Decision Support Systems 48 (2009) 23–32

Contents lists available at ScienceDirect

Decision Support Systems

journal homepage: www.elsevier.com/locate/dss

Intellectual Property Bundle (IPB) theory: Managing transaction costs in technology development through network governance

Nitin Aggarwal [a,*], Eric A. Walden [b,c]

[a] College of Business, San Jose State University, One Washington Square, San José, CA 95192, United States
[b] Tepper School of Business, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, United States
[c] Rawls College of Business, Texas Tech University, P.O. Box 42101, Lubbock, TX 79409-2101, United States

ARTICLE INFO

Available online 19 May 2009

Keywords:
Intellectual property bundle
Transaction cost economics
Patents
Technology development
Governance forms
Networks

ABSTRACT

Technology is a bundle of inventions, which are increasingly protected by intellectual property rights. Typically, these rights are owned by multiple different entities, operating in different industries and countries. Moreover, once an invention protected by intellectual property right is incorporated in a product, it becomes very difficult to substitute it with an alternative technology, especially when the product has been widely adopted. Thus, technology creators must coordinate the disparate interests of various intellectual property owners in order to create useful technology. In this paper we introduce a new theory as an extension of transaction cost economics to explain the relative merits of different governance forms vis-à-vis the creation of technology that is a bundle of inventions. From this theoretical extension, we derive a number of testable hypotheses.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

Technology development is an inventive process. To create a useful technology, developers must invent the solutions to a variety of interrelated problems. In fact, this is the dominant paradigm behind the object-oriented approach which holds that a useful technology is developed in components that perform a specific task and are reusable. However, what is little appreciated is the fact that many of these inventions can be and are protected and owned separately by way of intellectual property rights (IPR). For example, an Intel microprocessor is a complex combination of around 10,000 different patents bundled as a single product [25]. This view of technology as a bundle of intellectual property is new but important in the sense that it will fundamentally alter our perceptions about the nature of technology ownership. Table 1, below illustrates the numbers of entities and patents in some common technologies.

There is a growing trend toward development of technology by multiple entities [13,33]. As of 2008, more than 450 such alliances, like the smart card and the Wi-Fi alliance, are listed on Consortiuminfo.org. Yet there is a widely held belief that development by groups results in slower development, greater setup costs, and even inferior technologies [15,26]. Even with such beliefs, which suggest that alliances have sub-par outcomes, we observe a large number of alliances and new ones being formed regularly. We theorize that the primary reason for this is the need to transact for intellectual property rights associated with the development of the technology. Beyond technical considerations, organizing technology development as an alliance helps developers locate and procure IPR and protects the technology from frivolous litigations. We introduce an Intellectual Property Bundle (IPB) theory as an extension of transaction cost theory [42] to understand how IPR give rise to transaction costs in the technology development area and how governance moderates those transaction costs.

In the next section we present a literature review on transaction cost economics and intellectual property rights. Following that we discuss the assumptions and constructs of our theory. Then we describe the causal mechanism linking the constructs and propose testable hypotheses based on those constructs. We conclude with a discussion and directions for future research and implications.

2. Discussion of related literature

The theoretical extension that we develop in the present paper fits into an area of scholarship termed *New Institutional Economics*. This field of inquiry studies the rules by which economic activity takes place. In this case, the economic activity is the creation of a technology product.

There are two main institutions in which we are interested. The first is the property rights regime as it relates to technology. Williamson [44] notes that this institution changes on the order of decades or centuries. Thus, we take this institution as fixed. Specifically, we take it as fixed to the United States today. As we move away from the US laws and from current time, this institution can change. The second institution of interest is the governance of the

* Corresponding author.
E-mail addresses: aggarwal_n@cob.sjsu.edu (N. Aggarwal), eric@ericwalden.net (E.A. Walden).

0167-9236/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.dss.2009.05.008

Table 1
Number of patents and owners for some well known technologies (approximate numbers).

Technology	No. of patents	No. of countries	No. of patent holders
DVD Media	500	28	9
MPEG 4 (Motion Pictures)	196	21	22
802.3 Ethernet	70	4	65
802.11 wireless	100	7	91

development process. Roughly speaking, we compare development by a single entity to group development. We strive to answer the question of how the governance structure can moderate the causes of transaction costs in the development of technology.

A few studies have directly addressed the role of IP in technology development. For example, Farrell and Katz study the effects of intellectual property and antitrust on innovation in the technology arena [10]. Shapiro describes the emergence of patent thickets and discusses the role of patent pools in mitigating the risks [35]. Farrell and Shurmer, separately, discuss the merits of the IP protection in network industries [9,36], and Lemley focuses on existing practices of IP treatment in various standard-setting organizations [24]. Gandal et al. analyze the IP holding patterns of firms participating in standardization [11]. However, these views are restricted to either single institutional form or a discussion of the intellectual property issues in a specific technology. Though these studies cover a substantial ground, none of them examines the implications of technology as a bundle of IP.

The work in this paper is probably most closely related to the theory of the anti-commons [17]. This theory was formulated to explain the dysfunctional outcomes of property rights regimes in post-communist Russia. The anti-commons existed in Russian real estate because a variety of different entities held effective rights of exclusion over the use of real estate. For example, the right to lease, the right to receive sales revenue, and the right to occupy real estate were held by different entities. Thus, for a retailer to effectively use the building, it must collect lease rights from one entity, revenue collection rights from another entity, and the occupation rights of the building from yet another entity. Thus, the retail situation observed in Russia, until quite recently, was big deserted malls and small shabby kiosks by the roadside. It was simply too difficult to secure all of the permissions to have a retail establishment in a building designed for that purpose, so instead retailers constructed their own portable buildings. Similar arguments about anti-commons have been used to illustrate the detrimental effects of privatization of biomedical research [18]. From the anti-commons literature we borrow the idea that legal regimes in which property rights are distributed have consequences.

While our work is related to the anti-commons literature in that it concerns property rights and acquiring permissions from multiple entities, it also differs in several important aspects. Our work is focused on *intellectual* assets which are fundamentally different from physical assets such as real estate [40]. Hence, the rights associated with intellectual assets are also different from those associated with physical assets. In particular, real estate is highly observable. Inventions, on the other hand, are invisible and intangible, so it is not always obvious that they exist (more on this later). Furthermore, many inventions are "un-owned", so they may or may not have rights attached to them. The other important distinction is the institution of interest. The anti-commons literature is interested in comparisons of legal institutions. Our work holds legal institutions constant and instead focuses on governance of the development process. We propose specific antecedents and specific transaction costs that arise in technology development and address how governance moderates those relationships.

In examining the governance structures, we rely on transaction cost economics, particularly Williamson [41,42]. Williamson proposes that different governance structures have different setup costs and different abilities to moderate transaction costs. The best known work in this area proposes that asset specificity, frequency of transactions, and uncertainty cause transaction costs, and governing transactions in a hierarchy moderates these effects [41]. We extend this basic setup to examine how governance moderates the antecedents of transaction costs. We have different antecedents due to our focus on intellectual property (or inventions) instead of physical property, and we consider a bundle of assets rather than just one.

