Networks, Standards and Intellectual Property Rights

Johannes Moenius
University of Redlands

Vitor Trindade
University of Missouri

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Johannes Moenius, School of Business, Redlands, CA-92373-0999, Tel: (909) 748 8779, johannes_moenius@redlands.edu.

Vitor Trindade, Department of Economics, Columbus, MO-65211-6040, Tel: (573) 882-9925, trindadev@missouri.edu.

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1. Introduction

This chapter addresses issues that lie at the intersection between intellectual property rights (IPR) and network effects, especially in the context of the global economy. Some of the relevant questions are: (1) How do IPR influence the provision of goods exhibiting network effects? (2) How do network effects in turn influence the creation of intellectual property (IP)? And (3) how do aspects of the global economy interact with both IPR and network effects? We synthesize what is known from the existing literature to answer these questions.[1]

1.1 Outline of the Issue

Katz and Shapiro (1985) define that a good has (positive) network effects if its utility to each single user increases with the number of users consuming it.[2] Common examples are communication devices such as telephones, fax machines, and computers. Obtaining one such machine serves little purpose, if no other users have a compatible one. Cultural goods also tend to have consumption network effects. For example, one reason why we watch sports is to be able to discuss them with friends. Language is both a communication device and a cultural good, for its usefulness to a speaker relates directly to the number of people who understand it.

The foregoing are all examples of so-called direct network effects. Katz and Shapiro also define indirect network effects, which occur when complementary products or infrastructure are needed in order to use a good. For example, software needs hardware, electrical machinery needs

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1 We do not attempt to cover all of the available literature. For a summary on IPR, see Menell and Scotchmer (2007). Maskus (2000) provides a comprehensive overview of all the issues of IPR in the global economy. An early review of the literature on network effects can be found in David and Greenstein (1990). For a recent comprehensive review, see Farrell and Klemperer (2007).

2 See Liebowitz and Margolis (1994) for a discussion on network effects versus network externalities.

electricity, and automobiles need gasoline and service stations. The higher the quality and the wider the variety of the complementary products, the higher is the willingness to pay for the original product.

Many – although not all – of the goods that exhibit network effects are technologically sophisticated. As such they tend to have the following characteristics. First, many are goods where the creation and protection of IP is of paramount importance. Second, for complementary products to work properly with each other, an interface between different types of products needs to be defined. The specifications of these interfaces are frequently established as standards. If different countries adopt different standards, trade in products adhering to standards is affected. Since this influences the size of a given network, social welfare changes beyond the usual relative cost considerations.

How do IPR interact with network effects in the global economy? Note that insufficient IPR protection in a country may affect the provision of complementary infrastructures, goods and services needed for the consumption of a good. For example, software makers may be reluctant to supply in countries where a single copy can be pirated into millions of copies. This reduces the potential consumption network effects for hardware users. Therefore, one might favor complete and universal coverage of IPR in the world as the best means to maximize (world) welfare. However, that view would have to be qualified, on several fronts.

First, it is well known that in the presence of market imperfections, in particular when strategic interaction is important, maximizing world welfare is different from maximizing the welfare of any single country. Such strategic interactions are likely to be important for goods that exhibit network effects, since their very nature may lead to monopoly or oligopoly production. Moreover, dynamic effects such as “tipping” render the potential payoff for a single firm quite large.[3] Therefore individual countries may attempt to tip world markets towards their domestic network products, a strategy facilitated by sufficient IP protection. Second, standards for complex products often embody IP owned by firms from different countries. When establishing a standard, individual firms may use their IPR to bargain monopoly rents away form other firms, which in some cases may lead to inefficiency. Finally, it can be in firms' own interest to have low protection of IPR. Firms may even condone piracy, as an effective means to enlarge their markets. This can be profit-maximizing, since it increases the willingness to pay of legitimate consumers. Furthermore, if tipping is expected, firms may allow piracy to cause tipping in favor of their network products.

We conclude, therefore, that the interaction of network effects and IP issues is both important and complex to analyze. Goods that embody both are globally ubiquitous and economically important. It is this interaction that we address in this chapter.

1.2. Empirical Evidence on Networks Effects

Much of the evidence on goods with network effects, and on IP issues of such goods, has been gathered in the information technology sector. For example, Gandal (1994) estimates a hedonic pricing model for the market for spreadsheets, which in the time period concerned (1986-1991) was dominated by one product Lotus 1-2-3. Besides using variables that measure the desirability of different spreadsheets,[4] he includes a variable for compatibility with the Lotus format, and a variable for whether the program can link with external databases. His results suggest that the latter two characteristics enhance the value of a spreadsheet. Arguably, the first characteristic measures direct network effects, while the second measures indirect network effects.

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3 Tipping can occur when two or more network technologies compete with each other, such as Apple PCs versus WINTEL PCs (those that use Intel Processors and the Microsoft Windows Operating System). One system's small advantage leads all new complementary goods producers or consumers to join the marginally stronger system.

4 For example, whether the spreadsheet can recalculate automatically when new entries are made,,sort data on at least two levels and has basic graphic capabilities.

Givon *et al.* (1995) adopt a more structural approach to estimating network effects. They also investigate the influence of piracy on legitimate purchases. Specifically, they set up a diffusion model for the markets for spreadsheets and word processors in the United Kingdom and then fit it to the data. Their results indicate that over 80 percent of software purchases between 1987 and 1992 were influenced by pirates through word-of-mouth. While this is evidence of a network effect, it also highlights the importance of piracy. Interestingly, word-of-mouth influence by pirates and legitimate users is practically indistinguishable, indicating that all users (legitimate or not) participate in the same network.

Brynjolfsson and Kemerer (1996), like Gandal (1994), also estimate a hedonic pricing model for spreadsheets. However, they use a more direct measure of network effects. While Gandal's measure is based on features of the software (compatibility with the Lotus format may be a desirable characteristic in itself), Brynjolfsson and Kemerer use the market share of each product as an explanatory variable (they also use a measure of compatibility with the Lotus program). Their results indicate that an increase of one percent in market share of a product leads to a 0.75 percent increase in its price, which is consistent with network effects in this market.

More recently, Oberholzer-Gee and Strumpf (2007) analyze the impact of illegal music file downloads on legal sales of music. Since downloads have no effect on sales, they interpret this as the net result of two opposing mechanisms: downloads replace sales; but they also create network effects through word-of-mouth promotion for good songs, which enhances sales.

We conclude that there is evidence for the presence of consumption network effects in the software and music industries. At a more macro level, we have found no direct evidence on the importance of network effects in international trade or foreign direct investment. Nor is there any direct evidence on how important IPR are for network goods. However, some indirect evidence can be gleaned from data on pirated goods. The value of worldwide sales in pirated and counterfeit goods is estimated to be around $650 billion, more than double the amount of illicit drug trade and roughly seven percent of world trade (Havoscope 2006). While these estimates may be imprecise, virtually all counterfeit and pirated products can be sorted into three categories: branded final products such as clothes and cosmetics, branded parts, such as those for cars and airplanes, and complementary products, such as software, videogames and DVDs. As we argue below, all of these types of products are likely to exhibit direct or indirect network effects. IPR issues are also likely to be important for all types, hence the focus in this chapter: goods that exhibit network effects *and* that have a strong IP content.

2. Basic Concepts and Definitions

A network is a system composed of nodes and links between nodes. Network effects exist when adding to the size of a network increases the value of each node.[5] Network effects can arise in complementary-goods relationships. For example, the more software varieties are developed for a particular hardware, the more consumers value the hardware. The higher level of hardware consumption in turn increases the incentives for software producers to develop new varieties (Church and Gandal 1992) or higher qualities (Markovich and Moenius 2006a) compatible with the hardware. Such systems of complementary technologies and products are called *platforms*, defined

5 The industrial organization literature defines network effects strictly in the context of the demand side (also referring to them as “economies of scale in consumption”), while attributing all comparable production-side effects to economies of scale and scope. However, some of the phenomena that we review in this chapter (for example, in research networks) are hard to describe solely through economies of scale or scope, and are equivalent in nature to demand-side network effects. Therefore, similarly to Love and Roper (2001), Mika *et a*l. (2006) and Rauch (2001), we will refer to those factors as network effects. In this chapter, we generally assume that network effects exist, instead of deriving them explicitly from the network structure. See Economides (1996) for a discussion of assumed versus derived network effects.

by Bresnahan and Greenstein (1999) as a technology around which buyers and sellers coordinate efforts.[6] This broad definition includes any kind of component that a technology may require. For example, computer platforms include hardware, software, operating systems, peripherals, network connections, services, and so on. Adding and improving complementary components increases the value of a platform.

To ensure interoperability of all complementary components, *interfaces* are necessary. If an interface is to be shared among a variety of components, an interface *standard* needs to be specified to ensure that the components work adequately with each other. This standard can be proprietary or freely accessible. Proprietary standards are called "closed," all others "open." If the owner of a closed standard keeps it in-house, then innovation around the standard occurs only within the firm. Alternatively, the firm may license a standard, allowing the development of components by others. By contrast, open standards allow free competition in the component market. Thus, closed standards can be used to limit competition.

A distinction should be made between *de jure* and *de facto* standards, which can be understood in light of network effects. *De jure* standards arise through an explicit standardization policy by governments towards an industry to ensure minimum quality or safety, but also to increase network effects and thus social welfare. On the other hand, the network effect itself may help to expand the reach of a technology until it becomes so dominant that it is called a *de facto* standard. A third category is called *institutional* standards. These are developed by committees within standards-setting bodies such as the International Organization for Standardization (ISO).[7] The application of these standards is voluntary in principle, but it is frequently mandatory as part of contractual

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6 For a different use of the term technology platform, see Economides and Katsamakas (2006).

7 See Farrell and Saloner (1988) for a formal analysis of standards choice in committees.

obligations. Sometimes institutions develop standards upon requests by governments. These norms then become *de jure* standards.

Institutions that develop standards can operate at the industry, country or international level, depending on what level the network effects are expected to emerge. This is related to the *scope* of a network, which refers to its relevant size for each consumer (Katz and Shapiro 1985) and can thus be interpreted as a measure of the extent of the network effect enjoyed by consumers. The scope may consist of only one brand if different brands are mutually incompatible. It may also be an industry or a sub-sector thereof. The former is more likely when a single standard is shared across the industry. Software provides examples of different levels of scopes. While the Windows operating system has become a global standard, some application programs only have national benefits (e.g., tax software), or may matter only locally for some users (e.g.. document exchange within one's circle of friends) while mattering globally for others (e.g., document exchange across international organizations). Katz and Shapiro discuss the relationship between the scope of a network and the adoption of a standard in the context of firms' decisions on compatibility with one another. They find that firms with the best reputations may choose degrees of compatibility that are below the social optimum, and vice-versa for less reputed firms. It is further useful to distinguish whether the scope of a network is national or international, since consequences of IP protection differ for global versus local networks.

