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# New Industry Formation, Inverse Demand Curves and the Rewiring of Networks

by

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## Abstract

This paper combines the concepts of inverse demand curves and small world networks to present a conceptual framework of industry formation and the rewiring of networks. Using these concepts and descriptive data from a number of industries, the paper argues that some industries that display strong network effects can be represented with inverse demand curves and in some of these inverse demand curves, there are multiple local maximums, which the paper calls "bumps," where a critical mass of users must be created in each bump. The existence of these bumps reflects the existence of sub-populations of users, particularly in industries that display direct network effects. Initially these sub-populations represent fragmented networks of users that are served by fragmented networks of firms where connected networks of both firms and users later emerge.

## 1. Introduction

This paper links two seemingly unrelated and insufficiently answered questions. First, how do new industries emerge and their associated products diffuse when there are strong network effects? For products in which there is zero utility in a network of zero size or there are immediate and large external benefits to the expansion of very small networks, we can represent their demand in terms of an inverse demand curve (Rohlfs, 2001; Economides and Himmelberg, 1995). According to Rohlfs (1974) seminal paper and subsequent research on network effects, a user's willingness to pay is a function of quantity in an inverse demand curve (as opposed to visa versa in a traditional demand curve) where a critical mass of users must be created before growth will occur (Rohlfs, 2001; Economides and Himmelberg, 1995). But how does a critical mass of users emerge, do they emerge in a single population or in multiple sub-populations, and if they emerge in multiple sub-populations are these sub-populations later connected and if so how? For example, why did someone buy the first telephone, did fragmented sub-populations initially emerge, and if so how did they later become connected?

Second, how does the rewiring of networks occur? Scholars have applied network theory to firms (Kogut, 2000; Dyer and Nobeoka, 2000), individuals (Burt, 1997; Coleman, 1990), and physical phenomenon (Strogatz, 2003) and most connected networks appear to display small-world characteristics of short path length and high clustering (Milgram, 1967, Uzzi, 1996; Kogut and Walker, 2001; Davis et al, 2003; Watts and Strogatz, 1998). Networks with these characteristics appear to be most resilient to abrupt external shocks (Nishiguchi and Beaudet, 1998). But where do these small world networks come from, i.e., how does rewiring occur? Do these small-world networks come from fragmented networks like the ones referred to in the last paragraph or from ordered ones that are emphasized elsewhere (Watts, 2003; Baum et al, 2003)?

This paper combines the concepts of inverse demand curves with small-world network theory to present a conceptual framework for addressing these questions. The framework builds on existing theoretical work on inverse demand curves (Rohlfs, 1974, 2001; Economides and Himmelberg, 1995) and uses descriptive data on a number of industries to show that 1.) some industries can be represented with inverse demand curves and these industries represent a subset of those industries that display network effects; and 2.) some of these inverse demand curves contain multiple local maximums, which the paper calls "bumps," where a critical mass of users must be created in each bump. Drawing on small world network theory (Watts, 2003), the framework shows how 3.) the existence of these multiple bumps reflect the existence of sub-populations within a potential population of users, particularly in industries that display direct network effects; 4.) these sub-populations initially represent fragmented networks of users that are served by fragmented networks of firms; 5.) in industries that display indirect network effects, the existence of these multiple bumps also reflect the existence of different applications that in some cases may represent different sub-populations; 6.) these applications are initially served by fragmented networks of firms; and 7.) the interaction between firms and users may lead overtime to the emergence of connected networks of both firms and users (i.e., rewiring). Although some research has addressed the first two items (Rohlfs, 1974, 2001; Economides and Himmelberg, 1995), as far as we know no one has combined items 3-7 with items 1 and 2.

This paper first discusses the existing literature on inverse demand curves and on small-world networks that are relevant to the proposed framework. Second, it applies the framework to industries that can be represented by inverse demand curves and contrasts these industries with those that cannot be represented by such curves. It does this for products that display direct network effects and then for products that display indirect (complementary) network effects. It focuses on U.S. industries since the institutional characteristics (Kogut, 2000) of the U.S. market (e.g., low regulatory barriers to entry) have enabled a larger diversity of firms to enter the markets and thus more easily find the sub-populations that are represented by the multiple bumps in an inverse demand curve.

2. Key concepts/proposed model

Inverse demand curves (See Figure 1) plot price (willingness to pay) as a function of quantity (as opposed to quantity as a function of price in a traditional demand curve). The left side of the curve reflects the users' greater willingness to pay as the number of users increase (Rohlfs, 1974, 2001) and this greater willingness to pay reflects the existence of network externalities (Arthur, 1994; Katz and Shapiro, 1985; Katz and Shapiro, 1986; Katz and Shapiro, 1994). An inverse demand curve exists for products in which there is zero utility in a network of zero size or there are immediate and large external benefits to the expansion of very small networks. Some products that exhibit direct network effects (e.g., telephone) satisfy the first criteria while some products that exhibit either direct or indirect network effects (e.g., personal computer) satisfy the second criteria (Economides and Himmelberg, 1995).

It should be noted that the left side of the curve in Figure 1 is unstable and the number of users will return to zero unless a critical mass of users is created. This occurred with AT&T's picture phone service (described in the results section), digital audio tape, digital compact cassette, mini-discs, high-definition television, (Rohlfs, 2001; Grindley, 1996), and AM stereo (Shapiro and Varian, 1999). The critical mass of users depends on the price of the service and is defined as the number of users on the left side of the inverse demand curve that correspond to each price. Since the left side of the curve is unstable, the achievement of a critical mass of users causes the number of users to rise to the level corresponding to the right hand side of the curve (See Figure 2) (Rohlfs, 2001; Economides and Himmelberg, 1995).

