 \end{pmatrix} \begin{pmatrix} PV_{f,t-1} \\ PV_{m,t-1} \end{pmatrix}^3 + \beta_9 Mon_t + \beta_{10} Sat_t + \beta_{11} Sun_t + \begin{pmatrix} \varepsilon_t \\ \nu_t \end{pmatrix} \qquad (2)$$

[12] http://networkconference.netstudies.org/2010/05/why-the-number-of-people-creating-fake-accounts-and-using-second-identity-on-facebook-are-increasing/

[13] http://brainstormtech.blogs.fortune.cnn.com/2007/11/15/nielsen-facebook-growth-outpaces-myspace/

$$\begin{pmatrix}\Delta R_{f,t}\\ \Delta R_{m,t}\end{pmatrix}=\begin{pmatrix}C_1^{"}\\ C_2^{"}\end{pmatrix}+\begin{pmatrix}\gamma_1 & 0\\ 0 & \gamma_4\end{pmatrix}\begin{pmatrix}\Delta R_{f,t-1}\\ \Delta R_{m,t-1}\end{pmatrix}+\begin{pmatrix}\gamma_5 & \gamma_6\\ \gamma_7 & \gamma_8\end{pmatrix}\begin{pmatrix}\Delta PV_{f,t-1}\\ \Delta PV_{m,t-1}\end{pmatrix}+\begin{pmatrix}\gamma_9 & \gamma_{10}\\ \gamma_{11} & \gamma_{12}\end{pmatrix}\begin{pmatrix}\Delta PV_{f,t-1}\\ \Delta PV_{m,t-1}\end{pmatrix}^3$$
$$+\gamma_{13}Mon_t+\gamma_{14}Sat_t+\gamma_{15}Sun_t+\begin{pmatrix}\varepsilon_t^{"}\\ \nu_t^{"}\end{pmatrix} \quad (3)$$

Descriptive statistics show that both Reach and Pageviews increase twice as much after “Open API.” In case of Myspace, on the other hand, the data shows s slight decrease in Reach data, but in Pageviews the amount of interaction drops by almost half after “Open API.”

Table 1. The data before and after “Open API (2007.05.24)”

SNS		Pageviews	Δ%	Reach	Δ%	Obs
Myspace	Before “Open API”	22431	1.22	41932	0.58	204
	After “Open API”	25110	-0.63	50901	1.22	161
Facebook	Before “Open API”	4865	4.50	9882	3.86	204
	After “Open API”	13736	3.98	31136	5.13	161

F-statistics of the Chow breakpoint test between before and after “Open API” is 2.88, which rejects the assumption that no structural change exists after “Open API.” The result confirms that there are significant effects of interaction in the previous period to new adoptions in both Facebook and Myspace. In Facebook, it can be observed that there are positive effects on Monday and Sunday, but negative effects on Saturday. Out of seven days of the week, we only use Monday, Saturday and Sunday, which show significance in the model, as control variables. In fact, in April 2008, Facebook overtook Myspace in terms of web traffic which was recorded by Alexa Web Information Service. This result implies that the implementation of “Open API” changes the effect of user interactions to the growth of Facebook adoption.

Table 2. The result of regression from 2006.11.01 to 2007.10.31 (breakpoint: 2007.05.24)[14]

variable	Myspace		Facebook	
	before	after	before	after
$\Delta R_{f,t-1}$	-	-	-0.390***	-0.136
$\Delta R_{m,t-1}$	-0.297***	-0.214**	-	-
$\Delta PV_{f,t-1}$	-0.055	-0.081	-0.009	0.036*
$\Delta PV_{f,t-1}^3$	0.002	0.006	-0.004	0.006*
$\Delta PV_{m,t-1}$	-0.009	-0.211***	-0.220***	-0.001
$\Delta PV_{m,t-1}^3$	0.007**	0.011***	0.012***	0.009***
Monday	0.636	-2.087**	5.287***	6.426***
Saturday	-1.081	-0.274	-3.225***	-6.486***
Sunday	0.569	1.197	2.894***	3.673***

[14] *, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

Adjusted R^2	0.154	0.383	0.317	0.463

The effect of "Open API" to the network growth

The first test shows that there were a significant structural change in the network growth of Facebook and Myspace after "Open API" policy. In this section, we use the traffic data of 5 famous online SNSs to generalize our results in the simulation. After Facebook announced "Open API" policy, many online SNSs tried to innovate their mechanisms of interactions. Out of the top 15 most popular SNSs based on eBizMBA[15], we select five sites which implemented "Open API" policy. Theses SNSs usually maintain over tens of millions of unique visitors. We collect monthly traffic data of these five sites, from August 2007 to December 2010.