Network effects also raise questions about efficiency, since the adopted standard may not be the best possible. That may happen because imperfectly informed or corrupt governments adopt the wrong (*de jure*) standard, or because lock-in effects cause an inferior (*de facto*) standard to become prevalent.[8] There is a debate in the literature over whether the adoption of inferior standards has actually occurred. While David (1985) and Diamond (1997) argue that the QWERTY keyboard was adopted despite its technological inferiority, Liebowitz and Margolis (1990, 1994) challenge this view. Katz and Shapiro (1986) study the dynamics of technology adoption in industries with network effects. In their model several incompatible technologies compete in the market place, and *de facto* standardization may be achieved through the locking in of one of the technologies. Whether the market chooses the socially optimal standard may also depend on the IPR ownership structure. For example, if the inferior technology is owned by a firm, while the superior technology is not owned by anyone, the former may gain predominance through sponsorship by its owner.

A common feature of platform development is cumulative innovation, such as the constant development and improvement of components that are close substitutes for each other. One example is the myriad of CD-players that are marketed, all able to play the same CDs, due to the existence of a common data-encoding standard. Similarly, Economides (1996) describes the information superhighway to consist of "substitutes of complements." Cumulative innovation benefits from knowledge spillovers, which frequently take place within *research networks*. By analogy with the language of platforms for complementary goods, we call research networks *knowledge platforms*, which are then defined as networks of researchers and engineers, all interested in the development of a common area of knowledge around which they coordinate their research efforts. If the skills and know-how of those researchers are complementary, then adding researchers to a knowledge platform extends the available skill-pool to all researchers in the network. Thus, network effects exist in the *creation* of IP when cumulative innovation is present.

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8 See Farrell and Saloner (1985, 1986) for a model of this effect.

The creation of IP within knowledge platforms can occur even for products that do not exhibit network effects. At the same time, IP for goods that do exhibit network effects can be created by actors that do not participate in knowledge platforms. Thus, there is no one-to-one correspondence between knowledge platforms and products that exhibit network effects. However, since cumulative innovation is common for such products, knowledge platforms frequently arise for their creation.

Network effects exist not only in the creation but also in the diffusion of IP, where such effects are significant and best studied in the context of ethnic networks. Ethnic networks may constitute a substantial part of knowledge platforms (Kerr 2006). Using patent citations, Kerr (2007) finds strong and significant international technology transfer through ethnic scientific communities, with measurable effects on manufacturing output in the recipient countries. Besides patentable technology, other information relevant to doing business abroad may be exchanged in ethnic networks, with measurable effects on international trade flows (Rauch and Trindade 2002).[9]

In sum, we argue that network effects in the global economy exist both in the creation and transmission of IP as well as in the consumption of a broad range of goods, many of which frequently carry a high IP content. Due to the need for cumulative innovation in network industries, knowledge platforms are often the relevant structure to create IP in those industries. In spite of this fact, it is methodologically most appropriate to analyze the relevant effects one at a time. Thus, the remainder of this chapter is organized as follows. First, we discuss the interaction between network effects and IPR, followed by an analysis of network effects in knowledge platforms. Then we discuss some specifics of network industries and how they are influenced by IPR in the global

9 The mechanism in such networks is similar to that of research networks: adding reliable international traders to the network increases the probability of a successful deal for all members. Thus ethnic networks, for example, exhibit a direct network effect.

context. Next we present issues of strategic choice of IPR protection for network industries. The last section provides a summary of the different strands of the literature.

3. Network Effects and IPR

Governments do not typically target their IPR legislation towards goods with network effects. However, IPR play an almost defining role in the economics of such goods. Moreover, the existence of network effects can, through their influence on market structure, either increase or reduce the value of a patent or copyright.[10] On the other hand, different forms of IPR, the specifics of their use[11] and even their infringement can enhance or reduce the strength of a network effect. Therefore we review in this section some possible interactions between IPR and network effects. We do so in three steps. First, we analyze how network effects influence the economic value of intellectual property rights. Next, we summarize how awarding IPR influences network industries. Then we describe how the relationship between network effects and IPR varies by type of policy.

3.1. How do Network Effects Influence the Value of Intellectual Property Rights?

Consider how network effects affect the shape of the demand curve.[12] In the presence of network effects, an individual's willingness to pay depends on how many other customers purchase the same product. So for each *expected* demand, there is a different downward sloping demand curve. Let $D(p,q_e)$ describe the demand when expected total sales equal q_e. It is decreasing in its first argument, but, due to the network effect, increasing in the second. Several such demands are shown in Figure 1, for example, $D_1 \equiv D(p,q_1)$. When for a certain price p, $D(p,q_e) = q_e$, expectations are

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[10] The value of an IPR is simply measured as the discounted future monopoly rent it grants.

[11] For example, the extent to which the market power granted by them is used in licensing agreements.

[12] This description is adapted from Economides (1996). Economides and Himmelberg (1995a) provide additional details.

fulfilled and an equilibrium is reached. For example, for D_1 expectations are fulfilled at q_1. This analysis can be repeated for various expected demands, tracing out the locus $p(q)$, which depicts the willingness to pay at points where expected and actual demands are the same.

Figure 1 about here

Suppose now that the good is competitively supplied. For a given level of (constant) marginal costs c, three equilibria are possible as shown in Figure 1, one at zero, one at q_1 and one at q_4. Consider first the fulfilled-expectation equilibrium at q_1. Suppose that consumers revise their expectations slightly higher, say, to q_2. Then D_2 becomes the relevant demand curve. With a competitively supplied good, actual demand will be q_3, inducing consumers to adjust their demand to D_3, and so on. This process will only stop when consumers correctly expect the quantity demanded to be q_4. Therefore, q_1 is an unstable equilibrium, while q_4 is stable. Now consider a small deviation to the left of q_1: there, actual demand is below expected demand, which leads to an adjustment of expected demand downwards all the way to zero, making zero demand also a stable equilibrium. Thus we see that goods with network effects exhibit multiple equilibria.

This multiplicity is important for two reasons. First, social welfare is by no means the same at the two equilibria. In particular, consumer surplus is higher at q_4 than q_1, since more customers are served at the same price. Due to the larger network size, each one also receives higher utility. Note that producer surplus is identically zero at both equilibria. Second, nothing guarantees that the efficient equilibrium will be reached. In order for the system to reach the stable equilibrium q_4, it is essential that it gathers at least q_1 customers. Customer level q_1 is therefore a threshold value or critical mass.[13]

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[13] This definition of critical mass is less restrictive than that in Economides and Himmelberg (1995a), who do not take expectation adjustment into account and therefore define critical mass as the point where $p(q)$ reaches a maximum.

How do network effects impact the value of IPR?[14] IPR reward their creators with market power. Depending on the resulting market structure, this can make it easier or harder to reach the critical mass of a network. If the critical mass is not reached, any IPR specific to this network would have no value. If the critical mass is reached, the network effect would raise sales and thus the value of IPR.

Consequently, the value of IPR embodied in a network good depends on what equilibrium will be reached, which in turn will depend on such factors as the institutional arrangement for different IP owners and the strategic interaction among them. Consider, for example, the case where competing but incompatible network goods can be developed. The regulator or the competitors themselves can choose between coordinating on one standard or allowing several specifications to compete for the market so that multiple standards might coexist.[15] Coordination implies larger market size with higher network effects, and thus higher value of the IPR included in a common standard. Thus, institutional arrangements that encourage coordination are likely to enhance the expected value of an IPR.

To examine the importance of strategic interaction, note that the expected value of an IPR should be reflected in its licensing contracts. However, if coordination and its outcome are uncertain, the determination of licensing fees becomes difficult, since the licensed technology could lose the market to a competing system, or more than one system could coexist, while coordination on this technology would promise monopoly power.[16] This uncertainty may induce firms to develop

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[14] Farrell and Shapiro (2004) discuss this question in the context of information technology.

[15] Researchers interested in the differences between adopting one standard versus multiple standards frequently cite the example of the GSM standard for second-generation mobile telephony in Europe, as opposed to the multiplicity of standards allowed to coexist in the United States (D-AMPS, GSM, CDMA2000, among others). See also Besen and Farrell (1994).

[16] Menell and Scotchmer (2007) provide an overview of the relevant literature on licensing issues.

their own proprietary technology, which can be used as a threat-point in the bargaining process in order to negotiate lower licensing fees. It also allows them to compete independently in the market should negotiations for a common standard fail. Therefore, firms are less likely to coordinate, which reduces the expected value of the collective IPR, both because the network effect is reduced, and because there is a lower probability of reaching the critical mass.

Note that even in the absence of network effects, the value of IPR is also influenced by how concentrated their use is in complementary products. For example, assume IPR establish a monopoly for each of two complementary components that are assembled into a final good. Contrary to what intuition might suggest, prices in this case are higher and profits lower than if an integrated monopolist produced both components, a result long ago pointed out by Cournot. Thus, IPR held by two complementary-goods producers may have a lower value than if they are held by a single firm.[17] Since price reductions of any component benefit the whole system, it is always beneficial for a monopolist if the complementary good is sold at a lower price. Therefore, introducing competition into the complementary market (and fending it off in one's own component) is a profit-enhancing strategy even in the absence of network effects. However, network effects enhance the power of this strategy. For example, Microsoft ensures competition in the hardware market through a Windows Compatibility Lab. This increases the network effect since it ensures higher sales both in hardware and in complementary software provided by Microsoft (Varian 2004).

3.2. How Do Intellectual Property Rights Influence Network Effects?

As discussed above, network effects can influence the value of IPR. But the chain of

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[17] While instructive, this result is specific to this particular market structure. For more general treatments of complementary relationships without network effects, see Matutes and Regibeau (1988) and Einhorn (1992).

causation can also run in the opposite direction. First, the concentration of IPR ownership matters for the creation and survival of the network. Second, optimal incentives for the creation of network goods depend on whether cumulative or one-step invention is required. Third, network formation and persistence depend on whether the IP is for interfaces or for components. The following exposition exemplifies these three aspects.

3.2.A. Intellectual Property Rights Ownership and the Creation of Networks[18]

We already saw that if a network good is competitively supplied, the fragmented market may be unable to commit to an amount above the critical mass, preventing network formation. By contrast, suppose that one monopolist holds all the IPR for the good. It can commit to a price-quantity combination that ensures an equilibrium at a quantity q_m, $q_1 < q_m < q_4$ in Figure 1, a level above the critical mass. Therefore if the development of the network good is based on one major invention and the inventor can establish a monopoly position, provision of the good can be guaranteed, albeit at a higher price than at the competitive equilibrium q_4. The argument can be extended to cases where compatible network goods are supplied by oligopolists, as long as each supplier has the capability to serve the whole market (Economides and Himmelberg 1995a, 1995b).

However, once a single supplier cannot serve the whole market, this argument fails since there needs to be sufficient coordination for entry into the market to reach critical mass. As market power reduces supply per firm, it may reduce the likelihood of reaching the critical mass. IPR establish market power and can thus contribute to surpassing the critical mass necessary to provide network goods, but can also hinder sufficient entry into the market. The higher the number of

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18 This subsection discusses the findings in Economides (1996) in light of IPR. See also Economides and Himmelberg (1995a, 1995b)

components and the lower their degree of substitutability, the less likely it is that the critical mass would be reached.[19]

Finally, consider two incompatible network goods competing against each other, such as two different hardware platforms. Incompatibility implies that the network effect only exists within each platform separately. In this setting, market power may still ensure that the critical mass will be reached. But the individual interests of firms on the same platform may weaken the network effect on that platform, since the exploitation of market power will lead to reduced sales. This creates the potential for losing the whole market to the competing platform (Markovich and Moenius 2006b).

