The Processes, Challenges, and Location of New Industry Formation: Evidence from the mechanical, electrical, and electronic sectors

by

Jeffrey L. Funk

Professor, Hitotsubashi University

Institute of Innovation Research

2-1 Naka, Kunitachi, Tokyo 186-8603 Japan

Phone: 81-42-580-8430

Facsimile: 81-42-580-8410

e-mail: funk@iir.hit-u.ac.jp

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Abstract

This paper analyzes the processes, challenges, and location of industry formation using a two-by two-classification of industries. It classifies industries from the mechanical, electrical, and electronics sectors in terms of the supply (complexity of their products) and demand (difficulty of solving the “startup problem”) side. While the formation of most industries depends on the existence of appropriate capabilities and on economies of scale and scope, complex industries and ones with difficult to solve startup problems involve additional challenges. Because complex industries involve numerous technical, business, and customer decisions, different countries, including their firms and governments, often make different decisions that lead to different levels of growth in these different countries. Industries that have large “startup problems” are ones in which we can represent the demand for their products in terms of an inverse demand curve. The paper then addresses industry location and the impact of globalization on industry formation. It concludes that although globalization enables firms to more easily introduce products simultaneously in multiple countries, globalization may also reduce the variation in the approaches to industry formation and thus may slow new industry formation.

1. Introduction

In spite of the recognized importance of new industries to economic growth (Schumpeter, 1942), there are few cross-sectional analyses of new industry formation or discussions of the challenges involved with their formation. Porter's (1990) cross-country analysis of industry competitiveness focused on the current state of and reasons for competitiveness in specific industries as opposed to their processes of formation or the reasons for their formation in a specific location. The product life cycle model (Abernathy and Utterback, 1978; Klepper, 1997) assumes industry formation and focuses on the evolution of them. Although Van de Ven and Garud (1989) extended this framework to include the evolution of both social and technological systems, their focus was also on the evolution as opposed to formation of an industry.

Diffusion models also provide little help since they ignore the developers and providers of the products and services and why they are from a specific country. Furthermore, since they are primarily used to address the global rollout of new products, they address the rate of diffusion after the system/product has been introduced (Agarwal and Bayus, 2002; Tellis et al, 2002) and ignore the fact that some countries have been able to introduce the system/product before other countries have been able to do so. By doing so they often imply that diffusion has more to do with culture than government policy and firm decisions and they can cause late-comers to appear as if they have a faster rate of diffusion than the countries that first introduced the systems; an interesting example of this phenomenon can be found in (Dekimpe et al, 1998).

On the other hand, research on capabilities (Nelson and Winter, 1982; Barney, 1991), national innovation systems (Nelson, 1993; Mowery, 1991, 1998), network effects (Shapiro and Varian, 1999), inverse demand curves (Rohlfs, 1974, 2001), and industry classifications (Tushman and Rosenkopf, 1992) provide us with tools for addressing the formation of new industries. Management theorists have long recognized the importance of capabilities[1] and there is a large literature on the historical development of them in the U.S., Europe, and Japan (Chandler, 1962, 1977, 1994, 2001). Research on national innovation theory also addresses the creation of capabilities at a national rather than a firm level. Many scholars have addressed network effects (Katz and Shapiro, 1986; Farrell and Saloner, 1985) and the demand for some products that exhibit very strong network effects can be represented with an inverse demand curves Rohlfs (2001). Tushman and Rosenkopf (1992) classify products into four categories: materials, simple assembled products, closed assembled systems, and open assembled systems.

This paper combines the concepts of inverse demand curves and Tushman and Rosenkopf's (1992) classification of industries to propose a typology of new industry formation and it uses this typology to analyze the processes and location of new industry formation. It focuses on the mechanical, electrical, and electronics sectors due to the large amount of new industry formation that has occurred in these sectors over the last 100 years and the author's background in these sectors both as a practitioner and as a researcher. The author chose specific industries in these sectors based on their size and the availability of information about them. Information on their formation, factors driving or inhibiting their formation, and the location of the formation was obtained from historical accounts and economic analyses of them of which only a subset of these accounts and analyses are referenced in the paper.

This paper uses both Porter's (1980) and Van de Ven and Garud's (1989) definitions

[1] There is a very large literature on capabilities. For example, see the special issue on capabilities in the Strategic Management Journal (Vol. 21, October-November 2000).

of an industry. They define an industry as a group of firms producing products that are close substitutes for each other. The larger the number and variety of final and intermediate products and services that can be subsumed within a single industry, the larger and more important the industry is. Innovations lead to new products and services and the larger the innovation or collection of complementary innovations the more likely that the new products and services can be defined as a new industry.

