Estimating Potential Size of Markets Characterized by
Three Types of Network Effects

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Abstract

Few studies in the literature of network effects have guided firms to estimate the potential size of a market. No study, as we know, has used various types of network effects in addressing this issue. This paper thus proposes a model for estimating the potential size of markets characterized by three types of network effects -- accelerating, stable, and decelerating -- in three types of markets: receptive, stable, and resistive. This study found that (1) receptive and stable markets with accelerating network effect will result in a very large market size; (2) receptive markets with stable network effect will also result in a very large market size; (3) stable and resistive markets with decelerating network effect will result in a constrained market size; and (4) resistive markets with stable network effect will also result in a constrained market size.

Keywords: Network Effects, Market Size, Estimation, Internet, Communication Systems
Introduction

The prevalence of the Internet has greatly shaped all aspects of our lives, especially our ways of doing business. Through the Internet, firms can efficiently communicate with their partners to share market information and coordinate their operations. Firms can also directly provide their customers comprehensive information and personalized services.

The Internet has also changed the rules of the game of business competition because of network effects, which refer to the phenomenon that the value of connecting to a network increases with the number of users already connected to the network (Shapiro & Varian, 1998). As a result, larger networks are more attractive to users than smaller ones. New users then tend to connect to larger networks and make larger networks even larger. Network effects exist in physical systems, such as telecommunication networks or railway networks, or in virtual systems, such as the network of Microsoft Windows users or the networks of members of a Web site.

Past studies on network effects have discussed inefficiencies in social welfare caused by network effects (c.f. Farrell & Saloner, 1986; Choi, 1994; Padmanabhan, Rajiv, & Srinivasan, 1997). Numerous researchers have begun to shift their focuses toward competitive strategies for individual firms in industries with network effects (c.f. Gupta, Jain, & Sawhney, 1999; Conner, 1995; Chiang & Teng, 2001, 2003; Teng, Tseng, & Chiang, 2006). However, the issue of market potential estimation was rarely addressed. Thus, the purpose of this paper is to estimate the potential size of markets characterized by three types of network effects. Such purpose is unique to past studies by providing information on potential market size for individual firms.

The following sections first review the relevant literature on network effects, construct a model, perform the analysis, and then present conclusions, implications, and suggestions for future research, respectively.
Theoretical Background

This section will review the origin and development of network effects literature, business wisdom challenged by network effects, the winner-takes-all phenomenon, social welfare inefficiencies and corrective activities, recent works on network effects, and comparing this study with the most-related studies.

Since the pioneering works of Farrell and Saloner (1985) and Katz and Shapiro (1985) many studies have addressed network effects. Researchers have proposed various strategies for players to survive in markets with network effects. For example, players can build alliances, obtain first-mover advantages, and manage customer expectations to increase profits (Shapiro & Varian, 1999). Other popular research issues include how to compete with market leaders in the presence of network effects (Witt, 1997; Chiang & Teng, 2003) and whether to make products compatible with those of competitors and the accessibility of complementary assets, forming the phenomenon of complementary network effect (Economides, 1989; Matutes & Regibeau, 1992; Brynjolfsson & Kemerer, 1996; Gupta et al., 1999). Some other studies also discussed the negative network effect or congestion effect (c.f. Stenbacka & Tombak, 1995; Westland, 1992). The best-known strategy or business model involves initially setting a low price for penetrating the market and then increasing the price once the network exceeds a sufficiently large size (Bensaid & Lesne, 1996; Shapiro & Varian, 1998).

Some conventional business wisdom has been challenged in markets with network effects. Conner and Remelt (1991) showed that the profits of leading firms in markets with network effects can be increased by permitting piracy if most pirates are low-end users. The logic to permit piracy is that pirates provide value to legal users via using the technology for communication. Conner (1995) further proposed that introducing clones (different but compatible products) can increase profits, something not envisioned by traditional business tenets.

A market characterized by network effects eventually becomes a winner-takes-all market (Farrell & Saloner, 1986), which is seldom optimum in terms of social welfare. Kristiansen (1998) proved that the enforcement of licensing policy could overcome such inefficiencies. The related literature is summarized in Chiang and Teng (2005) and the classic book Information Rules (Shapiro & Varian, 1998).