3.2.B. Cumulative versus One-Step Innovation and Network Effects

Merges and Nelson (1990) argue that there are substantial differences in the nature of innovation for different industries. While the ballpoint pen was an innovation that reached its goal in one step, systems innovations, such as those seen in the computer industry, require many incremental improvements in components. How should IPR be designed to provide incentives in such a way as to encourage optimal effort of innovators in either type of innovation?

The simple model in Farrell and Shapiro (2004) highlights the main issues. For one-step innovations, which require the success of one single inventor, they argue that the probability of individual success $p(x_i)$ is convex in effort. Innovator i's effort, denoted by x_i, is assumed to be proportional to the expected reward. By contrast, the case of cumulative innovation is better described as concave in effort. The objective function in either case is to maximize the probability of overall innovative success, denoted by P and is written as follows:

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19 Similarly, in an oligopoly with quality differences across suppliers there need to be enough suppliers of sufficiently high quality. See Markovich and Moenius (2006a), who call the increase in the overall market size due to entry and quality increases of suppliers a market-extension effect.

$$P = 1 - \prod_i \left(1 - p(x_i)\right) \qquad (1)$$

This formulation assumes that the success probabilities of inventors are independent of each other. Maximizing this function in x_i requires x_i to be as large as possible for one i and zero for all others if $p(x_i)$ is convex in effort. But x_i should be evenly distributed if $p(x_i)$ is concave. Therefore, a "one size fits all" IPR-policy that encompasses both one-step and cumulative innovations cannot bring about optimal innovative outcomes. In the former case a maximum reward should be given to a single inventor, while in the latter situation rewards should be equally distributed across all inventors contributing to the system.

In particular, how broad should patent protection be? Consistent with the model in Farrell and Shapiro (2004), Merges and Nelson (1990) argue that broad IPR scope might be warranted for one-step inventions, but may inhibit technical progress in cumulative inventions. This is because for one-step inventions, the optimal policy is to provide sufficient incentives for individual inventors, but is otherwise unconstrained by concerns of hindering further development of the industry. By contrast, suppose that a broad patent is granted to an inventor of a network component. Due to its breadth, the patent may prevent development of new varieties by other inventors, reducing network effects and possibly lowering the probability of reaching critical mass. This in turn reduces inventors' incentive to invest in this network technology, slowing down technological progress.

3.2.C. Intellectual Property Rights and the Use of Market Power in Interfaces

If a firm can appropriate a standard and even protect it through a set of IPR, it can obtain tremendous market power, as is well documented in the case of Microsoft's Windows operating system (OS). However, whether the firm decides to use the standard as a source of licensing fees or to keep it secret depends on whether it sees the standard as its core intellectual property. For example, Microsoft insisted on secrecy for its interface between its desktop OS and its server OS. Microsoft saw this interface as a major source of value creation, since the performance of a networked computer system depends on the performance of the personal computers, the server, and how well those two communicate. Keeping the interface at least partially secret allowed Microsoft to leverage its strong position in PC OS into an advantage in the market for server OS (Farrell and Shapiro 2004).

A contrasting example is Intel's licensing of its PCI bus. Intel initially developed this bus system because the slow development of bus systems by other firms lowered the capabilities of Intel's processors. Intel licensed its PCI technology liberally, and also started producing its own PCI bus systems to guarantee a minimum supply and to ensure that a critical mass was reached. Thus, unlike Microsoft's approach with respect to Windows, Intel viewed the IPR in its processor business as core and those in its PCI bus only as complementary. Intel's information-sharing on the PCI bus also facilitated network effects through the development of complementary products, which further strengthened Intel's market power in the processor business (Gawer and Cusumano 2002).

Thus we conclude that firms may pursue proprietary policies in their IPR for core interfaces between components that the firm regards as critical sources of monopoly rents and that are made by the firm itself. By contrast, they may pursue a more open policy in non-core interfaces with other firms' products. In the latter case, this policy may spur innovation and increase competition in complementary-goods markets to increase network effects for their core technologies.

3.3. How Does the Interaction between IPR and Network Effects Vary by Type of IPR?

In this section, we describe how the different types of IPR can differentially influence or be influenced by network effects. We compare the four main types of IP: patents, trade secrets, copyrights, and trademarks. Because these types are protected, either by firms or by governments, in different ways, IP in network industries is frequently protected by a combination of rights, regulations, and business practices.

Three features of patents are most relevant for our discussion: (1) they confer to their owners the right to exclude others from making, using or trading the patented technology ("full exclusion"); (2) they have an expiration date ("time limitation"); (3) the patent holder must publish detailed technical specifications for the technology patented ("maximum information").

The time limitation of patents ensures that the monopoly power granted by them does not extend indefinitely. The time limitation of patents contrasts favorably with copyrights, which were originally designed as narrow protection for authors of creative work for as long as they (and their heirs) lived. Nevertheless, they have recently played a role in the protection of interfaces in network industries. The longevity of copyrights cements dominance of existing product platforms, making it hard to replace them with technologically superior products that require the use of copyrighted information. However, in contrast to the full protection of patents, copyrights are treated differently by the courts. Farrell and Shapiro (2004, p. 57) report a case in the 1990s in which Lotus sued Borland under copyright law, accusing Borland of emulating its user interface:

> "To economists, an odd feature of the case was that *Borland* argued that *Lotus* had put considerable research and effort into the design of its user interface. While this would if anything have helped Lotus had it been a patent case, in a copyright case this helped Borland argue that there were no comparably efficient alternative interfaces, so that if Lotus got copyright protection on the interface, that would give it market power in a way that copyright is not meant to do."

The information published in patent applications helps researchers within the field build on current knowledge. However, this requirement may prevent standards owners from patenting. For example, if an interface was patented in its entirety, everyone would know its specifications *exactly*, which, as discussed earlier, may not be in the interests of the interface owner.

Contrast this feature of patents with trade secrets, defined as economically valuable information that is not publicly shared. Trade secrets have the following characteristics: (1) they are IP in a wide sense of the term; (2) they never expire; but (3) they are only protected against illegal discovery methods. [20] In other words, they do not enjoy the same broad protection as patents, but their owners are under no obligation to disclose information. If they can be effectively protected, they generate a formidable barrier against access to information. However, due to the lower protection of trade secrets, poaching may occur. In the US, a company that discovers a mechanism identical to one previously used by another firm and protected by a trade secret can patent its (re)discovery and then prevent the original firm from using the mechanism. If a firm protects the part of an interface it wants to be publicly known with patents, and those parts it wants to keep in-house with trade secrets, it risks having those trade secrets being discovered and patented by another firm. If this happens, market power can shift rapidly. This contrasts with the market power afforded by patents, which support slower change.

Finally we consider brands and trademarks. Trademarks are unique identifiers (words, logos, brand names, and the like) of products or organizations. They do not expire (unless they acquire a generic meaning, such as Kleenex for paper-tissue) and they are protected by national and international trademark law through registration or usage in the market place.[21] Trademarks are a part of firms' strategies to establish a brand. The concept of a brand, however, is much broader and reflects a multiplicity of information and expectations associated with a company, product or lines of products. Note that brands in this broad sense are not protected by IP law, while trademarks are.

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[20] In legal terms, trade secrets are protected by laws against unfair competition and fraudulent means of one firm acquiring another firm's confidential business information. If the information is learned through legal means, such as reverse engineering, it is available for use by the acquirer. While trade secrets are not, therefore, IPR in the strictest sense they do have the effect of protecting exclusive use of an undisclosed technology.

[21] Trademarks do expire if their owners choose not to incur the costs of renewing their registration.

Thus trademarks are the relevant legal part of a brand that can be used to fight brand imitation, but it is brands in their entirety that exhibit network effects.

For example, brands may increase consumer confidence or information, and therefore the willingness to pay. Kerin *et al.* (2006, p. 300) define "brand equity," as the "added value a given brand name gives to a product beyond the functional benefits provided". Brand equity values are estimated to be substantial (Interbrand 2006), potentially a reflection that network effects contribute to them. This can be especially important in countries with inefficient market information. For example, India's house of Tata uses its brand in a vast variety of products and industries.[22] By focusing on quality control and brand-name promotion, Tata has created a network effect, which is that adding product groups of reliable quality to their portfolio strengthened consumer confidence in the quality of other Tata products.[23] The converse of these effects is also important. Mellen and Scotchmer (2005) point out that trademark violations reduce the positive network effect of brands, thus reducing consumer confidence and willingness to pay.

We conclude that different intellectual property rights protect different aspects of a technology, but also open different doors for evading protection. It is, therefore, not surprising that proprietary technologies, and in particular proprietary interface standards, are usually protected by a portfolio of patents, copyrights and trade secrets, making it hard to break the market power of such a standard.

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22 Tata currently lists about 25 consumer product groups from agricultural appliances to watches on their webpage. They also offer products and services to other companies in 16 different industries. See www.tata.com for details.

23 For a description of Tata's strategy, see Khanna and Palepu (1997). While they do not mention network effects in particular, they offer a description of the mechanisms labeled here as such. Note that there are also economies of scale and scope in marketing efforts. Beggs (1989) explains how supply-side economies of scale can induce demand-side network effects. Bagwell and Ramey (1994) indicate how coordination economies (essentially a network effect) can be realized through advertising.

4. Network Effects in the Creation, Dissemination and Protection of IPR

We mentioned in the introduction that besides their role in consumption, networks play an important role in the creation, dissemination and protection of IPR. In this section, therefore, we focus on the role of networks in the process of knowledge creation and dissemination. Network effects that rely primarily on the consumption side are discussed in the next two sections.

4.1. Knowledge Platforms

Within a research field, each researcher's knowledge is likely to be complementary to that of her peers. Projects that require collaborative contributions exhibit network effects in their efficacy if each researcher's contribution increases the productivity of others in the network. Intuitively, the strength of the network effect in research networks will depend on three parameters: (i) the degree of complementarity of knowledge; (ii) the transactions costs of coordinating different researchers, possibly across institutions and countries; and (iii) the quality and cost of information transmission within the network. These three factors also jointly determine the size of research networks (or what we have called *knowledge platforms*). The strength of the network effect and size of the network of researchers then determines the quality and quantity of IP created.

We begin with a model adapted from Rauch and Watson (2007) to see how the three issues listed above help explain the structure of research networks. The main assumption is that research collaborations exhibit network effects because forming a research network delivers a higher benefit to participants than the sum of their separate efforts. Researchers have exogenously determined close ties to other researchers working in the same lab, but have the choice to engage in a costly search for partners in different labs. In the latter case they obtain a benefit that is more uncertain, but potentially greater due to higher complementarity and less overlap in knowledge. The search for outside partners is modeled as a random matching of researchers. Once a match is formed, the joint benefit of the collaboration is revealed to both researchers, who decide to pursue the project only if it yields a higher benefit than working with a researcher in their own laboratories.