Defining the actual products and services that are included in a specific industry is more problematic. This paper does not use the Bureau of Economic Analysis' (BEA) classifications since the BEA emphasizes continuity while this paper emphasizes change, in particular electrical, electronic, and mechanical-related technological change. For example, this paper considers the Internet to be an industry that offers a variety of products and services in spite of the fact that the Internet is not considered a separate industry by the BEA.

This paper (Section 2) first describes a typology of industry formation that considers both the supply (complexity of their products) and demand (difficulty of solving the "startup problem") sides of industry formation. While the formation of most of the industries covered in this paper depends on the existence of appropriate capabilities and on economies of scale and scope, complex industries and ones with difficult to solve startup problems involve additional challenges (See Figure 1). Section 3 summarizes the locations of industry formation and the reasons for them. This section draws on the discussion in Section 2 on how a different set of factors determine the location of industry formation in complex industries and ones with difficult to solve startup problems than with ones that involve simple products. Section 4 discusses the effect of globalization on the formation of industries with a focus on those industries that are either complex and/or have difficult to solve startup problems. The emergence of global firms and standard setting activities is moving the process of industry formation from a national to a global level. As with other aspects of globalization, this one also has a negative side. Whereas industry formation at the country level enables different countries to approach industry formation in different ways, the globalization of industry formation reduces this variation and thus may eventually slow industry formation.

2. Typology of Industry Formation

Figure 1 classifies industries in terms of complexity and the difficulty of solving the startup problem. The complexity of an industry can be measured in terms of the complexity of the technology or the number of sub-systems, parts, process steps, or lines of software code in the products or services offered in the industry (Tushman and Rosenkopf, 1992). Greater complexity increases the chances that firms and/or governments will make different technical and business decisions that lead to different levels of growth in different countries (David, 1986). This is partly because social factors play a larger role in the determination of dominant designs for complex than simple industries (Anderson and Tushman, 1990).

This definition of complexity is similar to the one used by Tushman and Rosenkopf (1992) in their distinction between simple assembled products and assembled systems. The major difference with their definition is that this paper focuses on the different levels of complexity within what they call assembled systems. The reason for focusing on assembled systems is that this paper's analysis of new industry formation suggests that firms and governments are much more likely to make different decisions for complex assembled than for simple assembled systems.

Industries that have large "startup problems" are ones in which we can represent the demand for their products in terms of an inverse demand curve. As shown in Figure 2, inverse demand curve 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, 1986; Farrell and Saloner, 1985). 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).

Place Figures 1 and 2 about here

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. Examples include AT&T's picture phone service (Rohlfs, 2001) and several music and television formats (see subsequent sections). 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).

The difficult of solving the startup problem is a very different concept from the ones of open assembled systems (Tushman and Rosenkopf, 1992) and dynamic returns (Arthur, 1994; Nelson et al, 2004) that are emphasized by other researchers. Both open assembled systems and dynamic returns can be applied to many of the industries shown in the lower half of Figure 1 and the existence of dynamic returns is one reason why location is an important issue in industry formation (Porter, 1990). However, it is argued below that the demand for the products in the industries shown in the lower half of Figure 1 cannot be represented by an inverse demand curve since they have value even when the network size is zero and there are not large external benefits to the expansion of *very small* networks.

2.1. Simple Products

The bottom-left quadrant of Figure 1 refers to products with low complexity and little difficulty with solving the startup problem. The formation of these industries largely depends on the existence of appropriate capabilities and on economies of scale and scope. For example, the appliance industries were first formed in countries such as the U.S. and Germany that had capabilities in electrical technologies (including the early use of electrical power) and mass production techniques Germany (Chandler, 1980, 1990; Hughes, 1983).

It was only after Japanese firms had developed a broad range of capabilities in existing mechanical and electrical-related industries that it began creating new industries. For example, their creation of the VCR industry followed a long period of capability development in tape recorders, transistor radios, stereo phonographs, and televisions (Cusumano et al, 1992; Chandler, 2001) where Japanese firms first applied magnetic tape and transistors to low-end products that U.S. firms largely ignored in the 1950s and 1960s (Christensen and Hart, 2001). The creation of the digital watch, pocket calculator (Numagami, 1996), digital camera (Johnstone, 1999) and personal copier industries in Japan also depended on capabilities that were developed in previous generations of industries (Chandler, 2001).