In this sense, this work is similar to Joskow's [20] which looks specifically at coal mines and power generation, and hence uses antecedents like region of the country — because coal from different regions of the country require different types of power plants. Our work is also similar to Saussier [34] who looks at the rivers on which goods are shipped on. On some rivers boats need to be specialized, while on others they can be the same as those used at sea. The point is that we look at the characteristics specific to the domain of technology as bundles of intellectual property.

The binary choice of markets or hierarchies has given way to a variety of other governance forms. One that applies in our context is network forms [29]. Network forms of organization are groups of firms that are interdependent. They govern transactions by consensus and make use of both formal and informal rules of exchange and reciprocity. They share knowledge and other resources and operate, at least to some degree, for the collective good rather than just the individual good.

From transaction cost economics, we borrow the idea that governance moderates the antecedents of transaction costs. We also borrow two basic forms of governance—hierarchies and networks. To transaction cost economics we add considerations for intellectual property rather than physical property, antecedents specific to technology development, and transaction cost specific to technology development. We also go into some specific detail about the causal mechanisms for this specific domain rather than keeping everything at an abstract level.

Another major stream of work from which we borrow ideas is the literature on the impact of IT on institutions. Several authors have examined how IT may change the transaction costs associated with different forms of governance. The first idea in this stream was that information technology would reduce the costs of coordinating market transactions more than it would reduce the cost of coordinating internal (hierarchical) transactions, which would result in more market transactions and vertical disintegration [27]. More advanced theory was proposed in the move to the middle hypothesis [7], which suggested that IT would reduce the dimensions of transaction costs that lead to vertical integration, but it would also reduce the dimensions of transaction costs that lead to using a large number of suppliers. Thus, we would expect to see more outsourcing, but to fewer suppliers.

From this stream of literature, we borrow the notion that governance structures moderate transaction costs in particular ways. It is the moderation of those transaction costs that is the main concern of this paper. However, our focus is slightly different than in this literature. Our paper focuses on how governance can moderate the transaction cost effects of the legal regime that currently dominates technology development. Thus, we explicitly assume a fixed technological regime; specifically the current regime. This is a limitation of the work, and we certainly recognize that there are interesting questions about how technology (like Google patents search) might change the situation.

Finally, from the incomplete contracts literature [14], we borrow the notion that property rights help determine optimal governance form. In particular, we borrow the idea that intellectual property rights are not necessarily subject to the same rules as physical property rights because inventions are not subject to the same rules as physical assets such as real estate [40]. However, our theoretical perspective is different from the property rights literature, which is concerned with ownership as a

way to allocate residual rights of control. The incomplete contracting problem is that contracts are poorly written. Our concern is with explicit rights, and the problem that developers do not know if the explicit rights are owned or who owns them. Thus, we must form a governance structure to address the fact that some of the inventions that will be created in the technology development process may already be owned by someone else.

3. IPB theory

Technology can be thought of as bundles of intellectual property, which may be owned by different entities. This can result in high transaction costs in the form of opportunism at the adoption stages. Some of these costs can be appropriated in the form of search and coordination cost during the design phase. Still these costs are substantial. Since little can be done about the nature of the ownership of the bundle, we focus our attention on the causes of these transaction costs and the overall administration of the bundle. We explore whether tinkering with the governance form of administering the bundle reduces the transaction costs.

We make several important assumptions that reflect the context of this study. The proposed theory is plausible and valuable insofar as it is built on realistic assumptions, and hence we spend some efforts to make them explicit.[1]

Assumption 1. Technologies are bundles of inventions, some of which are patentable.

For example, the MPEG-4 standard is protected by more than 196 patents, and a typical Intel microprocessor is a bundle of 10,000 patents [25]. Though technologies are conceptualized as bundles of inventions, that is not the only thing they are. They are also human goals and value adding technology and a variety of other things. However, the view of technology as a bundle of inventions is important because sometimes the cost paid for individual components in the bundle can overshadow the value of the technology itself [25].

Assumption 2. To make use of a patented invention, the technology developer must obtain permission to use it from the patent owner.

This arises directly out of patent law, which says that the patent holder owns the patent like a property and is entitled to property rights. The main property right is excludability [17,40], which means that others must obtain the owner's consent to use the property. This consent may be purchased or given free, but it must be obtained or else the user will face legal action. Implicit in this assumption is the notion that legal action is so undesirable that trespass will never be voluntary.

Assumption 3. Transacting for patents is costly.

This is the cornerstone of our theoretical view, and a perspective that has largely been ignored in technology development [31]. There are several things that make transacting costly and hence several dimensions of transaction cost. Search costs arise because the patent and the patent owner must be located. Coordination costs result because the terms must be communicated and negotiated. Opportunism costs arise because search may be imperfect and thus involuntary or unintentional trespass may occur.

Assumption 4. The technology creation process is not separable from the technology adoption process [28,31].

The way technologies are developed influences the way they are adopted, and the expectation of adoption motivates the development. In particular, the ability of the developer to protect the user of the technology from patent enabled hold-up is of primary importance. Hold-up occurs when a patent owner refuses to allow a technology developer the use of a patent after the technology has already been developed. While the development of a technology cannot infringe on a patent, the use of a technology, particularly when embedded in a product, can infringe. Thus, a user will either have to be confident that the technology does not infringe on any patents, or it will have to incur the costs of searching.

This assumption is a particularly important, if subtle, differentiator of our work. We focus on how technology developers choose to govern the development process ex ante—that is, before they even know what inventions will be necessary for the technology (and hence before they can form patent pools), and long before anyone can conceivably adopt the technology. However, the ex ante choice of governance is made with the future in mind.

Assumption 5. There is a credible threat of opportunism.

By opportunism, we mean that (1) patent holders can take legal action (2) with significant consequences against technology developers who use their inventions and (3) that patent holders are "*self interest seeking*, and (4) *with guile* [42, p.30]." Thus, not only can patent holders interfere in technology development, but they have a reason to interfere in technology development. They can cause a lot of problems and may be pretty slippery about it.

We examine two types of governance form, IP network and IP hierarchy. We append the term IP to denote that these are governance structures that arise within the context of intellectual property rather than in the context of physical property. They are similar, but not identical to networks [29] and hierarchies [41].

A hierarchy in traditional transaction cost analysis refers to a transaction that is governed by fiat [42]. More generally, the term hierarchy implies some ordering so that one element takes precedence over others. Thus, an organizational hierarchy means that there is an ultimate authority whose decisions take precedence over others. For technology development, there is a bundle that is being transacted for, and some of the elements of the bundle are beyond the boundaries of the firm. In theory, a firm could potentially purchase all of the other firms that own intellectual property related to the technology. In practice, integration is often beyond the capability of one of the parties [16]. Firms that own many patents tend to be large firms, like IBM and Microsoft. It is unreasonable to believe that any technology developer could purchase all of the firms that own relevant intellectual property. Moreover, it is not economically rational, in the sense that the cost would outweigh the benefits, even if the technology developer had the resources.