Inefficiency in social welfare and associated corrective activities has also been a focus of research. Farrell and Saloner (1986) indicated a leading firm in markets with network effects will capture the whole market and that theoretically no challenger firm has any chance to survive in such markets. Farrell and Saloner predicted the competitive outcome: even a
challenger with a superior technology cannot survive, which may reduce social welfare. On the other hand, the monopolist (a leading firm capturing a whole market) has incentives to practice so-called planned obsolescence, offering new products that are incompatible to their previous-version (Choi, 1994). Planned obsolescence also reduces social welfare. The monopolist also has incentives to first offer poorer-quality products (when better-quality products are ready to market) and then offer better-quality products as “upgrades” when information is asymmetrical (Padmanabhan et al., 1997), clearly damaging social welfare. The monopolist can also preannounce their upgrade version product to make it harder for competing technologies to attract prospective users (Farrell & Saloner, 1986), utilizing user expectation to deter challenger entries.

Economists argue that governments are accountable for correcting, reducing, or eliminating these inefficiencies. An intuitive reaction by the government is regulating the standard-setting process to prevent a race of research and development among firms which reduces social welfare. Standard-setting policy, however, does the contrary: urging firms to compete more than ever to be the standard chosen by the government (Kristiansen, 1998). Kristiansen also proved that a forced licensing policy, which forces the winner license his/her technology to other firms, can correct the inefficiencies from network effects.

Recent works on network effects have examined product-launch strategies (Sun, Xie, & Cao, 2004; Lee & O’Connor, 2003), pricing (Chiang & Teng, 2001; Gallaugher & Wang, 2002), innovative and strategic activities (Ehrhardt, 2004; Ende & Wijnberg, 2003), competition on value thresholds (Tseng, Teng, & Chiang, 2005), the degree of network externalities in markets with network effects (Gowrisankaran & Starvins, 2004), and strategies for capturing customers (Teng, Tseng, & Chiang, 2006). Therefore, companies should incorporate network effects into demand estimation and focus on improving network effects (Bonardi & Durand, 2003). The issue of network-potential estimation in the context of network effects, however, has yet to be discussed, demonstrating the needs for research on this issue.

The study of Tseng, Teng, and Chiang (2007) is closely related to this study. Tseng et al. (2007) proposed a conceptual model for describing market situations characterized by network effects and suggested two major generic strategies: increasing total customer value and reducing total customer costs. Although this study is consistent with Tseng et al. by using network effects and customer perceived value to construct a model to provide information for individual firms, it is unique in two points. First, it provides the information on (estimated) market potential (in term of market size), while Tseng et al. provided the information on how to deliver superior value to markets. Second, this study enriches the knowledge on
how to predict the potential sizes of networks, while Tseng et al. adds on the knowledge on how to better serve markets with network effects.

**Modeling Markets with Network Effects**

This section introduces a model for describing the situations in markets characterized network effects. In our model, each customer of a network enjoys two kinds of values. The first one is the stand-alone utility (denoted by $S$) provided by the network infrastructures. The second one is the network value provided by all other customers using the networking technology to communicate with each other. We use a function $V(m)$ to denote the network value, where $m$ is the current network size. Since this study conducted the analysis in the monopoly setting, the network is equivalent to the market. Thus, the network size is used interchangeably to the market size from now on.

Function $V(m)$ can be estimated as follows: the network owner may survey the network subscribers about the value (in monetary units) obtained from using the network for communicating with other network members at various network sizes. Averaging their answers at each network size provides a rough picture of the function $V(m)$. Usually, function $V(m)$ is increasing with $m$ to reflect positive network effects of network sizes. The total value comprises the network value and stand-alone value.

While obtaining the values from using the network, every user must overcome a value threshold to participate in the network. The value threshold represents the cost that a user must overcome to use the network, such as the fee charged by network providers, the cost of purchasing computer hardware/software, the cost of learning and training, and the cost of switching from a network to one another. Because value thresholds can vary among users, in our model we sort the users in ascending order of their value thresholds, and denote the user with the $i$th-lowest value threshold as $C_i$.

For later analysis, this study uses a function $f(i)$ to represent the value thresholds of the users. That is, $f(i)$ is the value threshold of user $C_i$, where $i$ is an integer between one and $m$. Since we are numbering the users in ascending order of their value thresholds, function $f(i)$ must be an increasing function of the index $i$. Network owners may survey their users on how much the cost (in monetary units) they bear from using their networking technology. Sorting their answers provide a rough estimation of function $f(i)$.