On the other hand, dynamic returns have emerged in many of these industries due to the complementary nature of the products (Arthur, 1994; Nelson et al, 2004). For example, although home VCRs were initially used for time shifted playback (Cusumano et al, 1992; Levy, 1991), the success of pre-recorded tapes for home VCRs strengthened the network effects of the VHS standard (Cusumano et al, 1992) and led to the later emergence of the DVD (digital video discs) industry, which can be placed in the upper-left quadrant of Figure 1. The diffusion of digital cameras, PCs, the Internet, and in general the proliferation of product categories has increased the importance of indirect network effects and made it more difficult to define substitutes for many products (Shocker et al, 2004). The formation of a "home network" industry that supports the integration of these products probably occupies the upper right quadrant of Figure 1.

2.2. Simple 'Network' Products

The difference between "simple network-products" and "simple products" is in the difficulty of the startup problem. Whereas users of "simple products" can obtain value from a product even if there are no other users; a critical mass of users had to be created before they could obtain value from products such as facsimiles, local area networks (LANs), and many music and computing formats. For example, the first facsimiles and

LANs were introduced by firms to support intra-firm communication and it was not until standards emerged that inter-firm and inter-consumer communication became possible (Rolfs, 2001; von Burg and Kenney, 2000). Japan was the first country to create a critical mass of facsimile users through an early development of the appropriate capabilities (Chandler, 2001), the early elimination of rules against connecting fax machines to office and home telephones, and the difficulties of using telex machines (the previous technology) to transmit Chinese characters (Peterson, 1995; Rolfs, 2001). Largely due to their lead in the usage of personal computers, U.S. firms were the first ones to introduce LANs and these firms created a critical mass of internal users that later led to their interlinking and connection to the Internet (von Burg and Kenney, 2000).

The high startup problems with the other products shown in the upper left hand quadrant are due to indirect network effects. Since the value of new music and computing formats depend on the amount of software available for them, there are large external benefits to the expansion of very small networks. Each new music format including cylinders, discs, LPs (long playing), cassette tapes, and CDs (compact discs) required music to be made available with the new format (Millard, 1995). Some firms have attempted to solve these startup problems by supplying both hardware and music while other firms have only provided one of them. The largest examples of the former were RCA during the first half of the 20th century and Sony, Panasonic, and Philips during the latter decades of the 20th century (Huygens et al, 2001). Hardware and music companies have also cooperated to promote new technologies, particularly following the so-called battle of the speeds in the late 1940s (Langlois and Robertson, 1992).

Recently, several new music formats have failed and legal on-line music services have diffused much more slowly than those of other on-line services. Digital Compact Cassette (DAC) and the Sony's Mini-Disc have not succeeded in most countries due to competition between them, the resulting consumer confusion (Grindley, 1995; Rohlfs, 2001), and a lack of appropriate marketing (Hill, 1997). Music companies did not support Digital Audio Tape (DAT) and have not strongly supported on-line music services largely because they have been concerned with illegal copying (Grindley, 1995; Rohlfs, 2001) and the greater difficulties of selling bundles of songs that include "second-rate" ones in on-line services (Economist, 2004b).

The PC industry is probably an even better example of an industry that is immune to "creative destruction." Microsoft and to a lesser extent Intel control the interfaces between the microprocessor, the operating system, and application software. Combined with large switching costs, these firms are able to slow the introduction of new technologies for the PC such as Java (Bresnahan, 2004). The startup problem was initially solved by a variety of firms such as Apple and Tandy in the late 1970s through applications such as games, education, and later business ones (Campbell-Kelly, 2003). IBM offered a more open platform than Apple did (Langlois, 1993) and a PC that contained the first 16-bit microprocessor, which was backward compatible with existing software (Steffens, 1994; Rohlfs, 2001). Unfortunately, the openness of the platform basically ceded control of the key internal interfaces to Microsoft and Intel (Langlois, 1993; Grindley, 1995). Many researchers now argue that their control of these interfaces reduces the chances of creative destruction (Bresnahan, 2004).

2.3 Complex Products

The products shown in the bottom-right hand quadrant are very complex but involve a low difficulty in solving the startup problem. The complexity increases both the number of design choices and the barriers to entry. The large number of design choices increases the number of possible design alternatives while the high barriers to entry reduces the number of design alternatives that will be introduced.

Table 1 summarizes the critical design choices for the early years of several industries that contain complex products. Firms had to choose between different types of current for electric power systems (Hughes, 1983), power sources for automobiles (Kirsch, 2000), high speed memory cache for computers (Flamm, 1988), reactor designs for nuclear power stations (Cowan, 1990), materials and transistors for semiconductors (Tilton, 1971), and wings, propellers, and engines for airplanes (Tushman and Murmann, 1998).