Our definition of an IP hierarchy is that a single firm unilaterally develops the technology. We use the term hierarchy in the general sense that there is an ordering and that a single decision maker's authority takes precedence over other decision makers. This implies that it either develops or procures the appropriate IP, with its own internal resources. Notice that because the IP may already be owned outside of the hierarchy, the hierarchy may have to procure it from outside. This is the central difference between an IP hierarchy and a hierarchy in the traditional sense. Please note that the inclusion of IP rather than physical property has already required the development of a different type of governance, because unlike a manufacturing plant or a rail head, IP rights forbid other firms from building their own.

The other governance form is an IP network. Like a traditional network, this is a group of many firms that participate on an equal basis. Thus, in contrast to an IP hierarchy where one decision maker's opinions take precedence, decisions about what to include are made by mutual consent rather than fiat. Procuring and developing the appropriate IP is a joint effort of all of the parties. An IP network has formal rules of governance for the decision making process. In general, the members of the IP network agree in writing to share their patents

[1] We thank an anonymous reviewer for both this idea and the actual text.

on reasonable and non-discriminatory terms. Even when they do not have this as part of their charter, antitrust law generally requires it. The Department of Justice takes a dim view of groups of firms who create products that are shared on monopolistic and/or discriminator price terms. Moreover, patent law requires patent owners to notify potential infringers of the potential infringement. A firm that is part of an IP network finds it difficult to deny knowledge of the infringement of its own patents, and hence difficult to seek legal recourse [2]. Members of the network may negotiate a fee for the use of their patents, or may willingly surrender their patents. The important thing is that these issues are resolved upfront in the charter of the organization, so further negotiation among members is not necessary (or at least is greatly simplified). Again, the IP network may be forced to procure some IP from outside of the network, which is the central difference between a network and an IP network.

The IP network is a generalized form designed to capture a high level detail of some forms of technology development that we observe today. Some specific examples of forms that would fall under the form of IP network, would include consortiums like CalConnect, the Calendaring and Scheduling Consortium. CalConnect is focused on promoting interoperability between different scheduling and calendaring applications through standardized data exchange. The consortium, started in 2004, is backed by industry leaders such as Microsoft, Google, Apple, IBM, Oracle, SUN, Yahoo, and many others. IP networks also include standard-setting societies such as IEEE, IETF, and ANSI who sponsor many different types of standards like the wireless 802.11, and 802.15 RFID standards. Another form of networks manifest themselves as patent pools wherein the IP holders get together, *after* the technology has been developed, to facilitate IP transactions.

These forms would be IP networks. However, each form may have some specific characteristics which would be worth investigating in the future. For example, consortiums are often of limited duration or focused on a single technology, while societies are ongoing and take up multiple technologies as needed. We encourage the use of our theory as a starting point for further investigations of these differences.

Before any specifications for a technology are written, a decision must be made on how to govern the technology development process. Will it be governed by fiat within a single firm or will it be governed by collaboration between many firms? This choice has two ramifications. First, setting up the governance structure itself is costly. Second, we hypothesize that the governance structure will determine the size of the effects of the antecedents on the transaction costs.

It is widely held that an IP network has greater setup cost than an IP hierarchy [38]. The prospective members of the IP network must locate one another (search costs). They must then forge a working relationship and formal ways of making decisions (coordination costs). Moreover, they must do this across many members. On the other hand, IP networks should reduce opportunism cost because they are self-policing groups, where deviance of an individual member can be punished by many other members. Thus, we theorize the direct effects of governance as a set of three propositions.

Governance–Search hypothesis. IP networks have more upfront search costs than IP hierarchies.

Governance–Coordination hypothesis. IP networks have more upfront coordination costs than IP hierarchies.

Governance–Opportunism hypothesis. IP networks have less upfront opportunism costs than IP hierarchies.

Unlike a traditional hierarchy, an IP hierarchy cannot guarantee that it will not have to transact for some IP in the market. In fact, an IP hierarchy will, in general, have to transact in the market more often than an IP network because the members of the IP network are not considered to be part of the market and they probably hold some of the relevant IP.

The second effect of governance is the ability to moderate the causes of transaction costs. IP networks moderate the causes of transaction costs in several ways. First, they bring more knowledge resources to bear, which allows for more efficient search for inventions. They also have (after paying the setup costs) formal means of communication to bargain with one another. Perhaps the most important way they moderate transaction costs is by being subject to antitrust laws. Government regulators pay particular attention to *groups* of collaborating firms. Thus, when firms organize as groups they must do all they can to demonstrate their commitment to positive outcomes.

The moderating and setup effects for one particular antecedent and one particular transaction cost are shown in Fig. 1.

Thus, our theory suggests that the costs of organizing as an IP network may be outweighed by the benefits of this particular governance form with respect to moderating transaction costs. The basic theory is summarized in Fig. 2.

3.1. Causal theory

3.1.1. Constructs

We now move to the discussion of the constructs in the theory and how specifically they relate to each other. We first discuss the transaction costs and then explain the bundle characteristics. We then develop hypotheses about the impact of the bundle characteristics on transaction costs. Finally, we explain the governance structures, describe how they moderated the impacts of the bundle characteristics on transaction costs, and propose hypotheses.

3.1.2. Search costs

Search cost is the cost of finding the legal rights that somebody might hold on the invention used in the technology. Search in the IP context is different from search in physical transaction cost economics. In physical transaction cost economics, search is done for the purpose of reducing cost by outsourcing to specialized firms. Search is done to choose among suppliers. Unfortunately, in the case of intellectual products like technology, search cannot be avoided just because the invention was invented in house. Thus, search in the IP context is to see if someone else has already patented the invention. Search in this case is not a question of cost and quality, but of whether or not the technology developer will be allowed to make use of a particular invention.

Search costs can be quite substantial. It costs anywhere from $1000 for a basic database search to $50,000 for a patent opinion, per patent [39]. This translates to an amount anywhere in between ten million to half a billion dollars for a semiconductor chip or a complex computer program. This still does not guarantee final results because patent applications are a secret for the first 18 months after they are filed [21]. One can see that moderating the impact of search costs even a little can be very valuable.

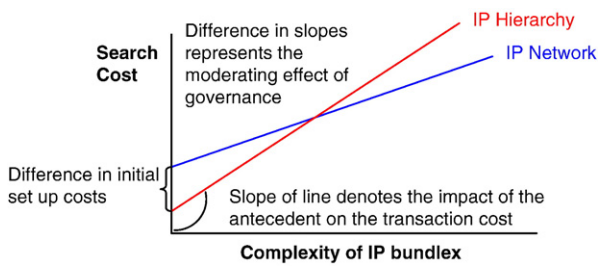

Fig. 1. Moderating effects of governance on transactions (adapted from Williamson's [43]Fig. 1, p. 284).