Place Figures 1 and 2 about here

Another way to contrast inverse and traditional demand curves is to show how the supply curves interact differently with inverse and traditional demand curves. Although demand curves also shift over time, particularly through income effects, technological change and other factors, including institutional changes generally cause supply curves to move much more than demand curves overtime in the manner shown in Figure 3 (Samuelson and Nordhaus, 2005). The key difference between the traditional and inverse demand curves is that price-insensitive consumers only exist when a traditional demand curve is applicable. When an inverse demand curve is applicable, the willingness to pay is a function of quantity and thus price insensitive consumers do not exist until a critical mass of users emerges. This may delay the start of consumption until technological improvements move the supply curve farther to the right than would be needed with a traditional demand curve (Rohlfs, 2001).

Focusing on the concept of an inverse demand curve, some research suggests that there are multiple "bumps" (i.e., local maximums) in some inverse demand curves (See Figure 4) and thus a critical mass of users must be created in each bump of the inverse demand curve. Each bump represents a sub-population of users that can also be thought of as a fragmented network of users within the entire population of potential users, particularly in cases where direct network effects apply. A mathematical appendix in Rohlfs (2001) shows the figure of an inverse demand curve that has multiple bumps and the cases in the main part of this book *imply* that multiple bumps exist in the demand curves for many industries, albeit Rohlfs does not actually reference this figure in the cases. Shurmer's (1993) quantitative analysis of network externalities in the packaged PC (personal computer) software market concludes there were multiple sub-populations of users that caused multiple PC standards to emerge in the late 1970s. Suarez's (2005) quantitative analysis of South American mobile phone service providers concluded that their adoption of standards reflected different sub-populations of final users where network effects worked on the individual sub-populations and not the total population of users.

Place Figures 3 and 4 about here

These different sub-populations, the concept of multiple bumps in an inverse demand curve, and fragmented networks are consistent with some descriptions of how small world networks emerge and thus how rewiring occurs. Watts' (2003) uses the variable alpha to characterize the rules of interaction between individuals. When individuals only interact with those they know, alpha is zero; when the interactions are random, alpha is infinity. Low values of alpha lead to so-called "caveman worlds" that sound similar to the sub-populations and fragmented networks that are described in the last paragraph. In these caveman worlds, individuals only interact with a small number of people within a sub-population (Watts uses the term cluster) and thus there are short path lengths within these small clusters (i.e., sub-populations). Increasing alpha causes individuals to interact with people outside their cluster (i.e., sub-populations), thus causing the path length to increase until all the individuals in a population are connected in one network (i.e., one population). Further increases in alpha cause the path length (and later the clustering coefficient) to fall eventually leading to a so-called Solaria world where the interactions between people are random. The process by which the fragmented networks of the caveman world evolve into a connected (i.e., small-world) network of Solaria can be interpreted as one method of rewiring.

This change from the fragmented networks of the caveman world to a connected network of Solaria also impacts on firm competition and firm networks. The initially fragmented networks provide opportunities for both users and firms to fill these structural holes (Burt, 1997) and thus obtain "Burt rents" from connecting these non-redundant ties (Kogut, 2000). Firms must physically connect the fragmented networks and the physical connections between the fragmented networks might be interpreted as a dominant design (Anderson and Tushman, 1990). Connecting the fragmented networks also reflects a change of competition from "within bumps" to "between bumps." Although some firms may continue to successfully compete in specific bumps and the sub-populations they represent (i.e., a niche strategy), the largest firms will connect the bumps and the fragmented networks they represent. The largest firms may do this through internal growth, acquisitions, or alliances. In the case of alliances, a network of firms may emerge that reflect the institutional arrangements and the inherent characteristics of the technologies that populate the industry (Kogut, 2000).

One quantitative study of firm rewiring (Baum et al, 2003) supports the notion that fragmented networks are the source of small-world networks. They found that the initial network of Canadian investment banks in 1952 was highly fragmented. Perhaps because of this, chance partnering of firms from different networks (Baum uses the term cliques) and “insurgent” partnering by peripheral firms had a much greater impact on the rewiring of the network than “control” partnering by core firms.

## 3. Methodology

This paper uses published information to identify the direct and indirect network effects, the bumps in the inverse demand curves, and the process of connecting these bumps for both firms and individuals in a selected number of industries. The published information includes academic literature from the business, economic, and other social sciences and historical accounts of the industries. More than five independent accounts were considered for each industry and triangulation was used to interpret these different accounts.

It is important to recognize that we can only infer these bumps from the diffusion of the products. For example, these bumps are much less visible in the descriptions for countries that only implemented public services to handle the telephone, radio, and television since the services were implemented on a large and uniform scale. These centralized implementations prevented a diversity of firms from emerging and finding specific sub-populations and applications within the entire population of potential users and applications.

## 4. Results

Tables 1 and 2 summarize the bumps in the inverse demand curve for several industries that can be represented by such a curve. Table 1 summarizes these bumps for industries that display direct network effects while Table 2 summarizes these bumps for those that display indirect network effects. A critical mass of users must be created in each bump before growth can occur in the bump. The order of bumps listed in the tables corresponds to the order of bumps (from left to right) in an inverse demand curve (See Figure 4) where the bumps in the left hand represent a greater willingness of users to pay than the ones in the right hand side of the figure.

Place Tables 1 and 2 about here

4.1 Direct Network Effects

Many but not all products that display direct network effects have no value when the network size is zero. For example, the first telegraph provided value to users and would have continued to provide users with value even if the number of users or telegraph offices had not increased. On the other hand the telephone, radio (pre-commercial era), facsimile, and Internet mail did not provide value to users until there was a critical mass of them. As shall be described below, the manner in which these products diffused suggests that the demand for them can be represented with an inverse demand curve where there were multiple bumps in the demand curve. These bumps represent different sub-populations of users and a critical mass of users had to be created in each bump/sub-population. Achieving a critical mass of users in these bumps initially resulted in the emergence of fragmented networks that sound similar to Watts' (2003) caveman world. Connecting these fragmented networks into one large network of users produces a network that sounds similar to Watt's (2003) Solaria.