Rauch and Watson further distinguish between laboratories that are close to each other (dubbed to be in the same cluster) or further away (said to belong to a different cluster), which introduces geography into the model. Researchers find the optimal search effort by equating the expected benefits of search to its cost. The outcome is a distribution of research collaborations within laboratories, between laboratories that are close by (called cluster ties) and between laboratories that are more distant (bridge ties). Since matching is random, the model delivers cluster ties and bridge ties in proportion to the size of the own cluster relative to all other clusters. With the help of this simple formal structure, we will now discuss the three issues relevant for the size and structure of the research network. In turn, these factors influence network effects in IP creation, which are complementarity of knowledge, coordination costs, and information transmission. [24]

4.1.A. The Complementarity of Knowledge in Knowledge Platforms

Researchers collaborate to reduce time to complete, to win a patent race, and to benefit from the exchange of ideas. They may also form partnerships both within- and across-organizations in order to work on complex problems that require specialization of complementary tasks.[25] How does complementarity affect the size and the scope of the research network? What implications does it have for the international diffusion of technology?

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[24] Mika *et al*. (2006) identify both size and diversity of networks as determinants for the number of publications and citations of researchers. In Rauch and Watson's (2007) model, network effects arise endogenously, since an increase in the search effort of a single researcher increases the probability of a high-quality match for all researchers.

[25] There is evidence that knowledge creation occurs across boundaries of single organizations. For example, in Gittelmann's (2007) data on biotechnology publications, 70 percent of scientific publications listed coauthors from more than one institution or firm, while 30 percent had authors from just one laboratory.

Our model assumes that distance creates a barrier to knowledge diffusion, therefore the knowledge of researchers located further away differs from the knowledge of local researchers.[26] In other words, knowledge of faraway researchers is less substitutable and more complementary than that of local researchers, thus adding more to a project. However, there is also a risk that the knowledge in distant laboratories is not fully compatible and therefore may not contribute sufficiently to a project to make a partnership attractive. In order to get access to the distant complementary knowledge, firms may contribute to the increase in the size and scope of research networks. For example, they can reduce barriers between researchers by establishing multiple research facilities in different locations that tap into local knowledge resources. Baldwin and Hanel (2000) provide evidence that multinational companies with research facilities in Canada use local partners such as Canadian universities and domestic customers as sources of ideas. Local R&D departments of multinational firms are more often partners of R&D collaboration projects, both in Canada and other countries, than are R&D departments of their Canadian counterparts. In the language of our model, these local R&D facilities create cluster ties in their local environment, feeding the newly acquired knowledge through existing bridge ties to parent and sister companies. This is an example in which high-resistance bridge ties are internalized, while low-resistance cluster ties are formed wherever the multinational establishes a subsidiary.

Note that a more international scope of research platforms – itself a consequence of the higher degree of complementarity of distant knowledge – immediately implies international technology diffusion. But diffusion is not automatic: Keller (2004) highlights the importance of complementary skills that must be developed locally in order to be able to absorb foreign

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[26] Gittelmann (2007) provides evidence that there is this dichotomy of distance, as well as that research collaborations with distant partners deliver higher-impact results.

technology. For this reason technology spillovers are weaker into developing countries than into developed countries. The literature on networks of inventors sheds light on the mechanism of these spillovers.

By assumption, networks are always formed by two researchers in the Rauch and Watson (2007) model. Note, however that the size of research networks can vary drastically (Beaucage and Beaudry 2006). Likely drivers of size include the complexity of the IP to be created, the financial payoff expected, as well as the available complementary knowledge embedded in researchers.

4.1.B. Coordination Costs in Networks of Researchers

For the creation of intellectual property, researchers may form cluster and bridge ties. Coordination costs arise especially for the latter because researchers need to monitor each other's progress, coordinate goals, and exchange information. These coordination costs are likely to limit the overall size of networks, vary with the structure of the network and reduce or even offset potential network effects. Foray and Steinmueller (2002) find that the choice of coordination mechanism among researchers depends on the degree of appropriability of knowledge. Appropriability is tightly linked with IPR, since formal codification of technology facilitates appropriation of each agent's contribution.

The choice between formal and informal research arrangements depends on whether trust and reciprocity can be established. Formal arrangements are more costly than informal arrangements and thus imply smaller networks. But high appropriability of IP in formal arrangements may allow the recovery of this additional cost. Informal arrangements can also exist under high appropriability, but under restrictive conditions. Either partners have established trust in each other in the past or the IP to be exchanged must already exist. In sum, high appropriability is more often associated with formal arrangements and smaller network size. The opposite is true for weak appropriability, which renders costly formal mechanisms inefficient. In that case, informal arrangements become the fallback solution, and network size can be larger due to lower coordination cost. Of course, formal arrangements are still possible even with weak appropriability. IPR can be pooled and jointly licensed or a shared benefit not directly related to the IPR exists that cannot be achieved by informal arrangements.

All possible combinations of appropriability and formality are shown in Table 1. An example of a formal arrangement with strong appropriability is a high-tech consortium. This is a contractual arrangement between firms that jointly develop and share IP that each partner can implement in its products. While costly to set up, the contracts detail rights and obligations in the partnership to set incentives for the joint research effort. The informal counterpart would be knowledge-trading arrangements, which are less costly, but can only handle existing knowledge, unless trust has been established. An informal arrangement with weak appropriability is informal knowledge-sharing. This arrangement is used if partners want to signal quality and build trust through reciprocity instead of earning immediate monetary benefits. Finally, formal standards-setting consortia select a specification that benefits all participants without joint development of new IP. Partners can then jointly license the established standard or benefit from its existence for their complementary component development.

Table 1 about here

4.1.C. Transaction Costs of Information Transmission

So far we implicitly assumed information to flow perfectly within existing networks. But not all information can be codified and, therefore, information transmission is never perfect. For example, certain types of information can only be passed on by demonstration that requires physical presence. This kind of information is very costly to transmit across clusters. Transaction costs in the transmission of information, as we shall see, influence the size and reach of a network, which in turn affects the type of IP that is created in different networks.

Scientists transfer knowledge in two ways: through publication of results and through direct communication, for example as they collaborate on a project. There is evidence that knowledge transfer that is closely linked to commercialization of inventions (namely patents) can only happen through more direct collaboration (Gittelmann 2007; Beaucage and Baudry 2006; Jaffe *et al*. 1993), which requires geographic proximity. In particular, Gittelmann (2007) documents the presence of two types of networks in the biotech industry. Her data has patent-to-paper and paper-to-paper citations, exploiting the practice in this industry to publish applied papers, while at the same time applying for a patent on the same topic. She finds highly active research collaborations within a 50-mile radius, which covered 18 percent of all papers in the sample. At the opposite extreme, about 60 percent of collaborators are located more than 800 miles away from each other. Of these 60 percent, more than one-third involved at least one non-U.S. coauthor and another one-third involved cooperation between researchers from both coasts of the United States.[27] She finds that local networks foster patentable knowledge, while collaborations between distant researchers produce highly cited scientific papers. Teams within the same cluster receive almost seven times more citations from patents than distant teams, while in scientific papers the former receive only about one-fifth the citations of the latter. Thus proximity is relevant for patentable innovation, but not for scientific research. In the latter, the small cost of information transmission for digitized knowledge makes the quality of the match more important than the cost of transmission.

[27] Similarly, in their sample of Canadian biotech-patents, Beaucage and Beaudry (2006) find that one-quarter of the collaborators live outside of Canada.

While it seems that firms need to be well connected in their local clusters to create patentable innovation, they also need access to a broad knowledge pool. Since adding ties to their networks is costly, firms face a tradeoff between local connectedness and access to globally available knowledge. Schilling and Phelps (2007) document that small-world connectivity (a situation of intense clustering with sparse bridge ties across clusters) can help overcome this tradeoff. They show that networks of firms in equipment and pharmaceuticals that exhibit these small-world properties have significantly higher rates of knowledge creation as measured by firms' patent output.

This may suggest that geographic distance is the main barrier to get access to global research networks. But distance may just proxy for other barriers. Trust has been identified to be one of them (Foray and Steinmueller 2002). Agrawal, *et al*. (2007) argue that trust is easily established within the Indian ethnic community and information exchange in informal agreements should thereby be facilitated.[28] They find that co-ethnicity can indeed substitute for co-location, and ethnic networks help transfer knowledge across clusters that could otherwise be shared only locally. This indicates that co-ethnicity facilitates bridge ties, which are expected to be more valuable for researchers in that they are linked to higher rates of IP creation. Since research networks are becoming ethnically more diverse, this might reduce the importance of local clusters in favor of wider networks.[29]

We summarize subsection 4.1 by simply stating that the lone-wolf researcher is an endangered species. Evidence suggests that the development of basic scientific research as well as

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[28] Rauch and Trindade (2002) document how both trust and information-sharing within a Chinese ethnic network across all countries increases trade.

[29] Kerr (2006) documents the increasing importance of inventors of different ethnicities within the United States. The share of patents with at least one Chinese inventor named on the patent doubled from about three percent to six percent from 1980 to 1997. Similarly for Indian inventors, whose share also doubled from two percent to four percent over the same period. In some industries, such as chemicals and computers, the share of patents with at least one non-U.S. inventor increased to almost 30 percent.

appropriable knowledge frequently happens in teams that can even stretch internationally. These teams are rarely exclusive and do not have clearly defined boundaries. Collaborators in one project may add a researcher in the next, with each researcher of the group exploring projects with third parties. Combining these links of researchers defines networks of scientists (or what we have called knowledge platforms), These entities exhibit network effects, for adding researchers increases the knowledge base for all researchers in the network, and thus should spur development of IP.

Further, networks develop by stage of knowledge and IP creation. Those involved in projects close to commercialization are localized in clusters of geographic proximity, while networks involved in basic research are more geographically dispersed. Different types of intellectual outputs, such as patented information and research papers, and the networks that create them, are complementary to each other. Knowledge published in research papers builds the foundation for new patents, and patents spur new basic research. Networks are inherently complex structures, which makes them hard to analyze. However, their importance in knowledge creation makes them an important issue for further study.

4.2. Developing Research Networks: The Role of Government Policy

The model and examples in the previous subsection allow the categorization of government policies that can promote the formation of networks. Government policy can increase network effects through enlarging the installed base of knowledge. It can promote policies to reduce coordination costs in research networks. It can also reduce resistance in the transmission of information. We analyze these government policies in this subsection. Theoretical considerations suggest focusing on the formation of bridge ties.

4.2.A. Increasing the Network Effect in Knowledge Platforms

The network effects in knowledge platforms are due to the recombination of information from a diverse knowledge base. Therefore, government policy could try to increase the diversity of the knowledge base. An indirect way to do this is to broaden applicability of the technological field that the government wants to develop.

In the case of the internet, three policies helped to develop it predominantly as a U.S. invention (Mowery and Simcoe 2002), all of which contributed to reinforce network effects, either within the community of internet researchers or in the final use of the internet. First, the Department of Defense supported generic research in computer technology, with the understanding that the civilian and the defense computer markets are complementary to each other, and that a larger market size could spur innovation and therefore benefit both segments. Thus, opening research in computers to the civilian market increased the diversity of knowledge. Second, the market power of incumbent telecommunication companies was reduced through antitrust and regulatory policies, arguably increasing the competitive provision of access to the internet.

Third, in contrast to Europe, funding was in some cases made conditional on the resulting technology being non-proprietary. For example, the National Science Foundation made funding for internet connections dependent on the use of the freely available TCP/IP transmission protocol. This broadened the installed base of internet connections and increased the incentives for researchers to work on internet-related topics. The willingness to accept foreign inventions and incorporate them into the overall structure (namely the document format HTML and the retrieval protocol HTTP) as well as the availability of free internet software like the MOSAIC browser further promoted the internet to grow. All of these factors combined to create a vast diversity of potentially recombinant knowledge. While U.S. policy did not intervene directly into IP markets, the indirect measures for increased market size and competitiveness *within* the United States ensured that a large portion of this new knowledge originated there. This fact supported positive implications for competitive advantage of the firms involved.

