Bundled Transactions of Intellectual Property: An Explanation for the Choice of Governance Form in the Information Technology Standard Setting

by

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ABSTRACT

In this thesis, I develop a contingency model to explain the factors affecting the transaction costs in the IT standard setting environment and how the choice of one governance form over the other moderates this effect. The aim is to understand what causes the transaction costs in the IT standard setting process and what governance form best mitigates these costs. The sub-objectives of this thesis are: To conceptualize and promote the intellectual property (IP) view of the technology standards; to identify different types of transaction costs involved in the IT standard setting process; to identify unique characteristics emerging from the IP view of the technology standard that affect the transaction costs; to show that these transaction costs, associated with transacting for intellectual property (IP), exist for all governance forms associated with the standards development process; and finally, to show that different governance forms moderate the effect of these unique characteristics on the transaction costs, making one governance form favorable over the other for a given set of circumstances.

To develop the model, I view IT standards as bundles of complementary IP (or methods) that are owned and controlled by multiple entities in multiple different locations and multiple different industries. To implement a standard necessitates transactions of IP between IP owners and standard implementers for the IP rights. However, these transactions are not simple. Due to the legal rights granted by the to the IP owner and the information asymmetry regarding their existence, there are substantial costs involved in locating and procuring the IP rights and later during the implementation of the IP due to infringement issues.

Three different transaction costs are considered: the search costs, the coordination costs, and the opportunism costs. The search costs are costs associated with identifying the necessary IP and the IP owner. The coordination costs are costs associated with procuring the IP by entering into negotiations and contracts with the IP owners. Opportunism costs are costs associated with IP infringement and other consequences arising out of IP laws. The unique characteristics, based on an IP view of standards, are identified as the complexity of the IT standard, geographical scope, industrial spread of the IT standard, and substitutability of a method in the IT standard. Complexity refers to the nature and number of interdependencies that exist between various methods that make up the standard. Geographic scope refers to the number of countries where the IP required for the standard may be held. Industrial spread refers to the different technical categories into which the IP may be classified. Finally, substitutability refers to the ability to substitute an IP in the bundle with the next best alternative without grossly affecting the functionality of the standard.

Two stylized governance forms considered in the study are hierarchies and networks. Hierarchies are characterized by a single firm (or a dominant firm and a few subservient partners) which controls the standard development process. Networks are characterized as a group of equals where the standard development process is controlled by multiple different entities.

The data were collected by surveying experts involved in IT standards development. A total of 436 people responded to the survey for a response rate of 32.0%. OLS regression and logistic regression were used to analyze the data. The

results show that there are significant transaction costs for all governance forms. Hierarchies or smaller networks are less expensive than bigger networks to start but lose their edge with the increase in bundle characteristics. The results also suggest that the complexity and geographic scope are significant predictors of search costs, and bigger networks are better at moderating the effect of geographic scope on search costs. The industrial spread and geographic scope are found to be significant predictors of coordination costs, and bigger networks are better at managing the effect of complexity on coordination costs.

Finally, complexity is a significant predictor of opportunism cost, and bigger networks are better at moderating this cost than hierarchies. We also found that bigger networks are better at moderating the effect of substitutability on opportunism, and hierarchies are better at moderating the effect of geographic scope on opportunism. Thus, it is concluded that if there is more complexity in a standard and if easy substitutes for patents are not available, then networks are preferred over hierarchies, and in case the standard has larger geographical implications, then hierarchies are preferred over networks.

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CHAPTER 1: INTRODUCTION

1.1. Problem Statement

An IT standards development project can be governed in several different ways (Aggarwal and Walden 2005). Apart from the traditional hierarchical arrangement, the IT standards can also be governed as a network (Powell 1990). Hierarchically, the standards are governed by a single company or a small group of companies which incur all the costs associated with the standards development, is solely responsible for all the intellectual property required, and is privy to all the benefits associated with the sale and consumption of the standard. Networks, on the other hand, rely on groups of firms for their standards development resources and share the outcome. Hierarchical governance usually results in proprietary, tightly controlled standards versus open standards arising out of network governance. The governance forms referred to here represent broad categories. In reality, there are hundreds and thousands of different combinations of governance forms possible, based on different ownership of intellectual property (IP) rights.

In the traditional literature (and the industry), the precursors of the various governance forms are clearly identified and well-documented (Coase 1937; Williamson 1991). This enables the researchers to hypothesize about the governance form based on advantages that different structures offer to minimize the dissonance caused by the antecedents (Bakos and Nault 1997; Gurbaxani and Whang 1991). For example, transaction cost theory suggests that an economic agent will choose a governance form that economizes on transaction costs arising due to the frequency of transactions, asset specificity, and uncertainty. The theory then highlights different

types of asset specificity and uncertainty to hypothesize about how different governance forms help mitigate these costs. However, for IT standards, there is no clear consensus on what advantages various governance forms offer to effectively predict the suitability of a governance structure for a specific IT standard setting process. The absence of a reasonable criterion to evaluate the governance forms leads many firms to choose a wrong governance form and consequently fight an expensive standard war to justify their decision or pay a heavy price in terms of litigation costs for infringed IP. There is a need for a model that can be used prescriptively to evaluate the governance forms before standard development activity occurs. This will help firms not only to avoid expensive standard wars, but also to save themselves from pitfalls usually associated with dealing in intellectual property (IP) bundles.

In this work, we build upon the classical transaction cost theory and update it to incorporate unique characteristics of knowledge-based industries. Broadly, we ask the same question as new institutional economists; why hierarchies and why networks? However, since the determinants of the transaction costs are different for the knowledge industry, we propose new antecedents. For example, in the case of traditional industries, repeated transaction means that the transaction should be organized hierarchically so that the coordination costs and opportunism are reduced. However, for intellectual and knowledge-based industries, the notion of repeated transactions does not arise because once the asset is transferred, the replications are costless. Moreover, asset specificity in case of physical products means the difference in the value of the asset in its first best use and its second best use. This

concept does not apply to knowledge-based products because they can be used simultaneously in multiple locations.

Finally, hierarchical governance in the case of a knowledge-based industry does not necessarily preclude the search costs since hierarchies still have to do searches to prevent IP infringement.

The main purpose of this thesis is to develop a contingency model to explain the factors affecting the transaction costs in the IT standard setting process and how the choice of one governance form over the other moderates this effect. The sub-objectives of this thesis are to conceptualize and promote the intellectual property (IP) view of the technology standards; to identify different types of transaction costs involved in the IT standard setting process; to identify unique characteristics emerging from the IP view of the technology standard that affect the transaction costs; to show that these transaction costs, associated with transacting for intellectual property (IP), exist for all governance forms associated with the standards development process; and finally, to show that different governance forms moderate the effect of these unique characteristics on the transaction costs, making one governance form favorable over the other for a given set of circumstances.

1.2. Conceptualization of an IT Standard

We conceptualize the IT standards to be made up of bundles of complementary intellectual assets that are protected and owned by different entities (Aggarwal and Walden 2005). For example, the IEEE 802.11 wireless standard is a bundle of more than 100 protected modules of intellectual assets owned by 91

different firms in more than 15 different countries. This is in contrast to the usual treatment of the IT standards as a single entity. In most research, a standard is viewed as a single item that is input into a technology product (Gandal 2002; Kauffman et al. 2000; Shapiro and Varian 1999a; Shapiro and Varian 1999b).

Conceptualizing IT standards as a single entity results in two problems. First, it ignores the fact that different pieces of the standard can be owned by different entities. This leads most research to inappropriately consider only the binary ownership of a standard (i.e., either company X owns the standard or it does not). The other difficulty is that the standard is almost always the unit of analysis. Though the standard as a whole is important, so too are the components of the standard. By conceptualizing a standard to be a bundle of more elementary objects, this research allows study of the operational level details of the standardization process that are usually overlooked when the standard is viewed as a single object. For example, at the operational level, apart from writing specifications, the standard setting body also has to worry about IP procurement.

Secondly, the intellectual assets that make up an IT standard represent ideas and knowledge of a company. They are intellectual in the sense that they are creation of minds and assets in the sense that they are valuable. As a result, the intellectual assets are increasingly protected by way of IP rights by the firms. The trend is very profound in case of mature industries like telecom and pharmaceuticals and catching up in nascent industries like software and information technology.

Third, the thesis recognizes that the IP used in the development of an IT standard are complementary to each other. To create value, the IP has to be consumed as a bundle. This introduces specificity in that the IPs are specific to each other. This also introduces *externalities*, so that one firm's use of an IP affects other firms. This means that it is inappropriate to analyze the standards and IP in isolation because the value of one IP in a standard depends on access to the other IP.

Finally, the thesis also recognizes that different pieces of the standard are the intellectual property of their respective owners. Thus, multiple entities that are geographically separated can own different pieces of a single IT standard.

1.3. Brief Overview of the Conceptual Research Model

Since the IP is distributed across the globe, and there are legal implications for the use of IP, the standard developers have to obtain the necessary permissions from all of the IP owners before using the IP. Based on this conceptualization, I identify the transaction of an IP bundle as one of the key characteristic of the IT standard setting process.

The transaction of the IP bundle involves activities like the search for all of the relevant IP that might be infringed as a result of standard specifications. Unique to IT standards is that the search has to be performed by both hierarchies as well as networks. Next, a communication channel needs to be established between the standard setting body and the IP owner for procurement of the IP. This is followed by negotiations for securing the terms of licensing the IP so that the standard specifications can be legally implemented. Post negotiation, a contract is signed

laying out the terms and conditions of licensing and the royalty payments, if any. Finally, both parties maintain an ongoing relationship, track usage and royalty payments.

Because of the bounded rationality, the activities described above are not completely accurate. There is always a chance that a relevant piece of IP will be overlooked or an important piece of information will be omitted in the contract. This can result in an expensive lawsuit, making the standards developer susceptible to IP holders' opportunistic behavior.

Thus, to ensure that a standard specification does not infringe on anyone's IP rights, the IP has to be procured. Based on the process described above, IP procurement in an IT standard setting incurs three different types of costs; search costs, coordination costs, and opportunism costs. Search costs are the costs associated with identifying the relevant IP and its owner. Coordination costs are costs associated with negotiating and contracting for IP. Opportunism costs are costs associated with the likelihood of getting sued.

These costs are affected by certain characteristics of the standard. Not every standard (the IP bundle) is made equal; some are more complicated than others (complexity). Some allow compatibility between many more products than others (industrial spread). Some are used internationally, while others are used locally (geographical scope), and finally, there are always multiple ways to do things, and as a result, the standard will have IP with varying degree of substitutability (substitutability). Thus we identify four unique characteristics of a standard that will

have an effect on transaction costs; complexity, industrial spread, geographical scope, and substitutability. The complexity in a standard measures how many different methods go into the standard. Since each method can be a potential IP held by another entity, a standard with large number of methods will require more searches and higher coordination efforts. Also, since the firm is searching for a bigger pool of IP and interacting with a bigger set of owners, the chances of opportunism increase.

Industrial spread of an IT standard refers to the number of products from different industries or categories that the standard allows to interoperate. With the technology converging very quickly, there is an increased need for products to be compatible with each other. Standards play a vital role in promoting this interdependence. This, however, also means that the standard developer needs to ensure that the standard does not infringe on IP held in these other industries. Thus, when a standard is created for more products to become interoperable, the need for search and coordination in multiple different industries goes up. More industries or categories also increase the scope of opportunism, as there is little bilateral dependence within firms of different industries.

Similar arguments, such as industrial spread, can be made for the geographical scope of technology standards. With the recent rush towards globalization, standards have gained even more importance. The only way firms across different countries with different technologies, different cultures, and even different languages, can become a part of the same global supply chain is if they agree on a common set of protocols or standards. However, this also means that IP in standard has to be

sensitive to local laws and not infringe on any countries' patents. This means additional search, coordination, and opportunism costs because search and coordination now involves new languages, new terms, new databases, and new laws. The transaction cost is also affected by the degree of substitutability of an IP. Since IP is the creation of minds, sometimes one can be replaced with another. However, this is easier said then done. There are retooling costs, and oftentimes, there is loss of functionality. This results in a potential for opportunism. If the IP owner knows that there are no substitutes available, then they can recover the entire surplus of the standard developers.

These unique characteristics were identified from different sources. First, I studied the patent portfolios of some major standards like IEEE 802.11, DVD, and PNG. Along with the patent portfolio, I also studied the process, as described in the IP policies, to acquire these patents. Then, I followed some popular IP infringement cases as reported in the popular press to identify factors affecting the standards development, what went wrong, and how the cases were resolved. Finally, there is no substitute for experience, so I used expert interviews to determine the antecedents of transaction costs.

The final ingredient in our model development is the governance form. To keep the discussion manageable, we only consider two stylized forms of governance, hierarchies and networks, ignoring the others. However, in reality, there is a whole continuum of governance forms that lie in between a hierarchy and a network. We consider this continuum in our measurement model and finally, in interpreting the

results. Thus, while interpreting results, we talk about hierarchy, hierarchical, smaller networks, or bigger networks. Hierarchies are individual firms, or a small group of firms with a dominant promoter, primarily engaged in developing proprietary standards. Networks are a group of equals where multiple firms contribute resources and vote on standards.

Transaction cost economics (TCE) suggests that different governance forms handle the transactions differently and hence, incur different costs. For example, hierarchies established by internalizing the transactions avoid search, coordination and opportunism costs. For an IT standard, however, both hierarchies and networks incur transaction costs. This is because the in-house developed IP can still infringe on external patents. However, because different governance forms have different organizations of people and power, they will have a moderating effect on the transaction costs. They are able to do this by either enhancing the search and coordination process and/or limiting the scope of opportunism. The hierarchies rely on in-house resources to conduct the search. They draw upon the talent and the expertise of engineers and lawyers working for the company. Even if hierarchies develop their own IP, they still have to search the external environment for potential infringement, and if the IP is found, they have to negotiate and contract with as many IP owners as required. The process is lengthy and tiresome as each contract contains different terms and conditions. Because the in-house resources are often limited and biased towards a mission of a particular firm, the search and coordination process is not perfect. This leads to opportunism later because of IP infringement.

Unfortunately, the legal system does not protect hierarchies against opportunism because of infringement. As a matter of fact, the penalties for willful infringement can be three times the actual damages because of treble damages, and rightly so, because the hierarchy profited from someone else's technology.

Networks, on the other hand, are mostly a not-for-profit organization of firms. Networks draw their resources from a diverse group of firms which helps in reducing transaction costs. Multiple firms, sometimes competitors, participate in the standards development and IP procurement. Some of these firms are also the majority IP holder of the IP required to implement the standard, greatly reducing the search cost. Moreover, the networks, because of their collusive nature, are governed by anti-trust laws that specify that the IP needs to be provided to everyone on a reasonable and non-discriminatory basis. To satisfy the anti-trust laws, networks have standardized contracts that are pre-negotiated for the standards developers and implementers, thereby reducing coordination costs. Some networks even require that IP be provided on royalty-free terms which greatly reduce the scope of opportunism. It is my theory that the governance structure eventually can be determined by which form best mitigates the IP transaction problem.

To summarize, the nature of the IT standards is such that it is composed of the bundles of intellectual property that have to be procured before standard specifications can be implemented. The procurement process results in substantial transaction costs. These costs are directly influenced by the complexity of the IT standard, industrial spread of an IT standard, geographic scope of the standard, and

degree of substitutability of an IP in the bundle. The relationship is specified below (Figure 1) in the form of a conceptual research model.