Place Table 1 about Here

Governments were involved with many of these decisions, at least indirectly since they provided land, set safety standards, funded research and development, and were the major customers for many of these products. For example, U.S. and German cities leased land to electric power companies on much more liberal terms than the UK did and this led to a much faster growth in electric power usage in the U.S. and Germany than in the UK (Hughes, 1983). The U.S. government purchased more computers and semiconductors than other governments did due to the higher military spending in the U.S. and the superior financial situation of the U.S. following WWII (Tilton, 1971; Flamm, 1988; Mowery and Rosenberg, 1998). The U.S. post office also began using aircraft before other post offices did, the long distances between cities promoted commercial air travel, and WWII generated large government purchases that still continue today (Mowery and Rosenberg, 1998).

On the other hand, the startup problem is much easier to solve for these products then for those that large initial network effects and thus can be represented by an inverse demand curve. Each of the complex products shown in the lower-right quadrant was easily used in combination with existing systems or was introduced as a stand-alone system. For example, automobiles used existing roads, fuel sources (gasoline cans in general stores), and repair shops (Kirsch, 2000). Mainframe computers used existing punch cards (Pugh, 1995) and nuclear power stations distributed their power over existing electrical distribution systems (Cowan, 1990). The first semiconductors were used in products that previously used vacuum tubes (Tilton, 1971). Examples of products that were introduced as stand-alone products include electric power for street lighting (Hughes, 1983) and airlines (Mowery and Rosenberg, 1998). In stand-alone products, an integrated supplier provides all the hardware and complementary software that the user needs and thus there are only supply-based as opposed to demand-based economies of scale (Rohlfs, 2001).

It is more difficult to say whether the lack of initial network effects will prevent these complex industries from exhibiting the same kind of purported barriers to innovation that are exhibited in the music and PC industries. The growth of the mainframe computer market did not prevent the emergence of the mini-computer, PC, or PDA industries and instead probably contributed towards their formation. The semiconductor has seen changes in transistor, process, and even system design albeit the material, silicon, may never change (Tilton, 1971; Braun and Macdonald, 1982; Morris, 1990).

On the other hand, while new forms of electricity generation can piggyback on existing distribution systems, economies of scale and the fact that many environmental externalities are not reflected in existing electricity prices may slow the emergence of alternative forms of electricity production. Furthermore, the other big energy user, the automobile, has become a network product. Investments in gasoline stations make it hard for other forms of automobiles and investments in roads make it hard for other forms of transportation such as light rail systems to succeed (Economist, 2004a).

2.4 Complex 'Network' Products

Complex networked-products combine the challenges of complex products (critical design choices) with those of network products. Table 2 summarizes the critical design choices and initial network effects that lead to the existence of an inverse demand curve for several of these industries. The different growth rates for these industries can be explained in terms of differences in government policies and/or firms' business models in different countries. The U.S. experienced faster growth rates in telephone usage in the late 1800s due to the greater emphasis on competition as opposed to government monopolies (Brock, 1981). Although U.S. cities had much higher prices for telephone calls than many European cities did in the early 1900s (Rohlfs, 2001; Mueller, 1997), the emergence of many types of networks, including commercial ones, mutual companies, and farmer lines enabled telephone usage to diffuse much faster in rural areas in the U.S. than in most European cities (Brock, 1981).

Place Table 2 about here

The U.S. initially experienced faster growth in radio and television because its government licensed private broadcasters and the broadcasters used an advertising-business model as opposed to a subscription one. European governments did not license private broadcasters and the national monopolies used a tax on the radio and television units (subscription model) to pay for programming (Bussey, 1990; Briggs and Burke, 2002; Spar, 2001). Private broadcasters in the U.S. emphasized popular programming for the masses while Europe's national broadcasters emphasized cultural programs for the elite. It took many years for European countries to admit that European audiences wanted the same type of "silly" programs that were popular in the U.S. (Spar, 2001; Briggs and Burke, 2001).

The faster growth in radio and television in the U.S. and the liberal licensing that supported this growth also led to the earlier introduction of FM radio and color, cable, and satellite television in the U.S. than elsewhere. The U.S. government was much faster to provide new licenses and also launch satellites; the latter provided cable operators with inexpensive access to national programs (Inglis, 1990; Briggs and Burke, 2002). On the other hand, the U.S. has not licensed new entrants in either high definition (HDTV) or digital television and thus these technologies have faced more difficulties in implementation than previous broadcast technologies have (Brinkley, 1997). Broadcasters have taken the licenses but have not fulfilled their promises to introduce new services largely because they do not perceive higher advertising revenues from either HDTV or digital television. Problems with standards and indirect network effects (receivers and programs), and questions of user needs have also plagued HDTV (Grindley, 1995; Rohlfs, 2001) and digital television (Brinkley, 1997; Hart, 2004).