4.1.1. Telephones

Bell Telephone and Western Union's telephone subsidiary (American Speaking Telephone) began leasing telephones in 1877 in the U.S. Although they managed to lease more than 3000 phones and lines connecting each pair of phones to stock brokers, newspaper offices, hotels, railways, and other large users of telegraph services (Huurdeman, 2003; Coon, 1971), it quickly became apparent that connecting phones to a switching center would provide lower costs and provide greater benefits to users. Both began to begin franchising local operating companies in major cities beginning in February 1878. After Bell Telephone's patent infringement suit caused Western Union to exit the business and sell its network of 56,000 phones to Bell Telephone in 1879 (Brock, 1981), Bell Telephone, which was now called the American Bell Company, basically had a monopoly until its patents expired in 1894 (Brock, 1981; Rohlfs, 2001).

The expiration of Bell's patents led to the start of other commercial services in cities and of "mutual systems" and "farmer lines" in rural areas (Brock, 1981). The other commercial services targeted lower income groups many of which displayed little interest in communicating with higher income groups (Mueller, 1997, Table 7-1). Merchants and farmers in rural areas implemented these "mutual companies" and "farmer lines" using their own capital and there were more than 6000 of them by 1902 (Fischer, 1987). Just in Southeastern Iowa, 222 mutual companies were started between 1900 and 1917 or more than eight times the number of commercial companies (Barnet and Carroll, 1987). The farmer lines often used fences as wires, did not include switchboards, and typically had less than 25 subscribers (Fischer, 1987).

This interpretation suggests that the demand curve for telephone services can be represented by many narrow, tall bumps and a smaller number of small, wide bumps where a critical mass of users had to be created in each bump. The narrow, tall bumps represented the intra-firm systems that were used by stock brokers, newspapers, and railways and the small farmer lines. Mutual companies and commercial services represented wider bumps. Furthermore, the way in which the intra-firm systems were connected into city-wide commercial services suggests that the narrow, tall bumps were also inside some of the small, wide bumps that represented the city wide-commercial services.

The diffusion of city-wide and later long-distance commercial telephone services also reflected the emergence of networks (i.e., rewiring) that connected the sub-populations. Using Watts (2003) terminology, the early telephone represented a caveman world where individuals could primarily communicate only with those people whom their superiors thought they should be communicating with (intra-firm applications) or with people in their own upper social class (early public systems). As the use of commercial telephone services spread, individuals began to converse with a broader range of people over the telephone thus starting the move towards the Solaria world of today where telemarketers and other people randomly bombard us with sales pitches and surveys (Collins, 1979).

The introductions of public telephone services in various cities and rural areas can also be modeled using an inverse demand curve where each bump represents a single city or rural area. The tallest and widest bumps represent public networks in large cities while the smaller and narrower bumps represent smaller cities and rural areas. Although the telephone diffused in cities before rural area in all countries, the success of the mutual companies and farmer lines in the rural areas, which did not emerge in most of the "centrally" controlled European countries, caused the diffusion of phones in rural areas to exceed that of urban areas in the U.S. by 1920 and the diffusion in the U.S. to exceed that of most European countries (Fischer and Carroll, 1988; Brock, 1981).

As these systems diffused in urban and rural areas, competition began to change from competition within bumps (i.e., local) to competition between bumps (i.e., long-distance and international). Firms began connecting these fragmented networks through alliances and acquisitions. Bell Telephone used its scale and network effects to make acquisitions and alliances that enabled its users to have more access to long-distance services than the users of other services. Bell's increasing market share led to the Willis-Graham Act of 1921 that made Bell a regulated monopoly and reinforced Bell's position at the apex of a network of service providers and equipment suppliers in the U.S. telephone industry (Mueller, 1997; Brock, 1981).

#### 4.1.2 Radio and Mobile Phone

First offered by Marconi, radio was initially introduced as a form of wireless telegraph in the early 1900s. Marconi leased his equipment to firms such as shipping companies that for physical reasons could not communicate with their ships using wireline telegraphs. Improvements in transmitters and receivers enabled wireless voice communication and led to the emergence of a second set of users in the early 1910s. So-called "radio heads" began using ham radio to converse semi-anonymously over long distances often using the same frequencies as the shipping companies. This radio interference came to national attention with the sinking of the Titanic and led to the regulation of radio spectrum in the Radio Act of 1912 (Lewis, 1991; Spar, 2001).

The explosive growth in radio began in 1920 when a Westinghouse employee, Frank

Conrad, began transmitting radio concerts using income from advertisements. The radio heads' stubborn refusal to comply with the regulation of radio spectrum provided an enthusiastic audience for the music programs and the sales of radios and applications for radio licenses grew quickly (Sawhney and Lee, in press). Reductions in the cost of vacuum tubes and radios also drove this boom and the use of private broadcasting systems for police and fire departments and taxi services beginning in the 1920s (Garrard, 1998; Lewis, 1991; Sobel, 1986).

This interpretation suggests that the demand for radio services can be represented by at least four large bumps. The first and fourth bumps each consist of many smaller bumps where each of the small bumps represent a firm that has either leased Marconi's wireless telegraph equipment (first large bump) or implemented a private broadcasting system (the fourth large bump). The second bump of ham radio users may also have consisted of many smaller bumps where each small bump may have represented different geographical areas or different topics for discussion among the ham radio operators. In the third bump, the demand for commercial radio programs involved indirect network effects, which we discuss in a separate section below.

The diffusion of commercial radio and later mobile phones also eventually led to the emergence of networks that connected the separate sub-populations and their fragmented networks (i.e., rewiring). Using Watts (2003) terminology, the users of Marconi's early equipment, private mobile radio, and to a lesser extent ham radios lived in a caveman world where they could primarily communicate only with a small numbers of people in a specific sub-population. The diffusion of commercial radio in the 1920s caused everyone within a certain distance from radio transmitters to gain access to radio programs and in a narrow sense become connected to a Solaria world where individuals are bombarded with advertisements and other random messages (Douglas, 1987). The long slow diffusion of private mobile radio systems in the second half of the 20th century and the more rapid diffusion of mobile phones in the late 1990s changed this from a one-way to a two-way (Garrard, 1998) Solaria network where we can be interrupted and our privacy invaded by almost anyone.