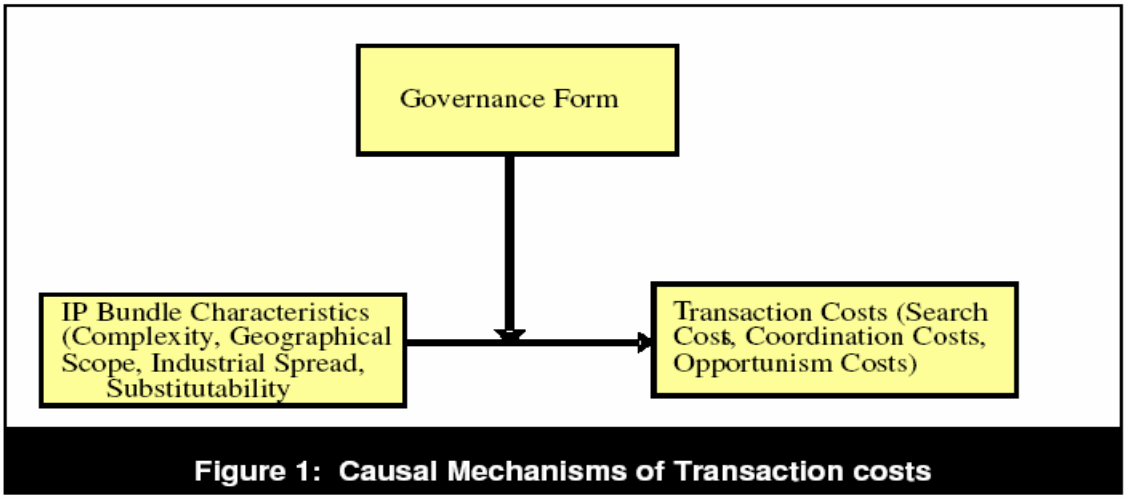

Figure 1: Causal Mechanism of Transaction Costs

Based on the conceptual model, I develop a testable model where specific instances of the characteristics of the IP bundle are identified and their impact on the various transaction costs is studied.

1.4. Research Motivation and Research Questions

In summary, the dissertation investigates the choice of governance structure based on the structure's ability to manage intellectual property rights held by multiple firms. The study identifies procurement of IP as a major activity for successful implementation of the standard specification. To do this, the study identifies various factors that affect the procurement of the IP. The purpose of this dissertation is to develop a contingency model to guide researchers and practitioners in selecting an optimal governance structure for the IT standard setting. The specific research questions to be answered are:

1. What are the antecedents of the transaction costs in the IT standard setting process?
2. How do these antecedents impact the choice of governance structure?
3. Can the governance structure in IT standards be explained by the structure's ability to manage transaction costs incurred in procuring the IP?

1.5. Timeliness of the Study

As the technology industry matures, the participating firms are realizing the value of intellectual property. Once created, the intellectual assets remain for eternity. As a result, there is a potential for long-term gains over the life of the asset. Moreover, the marginal cost of selling to a thousand customers is the same as the marginal cost of selling to a million customers, making investment in IP a very profitable venture. The companies are moving away from defensive IP strategies to aggressive IP strategies wherein the companies are using tools like patent mining to derive maximum value from their patent portfolios. IP is no longer considered a tool for protecting investment but as a strategic negotiating instrument which can be used to block competing standards. The IP issues are increasingly becoming a bottleneck for the standardization and innovation process so much so that the FTC is holding regular open discussions about how to handle the IP issues in IT standardization (http://www.ftc.gov/opp/intellect/). We are increasingly seeing cases in the popular press where a single patent is becoming a nuisance for well-established and widely accepted technology and standards, costing the industry billions of dollars in lawsuits and lost business annually. Unfortunately, there is very little awareness of the IP

issues facing the IT industry, and standards in particular. In a personal interview with a number of IT standards experts, I found that some of the respondents did not consider IP issues as a major problem, while a majority of others admitted that it was a growing problem and a matter of grave concern.

One of the respondents had just found out that their standard was infringing on an IP that was originally issued in Australia and went to the extent of saying that this was giving him sleepless nights. The IP issues non-existent a few years back now rank in the top ten issues facing CIO. There is a need for having an ex-ante policy for IP in IT standardization. This research addresses some of the issues arising out of the current patent regime. The IT field is still in the nascent stages of IP protection. As is rightly said, a stitch in time saves nine, and understanding how to provide for standards can save the industry a lot of money and ensures the success of the standard.

1.6. Research Significance and Contributions

The results of the study have multidisciplinary implications and contribute to several academic areas. First, it contributes to a small but growing field of IS standards and standardization literature. With a growing convergence of multimedia, communication and information technologies, the importance of standards cannot be overstated. There are a lot of technologies out there that have been standardized without following any formal procedure. However, there are a lot of new technologies on the horizon that will require standards. Governance structure can make the difference between success and failure of such standards. Instead of

following previous expensive ways to standardize technology, it will be beneficial if a formal tool can be used to select, beforehand, the governance structure that is suitable for a particular situation.

1.6.1. Contribution to IS Literature

Research like this is often classified in the domain of economics and law. However, IS professionals are in a better position to address these problems because of their deep understanding of the technology. Technology products are knowledge-intensive, and knowledge is the most important asset for IT firms. It is expensive to produce but relatively costless and easy to distribute. This makes information susceptible to copying and abuse relatively easily. Most economics and law research can only address generalized phenomena about standards and technology because of the absence of domain-specific knowledge. IS professionals are aware of the details and the intricacies of the technology and thus are in a better position to address issues related to technology. Economics and law research mostly treat information assets just like any other physical asset and make predictions accordingly. By incorporating unique characteristics of information assets, this study extends the scope of legal, economic and social implications of the IS research.

Second, most IS research treats information assets as a single entity. This leads most studies to characterize information assets to be owned by a single entity. However, information assets have different rights associated with them that can be owned by multiple different entities simultaneously (Walden 2005). By characterizing information assets as a bundle of IP rights, this study allows for a

complex form of organization. This extends the scope for current IS studies and opens potential floodgates for future research.

Third, technology is becoming increasingly important. Our day-to-day life activities are now dependent on the use of technology. Whether it is email or ecommerce, our personal lives are becoming dependent on technology. The evidence is moreso in case of businesses where technology has become a necessity for survival. Moreover, the rapid convergence of technology is creating new opportunities for existing technologies and for the introduction of new technologies. Fundamental to these changes are the IT standards that are enabling all of this convergence. Studying IT standards and how they affect the development, use, adoption and continuous use of technology is as important as studying the technology itself. This thesis contributes to the slow but growing sub-domain of IT standards by shedding light on the complexities of the standard setting process.

Fourth, a technology can only be as successful as the governance form that supports the technology. Inappropriate governance structure can lead to inadequate support of the technology, causing it to fail. This is especially true if the technology is in the early stages of evolution. On the other hand, a strong governance support will increase the likelihood that the technology will be successful. This study considers many different governance forms and recognizes that that there is no single best governance form to support every kind of technology. The choice of governance form should depend on the characteristics of the product that it supports. Thus, this

research work contributes to understanding the success of standards and to some extent, the success of technology.

Finally, this study focuses on legal aspects of the technology product development. There are very few studies in the field of IS that address such issues of IS research. As the IT industry matures, the intellectual property issues will gain more and more importance. New technologies can be severely constrained or never take off because of the lack of even a single IP. It is important to understand and address these issues as soon as possible so that future conflicts can be avoided. This thesis offers a small starting point for studying IP issues in the IS domain.

1.6.2. Contribution to Transaction Cost Economics Literature

The TCE literature predicts optimal governance of transactions between the economic agents under given circumstances. However, the costs and their implications on the governance of the transaction are unidirectional; i.e., they monotonously increase or decrease as one moves from one governance structure to the other. For example, on a continuum, the search cost goes from low to high as the governance of the transactions move from hierarchy to markets. Similarly, the coordination cost and the scope of opportunism increase as transactions move from hierarchies to markets. Moreover, the transactions themselves are viewed independently of each other; i.e., a transaction between a seller and a buyer does not depend on the seller's transaction with other buyers. In the traditional TCE, the nature of the product considered is physical. Thus, the nature of asset specificity is site, physical or human. Asset specificity itself is defined as the value of an asset in

its first best use and second best use. This study extends the notion of TCE to include information assets and shows the difference in treatments to various transactions for intangible products. Information assets like IP are protected by law. Irrespective of the fact of whether a firm wishes to develop its own IP or it procures IP from the market, the search costs, coordination costs and opportunism will still exist. As a result, cost does not go down in the traditional sense when the transactions are organized as markets or hierarchies. This thesis identifies other governance structures that better handle the IP issues and, in turn, manage the cost of transactions.

Other contributions to the TCE literature are also related to the informational nature of the product that is transacted. The concept of asset specificity like site, physical and human is not relevant for the information assets. Information assets can be deployed at multiple locations simultaneously. Information assets developed in one country can be easily deployed in any other country or prevented to be deployed in any other country due to trade-related intellectual property rights agreements. Similar information can be developed independent of one another and can be put to multiple different uses. Moreover, once the information is protected by way of IP, it is publicly available. Thus, the notion of asset specificity in the traditional sense is irrelevant, and new antecedents of transaction costs specific to IT should be identified. This study is a small step in this direction.

Last but not least, this study contributes to the TCE literature by recognizing the interdependence between the transactions, something that has not been considered until now. The nature of the IT standards is such that all of the IP has to be consumed

together as a bundle. Since these IP's are owned by different agents, the transaction for IP with one agent will influence the transactions of IP with all other agents, making the transactions interdependent. This study introduces the interdependence of transactions in the TCE literature.

1.6.3. Contributions to the Bundling Literature

Literature on bundling often talks about optimal pricing of a bundle (Bakos and Brynjolfsson 1999; Chuang and Sirbu 1999; Hanson and Martin 1990; Venkatesh and Mahajan 1993). A seller selling more than one item has two options. He can sell items individually or sell them together as a bundle. If the seller decides to sell the items individually, he will have to price individual items at the customer's marginal cost to extract maximum revenue. However, different customers assign different values to different components of the bundle. By having a fixed price for all individual components, a seller may only be able to extract limited value. This is because the selling price of a component may be higher or lower than what the customer is willing to pay. In either case, there is lost revenue. With bundling, the seller is able to extract maximum surplus from the buyers. This is because with bundling, a seller can target customers who have a high valuation for one product and lower valuation for others. This bundling, however, involves non-essential complementary products. This argument will not work when the bundles are made up of complementary essential elements like the intellectual property. Moreover, the components of the bundle themselves are owned by different entities, as in the case of IT standards. Individually, the components of bundles are not valuable, but when

combined together, they hold a great deal of value. This study introduces the concept of complementarities in the bundles.

CHAPTER II: LITERATURE REVIEW

2.1. Overview

This study is build upon literature from three broad areas: law, economics, and IS. Specifically, I use existing research in the area of IT standards, IP laws, and Transaction Cost Economics to develop my research model and test my hypothesis. Accordingly, this chapter presents an in-depth review of existing work in each of the three areas.

2.2. Information Technology Standards

"A standard is a published document that sets out specifications and procedures designed to ensure that a material, product, method, or service meets its purpose and consistently performs to its intended use." (IEEE-SA 2006)

2.2.1. Importance of Standards

The importance of any standard cannot be overstated. Technological advancements result in a cacophony of new products which, although desirable, are not compatible with each other or with their previous versions (Krechmer 1996; Libicki 1995). Often, the responsibility of making a product compatible with competing or complementary technologies rests with the manufacturer. All manufacturers painstakingly develop modules to allow compatibility among each other's products. This not only results in duplication of efforts but also shifts focus away from a product's core features for achieving compatibility. Standards are used to resolve these issues related to interoperability, compatibility, and scalability for both manufacturers and users. Standards ensure that products integrate and

communicate seamlessly with each other, leaving end-users and manufacturers free to focus on more critical issues. With standards, a manufacturer is only expected to make his product compliant, and this ensures connectivity with all competing and complementary technologies. However, as Andrew S. Tanenbaum, professor of Computer Science at Vrije Universiteit, Amsterdam, puts it, "The nice thing about standards is that there are so many to choose from." Thus, standards are important, but there are lots of them.

With the globalization of the economy and increasing scale of operations, standards have become a high reward, high risk game where winner takes it all (Shapiro and Varian 1999a). The scale benefits demand standardization of processes and products across industries (David 1985; Shapiro and Varian 1999b; Stigler 1951). However the process has become more complicated. There has been a gradual but significant shift in businesses' focus from manipulating things themselves to communicating and digitizing information processes (Libicki 1995). This has created interdependence and invariantly resulted in the increased complexity of organizational systems (Jacobs 2000). The complexity, coupled with the extent and diversity of strategic implications of IT, has made standards a complex and notable phenomenon (Cowan et al. 1991). These issues were formerly hidden in the products and rarely surfaced in front of the end user. However, today, these issues are on the forefront because people have to directly bear the consequences of incompatibility. As a result, standards have gained the attention of common people, business researchers and practitioners alike (David and Greenstein 1990).

The notion of standards has changed significantly over time (Krechmer 1996). Traditionally, standards were technical solutions for a common problem that were controlled proprietarily for exclusive and central exploitation; e.g., railroads and power generation (Cowan et al. 1991). This worked well for the products that were stable and used in a predetermined fashion. However, IT is a network technology, and its scope expands and changes frequently. IT is supposed to accommodate the needs of several different organizations, as well as several different technologies. As a result, the centralized control has given way to more democratic and collaborative development of standards (Axelrod et al. 1995). The problem of standardization itself has become more political and economic in nature than technical.

Incompatibilities in technologies do not exist because of the lack of technical expertise but because of the self-seeking nature of businesses (Shirky 2000). Standards form natural monopolies that guarantee long-term profits and decreasing costs (Arthur 1996; David 1985; David and Greenstein 1990; Katz and Shapiro 1985; Shapiro and Varian 1998; Varian 1999; Weiman and Levin 1994). They have emerged as a strategic weapon in the hands of competing firms to create value for themselves and for their users, in turn, establishing market dominance (Besen and Farrell 1994; David and Greenstein 1990; Shapiro and Varian 1998). This makes control of standards a very important business issue. There is often an implacable standards war before a dominant standard emerges (Besen and Farrell 1994; Shapiro and Varian 1999a). The nature of business is such that there are many losers.

Current business literature recognizes that there are differences in standards setting among IT products and services and their traditional counterparts (Bonino and Spring 1999; Burrows 1999; Cowan et al. 1991; Fomin and Keil 2000; Krechmer 1996). These differences are judged against inter-temporal differences in standards setting. It is recognized that earlier standards setting processes were basically centralized and internal to the organizations (Cowan et al. 1991). The focus was specifically on technical problem-solving and not on gains from the sale of standards. Standardization basically resulted in supply-side economies of scale, thereby lowering costs (Bakos and Kemerer 1992). There are a few cases of standards wars, but they are not as prominent or myriad as ones in IT. These wars were basically to avoid costs of switching to an alternate standard by making one's own standard into an industry-dominant standard (Besen and Farrell 1994; David and Greenstein 1990; Shapiro and Varian 1999a). Adopting an alternate standard would entail switching costs (Shapiro and Varian 1999a). On a more contemporary note, the literature recognizes that later periods of the standards setting process are basically decentralized (Cowan et al. 1991). There are economic profits associated with the control of standards (Arthur 1996; Besen and Farrell 1994; Shapiro and Varian 1998). The issues surrounding standards are social, political and economic in nature rather than technical, and standards exhibit both demand-side and supply-side economies of scale (Arthur 1996; Shapiro and Varian 1998). The control of standards has become important because profit can be made by the sale of standards. Thus, later standards wars are more challenging and the stakes are higher.