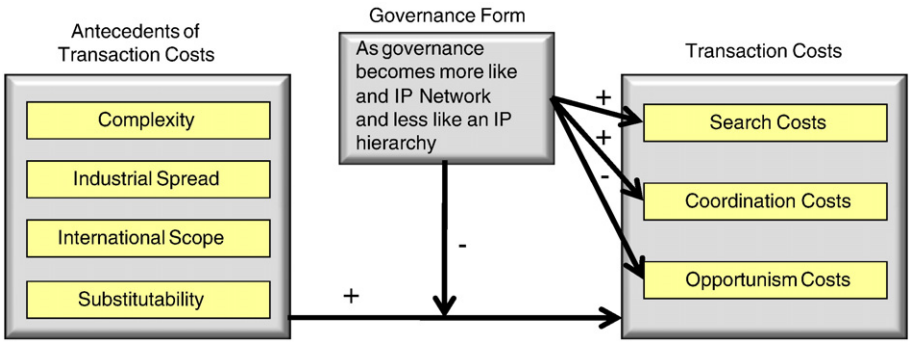

Fig. 2. A theory of how governance structure moderates the transaction costs involved in securing a bundle of intellectual property.

3.1.3. Coordination costs

The next type of transaction cost is coordination costs. This refers to the costs of deciding on a specific invention to use and, when necessary, negotiating an agreement for intellectual property rights with the holder. These include costs like bargaining, contracting, maintaining relationships, and communication costs. Note that there will usually be fewer IP rights holders than potentially patentable inventions. However, there may still be a large number of entities which are identified as holding IP rights. The effort dedicated to negotiating for the use of a patent may be substantial.

Coordination is also different for technology developers than it usually is for traditional firms. In traditional firms, coordination activities are between buyers and sellers. In IT, the coordination activities are for the benefit of users. This is because technology usage, and not technology development, infringes on a patent and is liable for damages. So if the technology developer is separate from the technology user, the liability of infringement shifts to the user. However, if the technology developer wants a technology to be adopted, it is responsible for coordinating with the patent holders to procure the patents or at least settle the terms. Nonetheless, there is significant effort required.

3.1.4. Opportunism costs

Opportunism costs are associated with a lack of bargaining power due to a technology being deployed [7]. Once a technology is deployed, the user has very little bargaining power relative to the bargaining power they have before the technology is deployed. The important thing in opportunism is that patent holders recognize that they have a vastly improved bargaining position once the technology is in place and will use *guile* to try to make sure that they negotiate licensing terms under these conditions.

3.2. Characteristics of the bundle and factors affecting the transaction costs

We conceive of four antecedents to transaction costs in the technology development environment. These are the complexity of the technology, the industrial scope of the technology, the international scope of the technology, and the substitutability of the technology. *Complexity* is a measure of the size of the technology. A bigger technology requires more inventions, and hence offers more chances to search, coordinate and be taken advantage of. *Industrial scope* is concerned with where the inventions will come from. The greater the number of industries that contain the knowledge, the larger the spread of patents. *International scope* is concerned with how many countries might use the technology because the technology must satisfy the patent rules of all the countries in which it is to be used. Lastly, *Substitutability* refers to how easy it is to substitute one invention for another in the bundle. If there are many different ways of solving a problem, then any one invention is less specific.

Note that these antecedents are characteristics of the technology being developed and that all of the antecedents are aggregate measures. They are characteristics of the bundle as a whole rather than of any particular component (invention) of the bundle.

3.2.1. Complexity

In this paper, we use the term complexity to refer to the number of inventions in the bundle. All technologies are not created equal. Some are created to address more complex problems than others. Effective problem solving in IT involves breaking down the problem into smaller sub problems that are easier to comprehend and can be solved independently. Later the individual solutions can be integrated together as a solution to the complex problem. Since each invention in the technology can be independently protected as an IP by anyone in the industry, there is a higher chance that the invention may infringe upon several of the externally held IP. To avoid infringement or potential infringement, IP rights have to be searched externally. The level of efforts required and the cost involved for this activity will be proportional to the number of searches. In other words n potentially patentable inventions will require n searches even if the actual number of patents required may be less. Considering that the search is expensive, the search cost increases as the complexity of the bundle increases. Thus, we hypothesize:

Complexity–Search hypothesis. Complexity is positively related to search costs.

Once the search concludes, it should result in a list of IP rights that have to be procured from the external entities. The situation in most areas of IT is similar to what Chiariglione describes for the audio and video industry, "It is virtually impossible today to develop an audio or video coding standard with a reasonable performance that does not require the use of one or, more likely, several patents [5]".

As a result one can expect that with the increase in inventions there will be more patents identified, which will result in an increase in coordination costs. Thus, we hypothesize:

Complexity–Coordination hypothesis. Complexity is positively related to coordination costs.

The complexity of a technology will also have a bearing on the opportunism costs. This is because, as the number of inventions in the technology increases, the probability that one patent gets overlooked also increases. Moreover, with the increase in the number of inventions there is increased likelihood that the technology will be targeted by someone holding broad patent claims just because of similarity in the components. Opportunism does not require actual infringement; just the perception is enough to cost a lot of money. Thus, we hypothesize.

Complexity–Opportunism hypothesis. Complexity is positively related to opportunism costs.

3.2.2. Industrial scope

This refers to how many different industries may hold the patents on the inventions in the bundle. For example, a cellular phone may include both telecom patents and semiconductor patents, while a technology related to computer memory may include only semiconductor patents.

To understand how this leads to search costs, it is worthwhile to explain patent searches. Patent databases do not necessarily have good metadata. There are no detailed subcategories for inventions, nor is there standardized language. It is a typical knowledge management problem. Moreover, it is not necessary to infringe upon every aspect of an invention to infringe upon the patent. Therefore, the relevant invention for the technology may be a rather trivial piece of a patent for a larger invention, or some subset of an invention for a technology may actually be protected. This was the case, for example, with Vonage's infringement of Verizon data. Verizon's patents claims were so broad that Vonage expressed its inability to use an alternate technology.[2] Engineers from different industries use different terminology to describe the same sorts of things. In fact, engineers from different industries may not even be solving the same problem, and hence, it may never occur to them that their solution is logically equivalent to a problem faced by another industry. Thus, the more the inventions for a technology are dispersed across industries, the more different vocabularies and customs must be incorporated into the search, and hence the more expensive the search. Thus, we hypothesize:

Industry–Search hypothesis. Industrial scope is positively related to search costs.

Increased industrial scope can also cause increased coordination costs for two reasons. First, the range of norms of behavior is more different between industries than within. The greater the industrial scope the greater the differences in norms. To the degree that norms govern the behavior of firms in an industry, some items in the contract do not have to be made explicit, or less effort is needed to make them explicit. However, when an agreement spans industries, more of the things that would otherwise be understood implicitly have to be spelled out in detail.