The diffusion of private mobile radio and mobile phones and in particular the emergence of standards, which drove this diffusion, also caused competition to change from "within bumps" to "between bumps." Although standards were slow to emerge for private mobile radio (Garrard, 1998), national and later global standards have emerged for mobile phone systems and their emergence have eliminated the fragmented networks that used to protect providers of proprietary private mobile radio systems and domestic providers of telecommunication equipment. For example, the emergence of global standards such as GSM (Global System Mobile) and CDMA (code division multiple access) caused a small number of firms such as Nokia, Ericsson, and Qualcomm to connect people at the global level and to occupy central positions within the standard setting organizations for GSM and CDMA and thus the overall firm networks in the industry (Funk, 2002).

### 4.1.3 Picture Phone

AT&T introduced a two-video communication service in Chicago called the Picturephone Service in the early 1970s. About 200 people leased the equipment for $86.50 a month and shortly thereafter AT&T discontinued the service. In a post mortem analysis, the most common complaint given in interviews was there was no one to talk to. Apparently no two subscribers knew each other. AT&T did not offer volume discounts and did not attempt to sell the system to friends of those that did purchase the system (Rohlfs, 2001).

This failure highlights the importance of understanding the multiple bumps that probably exist in the inverse demand curve for a picture-phone type service. Assuming there are people who would like to use such a service, they would probably only like to initially use the service to communicate with a very small number of their friends and relatives (i.e., those people in their sub-population that is represented by one bump in the inverse demand curve). In this sense, the demand curve for picture phone services probably resembled that for the first telephones in the late 19th century, which was discussed above. Thus, AT&T should have marketed the service to groups of users instead of individuals and provided volume discounts (Rohlfs, 2001). These groups could have included intra-firm networks and something similar to rural cooperatives where small groups of people could jointly purchase the service and receive a volume discount.

4.1.4 Facsimile

Although the first facsimile was built in 1843 and the first service was offered in 1865, the facsimile did not begin diffusing to any great extent until the 1980s. For most of the 20th century, firms used facsimile machines for the *intra*-firm exchange of pictures and other information that could not be easily transmitted via telex; the telex was the 20th century version of the telegraph. This information included pictures for newspapers, weather maps for newspapers and other firms, fingerprints and mug shots for police, and internal communications within railroads and other large organizations (Peterson, 1995; Costigan, 1971). Between 1945 and 1970, about 50,000 machines were sold in Japan (by one firm) (Business Week, 1970) and about 15,000 in the U.S. where machines from different manufacturers used different standards and thus could not communicate with each other (Peterson, 1995; Rohlfs, 2001).

The use of facsimiles for *inter*-firm communication began to increase in the 1970s and 1980s as standards were agreed upon, restrictions on connecting third-party equipment to phones were eliminated, and prices for the machines fell. Western European telecommunication providers agreed on standards in 1968 for so-called Group 1 machines and these standards were updated for Group 2 and Group 3 machines in 1976 and 1980 respectively with the participation of Japanese and U.S. firms. Restrictions on connecting third-party equipment to phones were loosened first in Japan in the 1960s, Europe in the 1970s, and the U.S. in the 1980s (Brock, 1981; Peterson, 1995; Rohlfs, 2001). The number of firms offering facsimile transmission services also began to grow in the U.S. in the late 1960s and the number just in Manhattan had exceeded 60 by 1989 (Baum and Korn, 1995). Consumers also began to purchase machines in the 1980s (Peterson, 1995; Rohlfs, 2001).

Like the case of the early telephone, this interpretation suggests that the demand for facsimile services can be represented by many narrow and tall bumps and a fewer number of small, wide bumps. The narrow and tall bumps represent intra-firm communication and the small, wide bumps represent inter-firm communication, facsimile transmission services, and consumer purchases of facsimiles.

The adoption of facsimiles by both consumers and businesses in the 1980s also reflected the emergence of networks (i.e., rewiring) that connected the separate populations representing the multiple bumps in the inverse demand curve. The emergence of standards enabled facsimiles that were from different manufacturers to communicate with each other (Peterson, 1995). Although it can be said that the emergence of these standards eliminated the “caveman” world (Watts, 2003) that existed in the early days of facsimile usage, the facsimile probably never produced a form of Solaria like commercial radio and the telephone have done.

On the other hand, the emergence of standards did reflect a change in competition from “between” to “within” bumps. For example, Japanese firms that supported open standards moved faster to connect the bumps than did U.S. firms that focused on proprietary systems and their customers that used them. Their support of open standards and the success this brought also reflected the fact that Japanese firms began to occupy central positions within the network of facsimile manufacturers including central positions within the standard setting organizations (Rohlfs, 2001; Peterson, 1995).

4.1.5 The Internet and Electronic Mail

The U.S. government funded the development of the Internet in the late 1960s and early 1970s. Computer science departments and research institutes were the first organizations to implement these packet-based systems in which mail was the largest application; they used it for internal communication and communication with their colleagues at other universities. Commercial packet services emerged in the mid-1970s that supported time sharing of mainframe and mini-computers. Universities began to expand access to the Internet to other university departments in the late 1970s. Commercial gateways that connected different packet services emerged in the mid-1980s as the diffusion of PCs accelerated. These commercial gateways enabled both consumers and business users to access both mail and one-way information services (Abbate, 1999; Mowery and Simcoe, 2002; Rohlfs, 2001).

This interpretation suggests that the demand for the initial Internet services can be represented by at least four bumps in the inverse demand curve: e-mail for computer science departments, time-sharing, e-mail for other university departments, and commercial gateway and e-mail users. Each bump represented a sub-population of the potential Internet users where the members of each sub-population were primarily interested in communication within their sub-population. Like the early telephone, the early Internet represented a caveman world (Watts, 2003) where individuals could communicate only with those people that also inhabited the rarified world of the Internet.