The impact of influence of IT on standardization is summarized in the following text by (Cowan et al. 1991), "The fact that IT, as network technologies, offers a steadily expanding range of service opportunities entails, as such, a number of essential economic consequences…. This requires increasing attention, in view of the fact that the IT standardization system is often viewed as being under stress; in particular, because of the accelerated pace of technological change and resulting demands for faster decision-making; because of the multiplication of standardization bodies at all levels, leading to increasingly complex and perhaps opaque proceedings and …" (Cowan et al. 1991)

2.2.2. Various Nomenclatures

To understand standards, it is first important to become familiar with various nomenclatures used in the field. Various classification schemes have been proposed to classify standards according to their origin, purpose or functionality (David and Greenstein 1990; Jacobs 2000; Krechmer 1996). Following, we present the most common and most acceptable classifications. The presentation is not comprehensive. There are many more classifications of standards in use; e.g., product and process standards, quality standards, minimum acceptability standards, etc. We only describe the most popular and most encompassing classification scheme.

2.2.2.1. Voluntary vs. Statutory: This classification differentiates the underlying process of standards making, as well as their legal orientation (Jacobs 2000). The voluntary standards are ones where the participation in the standard or adoption of the standard is not compulsory, but anyone can participate. There are no rewards for

compliance or penalties for non-compliance. To encourage participation, voluntary standards are intentionally broad to accommodate needs of multiple different firms. Though this slows down the development process, it increases the adoption. Voluntary standards are usually developed with participation of many different firms through vehicles like industry consortia and standard-setting organizations. Statutory standards are initiated by a legislative authority, and adoption is compulsory for all affected parties. These standards are usually proposed in the areas of public interest where potential of commercial gains are inadequate. For example, filing a tax return in a specific format is a statutory standard; all tax-designed software companies have to follow that code. Because of this, the standards have a very narrow scope.

2.2.2.2. de jure vs. de facto: This is one of the most popular classifications of standards in the literature that frequently talks about a standards war. It reflects the way in which standards emerge (Jacobs 2000). De facto standards emerge purely through competition as compared to de jure standards that are usually prescribed by an agency like the standard development organizations. The distinction can even be extended to identifying the beneficiary of royalty payments. In case of de jure, there is no default claimant of royalties, but in case of de facto, all the royalties, if any, go to the owners. De jure standards may be involved in a standards war with other standards and may eventually lose out to the de facto standard or, if they win, become the de facto standard.

2.2.2.3. Open vs. Proprietary: This classification is similar to de facto-de jure classification and basically distinguishes the ownership structure of the standards

(Jacobs 2000). Open standards are not owned or promoted by any specific firm or group of firms, but proprietary standards are. The second difference lies in the consideration involved in the use of these standards. Open standards are free, while proprietary standards usually involve exchange of monetary consideration. The above classification also has social implications. Open standards, on one hand, are desirable because they are free, and on the other, they are less desirable because of lack of dependable technical support from the developers; e.g., Linux and Windows. Proprietary standards are desirable to the extent that there is support and commitment of developers behind it, but their monopolistic pricing makes them less desirable.

2.2.2.4. Proactive vs. Reactive: This classification reflects the emergence of standards. Proactive standards are developed in anticipation of a future problem or requirement, and reactive standards are developed as a response to an existing problem. The proactive standards are riskier compared to reactive standards (Jacobs 2000).

2.2.2.5. Base vs. Functional: This classification is probably the most technical distinction made between classifications of standards. Base standards are more concerned with functional issues without going into implementation details. Functional standards deal with implementation issues (Jacobs 2000).

The above classifications are not mutually exclusive, implying a single standard can be classified in multiple ways; e.g., a standard can be classified as reactive, de facto, proprietary, and functional at the same time. The classification itself is universally applicable to all types of standards.

A more functional classification was given by Krechmer (1996) (Table 1) in a framework categorizing standards into four classes. This classification provides evidence about the progression of the standards from a simple to a complex entity. The roots of standards lie in the traditional world; however they have emerged to reflect the complexity of modern society and high tech information systems in use today.

Classes of Standards	**Examples**	**Purpose**	**Effect**
Units	Meter length, ounce (metrology)	Sameness	Replication
Similarity	AS metal gauges, methodology stds, character sets, X.3 PAD	Repeatability	Compatible with like
Compatibility	Group 3 facsimile, V.32 and V.34 modems, X.25 interface, wireless air interface	Internetworking	Transmitter compatible with receiver
Etiquette	Aloha Protocol, CSMA/CD, modem handshakes, WINForum spectrum etiquette	Expandability	Negotiate the variation

Table 1: The four classes of Standards (Krechmer 1996)

2.2.2.6. Units: The unit standards classified above can apply to anything that can be measured. The idea is normalization of quantities to make them comparable across the board. Historically, unit standards have been statutory in nature. Examples of unit standards in the traditional world are miles, gallons, and feet; for IT, bytes, Mhz and mbps.

2.2.2.7. Similarity: The similarity standard described above is used in close conjunction with unit standards. It defines the variability permissible between similar entities (Krechmer 1996). They can also be viewed as minimum performance or minimum quality standards, where these standards define the minimum performance or quality levels acceptable for the product or process. Since similarity standards define the bottom line for acceptable performance, the benchmark that itself is fast changing, the standards setting body will have to make decisions faster and more often (Cowan et al. 1991). This will result in fresh negotiations or renegotiations between various parties involved in standards development, making standards setting a complex task.

2.2.2.8. Compatibility standards: Compatibility standards define the compliance between two or more interfaces (Cowan et al. 1991). Compatibility standards usually involve at least two entities that need to interconnect. For example, compatibility between electrical devices and the electricity distribution system or residential sockets is important for interoperability of electric devices. In the case of IT, these standards define the common protocols based on which the devices communicate with each other; e.g., TCP/IP.

2.2.2.9. Etiquette standards: Etiquette standards are very prominently visible in the field of information technology. They define the initial negotiation between two disparate communication processes for the sole need of establishing connectivity (Cowan et al. 1991). Etiquette standards provide connectivity between past and future technologies by acting as a gateway of negotiations between various protocols.

The applicability of etiquette standards is more prominent in its ability to coalesce with future technology. The closest that traditional industries' standards come to etiquette standards are called gateway standards (David and Greenstein 1990). Gateways are usually devices that convert one thing into another; e.g., a rotary converter converts alternating current into direct current. Notice again, gateway standards are static; e.g., a converter will only convert AC into DC; however, etiquettes are dynamic.

The drive towards more comprehensive nomenclature can be attributed to changes in the purpose of standardization. The rapid change in information technology necessitates frequent decision making. The standards have to keep pace with this frequency; e.g., there are already a few versions of wireless standards. This is unlike the traditional industries where standards once set remain in existence for a long time; e.g., railroads and power distribution standards have not seen much change in decades (Cowan et al. 1991). Moreover, the nomenclature should be comprehensive enough to accommodate the scope, expandability, and compatibility of technology devices. Since it is hard to predict beforehand the convergence or the emergence of technologies in IT (Besen and Farrell 1994), the IT standards have to be sufficiently vague to accommodate disparate technologies and specific enough to maintain parsimony. On the other hand, traditional devices usually have a limited scope of compatibility and are usually developed to solve a specific problem; e.g., railroad standards were developed to facilitate free movement of goods from the west coast to the east coast (Shapiro and Varian 1999a). These standards have limited applicability to other problems or future problems.

2.2.3. Historical Perspective

This section provides the historical perspective of the standard and changes over time. Ever since their inception, there has been no clear consensus on the formal definition of standards (Cargill 1989; Fomin and Keil 2000; Jacobs 2000). The definitions have been modified and adapted to suit the specific industry to which the standards are applicable. Chronological analysis of the definition of standards suggests that they have evolved to encompass the changing nature of their application and its complexity (Cowan et al. 1991; Fomin and Keil 2000; Krechmer 1996; Shapiro and Varian 1998). Moreover, the definition also reflects partially on intertemporal importance granted to various activities in the economy. So while the earlier definitions reflected the importance of the industrial age, modern definitions are more reflective of the knowledge age (Cowan et al. 1991).

The original Oxford English Dictionary defines standards in the sense of the first industrial revolution of the 12th century as "*The authorized exemplar of a unit or measure of weight; e.g., a measuring rod of unit length, […] preserved in the custody of a public officer as a permanent evidence of the legally prescribed magnitude of the unit"* (Oxford English Dictionary). As is evident, the definition focuses on standard as a characteristic of a physical, tangible good as prescribed by law or public officer. This also signifies centralized authoritative control on the standards. This definition, though all-encompassing, does not remotely apply to the dynamism of the current knowledge age. It represents a static object in control of a statutory body with which other objects are compared to assert concurrence with a standard.

Out of the many accepted definitions for information technology standards, one that is often cited is, *"of quantity and quality in describing materials, products, systems or practices" (National Standards Policy Advisory Committee 1978 p.6.)* (also see (Jacobs 2000)). This definition of standards recognizes the intangibility inherent in the information technology and recognizes the importance of processes and procedures. The focus is no longer on prototypes in custody of a statutory body, but a prescribed set of rules and specifications available, in exactly the same form, to everyone. This also signifies loss of centralized control to more decentralized procedure. Even though more encompassing, it still lacks the applicability that appeals to information science professionals and economists.

A more recent definition illustrating the movement of standards domain from technical to social is, *"A publicly available definitive specification of procedures, rules and requirements, issued by a legitimated and recognized authority though voluntary consensus building observing due process, that establishes the baseline of a common understanding of what a given system or service should offer"* (Jacobs 2000). This definition focuses on end results without addressing the implementation and interoperability issues (Jacobs 2000), thereby recognizing the complexity inherent in IT standards setting. This definition also highlights the fact that standards development is a consensus building process, thus introducing the concept of partial goal congruence.

One important aspect of defining IT standards that has been disregarded in the previous definitions is demarcation between the boundaries of products and

standards. IT provides opportunities for products to become de facto standards, which can be used as a platform to launch complementary products and into which disparate applications can connect. The other aspect is products that are developed on proactive standards. This suggests that a comprehensive IT standards definition should incorporate this inter-transferability of concepts. One way to achieve this would be to define standards in terms of users' behavior towards technology instead of defining standards in terms of technology itself.

The above progression provides evidence of strengthening of economists' and political scientists' sphere of influence over standards. As mentioned earlier, standards making was the responsibility of a centralized standards setting organization with a focus on technical issues. There was one active promoter of standards and other passive adopters. However, IT standards by their nature involve complex problems and thus active participation of all contributors (Axelrod et al. 1995; David and Greenstein 1990; Farrell and Saloner 1988; Jacobs 2000). This has resulted in decentralization of control and behavior seeking goal congruence (Fomin and Keil 2000). The inherent underlying premise of standards has changed from a solution to a technical problem to compromise between participants (Hawkins et al. 1995; Libicki 1995). This chronological analysis illustrates that there has been temporal shift in the focus of standards problems from an industrial-based economy to an information and technology-based economy.

To summarize, standards have changed greatly, and so have people's perceptions about them. From earlier technical solutions to common problems,

standards have emerged to become a social and economic problem. However, there is still one critical area of IT standard development that is severely underdeveloped; the legal dimension. As mentioned earlier, standards are increasingly being developed by integrating modules held by different entities. This introduces legal distortions in the development of the standard that need to be incorporated in the definitions and understanding of standards.

2.2.4. Theories used to explain standardization

Overview of research papers and books on standards provide a generalized approach to the direction of research in standards. Standards literature draws heavily on the theories in the IS referenced disciplines. Specifically, most of the research on standards can be classified based on its contribution to technical, economic, legal (includes political) and social implications. In the business literature, standards have been extensively studied by economic and legal researchers, primarily because of their implications on the economy and hosts of anti-trust lawsuits in the last couple of years. Only recently, there have been efforts to supplement these economic issues with social theories (Fomin and Keil 2000). While technical issues are the domain of computer science researchers, we focus on economic and legal issues only. Fomin and Keil (2000), Table 2, gives a framework for theories used to analyze the standardization process. They aim to find deficiencies in the theory and supplement those deficiencies using social network theory. We present the framework below for illustrative purposes. We only go into details of the most widely cited theories and also some other economic phenomena associated with the process of standardization.

Theory/Model	Focus	Outcome	Explanatory Mechanisms	Deficiencies
A. Game theoretic: standard selection (Besen and Farrell 1994; Farrell and Saloner 1988)	Selection of type of standard: – committee – market – hybrid	Competing within vs. between standard(s). Fast vs. slow process	Rational (bounded rational) behavior of actors	Social forces are ignored. Determines outcomes, but can not account for process
B. Game theoretic: alliance formation (Axelrod et al. 1995)	Establishing alliances (selection of standard)	Joining in with: – collaborators – competitors – none	Rational (bounded rational) behavior of actors	Ignores timing of joining the alliance. Assumes acceptance of any member
C. Increased returns (Arthur 1989)	Selection/adoption of standard. Formation of dominant design	Dominant design. From competing between to within the standard	Adoption of technology increases attractiveness to third parties to support the technology	Points to complex socio-political processes, but does not answer "whys"
D. Bandwagon (Wade 1995, 1996)	Selection/adoption of standard. Formation of dominant design	Dominant design	Selection determined by organizational communities. Compatibility or sponsorship criterion	Processes within community are not addressed
E. Diffusion of Innovation (Rogers 1995)	Diffusion of innovation process	Character of innovation's adoption	Communication of information on innovation within a social ether	Assumes unlimited communication. Limited to micro level analysis
F. Power relations (Star 1991)	Decision making process	Explaining particular decision	Accounts for power and influences of individuals	Limited to micro level analysis
G. Knowledge creation (Cowan and Foray 1997; Michelis 1997)	Communication of knowledge	Expertise for standard creation. Information for decision on adoption	Knowledge distributed through personal and formal channels	Standard creation and diffusion are separated
H. Actor Network Theory (Callon et al. 1986; Latour 1987)	Analysis of choices/ paths. Passage points/ gatekeepers	Alignment of interests	Human and non-human actors have equal explanatory power. No micro-macro divide	Mostly descriptive

Table 2: Theories used to analyze Standardization Process (Fomin and Keil 2000)

2.2.4.1. Game Theory: Standards form natural monopolies, making it a fertile field for economists to research (Aggarwal and Walden 2003; Shapiro and Varian 1998). There are also economic gains that derive the formation of standards (Besen and Farrell 1994; David 1985; David and Greenstein 1990; Fomin and Keil 2000). These economic gains have to be divided amongst the owner and the user of the standard. Because standards have large economies of scale and form natural monopolies, control of standards can be very lucrative and guarantee businesses super-normal profits for a very long time (Aggarwal and Walden 2003). This makes standards an economic problem where industry players have to negotiate the division of gains (or

losses) amongst themselves. There are incentives (or disincentives) for firms to join standards setting bodies (Besen and Farrell 1994; Fomin and Keil 2000). The firm's incentives can range from simply influencing the standards setting process to gain a strong foothold on the winning standard, to delaying the standards setting process so as to buy more time to develop one's own standard (Shapiro and Varian 1998). Some of the firms also join just to know what the competitors are doing (Shapiro and Varian 1998). With game theoretic models, the researchers calculate the expected payoffs of each player under various circumstances and try to give the best response to the competitor's move (Besen and Farrell 1994). However, game theoretic models are best suited to identify expected payoffs under the various outcomes and fail to identify the process of standardization (Fomin and Keil 2000). Theories like path dependence, historical events and increasing returns (Arthur 1996) focus more on the process of standardization. Notice here that research only considers two entities as the claimants of the payoff, the user and the standards developer, and the claims of the ownership of the standard stem from the view that standards are a single object.