4.2.B. Lowering Coordination Costs

The literature that we have discussed thus far offers almost no suggestions on how to improve internal coordination within networks. However, suggestions on how to improve external coordination costs between networks of researchers are implicit in the literature, most prominently in the case of standardization. For example, if appropriation of knowledge is hard to achieve, coordination for standardization should start early in the process. Some standards-setting institutions, like the DIN in Germany, have already incorporated this concept into their activities. That is, standards are developed along with new technologies.

Should the parties that create intellectual property within a standards body regulate their coordination efforts themselves or is there a role for government activity? DeLacey *et al*. (2006) compare a self-regulatory standardization body (the IEEE in the United States) with a state-sponsored one (the SAC in China) for the case of wireless computer networking. They argue that the IEEE process for establishing the 802.11i standard was transparent and rules-based and offered the opportunity of participation for any interested party. In contrast, the Chinese government chose to limit participation in the development of WAPI, the Chinese standard competing with 802.11i, to 24 hand-picked firms. DeLacey *et al*. argue that both arrangements may have been reasonable given the specific technical, economic and political environments prevalent in the United States and China.

However, the very nature of the approaches, top-down, non-market based in the case of China versus bottom-up in the United States, and the fact that Chinese firms had no track-record of implementation, while the U.S. standard was developed by players with proven track records, hampered the chances for the Chinese standard to be approved at a higher level, namely the ISO.

Chinese government policy was successful in improving external coordination of research efforts (specifically defining the size and structure of the network of participating researchers), since WAPI would likely not have been developed in China otherwise. So the policy would have been successful if the issue had been one of purely domestic interest. But the policy did not fully recognize the requirements for the approval it was targeting, with immediate effects on the wealth positions through IP protection. Had WAPI become the ISO standard, substantive licensing fees would have been transferred to Chinese companies and away from U.S. and Western European companies. This implies that there may be a role for government policy to improve external coordination of research efforts, but a bottom-up policy that makes full use of market forces and utilizes the know-how of experienced firms is more likely to succeed.

4.2.C. Facilitating Bridge Ties

Rauch and Watson's (2007) model suggests that government policy should facilitate bridge ties, which can be achieved in two ways. One approach is for the government to sponsor trade fairs, conferences, and firm and campus visits by researchers. This reduces search costs and therefore unambiguously increases the probability of forming bridge ties. An alternative policy suggested by the model (however, with somewhat ambiguous consequences), might be to encourage non-compete covenants in employment contracts. These prevent researchers that leave a firm to use IP from the original firm for their new professional endeavors.[30] This policy will unambiguously increase the number of bridge partnerships. However, this outcome may not be as beneficial as it seems. Even under imperfect enforcement of the policy, researchers who do not want to stay with their current employer will not only increase their search effort outside their cluster, they will also accept bridge

[30] The range of IP protected under non-compete covenants can range from tacit knowledge to patents and customer lists. While the first two are of special interest in the context of research networks, the third example also constitutes IP and documents the relevance of non-compete clauses in the context of IPR.

ties that are of lower quality in order to avoid legal punishment based on the covenant. So the overall effect is ambiguous in theory and can be outright damaging in practice, as in the following example.

In particular, Gilson (1999) presents an example where non-compete covenants may have backfired. He argues that California was more successful at fostering computer research networks than Massachusetts because non-compete covenants prevented workers from moving freely between companies within the latter state. The absence of similar regulation allowed for larger knowledge creation in California. The intuition is as follows. Incremental innovation is essential for the development of computer technology. Knowledge flows through moving personnel broaden the overall knowledge base for all firms. These knowledge flows were hampered on Route 128 in Massachusetts because of non-compete clauses, providing an advantage for California's Silicon Valley, where transmission of tacit knowledge was easier. Interpreting these results in our model, researchers on Route 128 could not move to other firms within the same district, so cluster ties were prohibited. This only left bridge ties outside of local clusters, either leading to a brain-drain from Route 128, or forcing researchers to stay within the same firm. Either way, the creation of a local knowledge base was hindered.

Schilling and Phelps' (2007) results suggest that active coordination of research networks, as happened in the European Union's EUREKA program and the Japanese METI strategy, can contribute to improving connectivity of local cluster networks on a national and international scale. It remains to be seen, however, whether these efforts will be successful, for while the authors' econometric results are robust and statistically significant, their economic importance is on average fairly small and decays quickly with time. Their results also only address the additional quantity of patents but if bridge ties offer access to higher-quality knowledge, it should lead to higher patent quality. More research, including analysis of measures of patent or paper quality (such as citations), is needed to determine the contribution of bridge ties, and in particular government-induced bridge ties, to research performance.

Finally, policies that facilitate the education of foreign talent and immigration of highly qualified researchers into a country can contribute to the country's pool of ethnic research networks. Chellaraj *et al.* (2007) find the marginal productivity of an additional graduate student admitted to the United States to be 0.62 patent awards. While this has to be taken with a grain of salt in the context of the discussion on brain drain from developing countries, it likely contributed to the current U.S. technological leadership. However, it would be important to study the roles of ethnic networks in the early phases of a researcher's career to learn about the economic importance of ethnic network formation.

4.3. Optimal IPR Protection in the Presence of Network Effects

Two characteristics of the software industry make it a good case study for many of the issues in this chapter. First, it is an industry in which concerns about IPR, especially copyright infringement on a global scale, play an important role. For example, the Software and Information Industry Association (SIIA 2006) states that "the software industry loses about U.S. $11 billion to U.S. $12 billion in revenue to software piracy annually. Of the billions of dollars lost to piracy, a little less than half are lost in Asia, where China and Indonesia are the biggest offenders."[31] According to SIIA (2000), piracy rates in China in 1999 were 91 percent, and in Vietnam 98 percent, with Asia overall averaging 47 percent. Given these estimates one might ask why software producers do not use copyright law to better protect their products against piracy?

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31 These numbers carry a high degree of uncertainty. Havoscope (2006) report numbers almost three times as high based on data from the Business Software Alliance.

One answer may simply be that the cost of protection is too high. However, one strand of the literature is devoted to an alternative explanation, related to the second important characteristic of software. As reviewed in the introduction, there is substantial evidence that its consumption exhibits network effects, for variety of reasons. First, there are post-purchase costs to software, such as training and customization. The more users there are of one particular program, the more likely it is to be supported through manuals, services, and other forms of assistance (an indirect network effect). Second, consumer's valuation of programs increases if they allow file transfers between users (a direct network effect).

A simple model of copyright protection can then explain how a low level of anti-piracy protection may be profit-maximizing. The key ingredient of the story is that the network effects apply to all users, legitimate and pirating ones alike. Allowing piracy increases the size of the network, thus increasing the value of the product to legitimate buyers, and allowing firms to charge them higher prices. Conner and Rumelt (1991), Takeyama (1994), and Slive and Bernhardt (1998) model this effect for a monopolist software maker in a market with heterogeneous consumers, the latter assumption being necessary to ensure that both pirating and legitimate users co-exist.

The basic mechanics of these models can be understood with the aid of the following example. Take a continuum of consumers, distributed uniformly in a square of side one, as shown by the solid square in Figure 2. The horizontal axis represents each consumer's valuation for the software. Without network effects, consumers are uniformly distributed on the interval [0,1]. With network effects, consumer *i*'s valuation is:

$$v_i = u_i + \gamma M, \tag{2}$$

where u_i is a parameter uniformly distributed on the unit interval, M is the mass of total users (legitimate and pirating), and γ is a positive parameter that represents the strength of the network effect. Note that the distribution will shift horizontally as *M* changes. In the language of Section 3, we assume that consumers' expectations are fulfilled in equilibrium, such that their forecast of the mass of users turns out to be the actual mass.

The vertical axis on the figure represents each consumer's cost of pirating, written as:

$$t_i = c_i + \tau, \qquad (3)$$

where c_i is an intrinsic cost (perhaps the psychic cost of breaking the law) and τ is an additional cost imposed on all consumers by the firm through its anti-piracy protection efforts, which are assumed to be costless to the firm. Also shown on the figure is the price (*p*), which may be assumed to be the *ex-post* equilibrium price.

Figure 2 about here

Let us consider what different consumers do. There are three possible choices, depicted in different regions of the figure: the consumer buys the software (B), pirates it (P), or decides not to use the software (N). For example, in the B region (ignoring for the moment the dashed square and the shaded areas), consumers buy because their individual valuation is larger than the price ($v_i > p$); and because it is more costly to pirate than to buy ($t_i > p$). By contrast, in the lower trapezoid region, consumers decide to pirate because the cost of doing so is lower than their valuation ($t_i < v_i$) and lower than the price ($t_i < p$). Other cases are analyzed analogously.[32]

Now suppose that the software maker increases the cost of pirating to τ'>τ. Then the new distribution of consumers is represented by the dashed square. If there were no network effects the square would just move up as each consumer retains his valuation and faces a higher cost of

32 Other examples are possible. For example if $p < \gamma M$, then all consumers would use the software (and therefore *M* = 1). Our goal is simply to illustrate the main properties of the model, not to cover exhaustively all variants.

pirating. Thus, absent network effects, the shaded region on the right would not be there. The upper shaded area represents the additional number of buyers at constant price *p*. Intuitively, by increasing the cost of pirating, the firm induces some of the pirates (those in the region just below the B-P border with a mass equal to the upper shaded area) to become buyers. Thus it would always be profit-increasing for the firm to raise protection to the highest possible level.

When we consider network effects, the situation is different. Note that a mass of former pirates (represented by the shaded region on the bottom) no longer illegally copies software. Some former pirates became buyers, as we mentioned before. But some others cross over to become non-users. These are low-valuation consumers for whom the cost of pirating increased enough to deter them, but who do not find it worthwhile to buy. We see that the total mass of users decreases, lowering the value for each user, and shifting the distribution to the left. This shift causes some previous buyers to give up using the software. They are a set lying close and to the right of the N-B border, with measure identical to the shaded region on the right. It is clear from the figure that, depending on the relative sizes of the shaded regions on the top and on the right, the firm might end up with a lower demand from legitimate buyers than it had with the lower level of protection. In particular, assuming a reasonable marginal cost of software production, this lower demand will cause the firm to lower its price (we forego here the detailed analysis of the fulfilled expectations that we performed in section 3). This is the key to the result mentioned above: with a sufficiently strong network effect it may decrease profits to protect software to the maximum possible level, even when such protection is costless to the firm. Takeyama (1994) further shows that lowering the level of protection from the maximum increases welfare, which is an important result because the welfare impact on buyers is ambiguous. On the one hand they benefit from the larger network; but on the other they end up paying higher prices.

These models link in a natural way with international issues, because they assume consumers have heterogeneous valuations and different costs of pirating. Nowhere are these assumptions more likely to hold true (and to a higher degree) than in the global arena. For example, differences in anti-piracy enforcement levels may make piracy costs widely divergent for different countries. Of course, a richer model of piracy in the global context (which is missing from the literature) would have to take into account that the strength of the network effect is likely to be weaker across national borders, but may not be totally absent. For example, users in different countries may congregate in the same internet forum to discuss user tricks of trade.