Second, the vocabulary different industries use is different; therefore the difficulty inherent in creating any part of the contract increases as some terms may have different meaning. These two differences across industries suggest that more must be put into a contract and that each item in a contract is more costly to create. Thus, we hypothesize:

Industry–Coordination hypothesis. Industrial scope is positively related to coordination costs.

Finally, increased industrial scope can increase the opportunism in two ways. First, as we have argued above, industrial scope makes search more expensive. As search becomes more expensive, technology developers avoid searching. This leads to an increased chance of missing a relevant patent, and hence an increased chance of having to face opportunism. The second cause is the presence of hostages within industries. A hostage refers to some asset that one entity holds that can damage another entity. Within the same industry, firms each have the ability to damage other firms that sue them for patent infringement. Often this is done via a counter suit, but it could also be done by restricting the supply of customers or resources. However, as firms become distributed across industries, they have less leverage over other firms' resources. Thus, firms from different industries have less to lose by filing an infringement suit than firms within the same industry. This leads to our third hypothesis.

Industry–Opportunism hypothesis. Industrial scope is positively related to opportunism costs.

[2] http://www.theregister.co.uk/2007/04/16/vonage_and_verizon/.

3.2.3. International scope

The next construct we consider as a driver of transaction costs is international scope. This refers to the extent to which the technology will be used in different countries. Inventions patented in other countries can lead to transaction costs, especially where there is a reciprocal patent agreement between the countries. This is the case with most world trade organization members. The arguments for how international scope causes different types of transaction costs are very similar to the arguments for transaction costs across industries.[3] Culture and vocabulary are different across countries; in fact, the problem is worse across countries because people are using different languages *and* different legal systems.

Increased international scope leads to increased search costs because more patent systems must be searched. In addition, the language used is different and translations are not always perfect. This means that more time and effort must be devoted to searching. Thus, we hypothesize:

International–Search hypothesis. International scope is positively related to search costs.

The language and norms for negotiations are different across countries. This means that technology developers must spend more time and effort in coordinating the use of foreign patents. Moreover, different legal environments require that contracts be written to satisfy different courts, and different countries may actually require (or forbid) certain contract terms. Thus we hypothesize:

International–Coordination hypothesis. International scope is positively related to coordination costs.

Opportunism is even more elusive between countries than between industries. Foreign industries often have no overlap of resources with domestic firms and hence there is very little leverage against opportunistic behavior. Moreover, legal action between countries is even more costly than legal action within countries. Combined with the notion that search between countries is more difficult, this suggests that increased international scope leads to increased probability of missing a patent, increased use of legal rather than social pressures—all of which suggests higher opportunism costs. Thus, we hypothesize:

International–Opportunism hypothesis. International scope is positively related to opportunism costs.

3.2.4. Substitutability

Substitutability refers to the ease with which inventions in the technology may be substituted with other inventions. The higher the internal specificity, the more specific a patent is to the bundle and hence the harder it is to substitute. Some of the inventions are non-substitutable, so that if they are patented the intellectual property rights must be obtained to make the technology work. These are called essential patents. Other inventions may be easily substituted, so that if the invention is patented it is easy to substitute another invention. Thus, substitutability is an aggregate measure of the composition of the inventions.

Substitutability is akin to asset specificity in traditional transaction costs analysis. However, asset specificity is not meaningful when dealing with intellectual property [40]. This is a bold statement that needs to be explained. Asset specificity is the difference in the value an asset has in a particular use and the value it has in its second best use

[3] Rather than repeating our arguments at length, we just offer a brief summation of the issues and refer the reader back to the previous section for more detailed logic.

[42]. The amount of hold-up power the patent holder can exercise is determined by the patent holders bargaining power, which is determined by the patent holder's best alternative. This is only a meaningful concept if the asset can only be deployed in one use at a time, which is perfectly reasonable for physical assets. However, intellectual property can be deployed in both its best and second best use (and all other uses) simultaneously [6,40]. Thus, the difference between the best and second best use is irrelevant.

Substitutability asks a different question. It measures how easy it is to use a different asset. Thus, it is the difference in value of the technology if one asset is substituted for another. Asset specificity is the difference in the value of an asset if it is changed from one use to another.

We anticipate that increased substitutability leads to increased opportunism costs. The main source of opportunism cost is the injunction. An injunction prevents a firm from using one particular invention. If there is not an easy substitute for an invention, then an injunction will force a company to cease using the technology or settle. On the other hand, if there is an easy substitute, then an injunction only requires a substitution. The infringing firm may still have to pay damages, but the amount is trivial compared to the amount that it could lose if it were forced to stop using the technology. Thus, we hypothesize:[4]

Substitutability–Opportunism hypothesis. Substitutability is negatively related to opportunism costs.

3.3. Moderation effects

3.3.1. IP bundle characteristics and search cost

IP networks are better at moderating the effects of all variables on search costs because they can deploy more varied knowledge resources. IP networks moderate the impacts of complexity on the search cost, because as the number of participating firms in the network increases so do the resources available in terms of diversified manpower. The technology developers are more likely to become aware of patents since the engineers belong to different organizations. In fact, just forming an IP network is a form of patent search because the firms that are likely to participate are exactly those firms that have been doing research in the area (and hence are the firms that are likely to hold the patents). The more people with unique knowledge that are participating in the technology development process, the more likely that patent discovery can be resolved without formal search. Search process is also facilitated by the fact that the members of the network have incentives to disclose their patents because it creates a market for their technology [8]. The number of IPR disclosures in the collaborative technology design is growing because of several high profile cases where IP network members pulled out of a technology development just as it was completed, then tried to sue for IP infringement [37].

IP networks also moderate the influence of industrial scope on search costs. By incorporating members from other industries, IP networks increase the likelihood that the industry specific patents are identified in time. Network members are also the patent holders from different industries which will reduce the search cost more for IP networks than IP hierarchies. This is not to say that all patents are accounted for by the members, it only signifies that the search cost is eliminated for patents already held by the member firms and is reduced for patents held by external entities.

Similar arguments can be made about the moderating effects of IP networks on the effect of international scope on transaction costs. IP networks are more likely to contain firms from different countries that can overcome the language, cultural, and regulatory barriers arising from international scope.

Complexity–Search–Moderation hypothesis. The positive relationship between complexity and search costs is less positive for an IP network than an IP hierarchy.

Industry–Search–Moderation hypothesis. The positive relationship between industrial scope and search costs is less positive for an IP network than an IP hierarchy.

International–Search–Moderation hypothesis. The positive relationship between international scope and search costs is less positive for an IP network than an IP hierarchy.

3.3.2. IP bundle characteristics and coordination cost

IP networks have several advantages in coordinating with the varied patent holders. IP networks are more likely to have members from any specific industry and hence more likely to be able to overcome issues relating to norms. Moreover, IP networks are more likely to contain members who are able to apply leverage to make negotiation processes work smoothly. The same argument holds for international scope. IP networks are more likely to have some member who can relate to the different cultural norms, different legal systems, and the different languages.