However, if we view standards as a bundle of IP, the gains will have to be divided amongst the users, the standard developer, and the IP holders of the standard. The definition of the ownership itself becomes questionable.

Game theoretic models are best suited for studying the outcomes of IT standardization processes. As has been mentioned several times in the paper, because of the rapid pace of IT development, there are multiple standards competing simultaneously. The frequency and speed of decision making is a great deal more in

IT standardization than in traditional standardization. Standards have become a strategic tool in the hands of businesses to gain competitive advantage and control the market. There is often an implacable standards war before a dominant standard emerges (Shapiro and Varian 1999a). The nature of business is such that there are many losers. Even if there is no standards war, the cooperation in standards will be based on partial goal congruence, and firms are expected to participate only until the time they derive some benefits out of the coalition (Dagnino and Padula 2002; Shapiro and Varian 1998).

2.2.4.2. Path Dependence: Path dependence is a concept closely tied with the increasing returns (Arthur 1996). Path dependence basically posits that the winner of the standards wars is decided by way of small random historical events that happen along the way of the standards setting process (Arthur 1989). At the outset, the market has multiple standards competing against each other. The market is said to be unstable or tippy and may favor any technology at that time (Arthur 1990; David and Greenstein 1990). Due to some random historical events, the market locks into one standard, and due to increasing returns and positive feedback, the initial gains are magnified and a dominant standard emerges (Arthur 1989; Arthur 1990; Arthur 1996). Most often, de facto standards are set by the process of path dependence, irrespective of whether they are IT standards or traditional standards. However, IT is seeing a shift from competition between standards to consensus-based standards (Aggarwal and Walden 2003). The literature is not clear what these path-dependent random historical events are. The view of IT standards as a bundle of patents provides some insights on these random historical events. If a standard has a well-

defined IP portfolio that does not infringe on other firms' IP, this provides reassurance to the standards users and results in preference of this standard over the others. The initial preference can then translate into the standard becoming a de facto standard.

2.2.4.3. Increasing Returns: An important characteristic of standards is that they follow increasing returns (Arthur 1996). Increasing returns, contrary to traditional diminishing returns, imply that standards follow increasing returns to scale; i.e., returns on investment, grow at an increasing rate. This also suggests that more than one industry standard is undesirable. Increasing returns occur when the product is characterized by high up-front costs, network externalities (Church and Gandal 1992; Katz and Shapiro 1986; Katz and Shapiro 1992) and customer groove-ins. Standards show the substantial presence of all these elements. First, standards are knowledge products and hence, developing standards requires huge upfront costs (Arthur 1996). These costs are usually sunk costs and create entry and exit barriers for the standards suppliers. Thereafter, the replication of standards is relatively costless (Aggarwal and Walden 2003). This suggests zero marginal costs and decreasing average costs across the entire scale (Shapiro and Varian 1998). Second, standards exhibit network externalities, implying that the value of membership in a standards network is an increasing function of the number of adopters of those particular standards (Economides 1996; Gallaugher and Wang 2002; Kauffman et al. 2000). Finally, adoption of standards, like any technology product, creates lock-ins and switching costs for users (Shapiro and Varian 1998). Together, these three factors assure

dominance of a single standard in the market. For customers, this should translate into lower costs, higher value and lower transaction and learning costs over time.

Increasing returns cause standards to become natural monopolies (Shapiro and Varian 1998). With standards monopoly, the customer's welfare is dependant on the monopolists' pricing strategies (Aggarwal and Walden 2003). A single entity with control over dominant standards can behave opportunistically and charge monopolistic premiums over licensing standards to users. Thus, all benefits of falling average costs, network externalities and lock-ins accrue to the supplier of standards, and the customers may end up paying monopolistic premiums for its use. Note here that this claim ignores the fact that the controlling entity need not be a single firm.

Increasing returns are applicable to all types of standards. However, the magnitude of network externalities is enormous in case of IT standards. There are not only supply-side economies of scale but also demand-side economies of scale (David and Greenstein 1990). The customers favor using a standard which they perceive will be dominant and adopted by others as well. Oftentimes, increasing returns coupled with path dependence result in customers getting locked into inferior technology; e.g., the QWERTY key board is considered inferior to the DVORAK keyboard (David 1985). As compared, traditional standards often emerge from best practices or are company-specific and hence, exhibit lower demand-side economies of scale. Moreover, once locked into an inferior standard, it is relatively easy in case of traditional industries to switch to the superior standard; e.g., it only took two days in the Spring of 1886 to convert the entire rail gauge from 5' gauge to the now-standard

4'8Y2" gauge on more than 11,000 miles of track (Shapiro and Varian 1999a) and couple of years to convert the entire date format from 2 digits to 4 digits during the Y2K problem.

The theory of increasing returns applies only once the standard is written and ready to use and ignores the complexities in the development process itself. The standard itself is viewed as a single object. However, the IP bundle view of the standards clearly shows that activities during the standard development phase will affect the standard in its adoption.

2.2.4.4. Theories of industrial organization: Monopoly and Competition: IT requires complementary investments in organizational change to achieve full potential (Brynjolfsson and Hitt 2000; Brynjolfsson and Hitt 1998; David and Greenstein 1990). Likewise, standards require complementary changes in organization at an industry level in order to achieve full potential (Conway 1971). Standards implication on industry structure is closely tied in with its impact on competition and its role in the formation of a monopoly. Standards have been studied in their role of increasing competition as well as reducing competition (Besen and Farrell 1994; David 1985; Gandal 1995; Katz and Shapiro 1985; Katz and Shapiro 1994; Shapiro and Varian 1999b). Whereas, de facto standardization of proprietary standards is believed to reduce competition, de jure or cooperative standards are believed to increase competition in the end product market. The adoption of standards is also closely related to the notion of competition. Increased adoption

invariably leads to reduced competition, and market structure is characterized by monopoly or an oligopoly.

The standards can influence the structure of the industry by increasing competition within the products following the standard; however, in doing so, the standard itself becomes a monopoly. Apart from competition and monopoly, a relatively new theory from management, coopetition (Bradenburger and Nalebuff 1996; Dagnino and Padula 2002; Garraffo 2002), has been positioned to explain standards setting in the IT industry. Coopetition is based on economics game theory and has been used to explain cooperation amongst industry competitors. The basic underlying conceptualization is to remove the negative connotations associated with monopolies. Coopetition refers to simultaneous cooperation and competition amongst industry players. Specifically, the industry players cooperate on standards development and compete on final products. Coalition formation has also been studied in the context of the value it provides to the participants of the coalition (Axelrod et al. 1995).

Several other economists have approached the notion of industry structure in a different way (Varian 1999; Varian 2001; Weiman and Levin 1994). Coopetition is different from voluntary standards setting organizations. While coopetition has a definite time frame and is undertaken on a project basis, voluntary standards setting organizations may have a very long-term horizon. Voluntary standards setting organizations are industry consortiums and usually not-for-profit organizations who aim at gaining consensus on development and promoting industry standards. Usually,

it is considered that standards setting organizations improve the quality of industry standards, but at the same time, because of the need for consensus amongst participants, result in delayed responses to market needs (David and Greenstein 1990; Hawkins et al. 1995).

Market competition involving open and proprietary standards mainly deal with how the economic benefits are shared among industry players (Besen and Farrell 1994; Shapiro and Varian 1998). While in the case of open standards, the entire economic gains are appropriated by the users of the standards, the same does not hold for proprietary standards. In the case of proprietary standards, all the economic gains are appropriated by the firm holding the rights to the standards (Aggarwal and Walden 2003). In the case of open standards, no one has an incentive to promote the industry standard, and hence, they are slow to evolve as compared to proprietary standards, which might be heavily promoted by the owner (Hawkins et al. 1995). The owner of a proprietary standard may engage in promotional pricing to set the adoption bandwagon rolling before going back to predatory pricing (Shapiro and Varian 1998).

2.2.4.5. Bandwagon effect: A closely related phenomenon to network externalities, demand side economies of scale and positive feedback is the bandwagon effect (David 1985; David and Greenstein 1990; Shapiro and Varian 1998). Initially, when multiple standards are introduced, consumers are faced with uncertainty. Due to network externalities, all the customers want to adopt the same standard. However, if no one adopts the standard, customers are happy with their existing standard (David

1985; David and Greenstein 1990). Hence, there are two opposite outcomes for any standard; virtually everyone adopts the standard or virtually no one adopts the standard. For getting the bandwagon rolling, a standard should achieve a minimum threshold number of adopters (David and Greenstein 1990; Shapiro and Varian 1998). If it is not able to achieve the minimum threshold, the standard fails to achieve dominance and eventually dies; e.g., in the case of VHS and Betamax, Betamax failed to achieve the minimum threshold. Bandwagon effects have also been studied for their role in analyzing coordination problems (David and Greenstein 1990).

Bandwagon effects are particularly important in case of IT standardization. In the case of traditional standards, since they are internal to the organization, bandwagon effects don't make much difference. However, in the case of IT, due to demand-side economies of scale and the magnitude of users, the bandwagon effect takes a proportionately massive scale and can define the success or failure of a standard. It is the objective of every standard owner to roll the bandwagon in their favor (Shapiro and Varian 1998).

2.2.4.6. Legal Issues: Oftentimes, governmental intervention is required for development of standards. These interventions range from proposing the standards to monitoring the proprietary control over the standards. Usually, it is governmental policy to control consumption of public goods. With widespread adoption of information technology standards, they are sometimes considered as public goods. However, the technology industry until now has resisted governmental intervention, and to an extent has been successful at it. There are many reasons that governmental

intervention is not desirable by the technology industry. The most important amongst them is that governmental agencies are not experts in technology and often not able to predict the path that technology will take in the foreseeable future (Libicki 1995). Thus, standard setting, based on government intervention, will be most often slow and outdated. However, on the positive side, governmental agencies protect the interest of the customers.

A very important legal implication in standards is governmental stand on anti-trust cases. History provides evidence of some very successful anti-trust cases resulting in the breaking of a monopoly of standards and bringing down the overall costs for the customers; e.g., the AT&T monopoly was broken as a result of an anti-trust lawsuit, and the company was broken into many regional Bell companies operating today, making the telephone standards more accessible to new vendors. This also affects the industry structure of the firms. Though government recognizes that collusion in IT standards setting best serves the long-term interests of the industry, the anti-trust laws have been put in place to keep a check on opportunism in cooperative standards development.

2.2.4.7. Social Issues: Socially, standards increase options available to the customers and reduce their dependence on one vendor. Standards have value propositions for both consumers as well as producers. For consumers, standards can avoid expensive lock-ins, and for manufacturers, standards can result in increased premium on their products. Gallaugher 2002 provides empirical evidence on premiums due to standardized web servers and its complements (Gallaugher and Wang 2002).

In Table 3, we present the summary of implications of standards from various perspectives:

Standard	IT	Traditional
Technical Issues/ Implications	Multiple solution requiring constant change	One solution serves a life time. Little or no change required
Economic Issues/ Implications	Game theoretic with decentralized decision making	Centralized
Legal Issues/ Implications	Mostly non-regulated	Mostly regulated
Social Issues/ Implications	Reduced confusion, costs for consumers, lock-ins with inferior technology	Reduced confusion, costs for consumers, lock-ins with inferior technology

Table 3: Areas of Implications

In summary, standards are important, but there are many of them. Even though a single standard will survive eventually, this doesn't stop organizations from introducing competing standards. The reason being that the control of standards is very lucrative and can guarantee organizations super-normal returns. Most research in the literature is connected to the economic, legal, or social aspects of standardization. Though technical merits are important, they don't pose as much of a problem as commercial aspects. As a result, it is important to understand these problems in the commercialization of the standards. However, much of the research cited above ignores the fact that a standard has components and these components can be held by multiple different firms. Because of this, in some instances, the only way to proceed with a standard development is by cooperating with competitors. This conceptualization of standards also changes the value proposition and outcomes of

most theories. For example, even if a standard becomes a monopoly because of network effects, the question is, who owns the monopoly? If no one owns the monopoly, then the problems associated with the monopoly automatically disappear. This conceptualization is important and may hold a vital key to understanding the complex phenomena surrounding standards.

2.3. Intellectual Property and Intellectual Property Rights

2.3.1. Introduction

Before we define IP and IP rights, it will be helpful to understand the notion of property and property rights first. Conceptually, there are physical objects and there are intellectual objects. These objects have some value and hence they can be called as assets. Thus, there are physical assets and there are intellectual assets. When these assets are owned by an entity, in legal parlance, they are said to be the property of the owner, and the owner holds the property rights of the assets. The property rights are a bundle of rights that give the owner of the assets some exclusive control over their assets. The owner may then redistribute these rights for profit. For example, in case of an automobile, the legal rights of design, modification, and servicing are retained by the automobile manufacturer or its agent, but the right to use is transferred to the buyer. The important point here to keep in mind is that the manufacturer does not have the right to use anymore once the right is transferred.

Intellectual property (IP) is the term often used to describe assets that are owned by a person, a firm, or an entity that is intellectual in nature. The assets are called intellectual because they are the creations of mind and include scholarly things

like inventions, ideas, business processes, images, creative writing, drawings, artistic work, symbols, names, logos, and other similar things used by businesses (Field 2006). The assets are called property because someone owns the rights of ownership of these assets.

The IP is protected by the grant of intellectual property rights (IP rights). Property rights per se are a bundle of rights granted by law that determine the ownership of an asset (Grossman and Hart 1986). This view of property rights uses physical attributes of an asset in determining the ownership. The ownership allows the property rights holder to create value, transfer rights, and exclude others from the use of an asset. Similar to the notion of property rights are the intellectual property rights. Intellectual property rights determine ownership of ideas and innovations. Since the ideas and innovations cannot be protected in the same ways that physical assets are protected, IP rights provide an additional layer of stipulation that provides the necessary specifications for protection against and in case of IP infringements. The bundle of IP rights grants the IP owner the exclusive rights of use – a temporary monopoly – with regards to the subject matter of the IP. As a result, the IP owner can exclude others from performing a similar task.

The IP rights were established to serve two important functions in the society. They foster growth and innovation in the society by rewarding innovators and attracting investment (Gilbert and Shapiro 1990; Vemuri and Bertone 2004; WIPO 2004). They do this by giving temporary monopoly over the ideas and processes to the inventor by granting them exclusive rights on their inventions. This allows the

inventor to charge super-normal profits for their inventions. The notion is that the innovators will have an incentive to innovate and investors will have an incentive to invest in new technologies. However, in exchange for these exclusive rights, the inventors are required to place their knowledge in the public domain accessible by all, such as the USPTO searchable database. Hence, the second role of IP rights in the society is to encourage trade and growth by allowing knowledge transfer from the inventor to the actual implementer, thereby putting the invention to practical use (OECD 2005; Vemuri and Bertone 2004). This is possible because a creator of knowledge may not always have means and resources to pursue their ideas. With the help of IP rights protection, these ideas come into the public domain and can be implemented by others that have the resources to do so. Moreover, knowledge breeds more knowledge; hence, the open availability of this valuable knowledge provides a base on which new knowledge can be developed (Rivette and Kline 2000).

2.3.2. Need for Intellectual Property Protection

In a knowledge-based economy that is largely driven by ideas and innovations, it is important that the society recognizes the value of IP and accords necessary protection to it for continued investment and growth. The IP protection is necessary because ideas and innovations, unlike the physical assets, can be copied, imitated, or stolen easily and costlessly (Vemuri and Bertone 2004). The physical assets can be protected by way of possession, locks and chains that preclude others from using the same asset (Walden 2005). Even if the assets are stolen, they may be recovered and restored to their rightful owner. The point is that, for physical assets, there will only be a single possessor at any given point of time. However, the same is

not true for the intellectual assets. Intellectual assets are inalienable (Brynjolfsson 1994), implying that the theft of IP cannot be easily detected. Even if the theft is detected, the inalienability of the ideas makes it impossible to just delete the idea from the perpetrator and restore it to the rightful owner (Clemons and Hitt 2001).