The initial growth rates for the mobile phone industries can also be explained in terms of differences in government policies. Countries that chose an open analog standard in which multiple domestic and foreign manufacturers could sell as opposed to rent phones saw much faster growth rates than countries that did not do so. The U.S., Scandinavia, and Great Britain chose open analog standards while Japan, France, Germany, and Italy initially did not in the early 1980s. U.S., British, and Scandinavian service providers also set lower prices than other countries partly due to the existence of greater competition in the U.S. and Great Britain (Garrard, 1998; Funk, 2002; Lyytinen and Fomin, 2002).

With digital phones, Europe experienced much faster growth than the U.S. and also Japan did. While the U.S. did not choose a single standard and delayed the introduction of licenses until 1995, Western Europe chose a single standard and its countries began licensing new entrants in the late 1980s. European firms started services in 1992 and the new entrants experienced the strongest growth in subscribers for these services (Garrard, 1998). Europe's choice of a single standard and the early growth in these services caused GSM (Global System Mobile) to become the global standard for mobile digital services (Funk, 2002).

Returning to an industry that was created in the 1970s, the U.S. government played a very large role in the formation of the Internet. It funded the development and implementation of packet-switched networks that connected universities and other research institutions (Abbate, 1999). This funding also enabled universities to remain the leading source of sites and innovations until the mid-1990s of which the browser is just one example of these innovations (Mowery and Simcoe, 2002). The U.S. government's early deregulation of the telecommunications industry and U.S. firms' early implementation of PCs and LANs contributed to interlinking between the government-funded, commercial, and corporate networks. Following the diffusion of browsers, the U.S. venture capital industry financed the commercialization of the Internet (Mowery and Simcoe, 2002; Kenney, 2003).

Outside of Scandinavia and Great Britain, Europe and Japan were much slower to fund the implementation of Internet infrastructure and when they did they focused on the losing technology. Their universities were also slower to implement information technologies partly because their governments funded less university research and were slow to liberalize their telecommunications industry. This allowed other countries particularly Asian ones like Korea, Singapore, and Hong Kong to experience faster diffusion of Internet services than Japan and many European countries did (Kogut, 2003; Waesche, 2002).

The mobile Internet has experienced a completely different process of diffusion than the PC Internet in that it has been much harder for firms to agree on standards for displaying content on the phones than on PCs and different content and thus a different business model have driven its diffusion. Japanese (and to a lesser extent Korean) service providers created a critical mass of users in 1999 and 2000 with phones that displayed content in a consistent manner, entertainment content that was supported by a micro-payment system, inexpensive Internet mail, and site access via the input of a URL. The Japanese (and Korean) service providers have been able to obtain phones that display content in a consistent manner because they had always dictated phone specifications to manufacturers (Funk, 2002). In the micro-payment system, they include content charges on subscriber bills and passed on about 90% of these revenues to content providers (Natsuno, 2003; Fransman, 2002).

On the other hand, Western service providers have had trouble obtaining phones that display content in a consistent manner. Although Western manufacturers initially attempted to replicate the success of GSM in the WAP (Wireless Automation Protocol) Forum, their inability to agree on standards (Fransman, 2002) has forced service providers to determine their own standards and order custom phones. This requires new skills for both service providers and manufacturers and large manufacturers such as Nokia and Motorola were initially slow to produce custom phones (Economist, 2005; Reinhardt and Ihlwan, 2005). Furthermore, since the largest Western service providers can still obtain custom phones from manufacturers easier than small ones, they are attempting to use their market power to maintain high prices for SMS (short messaging services), not introduce and promote inexpensive Internet mail and site access via the input of a URL, and retain most of the content revenues for themselves (Funk, in press).

3. Locations of Industry Formation

Table 3 summarizes the country or countries that initially created specific industries in selected mechanical, electrical, and electronic sectors. Although the table focuses on industries/products that can be defined as complex and/or have a difficult to solve startup problem, the table also includes several "simple" products in order to consider the impact of the previous industry on the formation of the new industry. As expected, the U.S. has created almost every industry shown in Table 3 faster than other countries even when it has been a major user of the previous generation of product. This is also largely true with portable products, many of which can be defined as "simple" products. The U.S. was the first or one of the first countries to adopt portable (transistor) radios, calculators, computers, phones, and tape and CD players in spite of the fact that it was a leading user of the fixed-version of these products when the portable version began diffusing.