We note that one way to interpret this literature is as an instance of price discrimination. The software producer, in effect, charges a price of zero to one kind of "customer," the pirates. Note that, as Figure 2 shows, one way to prevent piracy is simply to lower the price. But price discrimination may still dominate a single-price policy.

Useful departures from this literature that we have not yet touched upon include strategic issues. The presence of network effects complicates the models of oligopolistic competition and trade in interesting ways. If there is a software maker in each country, for example, and we add a time dimension, one firm's product will almost inevitably become the *de facto* standard as it grows in network size (Markovich 2004). It may then be in the best interests of either country to subsidize exports in order to create a preemptive customer base.

A strategic model of copyright protection in software (but without the dynamic or international aspects mentioned above) is analyzed in a Cournot setting by Shy and Thisse (1999). Note that price competition may act in the same way as low protection of IPR, by extending the network effect to a larger customer base. Suppose that the firms can choose between a high or a low level of copyright protection before they engage in price competition. Then the key margin is what impact piracy has on legitimate sales. If network effects are weak, then firms choose a high level of protection, since the reduction in pirates does not significantly affect the number of buyers. If by contrast the network effects are strong, then both firms choose not to protect their IPR. Rather, they engage in price competition, trying to build a larger customer base.

5. Strategic Issues for Goods with Network Externalities and Standards

In the previous section we focused on network effects occurring at the level of creation and transmission of knowledge. We now turn our attention to market outcomes in which the driving force is the presence of network effects in consumption. The literature has emphasized the strategic consequences of such network effects, which can be divided into two types: private firms' strategies in the presence of network effects and government policies addressing those effects.

At the end of the previous section, we have already addressed one special case of IPR protection, the case of firms facing copyright piracy. To isolate the effect of piracy, we treated software as if it were an indivisible good, could be consumed in isolation and contained only one copyright. We will now consider more complex goods with deeper interactions among IP, standards and network effects. Note that we are no longer addressing *violations* of IPR, but rather the strategic but legitimate *use* of IP by its owners or countries in order to gain some advantage. Such interactions are only possible in a world with intellectual property rights and we discuss why weakening IPR may lead to different outcomes.

The technology for color television is an example of such a complex good. It is made of many complementary parts and services (for example the antennas, the TV sets, the signal transmission), which are made by numerous different companies. To guarantee interoperability of these parts and services, they need compatible interfaces between them, which often need to be standardized. In the case of color television a few standards were created (PAL, SECAM, and NTSC).

Thus, there exists a triple overlap in product characteristics. There are complex goods that benefit from standardization through interoperability requirements, goods that exhibit consumption network effects, and goods with a strong IP component. Some of the questions that arise for these products deal with private firms' strategies, when no firm is the single owner of the total IP content of the good. For example, firms may attempt to leverage their partial ownership of the IP content of some good in order to dominate the whole market. A different question is whether all types of IPR are the same in their ability to enable firms to achieve market dominance. Other questions relate to government policy towards standards. For example, should governments choose the single country, the region, or the world as a whole for the scope of a standard? What are some types of different institutional arrangements in the setting of standards, and what is their impact on the outcome? We address such questions in this section.

5.1. Government Strategies in the Choice of Scope: National or International

In designing their IPR policies, countries face a spectrum of choices that run from the purest national to the most international approaches. Each country might, for example: (i) insist on domestic registration or some form of adaptation for recognition of any IPR; (ii) establish agreements with other countries for the mutual recognition of IPR; or (iii) join international organizations for multilateral recognition of IPR.[33] If the product with IP content exhibits network effects, then the problem is complicated by some of the strategic and welfare considerations that we have been considering in this chapter. Goods that have strong IP content and exhibit network effects

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[33] For details on international treaties on intellectual property rights, see Maskus (2000).

are also subject to standards, as we saw. The literature that we review here has focused on this problem of geographic scope for standards.

Several mutually incompatible standards can exist in the world at the same time, especially across different countries. For example, there are different standards for color TV or for so-called third-generation mobile telephones. Governments may choose to mutually recognize each others' standards or adhere to an internationally recognized standard. Mutual recognition of standards decreases some transaction costs, but it also leads to the co-existence of different standards within one country, which may be detrimental to consumers.[34] An example is mobile telephony, for which many countries allow several standards to co-exist. By contrast, color TV is an example of the second approach, for hardly any country accepts more than one standard, and most countries adhere instead to one of the few international standards.

Gandal and Shy (2001) analyze the first concept, the mutual recognition of standards. Their model has three countries, which they call α, β, and γ. There are three firms, one from each country, called a, b, and c, respectively. They assume a circular market in each country (as in Salop 1979), which for country α is depicted in Figure 3. Each of the three firms sells a horizontally differentiated brand, represented by the firm's position on the circle. A continuum of heterogeneous consumers is uniformly distributed along the circle, their position on the circle representing each consumer's ideal brand. To account for consumption network externalities, Gandal and Shy augment consumers' utility by d ($2d$) if two (three) of the brands share the same standard. They also assume conversion costs in that if country α does not recognize the standard of firm c, say, then the firm has to incur a cost to convert its variety to country α's standard. Each consumer has a unit-elastic demand for the

34 The term "mutual recognition" is used both in the sense of recognizing other countries' standards and of accepting exporting countries' testing procedures to meet an importing country's standards. In this chapter we refer to the former meaning (see, for example, Costinot (2006) for this use).

good. In deciding which brand to buy, the consumer takes into account: the prices of each brand, the distance between the consumer's ideal brand and the brands available, and the expected network effect for each brand. Given prices, we define $X_{i,j}$ to be the consumer that is indifferent between brands *i* and *j*.

Gandal and Shy (2001) argue that if governments are restricted in their policy choice, such that they can only either recognize all other countries' standards or recognize no standards at all, then they always recognize all standards.[35] Simply put, this is because universal recognition maximizes consumers' benefits and minimizes conversion costs. They also consider standardization unions, defined as treaties of mutual recognition between two of the three countries, and a common policy (i.e., recognition or non-recognition) with respect to the third country.[36] If such unions are allowed, the outcome depends on the relative importance of the network effect versus the conversion costs. If conversion costs dominate, and they are moderate to large, standardization unions are formed, potentially even leading to complete exclusion of the third country's goods.

Figure 3 about here

Barrett and Yang (2001) address the second issue, namely the incentives of a single country to adhere to an international standard and forego its national standard. Their model is based on Katz and Shapiro (1985), and like them (but unlike Gandal and Shy), Barrett and Yang allow for the possibility of partial compatibility between products. For example, a spreadsheet user may be able to see files produced with different software, but may have to reformat them in order to do so. Barrett

35 The interpretation of their results is complicated by the fact that they assume (p. 370 and 377) that "if all foreign brands are recognized, the gross utility from each brand is $V^k=V+2d$," where V is the non-network portion of the utility and $2d>0$ is what is added due to the network effect. To the extent that recognizing foreign standards allows the number of standards to increase, the network effect would actually *decrease*.

36 One example of a standardization union may be the European Union, whose rules require each member state to accept products from all other member states if the product conforms with the standards of the originating country and it is actually marketed there (Costinot 2006).

and Yang extend the model to include two countries. Suppose that a product can be horizontally differentiated along the unit interval, as represented in Figure 4. Initially the home country produces the variety at 1, while the foreign country produces variety β (the international standard). If $\beta = 1$, then the foreign and domestic varieties are completely compatible, while if $\beta = 0$, they are completely incompatible. Consumers do not care which variety they consume, except that the less compatible two varieties are, the less network benefits consumers get across varieties. The home country can pick a new technology, denoted by α. It can choose to mandate that the new technology conform to the international standard ($\alpha=\beta$) or make it conform to its own old standard ($\alpha=1$). Barrett and Yang assume a cost function $C(\alpha)$, such that $C'(\alpha) < 0$ and $C(1)=0$, to convert the old domestic technology into technology α.

Figure 4 about here

They show that if unconstrained by any mandate by the government, the domestic firms would choose a technology that is intermediate between the international standard and the old domestic standard, though never equal to the former. That is, $\beta < \alpha \leq 1$. By positioning themselves in an intermediate position, domestic firms maximize the combination of network externality that new customers get both from old customers and the customers of foreign products. Furthermore, by not going all the way to β they also save on conversion costs.[37]

Barrett and Yang also argue that the optimal government policy in the home country is not necessarily to harmonize with the foreign standard. This situation is called a lock-in effect, in which a prevalent standard already exists in the country, and the decision is biased towards the existing

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[37] There is one scenario in which the international harmonization result ($\alpha = \beta$) is more likely to happen. This would be a case in which the old customers *were* allowed to switch either to the international standard or the new domestic standard. Such a modification of the model would be most relevant in the long run, as firms stop servicing obsolete technologies, and the expectation is that the old technology would disappear.

standard. In devising what course to take, governments consider the consumer surplus in their countries only.[38] Consumers gain with an intermediate standard because network externalities with all consumers are maximized, and conversion costs are relatively low, leading to low prices.

These results imply that domestic firms' technology choices have an impact on the volume of trade. As α approaches β, domestic firms' sales go down and foreign firms' sales increase. Therefore, international harmonization in standards increases the volume of trade, a point that has empirical relevance (see Moenius 2004). Using Barrett and Yang's (2001) paper, we can discuss the importance of IPR in this context. Those authors observe that, despite the fact that the globally most desirable outcome is complete harmonization, the most *likely* outcome is the parallel development of incompatible standards in different countries. This outcome can be avoided if one country or one firm in a country becomes the leader,[39] creating a candidate international standard which is then adopted by all countries of the world. To a large extent this is what happened with personal computers. However, to provide the leader with incentives to create such a standard, international IPR protection is necessary.

Therefore, one seemingly pessimistic conclusion from this literature is that standards are unlikely to become unified across countries, with consequent costs to consumer welfare. This is not the only possibility, however. An important point is that standards that differ across countries convey information about local tastes and technology, thus lowering adaptation costs and helping overcome information barriers. There is also a welfare gain through a broader variety of products

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38 The authors simplify the analysis by assuming monopolistic competition with free entry, leading to zero producer surplus. Furthermore, the assumption in this paper is that consumers do not get consumption network externalities across national borders. Rauch and Trindade (2006) argue in the context of cultural goods that such externalities are indeed possible, although with some dampening across international borders.

39 A likely candidate would be a large country. Questions about size have not, to our knowledge, been adequately addressed in this literature.

available to consumers. Finally, a variety of standards that represent local technology and IP broadens the world's knowledge base, which we identified as relevant for the creation of new IP.[40]

Jensen and Thursby (1996) analyze the question of national standardization policy if the outcome of technological progress is uncertain. They assume that there are two countries, with one firm in each country. Firms can engage in costly R&D with the goal of discovering either technology A or technology B. Once a firm discovers a new technology, it obtains a patent and the other firm may only engage in R&D for the undiscovered technology. There are two differences with the work already mentioned. First, this process is uncertain, in that either firm may discover a technology first (in which case it becomes a monopolist until the other firm discovers the other technology). Moreover, governments may commit to either technology A or technology B as a standard *before* any firms have invented the technology. This is what we could call pre-emptive standard setting (which as we shall see also plays an important role in private firms' interactions).[41]

Second, Jensen and Tursby seem to have in mind a scientific search for a general *effect*, for which it is not clear what the appropriate technology would be. For example, electronics firms may want to develop a system for color TV, or pharmaceutical companies may target a specific disease, but in both cases they do not know how to reach their goal. It is reasonable to imagine that different firms, pursuing independent paths of discovery, arrive at different means to achieve largely the same objective.