IP rights are also important for securing the future of the organization. If an organization fails to protect its ideas and innovations, someone else will (Rivette and Kline 2000). This is because similar ideas can exist with multiple different entities at the same time. As a result, an organization may need to secure a license of their own ideas from other organizations that applied for IP rights earlier. A lot of firms proactively engage in building IP portfolios that can be potentially used against other organizations (Shapiro 2001). To safeguard themselves from such a situation, it is important that organizations protect their ideas.

Intellectual Property constitutes a superior resource for the firm which can be used to achieve a sustainable competitive advantage. For a resource to be superior, it should be valuable, scarce, inimitable, and non-substitutable (Barney 1991). In the current knowledge age, ideas command enormous value. Good ideas are scarce to come by and are mostly non-substitutable. Unfortunately, the ideas are perfectly imitable unless protected (Mata et al. 1995). Thus, to gain any kind of competitive advantage in the knowledge-based economy, it is important that the firm controls dissemination of their ideas (Desouza and Awazu 2004). This can be achieved by obtaining necessary intellectual property rights.

An IP portfolio increases the valuation of the company and contributes to the bottom line of the company (Dang et al. 1999). Unlike physical products, IP, once created, can be reused and resold many times without diminishing it. Hence, the profits potential from the sale of IP is much more than the physical product. IBM, for thirteen consecutive years, has received more patents than any other company in the world. IBM generated USD 1.7 billion, with a 98% profit margin, in revenues from licensing IP in the year 2000. Taking the lead from IBM, other companies like Lucent and Xerox are aggressively mining their patent portfolios to generate additional shareholder value (Harreld 2001).

Intellectual property rights create an entry barrier for new entrants (Capes 2002). The incumbent firm takes all the risk and incurs the start-up costs. IP protection can protect these investments. For example, priceline.com, the name-your-price travel website, was successfully able to thwart entry attempts by the giants like Microsoft Expedia by exercising their patent rights (Wolverton 1999).

2.3.3. Disadvantages of IP Regime

The notion of protecting software by IP rights is that it prevents free riding, thus provides incentives for developers. Free riding is of two types; copying and distributing the whole software or copying parts of it and using it in other software. Strong IP rights are advocated to prevent these (Smith and Mann 2004). However, there is evidence that IP rights do not protect against imitation, piracy, or infringement (Mansfield 1985; Mansfield et al. 1981). As a result, researchers and practitioners believe that IP rights impede the development of technology and only

enrich the patent holder (Stross 2005). Other forms of activities like secrecy may be more effective in IP protection (Mata et al. 1995).

While most practitioners and researchers agree that some form of IP protection is necessary for safeguarding the interests of innovators, they are divided on the effectiveness of the current regime in promoting the growth and development of the IT industry. There is ample theoretical evidence suggesting that strong IP protection leads to higher investment in R&D and better returns (Graham and Mowery 2000; Porter 1980), but only few empirical studies that test this claim (Bosworth and Rogers 2001; Lerner 1994). These studies report mixed results on whether IP rights are necessary for shareholders' value, increased investment in R&D, or the overall health of the industry. A major subset of these studies actually find that there is little evidence that links IP protection with the returns on the R&D (Hall and Ziedonis 2001; Sakakibara and Branstetter 1999). While others find some support for IP protection, they don't agree that patents and copyrights are the best means to achieve them. The studies find that IP rights as a means for protecting innovation is not socially beneficial, and that other means like secrecy, learning advantages, and sales and service are much more advantageous and effective than patents (Cohen et al. 2000; Levin et al. 1987).

Lemley (2004) discusses two views of IP protection; the traditional, ex ante justification of IP protection; namely, incentives to innovate, and, contemporaneously, ex post justification of IP protection; namely, incentives to improve, manage and control the invention protected by IP. He argues that these

views are based on the flawed assumption that private companies will not innovate unless they get monopoly rents. His subsequent analysis gives convincing arguments to show that both views are flawed and severely undermine the notion of innovation by competitive markets (Lemley 2004). Studies also refute some well-known claims of patent owners, like Microsoft, that patent protection resulted in establishment of the computer and software industry (Smith and Mann 2004; Webbink 2005). Likewise, Oberholzer and Strumpf (2004) dismiss the claims of the music copyrights owner association (RIAA) that copyright piracy (illegal music download) is responsible for declining sales of record labels (Oberholzer and Strumpf 2004). These results are consistent with the claims of the open source software community where the proponents of free software often cite the example of the success of open source to argue against the need for IP protection. Almost all open source technology is available on copy left licensing, i.e., free to copy, replicate, distribute, and modify. The open source community has traditionally avoided having to deal with patents; however, the scenario is recently changing. In the long-term interest of open source software, it is suggested that the open source community should engage in defensive patenting to protect itself from future infringement claims like the recent case of Linux and SCO. To this extent most, researchers believe that there is an urgent requirement of much-needed reforms in the IP system.

IP rights, like patents on software, pose another problem. Software represents the idea and method of doing something using a computer. Since there are multiple ways of doing the same thing, the software patent leaves much room for interpretation, thereby increasing the scope of the patent to beyond comprehensible

limits. Even though software patenting is difficult, once granted, it can be infringed upon even without any knowledge of the infringer (Jakes and Yoches 1989). This can prevent other companies from introducing similar software products.

One of the major problems associated with IP protection is the tragedy of the anti-commons (Heller 1998). The tragedy of the anti-commons is a notion opposite to the tragedy of the commons where entities have non-exclusive rights on the consumption of a public good (Hardin 1968). The consumption benefits the individual, but the cost of consumption is shared by all entities. As a result, there is a tendency to over-consume by all entities, thereby depleting or making the public good unsuitable for future use for everyone. Opposite to the notion of the tragedy of commons is the tragedy of the anti-commons where there is a tendency to underutilize resources because of strong IP rights governing the use of the resource. This happens when too many entities are involved in the development of the resource and each holds the right to exclude everyone else. The original theory was developed to explain the empty store fronts in the former Soviet Union which were greatly in demand, but conflicting interests with multiple property rights owners prevented vendors from setting up their shops in the stores.

The theory was subsequently applied to show how competing patents prevent developments and introduction of affordable drugs in the market place. The tragedy of anti-commons is also widespread in the case of the IT industry. It is seen in the form of patent thickets where multiple overlapping patents from different entities are required for commercializing a new technology (Shapiro 2001). Since each patent

holder has the right to exclude everyone else, and infringing on a patent is highly likely (Jakes and Yoches 1989), patent thickets create problems of opportunism. As a result, everyone has a tendency to underutilize the new technology, resulting in its failure. The tragedy of anti-commons also applies to copyrights where some of the most popular sitcoms of the 1970s didn't make it to DVD because many different entities held the copyrights to the contents.

2.3.4. Types of IP Rights

IP rights are broadly classified into two sub-domains; the industrial property and the copyrights. The industrial property mainly refers to the class of IP rights that are used for commercial purposes, such as the patents, trademarks, industrial design, and trade secrets. The patents are legal rights granted for new, non-obvious useful inventions that give the inventor an ability to exclude everyone else from pursuing similar interests. The trademarks are signs or symbols that distinguish the products and services of one organization from another. Industrial designs protect the form and appearance of the products. Finally, the trade secret is confidential information privy to the holder of the information. In the second class of IP rights, the copyrights basically protect pieces of art, literary work, and creative writing. Copyright laws only prevent others from replicating the copyrighted work but do not prevent others from working on similar themes. Now, we describe each of these IP rights in more detail:

2.3.4.1. Patents: A patent is a piece of information that defines an invention with the following characteristics; the invention should be novel, non-obvious, practical,

useful, implementable, and patentable. This definition holds true for most patent regimes of the world except for slight variations in what is patentable. For example, some countries do not grant patents on methods for medical treatment and varieties of plants and genes (WIPO 2004). A patent can be viewed as a contract between the society as a whole and an individual innovator that, in exchange for the public disclosure of an innovation, the patentee is granted an exclusive right over her invention for a specified period of time, usually twenty years (Field 2006). The exclusive rights exclude others from making, selling, or using the invention.

Patents are not new to society. They have been in existence since the 15th century when the Republic of Venice and England offered legal protection to inventions in exchange for public disclosure. Ever since, patents have formed an integral part of every major industrialized nation. The first patent in the United States was issued in the year 1790 to Samuel Hopkins for his work in improving the making of potash. The earlier patent laws required the patentee to submit a miniature working model for the invention to be considered for patents; however, lack of skills and legal knowledge of patentees made Congress abolish this rule in the 1870's. Patents as a means to protect IP flourished until the 1930's when the U.S. government's antitrust policy started treating patents as anticompetitive by their nature (Rivette and Kline 2000). As a result, companies started to avoid doing anything with their patents to avoid attention from the FTC and the justice department. The apprehension of Xerox to patent many new technologies, including the Graphical User Interface, resulting from the FTC consent decree to license its xerographic patent to all, is a typical example of companies' attitude towards patents

in the 1970s. However, the introduction of a new court of appeals of the Federal Circuit that specialized in patent cases gave a fresh impetus to patenting technology in order to increase investments in research and development. The new court of appeals made patent hearings uniform and deemed all patents to be valid unless proven otherwise. The court also relaxed the requirements of non-obviousness that paved the way for software patents.

By the early 90's, software and business process patents were well-established and ubiquitous. Another initiative that contributed to the growth of patents was the introduction of the Bayh-Dole Act, which allowed non-profit and federally funded entities like universities to apply for patents. At the same time, the U.S. antitrust laws governing joint ventures in technology R&D were relaxed to accommodate the changing dynamics of the technology- driven business environment.

In general, a patent is applied for in the country in which the inventor seeks to protect his intellectual property. However, these rights are not transferable from one country to another. As a result, if a patentee wishes to seek protection in multiple countries, she should apply in each country individually. There are some international treaties which make this process simpler by allowing a single application to be considered in all member countries.

The patent rights can be enforced in the a of law by the patentee. The court, then, on the merits of the case, can enforce the patent and ask the infringer to stop operations or ask them to pay hefty fines or both. If the infringement is not on purpose, the court awards compensatory damages to the infringee, but if the

infringement is willful, the court awards compensatory damages as well as treble damages, which are up to three times the amount of compensatory damages. However, it is very difficult to prove that the infringement was willful. The court can also invalidate the patent if it feels that any of the conditions mentioned above do not hold. Once the term of the patent ends, the patent enters the public domain and anyone is free to use the information contained in the patent without paying any royalties.

There are several advantages of patents. Without patents, many new ideas won't come into existence. In the absence of a legal recourse, individuals and companies would keep their inventions secret, or even worse, hesitate to invest time or undertake expensive research and development projects for the fear that their innovations will be copied and become unprofitable. By way of patents, inventors can recover their cost of time and resources invested in the invention and also make substantial profits (Smith and Mann 2004). Patents can also be used to generate new revenues through licensing, which boost the total shareholder returns.

Patents are frequently used as currency for mergers, acquisitions, and joint ventures. For example, AOL and Sun Microsystems entered into a business relationship where AOL paid $500 million for Sun servers and Sun paid $350 million for market rights to AOL's recently acquired Netscape Enterprise Software. Even though Sun's cost of executing this agreement was higher than its revenue from the sale of the servers, the relationship was justified based on the merits of being able to control the Netscape's IP (Rivette and Kline 2000).

However, the patent system is not without its demerits. The opponents of the patent system claim that the current form of the patent regime only benefits patentees and is detrimental to the growth of the industry. They feel that the market system is sufficient to reward the innovators in place of a state-backed monopoly. Surveys have shown that firms in high-tech industries like semiconductors do not use patents to appropriate returns on their R&D, or a stronger patent regime does not necessarily translate into additional R&D or innovative output (Hall and Ziedonis 2001; Sakakibara and Branstetter 1999). One of the problems cited is that the patent system favors the first-to-invent or first-to-apply patentee, even if someone else develops the similar technology independently. This retards competition and encourages frivolous patenting. It has also been argued that patenting results in the problem of under development or under deployment of complex technologies which require multiple patents held by multiple entities. The problem is explained using the theory of anti-commons, which suggests that when many entities hold the right to exclude everyone else and no single entity holds all the rights to develop the technology, there is underinvestment. As a result, negotiations with all patent holders result in high transaction costs, or as Heller says, "collecting rights into usable private property bundles can be brutal and slow" (Heller 1998).

In light of the fast-changing business and technology environment, some critics also feel that twenty years is a long time for monopoly patents over a technology. The software and internet technologies require much less time and resources to develop as compared to traditional research and development (Krim 2003). As a result, patents should be issued for a shorter duration. In twenty years,

especially for IT, not only does the technology become obsolete, but it also is useless for further development.

There is also debate about the merits of various patent regimes' decisions to issue software and business methods payment. Software, for a large part in history, was protected by copyright laws. While this prevented others from using the same code, it did not prevent developers from developing the same functionality using alternate implementation. However, with software patents, not only is the code protected, but the underlying business process or method is also protected. This prevents others from developing software of similar genre. A software patent and business methods patent can be issued for a programming technique, a line of code, or even an online implementation of an age-old business practice. The novelty aspect of the invention is determined by the use of the computers, networks, and programs to complete a job. A software and business methods patent prevents others from using the same or even similar line of code, using similar programming techniques, or following the same business practice. There is much debate about the economic rationality of such action. Critics argue, while citing benefits of such an approach, that software codes or programming techniques don't pass the test of non-obviousness, as most of the codes can be easily derived using existing business practices or existing knowledge. Moreover, software programs solve problems by breaking them down into small modules. Since these modules can be independently developed by multiple different entities, the chances of infringement are very high.

Furthermore, it is also claimed that the monitoring cost of detecting infringement on a software patent is very high, which results in slow development and adoption of socially desirable open software and standards.

With an aim to reducing uncertainty related to software patents and improving public confidence, there have been recent non-profit initiatives to collect software patents and make them available, free of charge, to organizations developing software and standards in exchange for reverse favors. For example, a non-profit initiative called Patent Commons Project was started by a group of companies like Computer Associates, HP, IBM, Intel and others working as a consortium under the banner of Open Source Development Labs (OSDL), whose sole aim is to create an online repository of donated patents to be used by online communities. On a similar note, learning from the success of eBay, there are recent initiatives to create a patent marketplace where companies can buy or sell patents (BusinessWeek 2005). It is claimed that a patent auction place will create a liquid market for patents. However, this view is not shared by large, established corporations like IBM, Oracle, Microsoft, Sun, and Google, who feel that auctioning patents will have a detrimental effect on the development of technology like web services. It is argued that if patents fall into the hands of an aggressive company, they may stall the development of technology by charging high license fees (Gallen 2004).

2.3.4.2. Copyrights: Copyrights, like patents, are a bundle of exclusive rights that govern the use of an expression of the creator. In the U.S., copyright protection is provided under Title 17 of the U.S. Code to the authors of original works of

authorship. The expression can be in the form of music, art, poetry, books, views, ideas, and other similar things. Copyrights give authors the exclusive rights to do or authorize others to reproduce, distribute, improve, present, and display their piece of work. However, unlike patents, copyrights only protect a particular expression of the idea and not the idea itself. This is called idea-expression or fact-expression dichotomy. For example, if Coase patented the idea of transaction cost, no one else would have been able to work on the idea of transaction cost without Coase's permission, but since Coase's work on transaction cost was copyrighted, many researchers after Coase were able to work on the idea of transaction cost and could advance the theory. Moreover, unlike patents, which have to be formally applied for, copyrights are automatically granted the moment the thought leaves the brain into the fixed medium. An expressionist does not formally need to apply for copyrights, though a formal application may help strengthen the case in the event of infringement claims. Copyright protection in the United States is valid for the duration of the life of the author or the last surviving author in case of joint work, plus seventy years for copyrighted work.