The diffusion of Internet mail services led to the emergence of networks (i.e., rewiring) that connected these sub-populations. For example, the emergence of commercial gateways connected fragmented networks and brought Internet mail to the masses. As the Internet diffused, individuals began to exchange mail with a broader range of people thus starting the move towards the Solaria world of today where we are bombarded with spam and viruses. A change from competition “within bumps” to “between bumps” also accompanied the diffusion of Internet mail where there were mergers, alliances, and other linkages between packet service and gateway service providers (Abbate, 1999; Rohlfs, 2001).

4.2 Indirect Network Effects

This section considers industries for whose products display indirect network effects. While direct network effects cause increases in the number of users to *directly* increase the value of the product, indirect network effects cause increases in the number of users to indirectly increase the value of the product through their impact on the availability of complementary products such as hardware, services, and content/software. However, not all products that display indirect network effects can be represented by an inverse demand curve. For example, although video cassette recorders (VCRs) exhibit network effects, the existence of time shifted recording meant that the first users of VCRs were able to obtain value from them before software (recorded movies) became available. On the other hand, radio and television (TV) broadcasting services, personal computers, and the mobile Internet can be represented by an inverse demand curve because a critical mass of hardware, services, content/software, and users that were needed before users were able to obtain value from them (See Table 2).

The inverse demand curve for products that display indirect network effects is slightly different than the one for products that display direct network effects. Whereas each bump in the inverse demand curve for products that display direct network effects corresponds to a different sub-population of users, each bump in the inverse demand curve for products that display indirect network effects corresponds to a different application (See Table 2) that only in some cases may correspond to a specific sub-population. The historical accounts of the industries discussed below suggest that many users initially demanded multiple applications and thus there is a weaker correspondence between individual bumps and individual sub-populations than with the products that display direct network effects.

On the other hand, just as in the cases described above for direct network effects, a critical mass of users and complementary products must be created in each bump (i.e., application) in the inverse demand curve for the cases discussed in this section. The actions of both firms provide content, software, services and in some cases hardware for specific bumps (i.e., application) impact on the creation of these critical masses (See

Table 2). Also as in the cases of the industries that display direct network effects, there is a change in competition from competition “within bumps” to competition “between bumps.” In particular, there is an emergence of firms that integrate the applications into a single service. These firms do this because there are users that want integrated services and also because there are economies of scale that can be achieved with the integrated services. And in doing so, the largest and most successful firms have placed themselves at the centers of the firm networks in the industries.

### 4.2.1 Broadcasting

Following the success of Westinghouse’s music program, many firms began broadcasting musical programs in the 1920s. And as the number of radios diffused, broadcasters began offering other programs such as comedies (initially the most successful), dramas, educational talk, and finally news shows in the late 1930s (Lewis, 1991; Sobel, 1986).

This interpretation suggests there were multiple bumps in the inverse demand curve for radio broadcasting where each bump represents a different type of program. Although not to the extent found in the industries discussed in the section on direct network effects, different people listened to different programs and thus purchased radios for different reasons. Furthermore, advertisers can be considered a second kind of customer for broadcasters (Doyle, 2000) and they initially sponsored specific programs (Sobel, 1986; Lewis, 1991). Thus, to some extent we can associate specific programs and the firms that created and sponsored them with specific bumps in the demand curve where each bump required a critical mass of listeners, programs, and sponsors before growth could occur.

Radio broadcasters moved quickly to integrate these bumps, offer a full-line of programs at the national level, and create a network of firms (i.e., rewiring) that supported a full-line of programs. NBC, which was started by RCA, moved the fastest and was followed by CBS in the late 1920s and ABC, which was off spun off from NBC in 1940. NBC created studios, hired announcers, musicians, and engineers, and delivered these “national” programs to their affiliates via telephone lines (Sobel, 1986; Lewis, 1991). Musicians were particularly important since record companies and musician’s unions initially opposed the playing of records on radio programs (Inglis, 1990). The use of affiliates enabled NBC to develop economies of scale much more quickly than if they attempted to use their own capital to form local broadcasting stations. It also enabled the affiliates to offer both local advertisements and national ones from their parent companies (Doyle, 2000).

Similar things occurred with television although the shape of the inverse demand curve and the integration of the bumps emerged much faster with television than with radio. The success of radio broadcasting caused the leading radio broadcasters to use their political power to quickly acquire television licenses and thus in terms of the proposed model, the firm networks for television broadcasters can be seen as an extension of firms networks for radio broadcasters. Television broadcasters used the same business model (advertising) as radio broadcasters albeit they focused on different types of programming such as sports and news. Like radio, advertisers that sponsored a single program were also very common and NBC, CBS, and ABC developed a full-line of programs along with a network of advertisers, affiliates, newscasters, reporters, programming experts, actors, actresses, sporting event promoters, and news wire services (Sobel, 1986). They also did this at the national level with affiliates that offered both local and national advertisements (Doyle, 2000) where we can draw an inverse demand curve at the national level that represents the demand for television programs in different cities or regions.

4.2.2 Personal Computers

It is generally recognized that the Altair, which was released in January 1975, can be defined as the first personal computer (PC). So-called “hackers” or “hobbyists” were the major users of the Altair and became the main providers of software and other add-ons. With the release of the Commodore PET, Tandy TRS-80 Model I, and the Apple II in 1977, the applications expanded to game and education software. Software for spreadsheets and word processing had appeared by 1979 and they had become the leading applications for PCs by the early 1980s (Campbell-Kelly, 2003; Langlois, 1993).

This interpretation suggests that the initial demand for PCs can be represented by multiple bumps where each bump represents a different application. The hackers played a similar role to the one played by radio heads (in the 1910s) in that they were happy to tinker with PCs and write their own software while the other applications involved specific types of software packages, which to some extent appealed to a different sub-population of potential PC users. For example, there were sub-populations of users that played games, used educational software, and used business software such as word processing and spreadsheet software (Shurmer, 1993) where a critical mass of users was created in each application.