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40 Rauch and Trindade (2003) work out a model of information barriers in an international setting. Moenius (2004) documents the trade-promoting effect of harmonized standards as well as differing standards for complex goods. Maskus *et al*. (2004) document product adaptation costs for developing countries. Chen and Mattoo (2006) find that when countries engage in standardization unions – as defined above – the exports of excluded countries' products with low R&D expenses decrease, which is consistent with an interaction between standards and learning.

41 How can governments commit to a technology standard before it is discovered? One way is to commit to the technology of the firm in one's own country, whatever that turns out to be. Another way is to commit to a type of approach. For example, the domestic pharmaceutical firm may be taking a gene-therapy approach, while the foreign firm takes a chemical approach. The government may simply declare that the former will be the only acceptable standard.

Jensen and Thursby also assume that A is the superior technology, in that it provides larger profits once discovered than technology B, and that the foreign firm has an advantage in developing it. Considering first the equilibrium in which firms engage in R&D in the absence of any government policy, the foreign (domestic) firm engages in R&D for technology A (B).[42] But if the domestic country declares a standard in favor of the inferior technology B, both firms are more likely to do R&D on technology B, to the detriment of the superior technology A. Therefore standardization policy has a direct bearing on the process of IP creation, and it may lead to an inefficient result, when a pre-emptive standard is declared for the inferior technology.

5.2. Private Strategic Interaction in the Creation of Standards

Next we consider the interactions among firms themselves, allowing no role for government policy. For complex goods, as we have argued, the different IPR may belong to many different firms, whose interests may not be aligned. Furthermore, the IP embodied in the good may have different degrees of importance. In particular, the literature distinguishes between "essential" and "non-essential" IPR. Intellectual property rights are essential when the good cannot be produced without them, while non-essential IPR can be side-stepped, most likely because there are alternatives, or because they protect elective add-ons. In this subsection we illustrate the importance of essential IPR in the creation of standards.

We do so with the aid of one case study, namely the GSM standard for second-generation mobile telephony. To get a sense of the complexity of the picture, Bekkers *et al*. (2002) found 140

[42] One reason why firms do not always engage in R&D for technology A is the stochastic nature of the process of discovery, and network externalities. Since the domestic firm has a finite probability of finding technology B before the foreign firm finds technology A, it can be a monopoly for some time. Given network externalities, technology B becomes valuable for consumers, allowing the domestic firm to extract a large payoff.

individually distinguishable *essential* IPR embodied in this standard![43] The four largest owners of essential IPR were Motorola (with 27 patents), Nokia (19), Alcatel (14), and Philips (13). It is remarkable that the first three became part of the five dominant players in this market, along with Ericsson and Siemens. Bekkers *et al*. explain how these five firms gained their position through a complex interaction of factors, a primary one being the role played by Motorola. Through its U.S. experience Motorola was particularly attuned to the importance of patents and pursued from the beginning an aggressive policy of patent protection. When it became the holder of the most essential patents, it used its strong position to negotiate cross-licensing agreements with other holders of essential patents (namely Nokia and Alcatel), allowing them jointly to shut out some other firms from the GSM market. Thus, the possession of essential IPR helps in leveraging one's advantage.

The interesting aspect is that owning essential IPR is neither a necessary nor a sufficient condition to gain strategic advantage. For example, Philips decided in the early 1990s to largely abandon this market, in spite of its initial advantage (however, this literature does not explain why – or whether – this was the best course for Philips). The case of Ericsson is even more interesting, in that it exploits the concept of knowledge platform. Initially, Ericsson adhered to the old regime, in which patents were considered redundant in telecommunications since the market was dominated by one state-owned company. Therefore, Ericsson did not register patents on most of its IP. However, it was still a central player in the industry, through its connections with other firms.[44] Thus, Ericsson

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43 They initially found 380 IPR but whittled the list down based on the likelihood that some were different filings for the same content. Note that the number is likely to underestimate the essential IPR, since they restrict IPR to only those items that were actually patented. As we detail below, Ericsson was able to play a central role in this industry, even though it did not patent its IPR.

44 In particular, Ericsson was the main proponent of the GSM standard. We use the word "central" in the sense of network analysis. Using graph theory, centrality is defined in a number of ways. For example, "betweenness centrality" is higher the more times an agent is in the shortest path between two other agents. In this sense Ericsson was by far the most central player in the industry, according to the calculations in Bekkers *et al*..

performed the role of gatekeeper. Finally, it remains to be explained how Siemens gained prominence, even though it held neither essential patents nor a central role. According to Bekkers *et al*, this was due to Siemens owning technology that was strongly complementary to Motorola's, inducing Motorola to strike an alliance with it.

This case study highlights how complex the web of interactions can be. Unfortunately, we know of no attempts to model these interactions at any formal level. We list below some of the relevant analytical points that could be addressed by such models.

(1) What are the incentives of the firm to join an alliance versus going it alone, with special consideration to the global market? Note that a firm that pursues an individual strategy may hope that its product becomes a *de facto* standard in the market, perhaps due to a tipping effect.

(2) What are the welfare implications? Here, we are specifically thinking of the tension that arises between private ownership, as emphasized by IPR, and the public interest that is vested in standards.

(3) What is the optimal government strategy? Governments may try to influence the international adoption of a standard from their own country through the creation of an early installed base as described in Funk and Methe (2001). Given network externalities, this is more likely to happen if the standard originates in a large country, in what could be called a "network home market effect." This seems to be the case in third-generation cellular telephones (Glimstedt 2001).

5.3. Institutional Aspects of Standard Setting

The previous two subsections dealt primarily with the decisions of either one government or one single firm, as it engaged in strategic standard-setting behavior *vis-à-vis* other governments or firms. They had to do with the purely strategic aspects of IPR policies, and the institutional aspects lay in the background. We now consider the latter in more detail. We suppose that governments or firms engage in a process of negotiation and ask how the institutional design of the forums in which they do so influences the outcome.

In a recent paper, Costinot (2006) studies two types of standard-setting arrangements. These are the “National Treatment” (NT) principle, under which a country is obliged to accept any imports that conform to the standards that the government imposes on its own firms, and the “Mutual Recognition” (MR) principle, under which a country commits to accept any imports that conform to the standards of the country of origin. The former regime is most similar to the rules of the World Trade Organization, while the latter regime applies in the European Union. Costinot considers a model of two countries with one firm in each country, and with consumption externalities.

In the case of compatibility standards (for example the standard for color TV), suppose that there are two standards, *d* and *f*. It is costless for the domestic (foreign) firm to produce under standard *d* (*f*), but each firm incurs a cost to produce in the other standard. Consumers do not care which standard is sold, but they benefit if only one standard exists in their country. Costinot begins by showing that the efficient outcome is for each country to impose no standard if the network effect is weak (by allowing the foreign firm to sell with its own standard), and to impose the domestic standard if the network effect is strong. This is because in the first case the costs of standardization dominate the benefits to consumers, and *vice-versa* for the second case.

Suppose now that both governments can unilaterally and simultaneously decide on a policy. Then both governments will impose the domestic standard on the foreign firm, just as they do (by definition) under the NT regime. In this case the government only takes into account the benefits to consumers from having a unified standard, not the cost imposed on the foreign firm. Note that in the NT regime, the home country decides on the standard for *both* firms in a *single* market (the home market). Therefore, it takes fully into account the consumer externality in its market (for consumers of both firms), but it does not consider the costs of the foreign firm. By contrast, in the MR regime, the government decides on the standard of a *single* firm (the home firm) in *both* markets. In this case it takes the full cost of the home firm into account (for products sold in both countries), but it fails to take into account the externality for foreign buyers of home products. Costinot shows that in the MR regime governments may not impose a standard on foreign firms, even when the level of network effects is high enough to justify imposing a single standard on consumers. In this way, they ensure that their firm can export with the domestic standard and avoid the cost of adaptation to the foreign standard. Thus we conclude that the institutional arrangement matters for the mutual recognition policies of each country.

A different question deals with the institutional arrangements that pertain to standard *setting* (as opposed to standard *recognition*). Lerner and Tirole (2006) consider the choice of a standard-setting organization (SSO) by the owners of an IPR (more generally, the choice of a certifier by the sponsors of an idea). In their model, SSOs vary on how independent they are from the IPR owner. In practice, certifiers range from being direct arms of industry lobbies to being completely independent consumer advocacy organizations. In the model there are three types of economic agents: the "owners" of the IPR, the "users" of the product that is made with the IPR, and a continuum of "certifiers," where the latter vary in the degree of toughness towards the owners. Users have a utility consisting of three parts: $U=a+b+c$. Here, a is a common-knowledge parameter representing the intrinsic "attractiveness" of the good, b is a stochastic "benefit" variable unknown to both the owner and the user, but with known distribution, and c is an endogenous variable of "concessions" made by the owner to the user. For example, these could be improvements made to the product as a condition for certification. Or, if there is a license price, c could simply be the negative of the price. More generally, this parameter c will denote anything that the owner can do to increase the user's net utility. At the outset, the owner picks *c* and chooses a certifier among the range available. The certifier's role is to find out the parameter *b*, and then to either recommend or not recommend the product to the users. Each certifier is distinguished by the parameter *b**, the cutoff for *b* above which the certifier will recommend the product. For two possible certifiers suppose that $b^* < b^{**}$. Then the SSO characterized by *b** is less tough (or less independent from the industry) than the SSO with *b***.

Users know each certifier's cutoff value, but never find the actual value for the parameter *b*. Call $m(b^*)$ the expected value of the benefit parameter, given the known cutoff of the chosen certifier *b**. Then risk-neutral consumers will adopt the good if and only if: $a + m(b^*) + c \geq 0$. Given concession *c*, the owner always chooses the most complacent certifier, such that the equality sign applies above. This determines the choice of certifier (*b**) as a function of *c*:

$$b^* = m^{-1}(-a - c). \qquad (4)$$

The expected user utility then is $a + m(b^*) + c = 0$, and we assume that users adopt the good. The owner's problem reduces to choosing a concession level *c* to maximize profits.

Note that *b** and *c* are inversely related. This can be seem from equation (4), and by noting that $m(b^*)$ is a monotonically increasing function (the tougher the certifier is, the higher is the expected value of the benefit parameters that pass muster). Then, owners face a basic tradeoff: choosing a tougher certifier (higher *b**) allows fewer concessions (lower *c*), which given that concessions are costly, increases profits conditional on users buying the product. However, because the certifier is tougher, she is less likely to endorse the product and consumers are less likely to buy. Note that consumers only buy if the good is endorsed. Even then their expected utility is zero, therefore if the good is not endorsed the expected utility is less than zero.

We highlight only two results from this paper. First, as already mentioned, sponsors will always choose the certifier with maximal complacency, given concession *c*. Second, Lerner and Tirole (2006) show that the weaker the IP (the lower is *a*), the more independent the certifier and the more extensive the concessions will be (as represented by a higher b^* and higher c^*). Intuitively, the sponsor compensates for the decrease in *a* by increasing the concession level and also by increasing the independence of the certifier.