Most importantly, IP networks are more likely to include members who are patent holders. Because antitrust law governs relationships where potential competitors collaborate on a technology, there is also a well defined body of law that governs negotiations. In practice, collaborative networks often require members to fairly share their intellectual property, so actually forming the body solves many coordination issues. It is likely that the upfront costs of coordinating an IP network are greater than the upfront costs of coordinating an IP hierarchy by fiat. While having more members can have a negative effect in coordinating with outsiders if the IP network is poorly governed, having more members means there is less external coordination, and many of the coordination problems are solved as byproducts of the upfront cost of forming the group. The IPR requires coordination with some specific patent holders, and that coordination is easier if they are members of the IP network. This leads to our next set of hypotheses.

Complexity–Coordination–Moderation hypothesis. The positive relationship between complexity and coordination costs is less positive for an IP network than an IP hierarchy.

Industry–Coordination–Moderation hypothesis. The positive relationship between industrial scope and coordination costs is less positive for an IP network than an IP hierarchy.

International–Coordination–Moderation hypothesis. The positive relationship between international scope and coordination costs is less positive for an IP network than an IP hierarchy.

3.3.3. IP bundle characteristics and opportunism cost

IP networks are better at moderating the effect of all variables on opportunism cost because of the legal guidelines they need to follow. For a long time, IP networks were not allowed to discuss ex ante the intellectual property necessary for the technology development process. However, with the government relaxing the antitrust guidelines in favor of cooperation, IP networks became even better at reducing the scope of opportunism. IP networks benefit from the fact that it is more difficult and costly to litigate against a group of firms. Also, since the proceedings of a network are more open, it is more difficult for a litigant to claim that they did not have any knowledge of the infringement in advance of adoption. Two cases highlight our argument. Dell failed to enforce its patents relating to the VL-Bus

[4] Note, we do not propose hypotheses about the effects of substitutability on search and coordination costs. We do not anticipate that there will be direct effects on these two costs.

technology against the members of Video and Electronics Standards Association because the courts ruled that Dell representatives did not disclose the relevant patents during the standards development process of which Dell was a member.[5] Similarly, RAMBUS was held accountable for failing to disclose its patents when it was a member of Joint Electron Devices Engineering Council.[6]

Finally, since networks are arguably socially more responsible, they are in a better position to issue a public appeal for IP disclosure, and their request is received in a more favorable light than the request of an individual firm would be. For example, IBM donated a substantial number of patents to the Linux community. It is highly doubtful that they would extend the same gesture to Microsoft or any other proprietary firm. IP networks are also more likely to have reasonable and non-discriminatory licensing terms which greatly reduce the scope of opportunism.

IP networks also reduce the effect of industrial scope on opportunism. As the number of members in the IP networks increase, the chances that at least some members have an influence over the infringed patent owner also increase. This can be because of members' business relationships with the patent owners in other areas. Similar arguments can be made for international scope. Thus we hypothesize:

Complexity–Opportunism–Moderation hypothesis. The positive relationship between complexity and opportunism costs is less positive for an IP network than an IP hierarchy.

Industry–Opportunism–Moderation hypothesis. The positive relationship between industrial scope and opportunism costs is less positive for an IP network than an IP hierarchy.

International–Opportunism–Moderation hypothesis. The positive relationship between international scope and opportunism costs is less positive for an IP network than an IP hierarchy.

IP networks are better at moderating the effects of substitutability on opportunism costs because they can deploy more varied resources. First and foremost, unlike IP hierarchies, networks have a credible threat to abandon the technology reducing the scope of opportunism. IP hierarchies are limited because they are governed strictly by profit motives and ideally would be willing to pay a penny less than their profit if the substitute is not available. Patent policies of most IP networks clearly specify that they will discontinue work on a technology if they are not able to procure the IP on reasonable terms. Moreover, the diversity in the membership of the IP networks and their business relationship with one another and others in the industry lowers the scope of opportunism by allowing the substitute IP holders to participate in the design phase. The substitute IP holders benefit in terms of recognition and additional revenues they can derive by participation. These arguments lead to our last hypothesis.

Substitutability–Opportunism–Moderation hypothesis. The positive relationship between substitutability and opportunism costs is less positive for an IP network than an IP hierarchy.

To summarize, IP networks are better at searching because they have members with different knowledge sources. Thus, they should find more of the relevant patents in general, and across industries and geographic boundaries, which leads to lower scope for opportunism. Moreover, IP networks should have more leverage to prevent outsiders from taking advantage of them. Not only is it more likely that some firm in the IP network will hold a hostage against a potential patent litigant, but collectively the IP network holds more and better hostages. IP networks also have more resources to devote to legal defense, if necessary, than an IP hierarchy. Also, IP networks will tend to hold a higher percentage of the relevant patents than a single firm. Courts have thus far tended to reject infringement claims by members of a network against the users of the technology. For example, the Federal Trade Commission has found that Rambus unlawfully obtained monopoly power by failing to reveal to the Joint Electron Device Engineering Council (an IP network that defines technology for computer memory) that it held several key patents that would be included in the technology.[7] Rambus was a member of the IP network at the time it held the patents.

Table 2
Recent patent infringement cases.

Case	Plaintiff	Defendant	Settlement
IE Plug-ins [1]	Eolas	Microsoft	$521 million
Blackberry [3]	NTP	RIM	$612 million
DRM [30]	Intertrust	Microsoft	$ 440 million

4. Discussion

This paper introduces technology as a bundle of intellectual property rights which need to be acquired before the technology can be put to use. We then suggest that because there may be acquisition of IP rights involved, technology developers will incur transaction costs. We then develop a theory to examine the transaction costs of technology development. The theory parallels traditional transaction costs analysis, but because it focuses on intellectual property rather than physical property, it deviates enough to have a unique micro-structure. Ultimately the theory development leads us to hypothesize that different ways of governing the technology development process can lead to changes in the impact of the causes of transaction costs. Our analysis proposes that IP networks are better for developing complex technologies where one is mostly dealing with essential patents that are distributed across different industries and different countries.

We believe this paper has profound implications for the future of technology development. The relative proportion of transaction costs depend on the proportion of inventions that are protected by intellectual property rights. Technology firms are patenting more now than they have in the past [4,22,32]. More patents means greater potential for infringement. This notion of patent thicket is becoming increasingly important in law and economics [35]. Our analysis suggests that this should increase the relative benefits of using IP networks over IP hierarchies. This observation seems to be borne out by the rise of IP networks.

One of our main goals with this work is to stimulate more inquiry into intellectual property issues in technology development. Before proceeding to discuss directions for future research, we would like to put into perspective the size of the IP problem. Below we list some of the recent settlements that firms have agreed upon to avoid an injunction (Table 2).