Firms, particularly software providers initially focused on a single bump. Software providers initially restricted themselves to a single application/bump such as games, education, and later business applications. Hardware providers such as Apple and to even a greater extent IBM connected these bumps into an integrated platform that was modular and easily expandable where improvements in hardware expanded the number of applications. These platforms enabled both Apple and IBM to occupy central positions for many years in the network of firms in the PC industry (Langlois, 1993)

However, it was Microsoft that actually integrated the applications into a seamless system and thus enabled it to become the center of the PC firm network (i.e., rewiring). Microsoft provided the operating system for the IBM PC and it used its control of this operating system to enter and dominate the word processing, spreadsheet and presentation (e.g., Power Point) software markets. With the introduction of a graphical user interface called Windows, it provided seamless integration between these applications and it is now at the center of the network of PC software and hardware providers (Campbell-Kelly, 2003).

### 4.2.3 World Wide Web

The beginning of the World Wide Web, which is now known as the Internet, is usually traced to the creation of HTML (Hyper Text Markup Language) and URLs (Universal Resource Locators) by Tim Berners-Lee in 1990. His creation of HTML and URLs made it easier for research organizations, which were the largest users of the Internet until the mid-1990s, to post and access information on the Internet (Segaller, 1998; Mowery and Simcoe, 2003). The invention and diffusion of the browser in 1993 further facilitated the posting and accessing of information on the Internet and accelerated the change in the Internet from a broadcasting (point-to many) to the current paradigm (many-to many). The commercialization of the Internet in 1993 and the U.S.

venture capital system facilitated the entry of many firms and thus the appearance of applications such as pornography, employment sites, and auctions (Kenney, 2003; Mowery and Simcoe, 2002).

This interpretation suggests that the demand for the World Wide Web can be represented by several bumps in the inverse demand curve where each bump represents a different form of information or content sites. The leading role of university and other research sites until the mid-1990s suggests that these applications probably represented the tallest bump in the inverse demand curve where university professors and graduate students represent one sub-population within the population of current Internet users. Although the other early applications and the order of them are difficult to specify, other bumps include pornography, employment sites, and auctions, which also involve sub-populations and some involve large indirect network effects where a critical mass of users had to be created in each of them. For example, the initial users of employment sites such as Monster.com were professionals looking for national and international as opposed to local jobs and the number of employers that advertise on such a site depends on the number of job seekers that visit the site. Similarly, the numbers of people that attempt to sell products on an auction site depend on the number of people visiting the site and making bids for products (Evans and Wurster, 2000; Kenney, 2003).

Many firms are competing to connect these bumps and thus provide integrated services and technologies where this competition will is impacting on the structure of firm networks (i.e., rewiring). Portals, including Internet service providers, organize information for users, and search engines help them find specific information on more general sites (Kenney, 2003). Technology suppliers are attempting to connect these bumps in a less visible way. For example, not only has Microsoft connected the World

Wide Web with other applications by bundling its browser with Microsoft Word and Power Point, it is also attempting to provide integrated identification and payment systems. Google is attempting to integrate its search technology in all portals and sites. These technologies and their attempts to integrate the different bumps in the inverse demand curve are impacting on firm networks and enabling firms such as Microsoft and Google to occupy central positions in the network of firms that provide technologies, content, and services for and on the Internet (Guevin, 2005; Mills, 2005).

4.2.4 Mobile Internet

Although the name mobile Internet suggests that it is a combination of the mobile phone and Internet, a number of unique entertainment applications have driven its growth. Ringing tones, screen savers, and games have seen the largest growth in usage followed by news and other information services. In countries such as Japan that have seen the fastest growth in mobile Internet usage, third parties provide most of the content and service providers have facilitated their entry with open portals and generous revenue sharing arrangements. Service providers bill users for content charges and give a large portion of these content revenues to the content providers (Natsuno, 2003; Funk, 2004).

This interpretation suggests that the demand curve for mobile Internet services can be represented by multiple bumps in the inverse demand curve. Although each bump probably does not represent a sub-population of users to the extent that these bumps do in the World Wide Web and other industries discussed in this section on indirect network effects, it is possible to identify indirect network effects for each bump and thus describe how a critical mass of users must be created in each bump. For example, for a user to be able to download a ringing tone phones must contain a special chip and this chip must be compatible with the protocol that is used by content providers to format these ringing tones. With screen savers, the same protocol for formatting animated and photographic images must exist in the phone and be used by the content provider. Similarly, the type of Java program and "virtual" machine that is used by content provider to format the game must also exist in the phone (Funk, 2004).

The industry is currently undergoing a transition from "competition within bumps" to "competition to integrate bumps" (i.e., rewiring). For example, similar to the discussion of the PC, firms are competing to offer an integrated suite of operating systems, browsers, application processors, and Java virtual machines that will help users manage their ringing tones, screen savers, games, and other tasks and reduce the overall costs of the software and hardware in the phone. Like the other examples, these efforts reflect the coming integration of fragmented firm networks into a single global network of firms in the mobile Internet (Funk, 2004).

## 5. Discussion

This paper has combined the concepts of inverse demand curves and small world networks to present a conceptual framework of industry formation and the rewiring of networks. This framework builds on existing theoretical work on inverse demand curves (Rohlfs, 1974, 2001; Economides and Himmelberg, 1995) to show that multiple local maximums (i.e., bumps) exist in the inverse demand curves for some products/industries. Since a critical mass of users must be created in each bump, firms often initially focus on individual bumps and only later attempt to integrate these bumps.

Drawing on small world network theory (Watts, 2003), the framework shows how these bumps represent sub-populations of users primarily in those cases where direct network effects apply. Also drawing on small network theory, it shows how integrated networks of firms (i.e., rewiring) have emerged from fragmented ones to fill structural holes (Burt, 1997) and connect the different sub-populations of users/applications in all cases except television broadcasting. In television broadcasting, the network of firms emerged from the ordered network of firms in radio broadcasting. While the number of data points is small, these results suggest that small-world networks may emerge from fragmented as opposed to ordered networks in cases where inverse demand curves apply and multiple local maximums exist.