To apply the second result empirically one could consider a set of IPR, ranging in the (unobservable) attractiveness parameter *a*. We would then predict a *positive* correlation between b^* and c^*. Chiao *et al*. (2007) have collected a dataset of SSOs and some of their characteristics with the goal of checking such a correlation. They use several proxies for how independent the SSO is from the industry (how tough it is). These include whether the SSO is a special interest group, whether it accepts only corporate membership, and whether it uses a simple majority (as opposed to a super-majority or a consensus) as the rule for adoption of a standard. A positive answer to any of these questions indicates a low level of independence. To proxy for the concessions required by the SSO they use two measures. The first is whether the SSO requires either royalty-free or "reasonable and non-discriminatory" licensing of the IPR and the second is whether the firms must commit to a conflict-settlement clause within the SSO. A positive answer to these questions reveals extensive concessions (high *c*). They do find a positive correlation between the two variables.

6. Conclusion

In this chapter we have reviewed a large and varied literature that touches upon one or more of the interconnected topics of network effects; standards, IPR, and globalization. In these concluding remarks, we attempt to bring some of the strands of this somewhat disparate literature together.

The issues listed in the last paragraph are related in several ways. As the numerous examples spread through the text should show, many products that exhibit network effects can be found in technologically advanced sectors, in which IP plays an important role. Furthermore, differences in IPR protection across countries automatically require a consideration of international issues. We also discussed that for different types of products the relevant scope for the network effects may be different (i.e., national versus international), creating room for a rich set of interactions.

As one example of the complex web of interactions among the various issues, we focused especially on standards. Many network effects (in particular indirect ones) come about through the need for complementary products or components to work properly with each other, which necessitates a well-defined standard. Thus standards must be created in many network industries. Indeed, the opposite link also occurs frequently, for standards may be set in order to create or enhance a network effect where the effect would otherwise be weak or inexistent.

Since the IP embodied in standards can be (and very often is) protected, it is hardly possible to study standards without a consideration of IPR. We also observe that, given that one single standard may have IPR originating in many different firms, and indeed countries, strategic interactions among the several actors become of the foremost importance. For instance, firms holding essential standards may jeopardize the creation of better standards, or may use their position to gain market dominance. Countries may be tempted to wield their large markets to impose their domestic standards as *de facto* norms on the rest of the world, with the correspondent rents accruing to domestic firms, but potentially at the cost of efficiency if the inferior standard wins. One slightly different aspect of the interaction between standards and globalization is that the existence of different standards across countries may act as a deterrent to trade, which affects the strength of potentially realizable network effects, and thus affects welfare beyond the usual reasons. However, because standards may act as conveyors of information and diversity of knowledge, allowing different standards to co-exist may also be beneficial.

A different type of international resistance is created if IPR are not well protected in a country. This opens up the possibility that some products will not be marketed in that country, with potential losses for consumer welfare. On the other hand, it is interesting to note that under some circumstances it is actually in the firm's best interests *not* to have IPR protection, in order to gain advantage through the spread of a wider network.

We have also pointed out that in the global economy network effects are pervasive not only at the level of consumption of IPR-related goods, but also at the levels of creation and transmission of the IPR themselves. In particular, one aspect of complex products, such as color television or mobile telephony, is that they require step-by-step and incremental processes of innovation. These types of innovation pose their own problems. One challenge is the correct design of IPR policies that encourage such technological innovations. A different aspect is that the most efficient way to produce incremental innovation seems to be through the information flows that occur within networks of researchers, which we have called knowledge platforms. Even though there is not a perfect one-to-one correspondence between network products (and more generally product platforms) and research networks (or knowledge platforms), these often coincide.

We end this chapter with a word of caution. As we have shown, the multitude of interactions are likely to be complex. While they may not always be well understood by the actors in the field (where unintended consequences and wrong turns seem to be as much the norm as they are the exception), they also are not always well understood in the economics literature. Therefore, the need remains for future research that disentangles the relevant issues.

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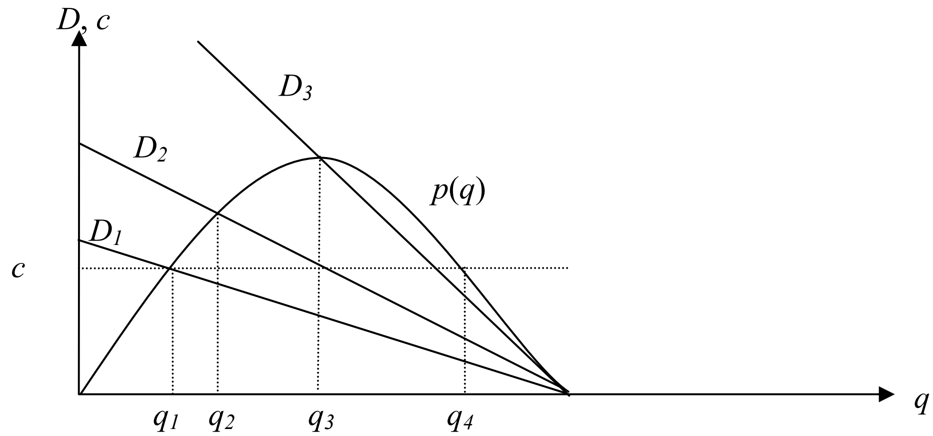

Figure 1: Multiple Demand Equilibria for Network Goods (Economides 1996).

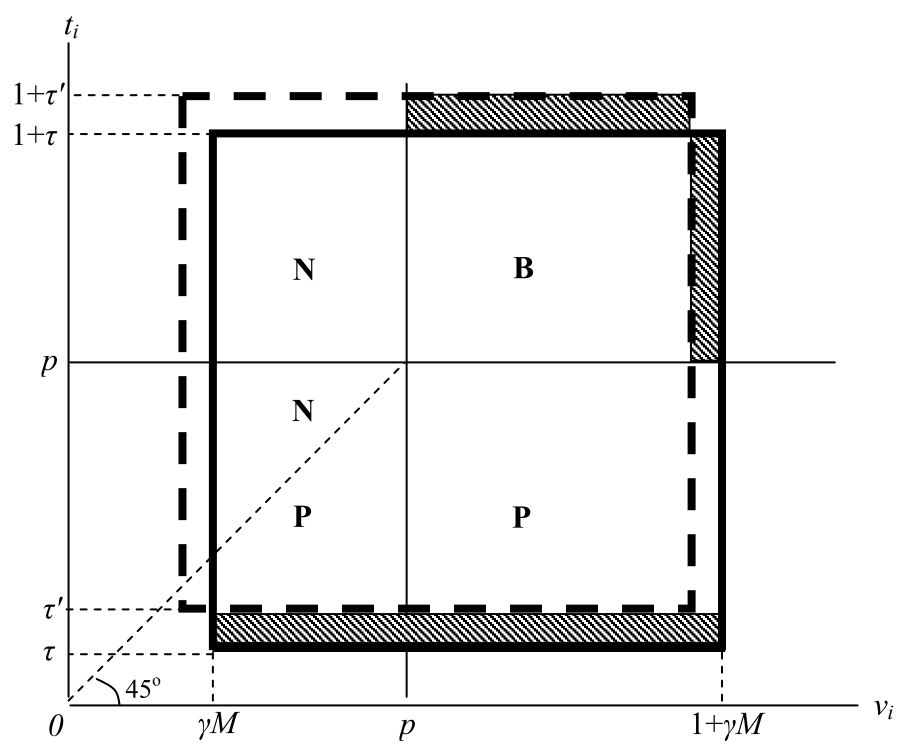

Figure 2 – Change when Anti-piracy Protection Increases.

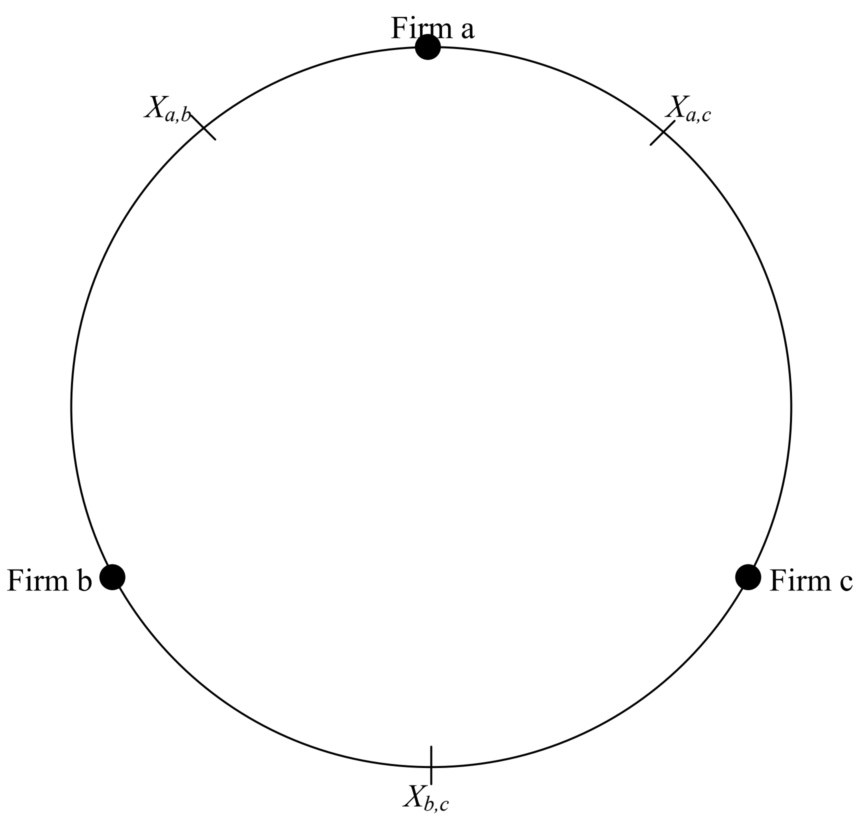

Figure 3 – Gandal and Shy's (2001) Circular Country α.

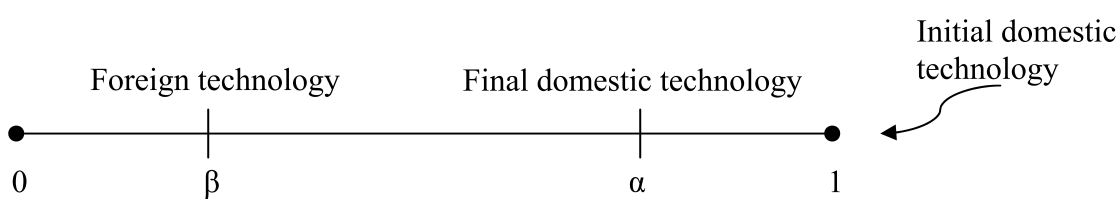

Figure 4 – Barrett and Yang's (2001) Technology Space.

Table 1: A Typology of Institutional Structure for Collective Inventions

	Formal Arrangements	Informal Arrangements
Strong Appropriability	High-technology consortia	Knowledge-trading in producer-user relations
Weak Appropriability	Standards-setting consortia	Informal knowledge-sharing between the members of a community

Source: Foray and Steinmueller (2002).