Finally, this study defines net value (NV) as the difference between total value and value threshold for one user. For user $C_i$, the net value $NV(i)$ is $S + V(m) - f(i)$. Since the users are sorted in ascending order of their
value thresholds, a user with a larger index will obtain less net value than a user with a smaller index. This study further assumes that user C_i will use the network if and only if NV(i) ≥ 0. For ease of reference, this study lists the notations and describes how the model uses them.

m: the total number of users in a network  
S: the stand-alone value to a user  
V(m): the network value to a user  
C_i: the user with the ith-lowest value threshold  
f(i): the value threshold of user C_i

**Estimating the Potential Size of Markets with Network Effects**

The following section will find the maximal number of users a system provider can acquire given the value and threshold functions. Since the net value for a user decreases with the user index i, finding the potential size of the market is equivalent to finding the index of the (last) user whose net value is zero. This study names this user the boundary user.

That is, the value of m can be determined by setting the net value (NV) of the boundary user to zero. Therefore, we are solving the following equation:

\[
NV(m) = S + V(m) - f(m) = 0 \quad (1)
\]

The above equation can be rewritten as:

\[
S + V(m) = f(m) \quad (2)
\]

Note the left-hand side represents the total value to the boundary user and that the right-hand side represents the value threshold of the boundary user. Both total value and value threshold are functions of m, and we can plot their curves and solve equation (2) graphically. For the boundary user, the total value equals the value threshold and the net value is zero. Therefore, at the intersection of the curves we can find the solution for m as the potential market size, and denote this value as M.

Note that predecessors of C_M, whose indices are less than M, will have positive net values and stay in the network; but successors of C_M, whose indices greater than M, will have negative net values and will not join the network.
1. Three generic types of network effects

In general, there are three types of network effects, according to the function types of the network value.

**1) Accelerating network effect**

The function type for the network value is convex. The network value increases with \( m \), and at rates faster and faster as the network grows larger and larger. This type of network effect was used in the literature (Farrell & Saloner, 1985; Choi, 1994). This means that the marginal network value increases with the size of the network. Accelerating network effect describes the situation in which network effects are accumulating more and more momentum as the network grows.

An accelerating network effect can happen when a firm is deliberately building its initial base of users. For example, when Sony launched PlayStation, the company had developed its own video games for it. At the same time, Sony licensed independent companies to produce video games running on PlayStation, ensuring an adequate supply of complements (video games) for the main product (PlayStation). Furthermore, Sony established a Web site for users to share their experiences with PlayStation. All these strategies strengthen user fun obtained from PlayStation. More users using PlayStation stimulates the creation of a greater variety of video games and greater interaction frequency and depth on the Web site, utilizing the force of complementary network effects and helping strengthen the network effects and the demand for PlayStation.

**2) Stable network effect**

The function type for the network value from stable network effect is a straight line with a positive slope. This type of network effect was prevalently used in studies of network effects (Padmanabhan et al., 1997; Kristiansen, 1998; Baake & Boom, 2001; Chiang & Teng, 2003; Teng, Tseng, & Chiang, 2006). For stable network effect, the marginal network value is constant. Adding one more user to the network contributes a constant amount of value to each current user, independent of the size of the network. Stable network effect describes the common case of markets characterized by network effects.

**3) Decelerating network effect**

The function type for the network value in this case is concave, which was used in the model of Katz and Shapiro (1985). The network value still
increases with $M$, but at rates slower and slower as the network grows larger and larger. That is, the marginal network value decreases with the size of the network. Decelerating network effect describes the saturation phenomenon of network effects.

Decelerating network effect can happen as a result of many reasons: technical limitations, managerial diseconomies of scale of system providers, and congestions on the Internet. For example, as more and more users join a Web site community, they are in some sense competing for the limited capacity of the Internet. The consumers may experience more and more traffic jams on the Web. The network effects, therefore, are increasing at slower rates while the congestion occurs but not seriously.

2. Three generic types of markets

Given that consumers are not always identical in their value thresholds (Chiang & Teng, 2003; Tseng et al., 2007), this study innovatively identifies and defines three generic types of markets, according to the function types of user value thresholds, which in turn depend on the characteristics of the users and the characteristics of products or services offered by companies. Also remember that the users are indexed in ascending order of their value thresholds.