For users of products that display direct network effects, the results also suggests that small world networks of users (i.e., rewiring) emerge from fragmented ones. The initial users live in a kind of caveman world where they are only connected to members of their own sub-population. As the new products diffuse across bumps and solutions that integrate the bumps have emerged, the telephone, radio, and Internet mail users became connected into a kind of "Solaria" where interactions between users became more random. We can say that the value of the variable alpha, which characterizes the interaction between individuals (Watts, 2003), increases as the product diffuses.

This framework has at least three implications for firms and policy makers. First, the formation of new industries involves the creation of a critical mass of users multiple times. Firms and policy makers must provide a slightly different solution for each bump in order to create a critical of mass of users in each bump. This is one reason why the telephone, radio, and television diffused much more rapidly in the U.S. than Europe. By allowing competition and thus decentralizing control of these industries, U.S. firms found these different bumps in the inverse demand curve and provided them with the appropriate solutions faster than European firms did.

Second, firms have used a variety of techniques to find and bridge these bumps. Bell Telephone and other firms leased their technology to commercial providers, mutual companies, and farmer lines. Governments required telephone companies to allow facsimiles and other third party devices to be connected to telephone lines. Governments licensed multiple broadcasters and the broadcasters created a network of affiliates. IBM designed its PC as an open modular system and Japanese service providers collected content charges for content providers in their mobile Internet services.

Third, there is in general an evolution of competition from “within bumps” to “between bumps,” albeit the timing of these changes varies considerably and some firms can survive in niches even after the competition changes. Competition initially focuses on individual bumps and creating a critical mass of users in a single bump. As the technology diffuses, however, it becomes necessary to provide users with integrated solutions. These integrated solutions provide users with additional value and the integrated solutions benefit from economies of scale, both supply and demand-based ones. The emergence of these integrated solutions is similar to the concept of a dominant design; the difference is that the inverse demand curves define the type of integrated solution or dominant design that is needed.

Future research should attempt to quantitatively test the framework with data on the number of users and firms. Can different sub-populations of users be identified? Do these sub-populations of users emphasize communication within their sub-population and or specific applications? Do most firms initially focus on specific bumps in the inverse demand and are these the most successful firms? Can we link such quantitative analysis of firm entry with quantitative analysis of firm networks? More broadly speaking, how do firms move from competition within bumps to competition between bumps?

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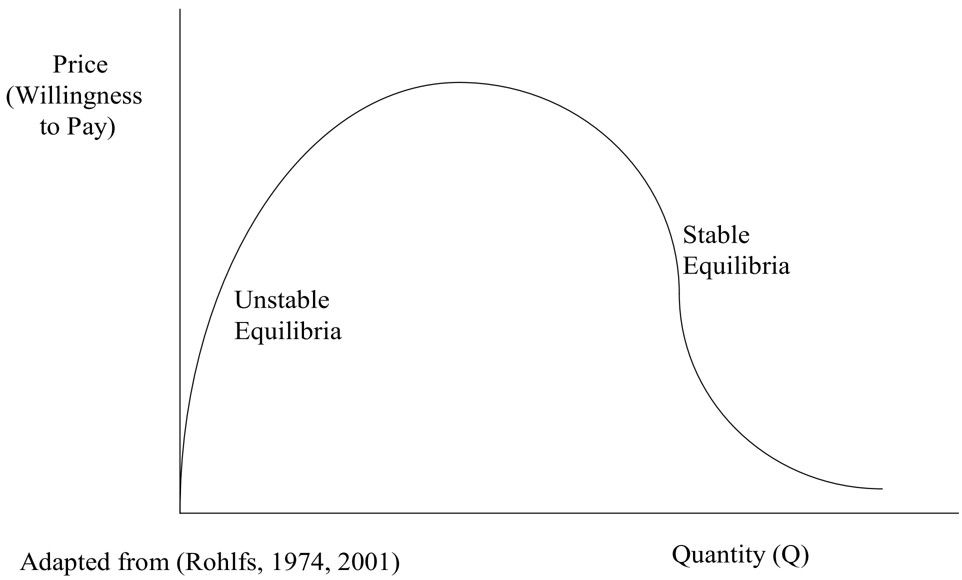
Table 1. Initial Bumps (i.e., local maximums) in the Inverse Demand Curves for Industries that have Exhibited Direct Network Effects and Products/Services that have Connected the Fragmented Sub-Populations

| Industry/ Product | Initial Bumps (which represent sub-populations) in the Inverse Demand Curve | Products/Services that Connected Fragmented Sub-Populations |
|---|---|---|
| Telephone | 1. Many intra-firm networks<br>2. Public networks in many large cities<br>3. Public networks in many smaller cities and rural areas (including mutual companies and farmer lines) | Medium and long distance and international phone services |
| Radio | 1. Many intra-firm wireless telegraph networks<br>2. Ham radio users (i.e., radio heads)<br>3. Commercial broadcasting<br>4. Intra-firm wireless telephone networks (e.g., police and fire) | 1.National broadcasting networks<br>2.Mobile phones for consumers |
| Facsimile | 1. Many intra-firm networks<br>2. Inter-firm networks<br>3. Consumers | Inexpensive fax machines that used common standards |
| Picture phone | Unknown since a critical mass of users did not emerge | |
| Internet mail | 1. Computer scientists (e.g., in universities)<br>2. Time-sharing applications<br>3. Other researchers (e.g., non computer science university professors)<br>4. Users of commercial gateways | Commercial gateways and standards that supported them |

Table 2. Initial Bumps (i.e., local maximums) in the Inverse Demand Curves for Industries that have Exhibited Indirect Network Effects