Place Table 3 about here

The early creation of an industry by the U.S. even when it has been a major user of the previous generation of product suggests that the early adoption and heavy usage of one generation of a complex and/or network-product/industry probably speeds up rather than slows the early adoption of the next industry/generation[2]. The early adoption and heavy usage of one generation of a complex and/or network-product/industry probably creates capabilities in both producers and users, drives the development of complementary technologies, and thus accelerates the early adoption of the next industry/product generation. This argument is consistent with with Van de Van and Garud's (1989) analysis of industry formation and the literature on national innovation systems (Mowery, 1998). The greater success of the U.S. in the radio and TV industries, the lower amounts of damage from WWII, and the effect of WWII on science in the U.S. caused the U.S. government and firms to strengthen their national innovation system faster than other countries did all of which helped the U.S. create the computer and semiconductor industries before other countries did. The U.S. government increased its support for basic research, firms increased their development expenditures, and a system of venture capital emerged (Rosenberg, 1994; Mowery and Rosenberg, 1998). The success of U.S. firms in computers and semiconductors created additional support for these government and firm policies thus creating positive feedback between this success and the social systems that are emphasized by Van de Ven and Garud (1989).

[2] As discussed in a previous section, facsimiles may be an exception to this argument

On the other hand, the U.S. has not been the source of a few new industries and these few exceptions can be explained in terms of government and/or firm policy. In the cases of digital mobile phones and the mobile Internet, there have been few new entrants, the most powerful incumbents have been slow to introduce services, and in the mobile Internet it was difficult to agree on standards. We now address the impact that globalization is having on industry formation.

4. Globalization and Industry Formation

The industries analyzed in this paper suggest that globalization can both accelerate and slow industry formation. On one hand, it enables global firms to more easily introduce products simultaneously in multiple countries, which has been occurring in simple and to a lesser extent in simple networked products for many years. This is probably why analyses of these products have focused on product diffusion rather than industry creation and on market as opposed to producer differences (Agarwal and Bayus, 2002). A major issue in the marketing literature is to what extent firms should introduce products simultaneously or in a "waterfall" strategy (Tellis, 2003).

On the other hand, globalization may exacerbate the problems associated with industry formation that were discussed in the previous sections for industries that involve complex products or involve a difficult to solve startup problem. Until recently, these industries were created at the country level and then spread via imitation and/or agents of diffusion from the country that first created the industry. For example, Great Britain and other countries learned from the U.S. and German approaches to electric power and also purchased the equipment from their firms (Hughes, 1983). Europe and Japan learned from the U.S. approach to radio and television and applied these lessons to digital television (Spar, 2001). Many countries copied the U.S, British, and Scandinavian approaches to mobile phones and Europe applied these lessons to digital phones (Funk, 2002). Most countries learned from the success of the U.S. Internet including the introduction of more competition in telecommunications and the purchase of equipment from U.S. suppliers (Kogut, 2003; Waesche, 2004).

Industry formation at the national level and the opportunity for cross-country learning supports variation in industry formation, which enables different countries to create industries in different ways. If one country's government policies or firm strategies are inappropriate for industry formation, another country's government policies and firm strategies may be appropriate.

The globalization of industry formation may reduce this variation and thus reduce the chances of new industry formation. The previous sections alluded to this problem in the music, PC, and mobile Internet industries. Partly due to the global success of Western music, the global distribution of music and the choice of standards are dominated by a few large firms (Huygens, 2001; Economist, 2003). These global firms have not supported DAT or on-line services (Economist, 2004b) and large manufacturers were unable to agree on the choice of DCC versus mini-discs (Rohlfs, 2001).

The PC industry is even a more graphic example of the problems of globalization. It is not just that Microsoft dominates and controls the U.S. PC industry (Bresnahan, 2004); it dominates and controls the global PC industry. Without the existence of this globalization, it might be possible for firms to create a critical mass of users for a new form of PC in a specific country or group of countries and then attempt to challenge the Wintel standard at the global level. The globalization of the PC industry reduces the chances of this form of creative destruction occurring in the PC industry.

Solving the startup problems in Western mobile Internet markets has also been made more difficult by globalization. The failure of the global standard setting process for WAP highlights one of the problems with global standard setting committees in any industry: the services either succeed or fail on a global level and there are no in-between levels of success. Before the globalization of this industry, local manufacturers and service providers in Western countries could have worked together to solve these standard setting problems. However, the globalization of the industry caused many of these “local” manufacturers to exit the industry in the 1990s (Funk, 2002) and the dominant firms such as Nokia and Motorola are global firms that initially had little interest in customizing phones for individual service providers (Economist, 2005; Reinhardt and Ihlwan, 2005). It was only because Japanese and Korean markets had not “globalized” that they were able to solve these problems. Similar to the quasi-vertical integration that existed in Western telecommunication industries until the early 1980s, Japanese and Korean service providers determine the mobile phone and Internet specifications and thus guarantee agreements between manufacturers (Fransman, 2002; Funk, in press). Western service providers are now trying to do the same thing in their global services but in a slow and deliberate way that will guarantee their profits at the expense of rapid diffusion.