For purposes of comparison, we have also provided the list of the top 10 information technology failures, as determined by Computerworld magazine. A quick perusal of the list suggest that the cost of failed mega systems is paltry compared to the cost of patent infringement. Obviously, the comparisons are not perfect, but we merely want to illustrate the catastrophic cost of patent litigation (Table 3).

This suggests to us that one of the largest sources of failure in information technology today is lack of proper consideration for IP issues [23]. The point is that IP issues in technology development are a

[5] http://www.ftc.gov/opa/1996/06/dell2.shtm.
[6] http://www.ftc.gov/opa/2006/08/rambus.shtm.
[7] http://www.ftc.gov/opa/2006/08/rambus.shtm.

Table 3
Top 10 IT failures (from Computerworld).[a]

Company	System	Financial outcomes
AMR, Budget Rent a Car, Hilton Hotels, Marriott International	Confirm reservation system	$125 million development costs
Snap on tools	Order entry system	$50 million lost sales
FoxMeyer	SAP ERP system	$500 million suit against SAP settled for undisclosed amount
W.W. Grainer Inc.	SAP ERP	$23 million in profits
Greyhound lines	Trips reservation and dispatch system	$61.4 million
Hershey Foods	ERP system integration	$150.5 million decline in revenue compared to same quarter a year before
Norfolk Southern	Systems integration	$113 million in lost business
Oxford Health Plans	Bill and claims processing	Not entirely clear, but $78 million quarterly loss (they had never had a quarterly loss before)
Tri Valley Growers	Oracle ERP implementation	$20 million suit against Oracle (Tri Valley Growers file for bankruptcy)
Universal Oil	Project cost estimation software	$100 Million lawsuit against Andersen Consulting

[a] Online at http://www.computerworld.com/computerworld/records/images/pdf/44NfailChart.pdf as of 11-11-08.

hugely important area where the IS field could make a contribution. We suggest a few places to start below.

There is a rich literature on the impacts of IT on transaction costs [7,12]. This issue is beyond the scope of the current work, but is a good direction for future research. If IT has differential impacts either on the upfront costs of setting up a governance structure or on the ability of a governance structure to moderate transaction costs, then there is room for theory development, which can lead to better systems. For example, if better patent search technologies (like Google patent search http://www.google.com/patents) reduce search costs, then it should also reduce the relative ability of organizational forms to moderate search costs. In the limit, if search costs are zero, then there is no search advantage in IP networks. It is worthwhile to examine how technology can substitute for and/or complement what governance structures do today.

One idea in this literature is the idea of the move to the middle [7]. This work is concerned with understanding the impact of IP law on the governance of technology development, and thus we take governance technology as fixed. The move to the middle work is concerned with how technology can change governance forms and enable new ones. Indeed, governance technology has and should continue to have an impact on the relative ability of different governance forms to moderate transaction costs. We see the emergence of middle forms today, where there is one central developer with a number of partners, who are not equals per se, but who have something useful to bring to the table. Technology allows a central firm to better identify the potential partners who have the most to offer and hence allow for the upfront cost advantages of an IP hierarchy while preserving the moderating advantages of an IP network. We would expect to see more of a move to the middle in this environment as technologies advance.

Another area of research is optimal rules of governance for IP networks. Groups typically set up some rules based on de facto standards of participation, like IEEE bylaws. However, we have observed laws change over the years, which suggest that IP networks are realizing mistakes. In particular, we have noticed older bylaws did not address how IP was to be shared among the members, while newer bylaws explicitly state that all IP of all members plus all discovered IP is to be shared [19]. The point is that IP networks probably do not currently have the best set of rules available. The rules are often made by lawyers and engineers, who could benefit from the additional perspectives of cognitive scientists, sociologists, and economists.

Related to this is a study of different forms of IP networks. We have lumped all groups into one category, but there are a variety of different IP networks. For example, there are ongoing groups like IEEE or OMG who have an open ended charter and can deal with any technology issues that might arise. There are also groups dedicated to a single issue, such as the DVD forum or Bluetooth SIG, who are created to solve a specific technology problem and who will vanish when the technology is gone. One of the main questions in this stream of research would be what sort of IP network for what sort of technology.

We would also encourage some study in the realm of legal consequences of IP networks. We have touched on the notion of antitrust, but we are not able to give it the treatment it might warrant. The bottom line is that collaborative design results in many antitrust issues. The nature of technology may drive changes in how the courts adjudicate antitrust, and how the courts adjudicate antitrust should drive changes in how firms develop technology.

5. Conclusion

This paper offers three major contributions. First, we develop the concept that technology is a bundle of inventions. By viewing technology as a bundle of inventions rather than an artifact or one of the other variety of representations we currently have, we argue that scholars and managers alike can find solutions to problems that are difficult to solve using a different perspective. The second lesson is that inventions or intellectual assets are different from physical assets. The third lesson of this work is to modify and extend traditional transaction cost theory, which is based on transactions involving a single physical asset, to take into account the problem of bundles of inventions. We theorize that IP networks may have higher setup costs, but also have a better ability to moderate the antecedents of transaction costs. Our theory provides a readymade analytic framework for a technology developer to choose a governance structure. Obviously, the developer in question will have to put numbers to the theory, but we believe we have made clear some of the transaction cost trade-offs of the different governance forms.

References

[1] D. Ackman, Microsoft Vows to Crush the Mouse that Roared, Forbes Online, , 2003 last accessed: July 18 2006 at: http://www.forbes.com/home_europe/2003/08/12/cx_da_0812topnews.html.

[2] Admin, FTC Reverses Itself, Blasts Rambus for Creating Unlawful Monopoly, 2006 Consortiuminfo.org, last accessed: May 16 2008 at:.

[3] AssociatePress, 'Patent Trolling' Firms Sue Their Way to Profits: Companies Amass Intellectual Property, then Accuse Others of Infringement, MSNBC, 2006 last accessed: March 18 2006 at: http://www.msnbc.msn.com/id/11860819/from/RSS/.

[4] J. Bessen and R.M. Hunt, An Empirical Look at Software Patents, Working Paper No. 03-17 available at http://www.researchoninnovation.org/swpat.pdf (2004).

[5] L. Chiariglione, Information Technology — MPEG Strides Forward with ISO/IEC 14496-2 (MPEG-4, Video), IEEE Briefings, 2002 (http://www.iso.org/iso/en/commcentre/isobulletin/articles/2002/pdf/mpeg02-05.pdf).

[6] E.K. Clemons, L.M. Hitt, Poaching and the misappropriation of information: transaction risks of information exchange, Journal of Management Information Systems 21 (2) (2004) 87–107.

[7] E.K. Clemons, S.P. Reddi, M.C. Row, The impact of information technology on the organization of economic activity: the "move to the middle" hypothesis, Journal of Management Information Systems 10 (2) (1993) 9–36.

[8] M. Dolmans, Standards for standards, FTC Hearing on Competition and Intellectual Property Law and Policy in the Knowledge-Based Economy, 2002.