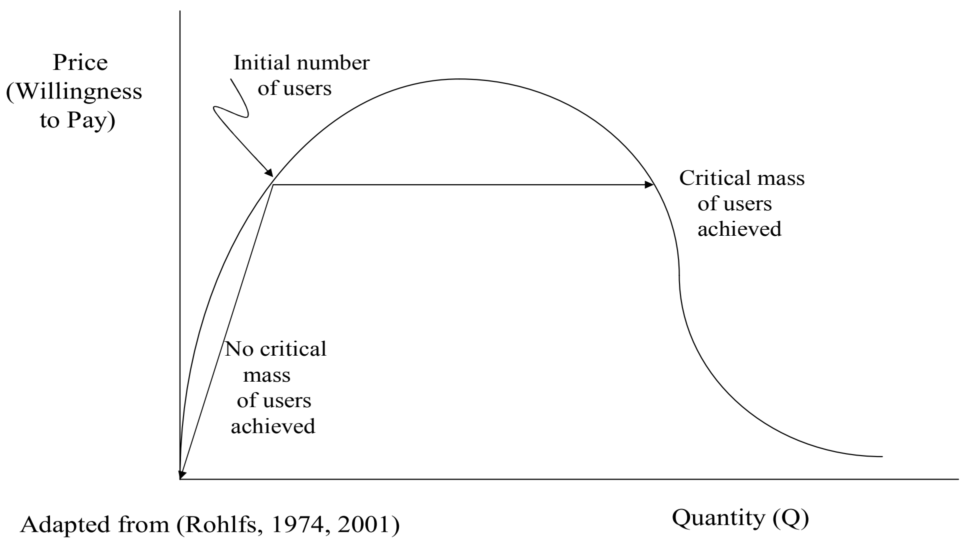
| Technology | Initial Bumps (Applications) | Indirect Network Effects Between Hardware, Service Providers and Content Providers | | |
|---|---|---|---|---|
| | | Hardware | Service Providers | Content Providers |
| Radio Broad-casting | 1. Music<br>2. Comedies<br>3. Dramas<br>4. Educational talk shows<br>5. News | Radio receivers | Broadcasters | Programs |
| Television Broad-casting | 1. Sports<br>2. News | Television receivers | Broadcasters | Programs |
| Personal Computers (PCs) | 1. Hobbyists/Hacker applications<br>2. Games<br>3. Educational software<br>4. Spreadsheets and word processing | Personal Computers | Integrators of software applications (e.g., Microsoft Windows) | Software |
| World Wide Web | 1. University sites<br>2. Pornography<br>3. Employment sites<br>4. Auctions | Personal Computers | Integrators of content sites (e.g., service providers, etc.) | Content providers |
| Mobile Internet | 1. SMS/Mail<br>2. Screen savers<br>3. Ringing tones<br>4. Games<br>5. Information | Mobile phones | Integrators of content sites (e.g., service providers, etc.) | Content providers |

Figure 1. Inverse Demand Curve




Adapted from (Rohlfs, 1974, 2001)

Figure 2. Achieving a Critical Mass of Users in an Inverse Demand Curve




Adapted from (Rohlfs, 1974, 2001)

Figure 3. Comparison of Supply and Demand Curves for Traditional Case and Case of Inverse Demand Curve

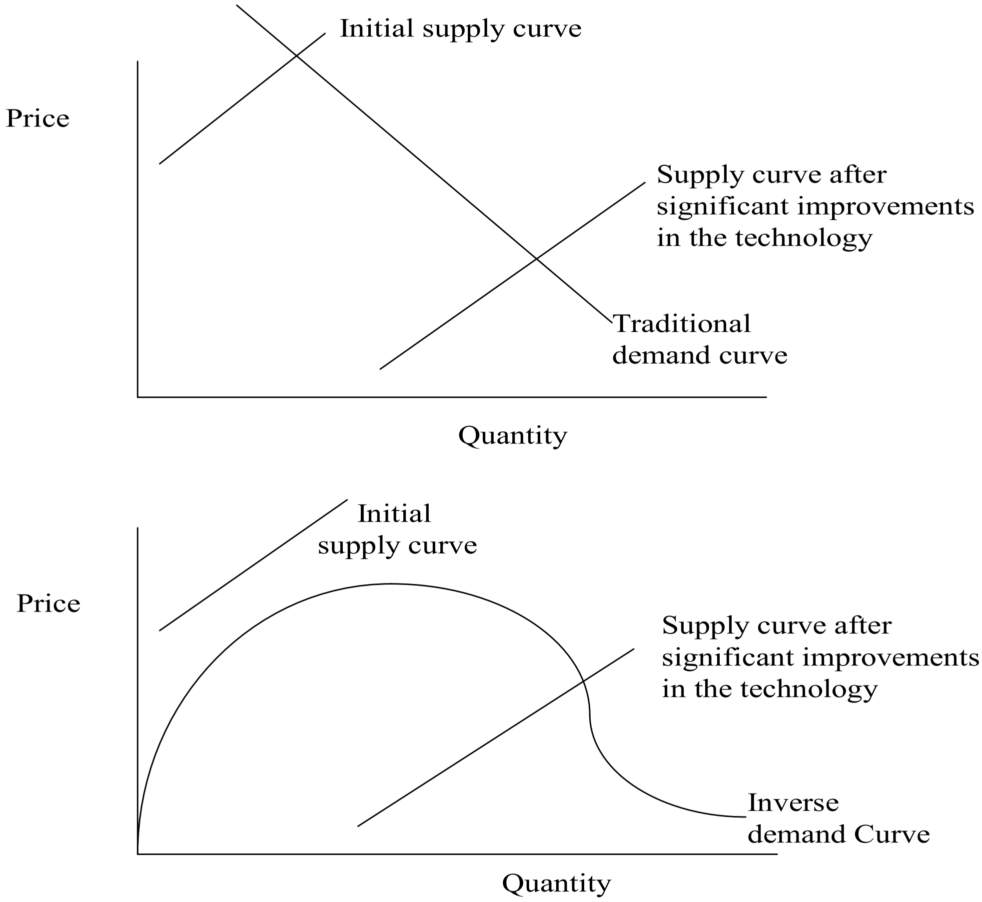


Figure 4. Inverse Demand Curve with Multiple Bumps