5. Discussion

This paper proposes a typology of industry formation and uses this typology to analyze the processes and location of new industry formation in the mechanical, electrical, and electronic sectors. The typology highlights the different challenges facing the formation of different types of industries. The formation of industries consisting of simple products largely depends on the availability of appropriate capabilities while the formation of industries consisting of other products also faces other challenges. For simple network products, industry formation also depends on firms' ability to solve the startup problem associated with the inverse demand curve through an appropriate strategy. For complex products, industry formation also depends on governments and firms' ability to make appropriate technical and business decisions. The combination of complexity and a difficult to solve startup problem further complicates the technical and business decisions faced by firms in industry formation.

Most of the industries analyzed in this paper were initially formed in the U.S. While the reasons for this go far beyond the limits of this paper, it is a story of the "rich getting richer." U.S. firms were the first firms to create new industries even when U.S. firms were already the leaders in the previous generation of technology. This reinforces the notion of capability building that is emphasized in research on national innovation systems (Mowery, 1998) and suggests that there are few cases of high "switching costs."

It was only in a few industries that industry formation occurred in other countries before it occurred in the U.S. Japanese firms created the facsimile industry before U.S. firms did and created the hardware side of the VCR, CD, and DVD industries largely through the accumulation of the appropriate capabilities. Europe created the digital mobile phone and Japan created the mobile Internet before the U.S. did. An inability to agree on standards was a common problem in the latter two industries where government policy played a role in the digital mobile and globalization was the key factor in the mobile Internet.

It appears as though globalization is changing the process of industry formation in a number of industry sectors. Although it can accelerate the international diffusion of new products, it may actually slow industry formation. A few global players now dominate the music, computer, and mobile phone industries and these high industry concentrations may slow new industry creation in these sectors. In the worst case scenario, the globalization of industries will provide a one shot improvement in efficiency and then slow new industry formation. Future research should look at this more closely.

Future research should also look at other industry sectors. It is likely that such research will lead to an extension or revision of the typology shown in Figure 1. For example, patent and other analyses (e.g., Murmann, 2003) suggest that some industries like those found in the chemical sector rely more on science than the electronic sector. Thus, it is possible that industry formation in the chemical sector will depend on a different set of factors than those highlighted in Figure 1.

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Table 1. Examples of Critical Design Choices in Early Years of Complex Industries

Industry	Examples of Critical Choices in Early Years of Industry	
	Firm-level	Government-level
Electric power	Alternating (AC) versus direct (DC) current	Right of way for power lines, safety regulations
Automobiles	Steam, electric, or internal combustion engines	Roads and safety regulations
Computers	High speed cache memory cache (magnetic cores & drums, mercury relay lines, cathode-ray tubes)	Purchases and R&D funding
Nuclear power	Pressurized (PWR) versus boiling water reactors (BWR)	Subsidies and R&D funding, safety regulations
Semi-Conductors	Type of material (germanium, silicon) and transistor (point-contact, junction)	Military purchases and R&D funding
Airlines/ Aircraft	Number of wings, location of engines and propellers	Military purchases and mail services

Table 2. Examples of Critical Design Choices in Early Years of Complex Industries with Large Startup Problems

Industry	Examples of Critical Choices in Early Years of Industry		Network Effects
	Government-level	Firm-level	
Telephone	Government service versus private licenses, degree of competition	Licensing of technology	Direct effects between users
Radio	Government service versus private licenses, degree of competition	Advertising vs. subscription business model	Radio programs and hardware (indirect effects)
Television	Government service versus private licenses, degree of competition	Advertising vs. subscription business model	TV programs and hardware (indirect effects)
Mobile phone	Privatization, degree of competition, openness of standard, sell or rent phones	Choice of air-interface standard, sell or rent phones	Phones and services (indirect effects)
PC Internet	Government subsidies, degree of competition in telecommunications, support of universities	Early issue of mail versus file sharing (1970s) and later choice of protocols and markup languages	Direct (mail) and indirect effects (PCs, content)
Mobile Internet	Degree of competition, 3G licenses	Micro- payment system, type of Internet mail, and agreement on protocols for displaying content	Content, phones, and services (indirect effects)