Table 3. The Profiles of SNSs[16]				
SNS	Adopting "Open API"	Launched	Users	Alexa Ranking
Facebook	2007.05.24	2004	640,000,000+	2
Myspace	2008.02.05	2003	100,000,000+	46
Friendster	2008.08.19	2002	90,000,000	979
Ning	2008.10.10	2005	42,000,000	128
hi5	2008.03.31	2003	80,000,000	265

In this test, we first verify the relationship between the growth of SNS adoption and its network value (the amount of interactions). For this issue, we use equation (4) for the panel data analysis. Like in the first test, the traffic data of the five SNSs show unit roots. Therefore we apply the difference of each variable in the equation. $Open_{i,t}$ is a dummy variable for classifying whether SNS i adopts "Open API" policy at time t ($Open_{i,t}$ =1). Therefore the coefficient γ_1 and γ_2 show the effect of "Open API" to the growth of SNS. Variable S_{it} is the market share of SNS i at time t. The results of simulation show that the effect of "Open API" cannot be activated without the sufficient number of users who can initiate group communications. the coefficient γ_3 and γ_4 implies the effect of interaction in other SNSs to the growth.

$$\Delta R_{i,t} = \beta_1 + \beta_2 R_{i,t-1} + \beta_3 \Delta PV_{i,t-1} + \beta_4 \Delta PV^3_{i,t-1} + \gamma_1 Open_{i,t} \cdot \Delta PV_{i,t-1} + \gamma_2 Open_{i,t} \cdot \Delta PV^3_{i,t-1} + \gamma_3 (1 - S_{i,t-1}) \cdot \Delta PV_{i,t-1} + \gamma_4 (1 - S_{i,t-1}) \cdot \Delta PV^3_{i,t-1} + \varepsilon_{i,t} \quad (4)$$

Table 4. The result of regression (2007.08 ~ 2010.12, 205 obs)		
variable	Pooled OLS	Fixed Effects
β_1	-290.77 *	604.276 *
$R_{i,t-1}$	0.033 ***	0.011 *

[15] http://www.ebizmba.com/articles/social-networking-websites

[16] These statistics are based on http://en.wikipedia.org/wiki/List_of_social_networking_websites

$\Delta PV_{i,t-1}$	0.268 *	2.310 *
$\Delta PV_{i,t-1}^3$	-9.67 E-09	-4.19 E-07 **
$Open_{i,t} \cdot \Delta PV_{i,t-1}$	0.594	1.378 *
$Open_{i,t} \cdot \Delta PV_{i,t-1}^3$	3.01 E-08	4.25 E-07 ***
$(1-S_{i,t}) \cdot \Delta PV_{i,t-1}$	1.173	-1.257 *
$(1-S_{i,t}) \cdot \Delta PV_{i,t-1}^3$	-1.01 E-07	1.86 E-08
Adjusted R^2	0.567	0.687

In the pooled regression, most variables are not significant except for the relationship between the change in Pageviews and Reach (β_2: 0.033). In the fixed effect model (the right column in Table 4), most variables show significances. Estimates of coefficient γ_1 and γ_2 are positive, which imply that adoption of "Open API" increases marginal growth of SNS adoption. The negative value in the estimate of coefficient γ_3 implies that lower market share decreases the effect of "Open API" on network value. This empirical result tells that implementation of "Open API" policy generally encourages users' group interactions and benefits the growth of SNS adoption. However, this innovation comes into effect when the SNS have a sufficient number of users than other competitors. Actually, after Facebook announces "Open API" policy, several SNSs tried to implement open platforms in 2008. However, due to the relatively small number of users (Table 3), other SNSs could not overtake Facebook which adopted "Open API" almost a year earlier than other competitors. In spite of this gap between Facebook and other SNSs in term of the number of users, every SNS showed slightly increase in the traffic amount after adopting "Open API." This is consistent with the result of panel analysis – the positive effect of "Open API" to the SNS adoption.