The copyright laws first came into prominence with the invention of the press. Before the press, copying books was a laborious and expensive task, and as a result, piracy was not a burning issue. However, with the introduction of the press, it became necessary to have strict copyright laws to prevent mass copying. The copyright laws worked reasonably well until the coming of the digital age. Modern technology poses new challenges for the copyright laws. Digital technologies like caching, podcasting, and search engines stretch the boundaries of the copyright laws.

Digital and recording technologies have made copying music and videos simple. Likewise, advancement in networking and communication technologies has made sharing these copyrighted materials convenient and traceless. As a result, government made some recent changes to the copyright laws by introducing the Digital Millennium Copyright Act (DMCA) to protect digital contents. The controversial DMCA penalizes infringers for both copyright violations and for designing technology that can circumvent the copyright prevention technology. At the same time, DMCA gives respite to the online service providers by not holding them liable for copyright infringement actions of their customers, provided they follow due diligence.

While both copyrights and patents serve similar role in the economy, to provide incentives to the people and to the companies to work on new and innovative ideas by providing legal safeguards, copyrights are different from patents in many ways. If a patent is licensed to a third party, all rights to the technology stay with the patentee unless specifically transferred. In the case of copyrights, the first-sale doctrine allows reselling of legally obtained copyrighted work. On a similar note, copyrights are covered by the fair use doctrine and compulsory exemptions which allow certain non-commercial unauthorized uses of the copyrighted material without considering it as an infringement. The same courtesy is not extended to patents where necessary permission needs to be obtained even for non-commercial use of the patent. Copyrights are automatically granted the moment the idea is transferred to a fixed medium. The same is not true for patents, which have to be applied for formally. Another important difference is that the copyright does not protect the idea;

it only protects the expression of the idea, whereas, a patent may protect the idea itself.

There are several benefits of copyright laws. The copyright protection provides incentives for authors to continue working on new creative ideas. The incentives can be in the form of monetary gains or social recognition granted by law. It is estimated that copyright infringement in the case of music the world over results in monetary losses of more than $4.6 billion in 2003 dollars (source: www.IFPI.org). Copyrights inculcate progress by promoting legitimate information exchange. By way of copyrights, the authors of original work can control how their work is used or distributed. However, people claim that these benefits are realized by publishers more than the authors since the copyrights are transferred before publication.

Copyright laws have their own critics. It is argued that the copyright laws favor publishers more than they favor the creators of the intellectual capital. For example, in the case of the music industry, the musician only gets eight percent of the royalties, and a major chunk of profit is shared by the recording industry. The number is even lower for book authors. Critics also feel that the current form of copyrights is a hindrance towards free speech and penalizes research. This notion is reinforced by the current DMCA, which leaves a lot of room for interpretation and can be effectively used against researchers working on software security and digital rights management flaws. The DMCA holds the person liable for infringement for developing a bypass for digital security. As a result, the DMCA can be misinterpreted and used against the copyright fair use doctrine.

The views against copyrights are further reinforced by the success of open-source software. Critics of copyrights often cite examples of the success of open source software to argue against the copyright laws and intentionally promote the principal of copyleft. While the copyright laws put restrictions on making and distributing the software, copyleft does not impose any such restrictions. Under the principals of copyleft, anyone and everyone is free to copy, modify, and distribute the original work. The only condition is that the modified version of the original work should also follow the copyleft licensing. GNU General Public License is a form of copyleft followed by the Linux community to develop and distribute the operating system and its derivatives.

2.3.4.3. Trademarks: A trademark is a distinct word, name, symbol, design, or a sign that signifies the origin of a product or a service and is used to distinguish between one good and another. The trademark protection gives exclusive rights to businesses or individuals to use or authorize others to use their mark. The trademark provides recognition to the businesses and inculcates trust in their customers. A trademark can be obtained in the U.S. by use or by registering it with the USPTO. Trademarks differ from copyrights and patents in the sense that they may not expire and can be renewed indefinitely. Correspondingly, a trademark which is not used for a long duration of time can be revoked and reissued to a third party. Similar to copyrights and patents, trademarks are enforceable by the courts of law.

There are several issues surrounding trademarks. A genericized trademark is one which has lost its distinctive appeal and become generic. Genericization of the

trademark occurs when most people associate the trademark with the generic product category rather than the brand itself. This can happen if the trademark gains substantial market share or mind share. A firm stands to lose much with the genericization of the trademark. With genericization, there is no distinctive appeal in the brand, and competing firms eat into the firm's market share. Another issue surrounding trademarks surfaced recently with the coming of the internet. Trademark infringements manifest themselves in the cyber world in form of the phenomenon called cybersquatting. In the case of cybersquatting, an individual – domain name poacher – would register the domain name, or a variation, of a well-established company or an individual with hopes of making a profit by reselling it to the original owner. The practice of cybersquatting is rampant even though it is frowned upon both by courts of law and by the business community. There have been recent developments to address the issue of cybersquatting, such as the introduction of ICANN Domain Name Dispute Resolution Policy.

Most IP issues in the case of technology are related to patents and copyrights. Out of all IP rights, patents are the most unforgiving. This is not because the penalty of patent infringement is any more or less than other types of IP rights, but because of the fact that patents are obscure. Patents provide a wgide range of protection to the inventor. With patents, not only is the other party restrained from using the technology, but it is also restrained from developing a similar technology for a specified period of time. Also, the patents are new developments and inventions that can be easily misclassified by the patent office, making the search difficult. As a result, it is more likely to unintentionally infringe on a patent than on a copyright or a

trade secret. Irrespective of the size, all companies are at risk. Litigations against software and internet businesses amount to 39% of all patent litigation.

2.3.5. Current State and Recent Trends of IP in IT

The debate as to whether intellectual property rights are good for the economy or bad has raged for decades and will probably continue until the foreseeable future. However, one thing that is clear is that the technology environment has considerably changed in the past decades, and mirroring this change have been types of IP rights that have been used to protect the IP. The transition of technology from tightly integrated proprietary hardware and software to packaged off-the-shelf software to current online services has seen corresponding changes in the types of IP protection sought. From earlier dependency on secrecy and contracts, the IT industry embraced copyrights for the packaged software, and now with the coming of the internet age, the patents are in the limelight (Smith and Mann 2004). The IP rights will continue to manifest themselves in one form or the other. As a matter of fact, it is widely believed that the IP issues will take center stage and become even more prevalent in the coming age. This is evident from the changes in views held by the industry and the courts regarding the changing role of IP rights (Lemley 2004) and the corresponding increase in IP protection-related activities. In today's environment, the IP rights are not sought to reward innovation but as a competitive weapon to control the supply of innovation and as an instrument for negotiation (Rivette and Kline 2000).

The patent as a form of IP protection is fast gaining popularity. This is evident from the rise in applications for and grants of patents over the last decade as shown in Figure 2. Another indicator of this is that patents now constitute 60% of all IP litigation, followed by copyrights and trademark infringement that constitute another 34% (Pearson 2001). The numbers are even more intriguing for software and business methods where the litigation rate is four times the normal patent litigation rate (Vemuri and Bertone 2004). Even though every litigation might not result in an injunction, there is loss of time, business, and good will while the case is pending. For the entire time the case is pending in the courts, there is uncertainty in the mind of customers, shareholders, and business partners about the future of the business. This was evident in the recent patent dispute between RIM Blackberry and NTP, where anxious customers flooded online forums with concerns on the future of Blackberry. Moreover, patent issues distract the managers from their real jobs to address bureaucratic issues. Patent cases are the most expensive, with an average cost of $2.5 million and growing at 10-15% per annum.

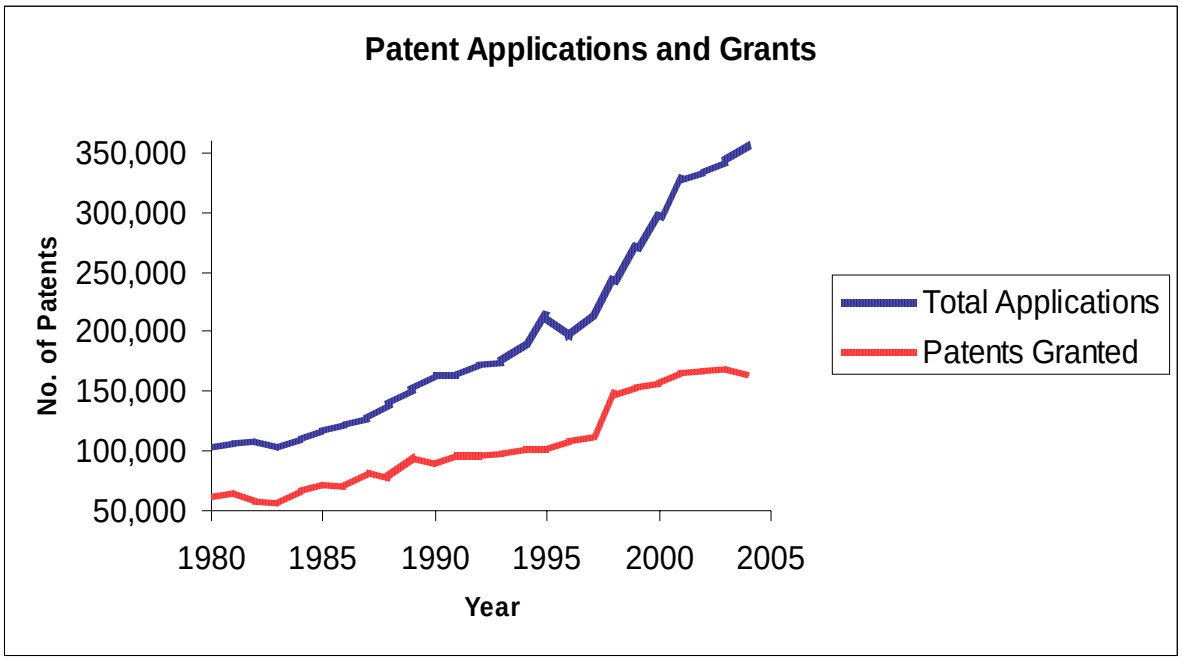

Figure 2: Patent applications and Grants (Updated Data: USPTO) (Rivette and Kline 2000)

The development in the information and communications technology has contributed much of this growth as is evident from Figure 3. ICT-related patents at the European patent office by OECD countries have grown much more rapidly than overall patent applications: 8.9% (1990s) vs 6.7% total.

The meteoric rise of patent popularity has given rise to phenomena that at best can be described as political rather than science or innovation. Researchers in economics and law often discuss problems associated with patents and how it hinders growth. Lemley (2004) finds that competitive markets are better suited to reward innovation, and IP protection unnecessarily puts strain on the economy (Lemley 2004). Webbink (2005) highlighted that patents had little role to play in the growth and development of the software industry (Webbink 2005). Shapiro (2000) compares

R&D with a pyramid where each subsequent block (research) is built on previous blocks and shows how research will slow down if a researcher, in order to develop new research, has to acquire rights from all previous building block holders (Shapiro 2001).

Most recently, the Supreme Court and the law makers in the United States have taken measures to reduce some of the problems associated with the patent law. First, the Supreme Court has issued guidelines which make it difficult to file for injunction in the case of IP infringement. Second, the Supreme Court has issued guidelines to test the patents validity against obviousness. U.S. Congress, on its end, has introduced the, "Patent Reforms Act of 2007", to update the current patent laws. The bill, if passed, would change the U.S. patent system from the current "first to invent" system to the "first to file" system. It would also make changes in how damages are calculated incase of infringement.

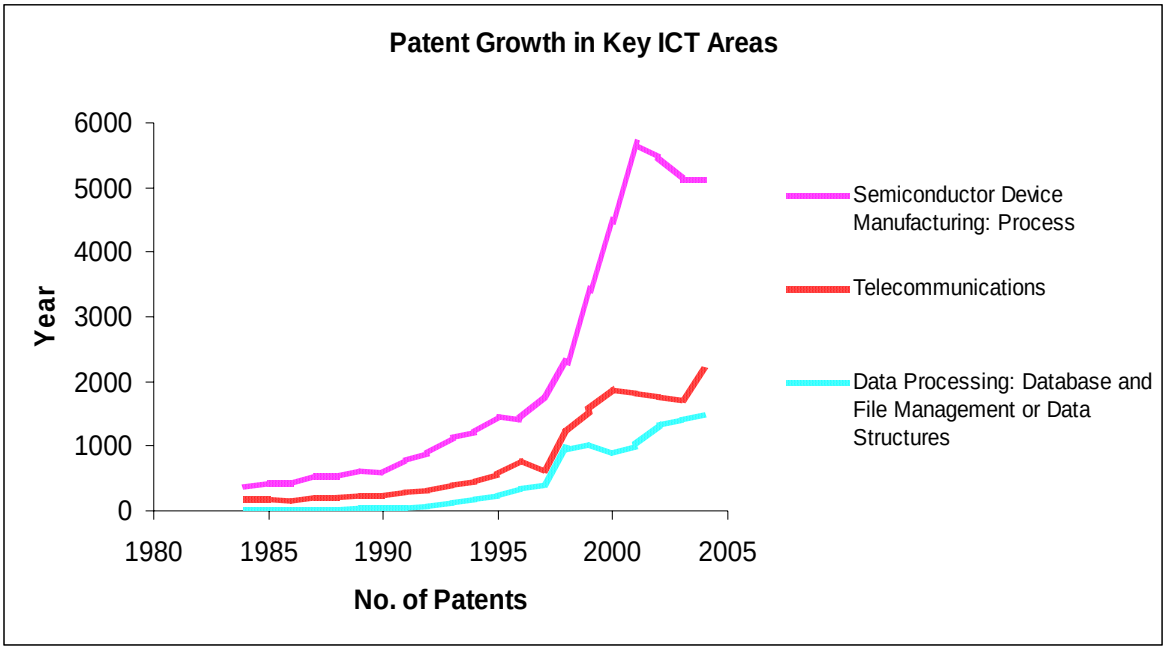

Figure 3: Patent Growth in the Key ICT Areas (Data: USPTO)

2.3.6. Some Common Issues Related to IP Rights:

2.3.6.1. Submarine patents: The notion of submarine patents is similar to actual submarines that surface from the depths of the water and catch the enemy off-guard. A patent holder will wait until the time the technology becomes a standard to exert its IP rights; for example, in the case of Dell Computer vs. VESA VL-bus standard.

2.3.6.2. Patent troll: This occurs when a company aggressively acquires a portfolio of patents without any intentions to commercialize them. The company then aggressively searches for potential infringers and seeks to license its patents. Most companies settle because they don't want to get into the hassle of becoming involved in legal cases which may cost more than the licensing fee.

2.3.6.3. Complement patents: The technology is fast emerging. As a result, interoperability is the key to new technology development. To develop any

technology, multiple IP rights are required that may be held by multiple different entities. This means that to implement any technology, collecting rights will be very important.