[9] J. Farrell, Arguments for weaker intellectual property protection in network industries, Standard View 3 (2) (1995) 46–49.

[10] J. Farrell, M.L. Katz, The effects of antitrust and intellectual property law on compatibility and innovation, Antitrust Bulletin 43 (3) (1998) 609–650.

[11] N. Gandal, N. Gantman and D. Genesove, Intellectual property and standardization committee participation in the US modem industry, CEPR Discussion Paper No. 4658 (2004).

[12] V. Gurbaxani, S. Whang, The impact of information systems on organizations and markets, Communications of the ACM 34 (1) (1991) 59–73.

[13] J. Hagedoorn, J. Schakenraad, The effect of strategic technology alliances on company performance, Strategic Management Journal 15 (4) (1994) 291–309.

[14] O.D. Hart, J. Moore, Incomplete contracts and renegotiation, Econometrica 56 (4) (1990) 755–785.
[15] R. Hawkins, R. Mansell, J. Skea, Standards, Innovation and Competitiveness: The Politics and Economics of Standards in Natural and Technical Environments, Edward Elgar Publishing Limited, 1995.
[16] J.B. Heide, G. John, The role of dependence balancing in safeguarding transaction-specific assets in conventional channels, Journal of Marketing 52 (1988) 20–35.
[17] M.A. Heller, The tragedy of the anticommons: property in the transition from Marx to markets, Harvard Law Review 111 (3) (1998) 621–687.
[18] M.A. Heller, R.S. Eisenberg, Can patents deter innovation? The anticommons in biomedical research, Science 280 (5364) (1998) 698701.
[19] K.A. Jakobsen, Revisiting standard-setting organizations' patent policies, Northwestern Journal of Technology and Intellectual Property 3 (1) (2004).
[20] P.L. Joskow, Contract duration and relationship-specific investments: empirical evidence from coal markets, The American Economic Review 77 (1) (1987) 168–185.
[21] B. Kahin, Common and uncommon knowledge: reducing conflict between standards and patents, in: S. Bolin (Ed.), The Standards Edge: Golden Mean, The Bolin Group, 2005, pp. 35–44.
[22] S. Kortum, J. Lerner, What is behind the recent surge in patenting? Research Policy 28 (1) (1999) 1–22.
[23] K.R. Larsen, K.A. Kozar, Diminishing IS Impact: The Marginalization of Information Systems in Business Schools, 2003, pp. 1–12.
[24] M.A. Lemley, Intellectual Property Rights and Standard-Setting Organizations, California Law Review, 2002, pp. 1–146, Available at SSRN: http://ssrn.com/abstract=31012290(1).
[25] M.A. Lemley, Ten things to do about patent holdup of standards (and one not to), Boston College Law Review 48 (2007) (149–168).
[26] P. Mahonen, The standardization process in IT — too slow or too fast? in: K. Jacobs (Ed.), In Information Technology Standards and Standardization: A Global Perspective, IDEA Group Publishing, USA, 2000, pp. 35–47.
[27] T.W. Malone, J. Yates, R.I. Benjamin, Electronic markets and electronic hierarchies: effects of information technologies on market structure and corporate strategies, Communications of the ACM 30 (6) (1987) 484–497.
[28] M.L. Markus, C.W. Steinfield, R.T. Wigand, G. Minton, Industry-wide information systems standardization as collective action: the case of the U.S. residential mortgage industry, MIS Quarterly 30 (2006) 439–465 (Special Issue on Standard Making).
[29] W.W. Powell, Neither market nor hierarchy: network forms of organization, Research in Organizational Behavior 12 (1990) 295–336.
[30] PressPass, Microsoft agreement with InterTrust paves way for accelerated development and adoption of digital distribution technology, Microsoft.com, 2004 last accessed: March 18 2006 at: http://www.microsoft.com/presspass/features/2004/apr04/04-12intertrustdrm.mspx.
[31] K. Raimers, M. Li, Antecedents of a transaction cost theory of vertical IS standardization processes, Electronic Markets 15 (4) (2005) 301–312.
[32] K.G. Rivette, D. Kline, Rembrandts in the Attic — Unlocking the Hidden Value of Patents, Harvard Business School Press, Boston, Massachusetts, 2000.
[33] T.S. Robertson, H. Gatignon, Technology development mode: a transaction cost conceptualization, Strategic Management Journal 19 (1998) 515–531.
[34] S. Saussier, Transaction costs and contractual incompleteness: the case of Électricité de France, Journal of Economic Behavior & Organization 42 (2) (2000) 189–206.
[35] C. Shapiro, Navigating the patent thicket: cross licenses, patent pools, and standard-setting, in: Adam Jaffe, Joshua Lerner, Scott Stern (Eds.), Innovation Policy and Economy, MIT Press, 2001, last accessed: 1 at: http://faculty.haas.berkeley.edu/shapiro/thicket.pdf.
[36] M. Shurmer, Telecommunications standardization and intellectual property rights: a fundamental dilemma? Standard View 3 (2) (1995) 50–59.
[37] T. Simcoe, Intellectual property and compatibility standards: a premier, Proceedings of the Cyberinfrastructure for Collaboration and Innovation, 2007.
[38] A. Updegrove, Participating in Standard Setting Organizations: Value Propositions, Roles and Strategies, , May 10 2008 consortiuminfo.org, last accessed: at: http://consortiuminfo.org/evaluating/.
[39] A. Updegrove, Personal Communication: Legal insights on IPR and standard setting, Lubbock, TX, (2004) Andrew Updegrove, Patent attorney, Gesmer Updegrove LLP.
[40] E.A. Walden, Intellectual property rights and cannibalization in information technology outsourcing contracts, MIS Quarterly 29 (4) (2005) 699–720.
[41] O.E. Williamson, Markets and Hierarchies, Free Press, New York, 1975.
[42] O.E. Williamson, The Economic Institutions of Capitalism, Free Press, New York, New York, 1985.
[43] O.E. Williamson, Comparative economic organization: the analysis of discrete structural alternatives, Administrative Science Quarterly 36 (2) (1991) 269–296.
[44] O.E. Williamson, The new institutional economics: taking stock, looking ahead, Journal of Economic Literature 38 (3) (2000) 595–613.

Nitin Aggarwal (aggarwal_n@cob.sjsu.edu) is an assistant professor of management information systems at the College of Business at San Jose State University. He received his Ph.D. at Texas Tech University. His research interests include intellectual property issues, market structures and interorganizational relationships in the IT-standards environments. His prior work has appeared in the International Journal of Electronic Commerce.

Eric Walden is currently a visiting associate professor at the Tepper School of Business at Carnegie Mellon University and the James C. Wetherbe associate professor at the Rawls College of Business at Texas Tech University. His interests include industrial organization, intellectual property law, economics, and decision making. Eric earned his Ph.D. at The University of Minnesota, and his prior research has appeared in Information Systems Research, MIS Quarterly, The Harvard Business Review, and other journals.