Implication

Our model investigates the growth patterns of SNS adoption according to laws of network value. If a user cannot make all interactions possible in the SNS, which implies the number of interactions per user is limited, the growth of SNS is an approximate odd polynomial function of time t with a given number of initial adopters of SNS. This usually shows an S-shaped curve. The model characterizes three factors which affect the network value law. These three factors are: a number of initial adopters, which is associated to the first-mover advantage; a number of interactions per user, and the network value law that is determined by the mechanism of interactions in a SNS. The result in the model shows that the change in the network value law from Metcalfe's to Reed's law increases marginal growth and gives a chance for the follower SNS to overtake the leader.

Applying the result of our model to the case of Facebook, it can be said that the "Open API" platform may have altered the mechanism of interactions from one-to-one messaging to group communication. At the beginning of its service, Facebook had a lower number of adopters than Myspace. This means that the gap of the number of adopters between Facebook and Myspace hindered the growth of Facebook. Moreover, users in Facebook did not interacted sufficiently enough with others users to overcome Myspace's first-mover advantage. "Open API" can be considered as a signal when user interactions in Facebook were transformed from one-to-one communications to group interactions. This change means two important things. First, as shown in the model, a unit of interaction creates more network value in group communication than one-to-one communication. Second, as mentioned in the Morgan Stanley Research (Morgan Stanley 2010), the method of interaction shifts from one-way (asynchronous) to multi-way (synchronous), which is one of the important features of Web 2.0 (Mannes 2006). These two characteristics attracted more interactions in Facebook than before. Facebook eventually overtook Myspace and took the leading position in the market. According to "Alexa.com," Facebook was ranked in the 2nd place, and Myspace ranked in the 18th place in the amount of web site traffic in 2010[17]. By letting users freely create and use APIs in the social network, each API can play a role of a subgroup in Facebook. In API statistics in Facebook, six out of top ten APIs are social network gaming such as "FarmVille (www.facebook.com/FarmVille)" or "Mafia Wars (www.facebook.com/MafiaWars)," which let massive number of users interact with each other in one environment[18].

The empirical analysis applies the result of the simulation model to the real data. The analysis verifies that Facebook had a structural change after "Open API" in terms of the network value and growth of adoption. This can be seen as evidence that Facebook started to activate group formation after "Open API." In the beginning of SNSs, people usually utilized them for self-representation and self-broadcast in the network (Boyd 2004). As the number of user increases, the network value shifted to one-to-one communications such as instant messaging. Nowadays, APIs become a kind of catalyst that increases subgroups in the social network nowadays. In conclusion, our study provides a theoretical explanation to the currently prevailing success of social networks. In addition, this may also be applied to explain disruptions in technology market that abruptly erase the leader's advantage created by positive network effects.

Conclusion

This paper investigated the growth of social network services adoption using the functional form of network value. We apply the generally accepted laws of the network value and derive the model of competition between two SNSs. The results derived by simulation show that social network adoption is a polynomial function of previous adoption, and a SNS under Reed's law gets higher marginal growth of adoption than the one under Metcalfe's law. We may apply this result to other networks or standard competition. As mentioned above, often the winner-takes-all phenomena in IT are attributed to network externalities or network effects but disruptions have been observed in those markets as well. Such disruptions may be caused by fundamental changes in network characteristics. Our approach may be used to model such more general disruptions.

The result of empirical analysis confirms that there exist significant structural changes in both Facebook and Myspace. Based on the regression of two types of traffic data, Reach and Pageviews, Facebook showed a rapid growth of traffic data after implementation of the "Open API" policy. On the other hand, the web traffic of Myspace showed a decreasing trend. By applying the analytical model to the empirical analysis, we can conclude that "Open API" drives the change in the method of interaction in the social network, which facilitates group formation in the network. This implies the significance of open/peer innovations.

Eventually, it can be said that "Open API" activates a transformation of the ways of interaction in the social network. APIs let users to create subgroups in the social network, and increase the network value. For Facebook, which was the follower at that time, it was important to accelerate group formation functions and to increase the network value more rapidly.

Several limitations of our research exist in both the simulation model and empirical analysis. We derive the growth patterns of SNS adoption by performing simulations under various assumptions for simplicity of analysis. In empirical analysis, we use traffic data as proxies for the network adoption due to limitations of data access. Nowadays, most of SNSs let users develop APIs in the social networks (Warren 2007). Detailed data of API statistics such as the number of API adoptions should lead the analysis of what kinds of APIs attract users more.

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[17] http://www.alexa.com/topsites, the above ranking is the recorded on April 10th 2010.

[18] http://statistics.allfacebook.com/applications

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