The question then arises of how to deal with the IP issue, given that there are IP rights. Several researchers are actively exploring options that can help address the IP protection issues. On the one hand, some form of IP rights are desired to reward creativity and encourage innovation, and on the other hand, this has a potential to create hold-up problems and retard innovation. Merges (2004), while agreeing that IP rights may be overreached, suggests that competitive markets are equipped to self-handle the IP problems. He suggests that as the IP rights become more restrictive, private companies will increase contributions in "property-preempting investments" to offset the competitor's property rights (Merges 2004). The property-preempting investments exploit the fact that if the knowledge is part of the public domain, it cannot be patented. As a result, individuals, private organizations, and non-profit organizations are working hard to bring as much knowledge into the public domain as possible so that it reaches out of the league of the predators. Open standards or open source is an example of one such initiative where people from across the world develop the technology and make it available in open domains. However, open source is not immune from the intellectual property issues by default. Since the underlying logic and algorithms are similar for both open source and proprietary software, open source is susceptible to challenges in court, as was the case in SCO vs. Linux. Unfortunately, the above argument puts boundaries on the scope of the knowledge. There will always be new and useful innovations which will be different

from the knowledge in the public domain and can be patented. Moreover, the patent office is not perfect in issuing patents and occasionally issues patents where prior art already existed.

More active approaches to addressing the specific IP problems have been proposed. The tragedy of anti-commons or complement patents can be resolved by the creation of patent pools (Shapiro 2001). Patent pools allow bundling of patents and licensing them for one price. The revenues are then divided amongst the patent holders. The patent pools reduce the transaction cost for the patent implementers (Merges 1999b). However, patent pools do not solve the problem of submarine patents or cases in which the patent itself is not identified during the technology development. Another possibility for addressing IP issues is cross-licensing the technology. Most firms are interdependent on each other because they need their products to be intra-operable. By way of cross-licensing, they ensure that the firms do not block each other. The disadvantages of cross-licensing are the same as that of the barter system. If there are multiple patent holders, cross-licensing will be tedious, some firms may not be interested in the patents that the firm has to offer, and if the firm is not strategically dependent on the other firm, they may not be willing to share the patent. Moreover, similar to patent pools, cross-licensing does not protect from patents that have not yet been identified. Some industry experts suggest reducing the duration of the life of the patent from the existing 20 years to 3-5 years in the case of software patents.

Another solution to patent problems which is addressed in this thesis is cooperative standard setting. In this case, a separate entity is organized consisting of major firms in the industry. These firms jointly develop and own the standard. This increases the likelihood that all patents are identified before the standard is set, reduces the scope of opportunism because of legal anti-trust issues, and reduces the chances of infringement because the IP owner may be a part of the organization or have a strategic relationship with a member of the organization. Other individualistic approaches exist like patent insurance, where the infringer or the infringed can use the insurance to pay for the legal fees associated with patent infringement. However, this really does not address the root of the problem. As the infringement cases become more common, the insurance rates may go up. Moreover, large companies with big patent or product portfolios may find it uneconomical.

2.4. Theory of the Firm

2.4.1. Introduction

A theory of the firm attempts to explain two separate issues; the existence of the firm as opposed to the market governance structure, and what determines the scale and scope of the firm (Coase 1937). A firm is a vertically integrated economic entity that facilitates transformation and transaction of goods. Coase (1937) identifies several reasons why a firm may exist. Some people like to work for others, and in the process are willing to take lower compensation than offered by market contracts. These people may be risk averse. Others like to lead and take control. These people are risk takers and are willing to pay higher wages to employees than what is offered by markets. Thus, a firm allows people to control their level of risk. Division of

labor and specialization in a firm is easier to achieve than in markets. Consumers may have a preference for commodities produced by a firm rather than dealing with markets. Firms are also a way around governmental regulations like sales tax. Though valid, each of the reasons mentioned above is, at best, a point of view. There are other strong theoretical perspectives that have been empirically tested.

Several researchers have given different theoretical perspectives on the existence of the firm. Notable among them are the neo-classical approach that views the firm as a production black box rather than an organizational form; the transaction cost approach that determines the boundaries of the firm based on the internal and external transaction costs (Coase 1937; Williamson 1985; Williamson 1991); the contract view of the firm that treats the firm as a nexus of binding contracts and boundaries as determined by the ownership of assets (Grossman and Hart 1986; Hart and Moore 1990); and the resource-based view of the firm that suggests that the firms exist because they can create a competitive advantage based on their superior resources.

The firm size is determined by the amount of productive resources that the firm employs (Conner and Prahalad 1996), and the knowledge-based view of the firm derived from the resource-based view that suggests that the firms are a mechanism for knowledge creation, sharing and transfer amongst groups or individuals (Demsetz 1988; Kogut and Zander 1992; Nonaka et al. 2000).

The neo-classical approach views the firm as a profit-maximizing production function rather than as an organizational structure. The firm is a black box, and the

resource allocation is determined by prices rather than by managerial decisions (Demsetz 1997). There is little attention given to the transformation of the resources as an input into the black box to the finished goods as an output. It uses the information on market demand and supply to calculate the equilibrium that determines the size of the firm, subjected to profit maximization. There are no bounds on the human rationality and hence, the notions of opportunism and uncertainty do not exist. The main assumptions here are costless transactions and perfect information.

The neo-classical approach, though widely used and very useful, makes unrealistic assumptions and does not clearly explain the existence of the firm over the market form of governance. To overcome the shortcomings, the new institutional economists proposed the transaction cost theory (Coase 1937). The transaction cost theory opened the black box to understand the operations of the firm. The new institutional economics aimed to answer the question of why some activities are organized within the firm while others are organized outside. It was found that the transactions within and outside the firm are not costless and information is not perfect. As a result, there are transaction costs. Outside of the firm, transaction costs are search, coordination, contracting, and costs associated with enforcement of contracts. Likewise, within the firm, there are production coordination costs, employee monitoring and supervising costs. Whether a transaction should be organized within a firm or outside depends on whether or not the transaction costs of firms are lower than markets. The firm boundaries will be defined where there is equilibrium between the marginal cost of organizing the extra transaction within the

firm and outside. The theory proposes that firms exist because they economize on the transaction costs and replace the market with command and control. Further developments in the transaction costs considered factors that affect the nature and the size of the firm. Specifically, the role of asset specificity, bounded rationality, and opportunism were studied as deciding factors in choosing hierarchy over markets (Williamson 1985; Williamson 1991).

Demsetz (1988) maintains that the reliance on transaction costs solely to determine the organizational structure is not without demerits. The transaction costs view of the theory is incomplete as it does not give due importance to the information costs. Furthermore, it is not always easy to segregate the operations of the hierarchy from that of markets because the inputs to the production need to be purchased from the markets. As a result, there are still transaction costs present in a hierarchy (Demsetz 1988). He further clarifies that the correct approach to the theory of the firm will be to consider the sum of the transaction and management costs and compare them in a hierarchy and a market. Moreover, the benefits provided by the hierarchy against problems like asset specificity and opportunism can easily be obtained by contracting. The theory of contracts views the firm as a nexus of contracts (Grossman and Hart 1986; Hart and Moore 1990). A contract is a legally binding agreement between two or more parties that outlines a set of contingencies and action to be undertaken. However, since one cannot possibly foresee, ex-ante, all possible contingencies, most contracts are incomplete. The theory of incomplete contract claims that ownership of an asset is dependent on who holds the residual

rights of an asset and that firms exist to take over these residual rights because complete contracts cannot be written.

The above theories represent the economic view of the firm. The critics often cite that the economic view of the firm fails to incorporate the social and psychological needs of humans. They are against the view that a firm is considered as just a substitute for a market or a series of short- term contracts (Ghoshal and Moran 1996). As a result, the synergies that come naturally by working together and the subsequent creation of knowledge assets are often ignored. The alternate resource-based/knowledge-based view of the firm is aimed to address these shortcomings (Conner and Prahalad 1996). The resource-based view of the firm claims that the firm exists to appropriate productive resources at its disposal. The size of the firm in turn is determined by the amount of these resources available that can be put to productive use. A firm is able to create a sustainable competitive advantage using resources that are valuable, rare, imperfectly inimitable, and non-substitutable (Barney 1991). Researchers have identified knowledge as one of the critical resources that can explain the existence of the firm (Conner and Prahalad 1996; Kogut and Zander 1992; Nonaka et al. 2000). Individuals interact and apply their knowledge differently when organized as a firm or contracted via markets. As a result, anticipating how the individuals will interact will impact the governance mode itself. The knowledge view of the firm is based on the individual's knowledge differences rather than the opportunistic behavior of individuals, as is the case with the transaction costs approach.

The different perspectives discussed above provide meaningful insights into the reasons behind the existence of a firm. With the widespread acceptance of the knowledge-based view of the firm, the criticism for the transaction costs approach has grown (Conner and Prahalad 1996). Transaction costs theory was first introduced to explain the organizational boundaries of firms engaged in the transaction of physical goods. It is convincingly argued why such an approach is not applicable for knowledge products. Nonaka et. al. (2000) gives five reasons for this. First, the outcome of knowledge creation activity is highly uncertain. It is difficult beforehand to determine the results of a research activity. As a result, transaction costs for knowledge products are very high. Second, it is difficult to anticipate beforehand the form and the nature of the knowledge because of its dynamic nature. Third, tacit knowledge is not transferable and not separable from the person holding it. The same holds true for the knowledge embedded in business structures, processes, and procedures. As a result, a transaction of tacit knowledge will require movement of the person holding the knowledge. Fourth, it is difficult to evaluate the value of the knowledge before actually using the knowledge. Finally, knowledge can be put to varying uses which might not be acceptable to the seller of the knowledge. Thus, market transaction of the knowledge is problematic (Nonaka et al. 2000).

In this thesis, I use the transaction costs theory for two reasons. First, transactions are a key characteristic of any business relationship. Any business function except for production functions will have characteristics of transfer of goods, services, or information across a boundary. Most research and activities in various business domains can be directly or indirectly attributed to some aspect of transaction

between various parties. For example, concepts of trust, commitment, and loyalty are all based on the satisfaction from a transaction between two or more entities. With so much importance given to the transaction in the business world, it is obvious that we want them to go smoothly. For this, we need to study how the transactions are organized in an economy. The theory is robust in that it has good predictive power. It has been validated empirically a number of times, both in economics literature as well as IS literature (Rindfleisch and Heide 1997; Shelanski and Klein 1995). Second, the TCE has specific relevance to the IP domain as discussed below. Though the transaction in IP only involves transfer of rights to use (Walden 2004), an agreement on the nature of the contract needs to be signed to transfer the rights. The knowledge involved in IP transfer is publicly disclosed and well-documented; however, it is legally protected. As a result, transaction of IP is not just a necessity but a legal requirement, even if the knowledge can be produced more cheaply in-house. If the knowledge is created outside the organization and protected by legal rights, it cannot be freely replicated or recreated without the permission of the owner. This makes transaction of the intellectual property an integral part of the standards development process.

2.4.2. Introduction to the Transaction Cost Economics

Transaction cost economics (TCE) is a branch of economics that concerns itself with the frictions involved in executing transactions (Coase 1937; Klien et al. 1978; Williamson 1985). A transaction is defined as movement of goods or services across a technological boundary (Williamson 1985). A technological boundary exists when one process ends and the other begins. Transition across the boundary incurs a

transaction cost, which is defined as the cost associated with an economic exchange. A transaction can be the purchase of coal for the power generation plant, laying of railway tracks for the transportation of the coal, or developing software using the internal means of the organization. To understand how these costs emerge, we look at what governs the transactions. The first and foremost step in carrying out the transaction is finding a partner with whom to transact. This is not always easy as there may be multiple entities supplying similar goods at different quality and prices. Once the partner is identified, parties to the transaction make investments in people, location, and technology in hopes of getting some favorable outcomes.

The investments can be general or they can be transaction-specific (relationship-specific). Returns on general investments can be recovered from the transaction as well as outside the transaction. However, returns on relationship-specific investments can only be recovered within the specific transaction. Outside the relationship, the value of the investment is zero or negligible. For example, railroads are required to transport coal. A transaction in this case will be for the laying down of the railroad. This transaction can be carried out solely by the coal mine or organized between the railroad company and the coal mine. The interesting point is that the investment is relationship-specific, as the railroad cannot be used by other entities because of location specificity (Joskow 1987). As a result, these transactions are governed by contracts that beforehand specify the investments and how to divide the surplus from the transaction. TCE maintains that due to environmental complexities, all contracts are incomplete (Grossman and Hart 1986; Hart and Moore 1990; Klien et al. 1978; Williamson 1985). It is difficult beforehand

to determine all future states of nature. With the change in circumstances such as legal or economic, there may changes in incentives and benefits to the parties. As a result, the party to a transaction that makes a relationship-specific investment exposes itself to the risk of being taken advantage of. TCE proposes that one way to safeguard against this risk is vertical integration. Alternately, it also suggests that the changes in the environment will result in different governance costs, which will lead to reconfiguration of the organization.

The nature of the product and the characteristics of the humans involved in the transaction cannot be changed; however, the organization of the transaction can be managed. It is this goal that the study of TCE aims to fulfill where it tries to reduce the transaction costs by organizing the transactions in a certain way.

To avoid these transaction costs, TCE concerns itself with the markets and hierarchies as alterative mechanisms of governance. It is a well- known fact that markets are price-efficient. Given that fact, the question then arises as to why firms exist and what determines the size of the firm. TCE posits that there are costs associated with using the market mechanism. These costs include search costs associated with finding the best prices, negotiating, and contracting (Coase 1937). By internalizing the transactions, these costs can be avoided or greatly reduced by a firm. The firm continues to grow by internalizing additional transactions until the marginal cost of organizing additional transactions within the firm outweighs the cost of carrying out the same transaction in the market. This determines the size of the firm. A firm's size is not limited to the scale of the transactions, but also the scope of

its operations. Adding complementary activities increases the size of the firm while maintaining the costs.

TCE makes two assumptions about the economic actors engaged in a transaction. First, that the economic actors are bounded rationally. The notion of bounded rationality is that humans are "intendedly rational, but only limitedly so"(Simon 1957) p.xxiv. What this means is that humans have limited cognitive capabilities that prevent them from anticipating all future states of the transaction and hence, they cannot make perfect choices. Simon calls it satisficing.

The second assumption is about opportunism and claims that humans "seek self interest with guile". What this means is that humans have a tendency to take advantage of bilateral dependency in a deceitful way. Transaction cost economics makes predictions about the governance form based on asset specificity, environmental uncertainty, and frequency of transactions subjected to bounded rationality and opportunism.

In summary, the central question of TCE is the economic organization of transactions. Thus, the unit of analysis is a transaction, and the question is how economic agents should organize the transaction in order to reduce potential conflicts arising out of bounded rationality and opportunism at a lower cost (Spraakman and Robert 1998). TCE claims that the firm economizes on the sum of production and transaction costs, rather than on production costs alone, as claimed by neo-classical economics. This viewpoint recognizes that producing a product is only part of the

economic activity of an economic agent. The agent must also procure its inputs and, in turn, sell those inputs to other economic agents.

The TCE literature can be broadly classified into two themes. The studies concerning the types of transaction costs, like the search cost and the coordination cost; the factors influencing them, like the introduction of technology, and how they affect the choice of organizational forms (Bakos 1997; Clemons et al. 1993; Coase 1937; Gurbaxani and Whang 1991; Malone et al. 1987; Powell 1990), and the studies concerning the attributes of the transaction cost, like asset specificity, bounded rationality, and opportunism, and how that affects the choice of governance structures (Bensaou and Anderson 1999; Joskow 1987; Williamson 1985; Williamson 1991).