(1) Resistive market

The function type for user value thresholds is convex. That is, the value thresholds increase at faster rates as the user index becomes larger. In such case, the majority of prospective users have high value thresholds. A situation in which some users are ready for using the technology while a large proportion of users are not may be covered by the resistive-market model.

For example, LaTeX is a document-preparation system for high-quality typesetting. Its usage, however, requires advanced technical efforts. Consequently, it is easier for the communities of scientific and technical researchers to use LaTeX than for ordinary users. That is, only a small proportion of users have a lower value threshold to overcome to use LaTeX. Therefore, LaTeX faces a resistive market.

(2) Stable market

The function type for user-value thresholds is linear with a positive slope. In this situation, the user cost increases at a constant rate as the user index increases. User-value thresholds form a uniform distribution. Stable market describes the situation in which users demonstrate constant
heterogeneity in value thresholds as the network becomes larger.

(3) Receptive market

The function type for user-value thresholds is concave. That is, the value thresholds increase at slower rates as the user index becomes larger. In such case, the majority of prospective users have low value thresholds. Receptive market may describe the situation in which most users are ready to use the technology while only a small proportion of users are not.

For example, Microsoft Word is a desktop document-preparation tool. Its usage requires little technical effort for most prospective users, and it runs on the already popular Windows operating system. That is, the value thresholds increase at slower rates as the user index increases. Consequently, there is less heterogeneity in user-value thresholds for a majority of prospective users. Therefore, Microsoft Word faces a receptive market.

3. Finding potential network size

We innovatively labeled the three types of network effects, labeled the three market conditions, and then conceptually created the nine combinations, as listed in Table 1. Both network value and value threshold increase with \( m \), but at different rates. As noted above, at the intersection of the network value and value threshold function curves we may find the value of \( M \) as the potential market size.

### Table 1: Nine possible cases for markets with network effects

<table>
<thead>
<tr>
<th>Network Effect</th>
<th>Market Condition</th>
<th>Resistive (convex value threshold)</th>
<th>Stable (linear value threshold)</th>
<th>Receptive (concave value threshold)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerating (convex network value)</td>
<td>Case 1</td>
<td>Case 2</td>
<td>Case 3</td>
<td></td>
</tr>
<tr>
<td>Stable (linear network value)</td>
<td>Case 4</td>
<td>Case 5</td>
<td>Case 6</td>
<td></td>
</tr>
<tr>
<td>Decelerating (concave network value)</td>
<td>Case 7</td>
<td>Case 8</td>
<td>Case 9</td>
<td></td>
</tr>
</tbody>
</table>

Although there are as many as nine cases, we can group them into three categories, based on the function types of the network value and value threshold.
(1) **Category One: both the network value and value threshold have the same function types**

This category includes Case 1, Case 5, and Case 9, where the network value and value threshold are both linear functions, or are both concave functions, or are both convex functions. The potential market size depends on their exact function forms. Figure 1 depicts one example where both functions are concave. The value function is \( S + V(m) = 350 + \sqrt{m-1} \) and the value threshold function is \( f(m) = 10 \sqrt{m} + 2 \).

![Figure 1](image)

**Figure 1** The network value and value threshold have the same function type

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(2) **Category Two: the network value increases faster than the value threshold**

This includes Case 2, Case 3, and Case 6. Since the network value increases faster than the value threshold, the market size can be potentially large. Since the network value increases faster than the value threshold, the network value will exceed the value threshold, and never fall under the value threshold. Thus, once the network value exceeds the value threshold, the market will grow nearly unbounded. Figure 2 depicts one example where the value function is linear: \( S + V(m) = 300 + 1.5(m-1) \), and the
value threshold function $f(m)$ is concave: $f(m) = 60\sqrt{m} + 10$.

As shown in Figure 2, initially the value threshold is greater than total value and users will have negative net value. However, the system provider can compensate the users (so they have positive net value) to build up the market. When there is a critical mass of users to offer more network values, the total value will rise beyond value threshold and there will be a chance for market growth.

Therefore, the intersection of the curves in Figure 2 represents the size of the critical mass, which the system provider has to accumulate to enact positive feedback from users. After this tipping point, network effects will exhibit the power and the market will grow drastically.