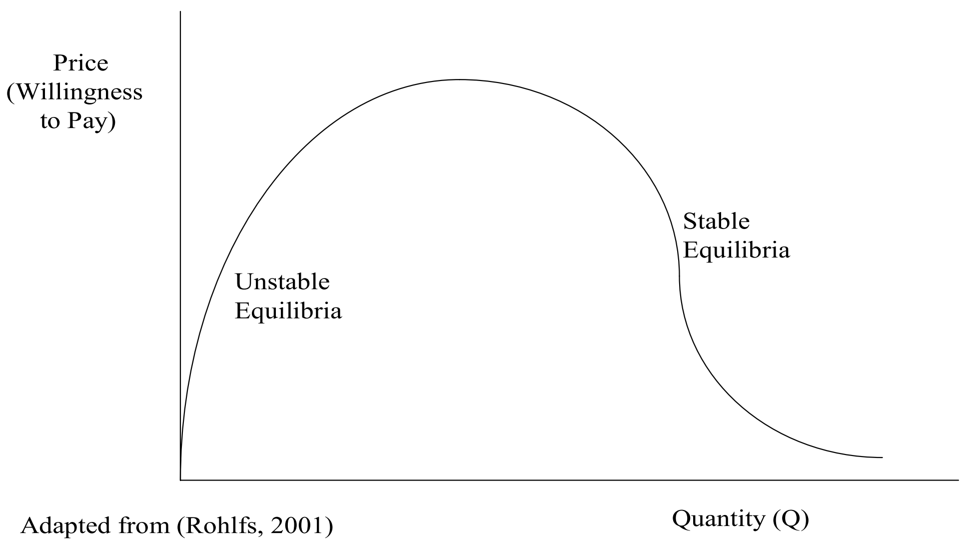
Table 3. Country of Industry Formation and Initial Product Usage

Industry/Product	Country(s)	Reference
Broadcasting		
AM Radio	U.S.	(Bussey, 1980; Briggs and Burke, 2002)
FM Radio	U.S	(Inglis, 1990)
Black and White TV	U.S	(Inglis, 1990; Briggs and Burke, 2002)
Transistor Radio	U.S., Japan	(Lynn, 1998; Partner, 1999)
Color TV	U.S.	(Inglis, 1990; Briggs and Burke, 2002)
Cable TV	U.S.	(Inglis, 1990; Briggs and Burke, 2002)
Satellite TV	U.S	(Inglis, 1990; Briggs and Burke, 2002)
Telecommunication		
Fixed-Line	Europe, U.S.	(Rohlfs, 2001; Mueller, 1997)
Facsimile	Japan	(Peterson, 1995; Rohlfs, 2001)
Mobile – Analog	Scandinavia, U.S.	(Garrard, 1999; Funk, 2002)
Mobile – Digital	Europe	(Garrard, 1999; Funk, 2002)
Internet		
Fixed	U.S.	(Abatte, 1999; Kogut, 2003)
Mobile	Japan	(Natsuno, 2003; Funk, 2004)
Music		
Records	U.S., Europe	(Read and Welch, 1976; Millard, 1995)
Tapes	U.S., Europe	(Millard, 1995; Chanan, 1995)
CDs	U.S., Europe, Japan	(Grindley, 1995)
Portable players	U.S., Europe, Japan	(Grindley, 1995; Partner, 1999)
Computers		
Mainframe	U.S.	(Flamm, 1988; Ceruzzi, 1998)
Mini-computer	U.S.	(Flamm, 1988; Ceruzzi, 1998)
PC	U.S.	(Grindley, 1996; Langlois, 1993)
PDA	U.S.	(Butter and Pogue, 2002)
Other products		
VCR	Japan, U.S.	(Cusumano et al, 1992; Levy, 1991)
DVD	Japan, U.S	(Chandler, 2001)
Portable Calculators	Japan, U.S	(Majumder, 1982; Numagami, 1996)
Digital Watches	Japan, U.S	(Numagami, 1996)

Figure 1. Classification of New Industries in Terms of Complexity and the Startup Problem

Difficulty of Solving Startup Problem (existence or lack thereof of inverse demand curve)	Low Relative Complexity at Time of Creation	High Relative Complexity at Time of Creation
High	Simple Network Products Digital Video Disc (DVD) Music Players (Phonograph, Cassette Tape, Compact Disc) Facsimile Personal Computer (PC)	Complex Network Products Radio (AM, FM) Television (B&W, Color, Digital) Fixed-Line Telephone Mobile Phone (Analog, Digital) PC Internet Mobile Internet
Low	Simple Products Refrigerator Dryer Vacuum Cleaner Home VCR Pocket calculator Washing Machine Air Conditioner Sewing Machine Digital Watch Digital Camera	Complex Products Electric Power Automobile Mainframe Computers Nuclear Power Airline/Aircraft

Figure 2. Inverse Demand Curve



Adapted from (Rohlfs, 2001)