![Figure 2](image.png)

**Figure 2** The network value function increases at a rate faster than the value threshold function

(3) **Category Three: the network value increases slower than the value threshold**

This includes Case 4, Case 7, and Case 8. Since the network value increases slower than the value threshold, the market size is inherently small. Since the network value increases slower than the value threshold, the network value will fall under the value threshold, and never exceed the value threshold. Thus, once the network value falls under the value threshold, the market growth will stop suddenly. Figure 3 depicts one
example where the value function is concave: \( S + V(m) = 1200 + \sqrt{m-1} \), and the value threshold function \( f(m) \) is linear: \( f(m) = 1.5m + 2 \).

![Network value and value threshold](image)

**Figure 3** The network value function increases at a rate slower than the value threshold function

**Conclusion**

This study found that (1) receptive and stable markets with accelerating network effect will result in a very large market size; (2) receptive markets with stable network effect will also result in a very large market size; (3) stable and resistive markets with decelerating network effect will result in a constrained market size; and (4) resistive markets with stable network effect will result in a constrained market size.

In this paper, we provided a theoretical framework for estimating the potential size of the market characterized by network effects. Two critical factors are found to be the underlying forces: the network value and value threshold. Our model can be used to estimate the potential size of the market by exploring the various situations of the network values and value.

For both challengers and incumbents, our work suggests two ways to increase the potential market size: by increasing the network value or by decreasing the value threshold.

From the above analysis, we see that in the context of network effects, the market size is determined by two opposing factors: the network value.
provided by the network, and the value threshold of a user to enter the network. Three basic prototypes are proposed for modeling the network value: accelerating network effects, stable network effects, and decelerating network effects. And three basic prototypes are proposed for the value threshold: resistive market, stable market, and receptive market.

When an enterprise is going to introduce new products or services characterized by network effects, it can utilize the methodology proposed in this study to estimate the potential attractiveness or difficulties of the markets. Examples are consumer electronics such as the new-generation DVD players (HD-DVD v.s. Blue-ray DVD), telecommunication devices such as 3G-beyond cell phones, and the infomediary business models (Tseng & Chen, 2005) of electronic commerce such as advertisement-brokerage services. In addition, our methodology is also applicable to traditional industries characterized by network effects. Examples are banking and airline industries (Shy, 2001).

From these prototypes, nine market situations are derived for estimating the potential market size. These, however, are only generic patterns. For applications in the real world, there should be proper modifications and specific considerations. Examples are given below.

First, for a generic function type, there can be many (actually, infinite) variations. For example, even as simple as linear functions, they may differ in their slopes and intercepts. The parameters for these functions, however, can be estimated using qualitative or quantitative psychometric tools such as in-depth interviews or questionnaires.

Second, function forms of network value or value threshold may change with M (the market size). For example, network value may initially start as a convex function when M is small, may become a linear function when M grows larger, and may become concave eventually, reflecting the fact that the marginal network value decreases as more and more users join the network.

Third, the functions used for modeling network values and value thresholds may change with time. For example, when a new system is first introduced, users may have very different value thresholds, since some of them are technical users and others are naïve users, which can be modeled as a convex function (resistive market). As time passes, however, the users may learn from each other, and the value thresholds of the users will be more similar. Then the value thresholds of the users can be modeled as a linear function with a small positive slope or a convex function.

Fourth, the network value and value threshold functions may differ for different system providers, depending on their system infrastructures, operation efficiencies, managerial skills, and so on. Therefore, the estimation should be performed for each system provider to measure the potential market share that may be achieved.
The prevalence of high-tech products and services has brought abundant research topics related to network effects, which can be classified into two categories: theoretical and empirical. For theoretical research, more theoretical analyses can be done to enrich and enhance our model to make it more precise and practical. Such research would provide more insights into the dynamics of industrial competition in the context of network effects.

This study addresses market potential in the contexts of positive network effect, while negative network effects such as congestion effect (Westland, 1992) may also occur, demonstrating one limitation for this study. Future studies may extend this model to include negative network effects as well as positive network effects as the network goes into a mature stage.

This study aims to provide theoretical directive guidance for network owners and thus does not comprehensively address the measurement issues, comprising one limitation for this study. For empirical research, researchers can find evidence to verify the models and arguments offered by this paper. Empirical research in the literature of network effects is still lacking. Therefore, practical evidence would be valuable in making the theories of network effects more solid and complete.

One may notice that a market may belong to one of three types included in this study, but belong to another type due to time, technological changes, or social changes. According to results of this study, market type change can trigger change in potential market size. Future studies addressing this issue can be welcomed in disciplines of e-commerce and technology management.

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