2.4.3. Governance Forms

TCE originally recognized only two governance forms; markets and hierarchies (Coase 1937). Later, reflecting the dynamic change in the business environment, hybrids were recognized as a viable governance form (Williamson 1985; Williamson 1991). Williamson (1985) acknowledged the possibility of a whole range of governance forms between the two extremes. However, he concludes that these forms are either too complex to exist or so unstable that they fail as soon as they come into existence (Williamson 1991). Network organizations (Powell 1990) belong to one such complex form that was previously ignored but has emerged in the recent years to accommodate the interdependent nature of firms today.

2.4.3.1. Markets: In a market, a transaction is arranged with an anonymous economic agent outside the boundaries of the firm. The transaction is usually based

on price, competition, and a series of short-term contracts (Williamson 1975). The transaction is independent of the parties involved and does not build on other transactions. Markets are considered price-efficient because the participants benefit from specialization and economies of scale. A transaction organized in a market involves searching for a product or service provider, contracting for goods and services, and maintaining relationships with the suppliers. Since the transaction is with an anonymous economic agent, there are some inherent risks involved in the market. As a result, there are higher transaction costs in the markets.

2.4.3.2. Hierarchy: In a hierarchy, a transaction is arranged with a specific, familiar economic agent within the organization. Usually, this is a different division of the same firm. The decisions are made by fiat and there is very little scope of opportunism. The transactions are usually based on internal transfer pricing. The key point here is that the agents are not anonymous. The transaction partner is predetermined and is specific to the parties involved. As a result, there are lower risks and lower transaction costs.

2.4.3.3. Hybrid: Hybrid governance falls somewhere between these two extremes. The identity of the parties matter and other transactions between the parties are important, but transactions can be shifted to other agents with ease. Hybrids are characterized by complex contracts and partial ownership of the structures (Shelanski and Klein 1995). In the current business environment, most business can be classified as hybrids instead of pure hierarchies or pure markets.

2.4.3.4. Networks: Networks are distinct from the market hierarchy continuum. In a network, multiple specific firms engage in interrelated transactions with one another (Powell 1990). It is the interdependencies among multiple firms that are not captured by the market hierarchy continuum. A network is concerned with the organization of a group of interdependent transactions. Networks manifest themselves in several different ways. When a network involves cooperation between competitors, it is called coopetition (Bradenburger and Nalebuff 1996). When several different private entities pool resources to jointly perform a task, they are called a consortium. Likewise, when several entities pool resources for a non-profit cause, they are called standard-setting organizations.

It is highly unlikely that all transactions in an organization will be governed as a hierarchy or a market. Ideally, some transactions will be organized in-house and some outsourced. The reason is simple. The only way to remain competitive in the current business environment is by focusing on core competencies (Porter 1980). As a result, firms invest in their area of specialization and outsource the rest. There are limits to what and how much a firm can outsource. Total outsourcing will be expensive to coordinate and result in high uncertainty. Similarly, pure networks do not exist because firms will be reluctant to share all their knowledge with competitors.

Since the unit of analysis is a transaction, what we are more likely to see is a mixed form of governance with elements of hierarchy, market, and networks. Organizations perform different functions in an economy. Some functions may be

performed in-house as a hierarchy, while others may be governed by a third party as a market. For example, IBM uses hierarchical governance for their transactions related to their proprietary mainframe servers, market governance for their PC division, hybrid for retail sales, and a network for standard settings.

The evidence of mixed governance forms is presented in the researchers' conceptualization of markets and hierarchies. The earliest and most common form of conceptualization is vertical integration with the supply chain entities. The forward integration with customers or backward integration with suppliers represents the hierarchical governance, while buying from suppliers and selling to customers represents the market governance (Balakrishnan and Wernerfelt 1986). Another study conceptualized the hiring of sales employees on payroll as hierarchical governance, and selling through commission agents as market governance (John and Weitz 1989). If the sales are managed via franchising, the same represents a hybrid structure. The market-hierarchy framework has also been applied in the areas of e-commerce and knowledge management. The specialized structures like the online marketplace or e-commerce firms are conceptualized as electronic markets and electronic hierarchies (Malone et al. 1987). The knowledge management researchers like to refer to their conceptualization of knowledge management strategies as knowledge hierarchies, knowledge markets, and knowledge communities (Dennis and Vessey 2005). The network forms of organizations are recent phenomena. As a result, only a handful of studies discuss the network form of governance (see (Bradenburger and Nalebuff 1996; Powell 1990; Shapiro 2001)). The TCE organizational framework is not limited to the economic organizations as we know

them. but also has been used to conceptualize the seemingly unrelated area of families and households (Pollak 1985).

2.4.4. Types of Transaction Costs

There are several different types of transaction costs. Broadly, these can be classified in three categories: search costs, coordination costs, and opportunism costs.

2.4.4.1. Search costs: Search costs are costs associated with identifying potential suppliers (Bakos 1997). TCE claims that these costs are high in a market because an economic agent must search a potentially large market in order to locate the best possible match for its needs. A market has no mechanism for transferring this information. The amount of communication and repetition involved is very high. Correspondingly, TCE holds that search costs inside a hierarchy are very small (Clemons et al. 1993; Gurbaxani and Whang 1991; Malone et al. 1987). The hierarchy mechanism is set up for the sharing of information across divisions. Hence, the central authority knows what is being produced in the hierarchy. Since hybrids lie in between markets and hierarchies, they incur moderate search costs. Once the partner is identified, search costs are lowered because of long-term relationships. To summarize, TCE predicts that search costs decrease gradually from markets to hybrids to hierarchies.

2.4.4.2. Coordination cost: Once the supplier is identified, the next step is to establish a relationship with the seller. Coordination costs refer to the costs involved in communicating with and gaining agreement from suppliers. They includes the costs of monitoring, negotiating contracts, gathering information, mobilizing

resources, and provision of opportunism (Malone et al. 1987). In a market setting, an economic agent has to separately coordinate with all suppliers. In a hierarchy, coordination costs are reduced significantly because a central authority coordinates activity via fiat. The hierarchy has, by its nature, standard operating procedures, communication channels, and meetings, which facilitate the coordination of activities. A hybrid, by design, has a medium amount of coordination costs because there are specific operating procedures in place in order to coordinate activity. To summarize, TCE predicts that coordination costs gradually decrease from markets to hybrids to hierarchies.

2.4.4.3. Opportunism: Opportunism costs arise when a party to a transaction charges more than the marginal cost for the item being transacted by willful misrepresentation (Williamson 1985). TCE suggests that the opportunism cost will be higher in a market than a hierarchy. In a hierarchy, transfer pricing only serves an administrative purpose. The central authority pays the same price regardless of how high the transfer prices are set. Anything that one division overcharges another division still goes to the central authority. Thus, even if the central authority fails to set prices to marginal cost, the net cost to the central authority is the same. In a market, each economic agent will charge as much as possible. This is especially true for relationship-specific assets. The charges may occur after the parties have entered into a relationship. Thus, if one economic agent commits to buy from the market, each seller sees an opportunity. Specifically, each market transaction can command more than its marginal cost. Like search and coordination costs, opportunism costs are moderate in a hybrid form of organization. This is because in hybrid organizations, there is

interdependence and hence, a mutual hostage-taking situation which prevents the other party from taking advantage of the other. To conclude, opportunism costs are highest in the market and gradually decline in hybrids and are lowest in hierarchies.

Thus, predictions are simple and straightforward for transaction cost economics. Transaction costs are lower for hierarchies than they are for hybrids, which are lower than markets. Still, markets exist because sometimes savings in the production costs outweigh the transaction costs. In such a situation, the transaction will occur in the market.

2.4.5. Factors Affecting the Transaction Costs

As noted earlier, TCE makes two behavioral assumptions which relate to bounded rationality and opportunism. Williamson (1985) identified three different attributes of a transaction cost; asset specificity, uncertainty, and frequency of transactions. Out of the three, Williamson admits and research shows, asset specificity and uncertainty are most profound.

2.4.5.1. Asset Specificity: Asset specificity refers to the class of assets that are relationship-specific. What this means is that the parties to the transaction make investment in assets that have little or no value outside the relationship. The assets may have been customized according to the specific needs of the transactors and thus idiosyncratic (Williamson 1985). Williamson (1985) identifies four different types of assets; human, physical, and dedicated asset specificity. This specificity refers to "durable investments that are undertaken in support of a particular transaction" (p.55). What this means is that the opportunity cost of reallocation of these assets to

the next best alternative is much lower than it is in the relationship. Asset specificity is a major cause for transaction costs and hence, it follows that if the transaction is characterized by relationship-specific assets, it is more likely to be governed by a hierarchy than by a market.

2.4.5.2. Uncertainty: The business market environment is usually very uncertain. This is because it is dependent on many external factors such as law, technology, the state of the economy, competition, people's perception, international trade and tariffs, weather, war, act of god, and others. Because of bounded rationality, it is nearly impossible for humans to envision all future possible states of the economy. Hence, all contracts that govern the transaction are incomplete. This creates ex post surplus which cannot be anticipated or shared ex ante. This surplus can be negative. As a result, there is ex post uncertainty. Because of opportunism, which is assumed by TCE, the situation becomes even more worrisome. As a result, if there is high uncertainty, the TCE proposes that the transactions be organized as a hierarchy.

2.4.5.3. Frequency of transactions: Frequency refers to the recurring nature of the transactions. Ideally, if the frequency of the transaction is high, it makes sense for a firm to internalize the transactions to take advantage of the economies of scale (Rindfleisch and Heide 1997). Internalization of recurring transactions also helps justify the costs associated with developing and maintaining specialized governance structures like firms a(Williamson 1985). If the frequency of the transaction is low, a firm is better off trading opportunism for market efficiency (Anderson 1985).

Unfortunately, frequency of transactions is considered the least important of factors affecting the transaction costs (Williamson 1979).

2.4.6. Operationalization of the TCE

The empirical validation of the TCE research usually hypothesizes about the likelihood of existence of a particular governance form for the given transactional relationship as a function of causal attributes of the transaction costs, such as asset specificity, uncertainty, and the frequency of the transactions (Shelanski and Klein 1995). Then outcomes are compared with the observed governance form under the given circumstances and conclusions are drawn.

The governance form is almost always the dependent variable of interest, while context specific variations of asset specificity, uncertainty, and frequency of the transactions are the independent variables. The governance form, or the dependent variable, is usually operationalized as a categorical variable such as make or buy (Masten 1984; Masten et al. 1991), integrated or independent sales force (Anderson 1985), total ownership or partial ownership (Gatignon and Anderson 1988), backward integration or contractual arrangement (Lieberman 1991), and the length of contract (Joskow 1987). Some studies have also considered opportunism (Anderson 1988; John 1984), and related constructs like compensation (John and Weitz 1989), and level of monitoring (Stump and Heide 1996) as a dependent variable.

With regards to the independent variable, asset specificity is the most difficult to operationalize. This is because there is no common agreed upon proxy for measuring the term. Different studies have operationalized asset specificity

differently. For example, site specificity has been operationalized with the physical distance between the contracting firms or the manufacturing facility (Subramani and Venkatraman 2003). Physical asset specificity has been operationalized as the complexity of the asset (Masten 1984). Human asset specificity has been operationalized as employee replaceability (John and Weitz 1989). The list is not comprehensive but just indicative of the different ways that asset specificity has been operationalized.

Similarly, uncertainty has been operationalized in several different ways, depending on the context. Anderson (1985) measured behavioral uncertainty as difficulty of evaluating employee performance, and environment uncertainty as environmental unpredictability (Anderson 1985). Balakrishnan and Wernerfeit (1986) operationalize uncertainty as technological uncertainty in the context of technology obsolescence (Balakrishnan and Wernerfelt 1986). The transactional frequency has been relatively easy to operationalize as it is the measure of frequency of recurrence of the event.

TCE has been extensively validated with most studies reporting a positive relationship between hypothesized governance and levels of asset specificity, uncertainty, and the frequency of transactions (Shelanski and Klein 1995).

2.4.7. TCE Application in supporting fields

TCE originated from the area of law and economics where it intended to replace the classical and the neo-classical view of the firm and the contracts governing the firm (Williamson 1979). Classified as the new institutional economics,

TCE challenged the basic assumption of the classical and the neoclassical theory. Specifically, the TCE considers humans to be opportunistic and limited in their cognitive abilities. This is a significant departure from the earlier view which considers humans to be rational and firms to be the black-box.

In law and economics, the TCE is primarily studied to explain the organizational boundaries. This is done in a number of different ways. With regards to goods and services, TCE predicts that organizational boundaries will be reached when the marginal cost of internalizing the transaction is the same as the in-house production cost. Similar studies in the context of human resources study whether the services of an individual should be outsourced to the market or internalized by way of long-term contracts (employment). Though the underlying assumptions conceptually remain the same, the opportunism is in the form of cheating. Asset specificity takes the form of human specificity, and uncertainty relates to the human behavior of shirking. The studies on human resources maintain that markets maximize output; i.e., minimize shirking using the price mechanism, but suffer from cheating, low quality of service, and inflated prices once the transaction is initiated (Hennart 1993).

Hierarchies, on the other hand, avoid these transaction costs but are plagued with problems like shirking. Since individuals are paid fixed rewards irrespective of their output, their tendency is to shirk. TCE predicts that hierarchies minimize the cost of shirking by using internal information, directing and monitoring (Williamson 1975). Thus, in the case of human resource transactions, the firm economizes on the sum of cheating and shirking costs and the firm boundaries are defined at the

equilibrium, "where the reduction in cheating costs achieved by replacing price constraints by behavior constraints exceeds the resulting increase in shirking costs and by the market in the opposite case" (Hennart 1993) p.529.

In the marketing literature, the TCE has been mainly applied to study the organizational boundaries as a function of asset specificity, behavioral and environmental uncertainty, and frequency of transaction. The organizational boundaries have been operationalized as the degree of sales force integration (Anderson 1985), and percentage of direct sales over total sales (John and Weitz 1998). Other main applications of TCE in marketing include determination of the sales and marketing channel based on idiosyncratic investments of transacting parties (Dutta and John 1995), salesperson compensation based on the salesperson's human asset specificity, behavioral and environmental uncertainty (John and Weitz 1989), and choice between franchising or going solo.

The finance literature concerns itself with the emergence of financial intermediaries that offset the transaction costs associated with the trade of financial instruments (Benston and Smith 1975). Similarly, in accounting literature, the TCE has been extensively used to describe the management accounting practices of the firm (Spraakman and Robert 1998). The studies use a combination of accounting context specificity, asset specificity, and uncertainty in explaining accounting mechanisms.

The law literature studies the role of governance structures, such as patent pools, in mitigating the transaction costs associated with the trade and transfer of

intellectual property (Merges 1999a). Patent pools have been studied for their role in reducing the transaction costs by addressing IP issues such as patent thickets (Shapiro 2001) and the tragedy of anti-commons (Heller 1998).

The IS field provides more than a fertile ground for TCE researchers. It not only allows the traditional testing of the TCE propositions, but also allows modifications to the nature of the transactions and the nature of the organizational forms. IS has redefined the way the transactions are carried out in an economy. The virtual boundaries are built on codes and logic rather than physical objects and machines. TCE research in IS is concerned with the impact of introduction of technology on the transaction costs (Bakos 1997; Singh and Walden 2003), or on the organizational boundaries (Clemons et al. 1993; Gurbaxani and Whang 1991; Han et al.).

Technology, by its nature, reduces the different types of transaction costs such as search and coordination costs (Malone et al. 1987). This is because technology allows organizations to search more efficiently and quickly than any manual methods. The coordination itself is fast and effective because technology allows people to collaborate and coordinate on a real-time basis (Malone et al. 1987). One outcome of this reduction in the transaction costs is viability of different forms of governance such as relational contracting (Ang and Beath 1993) and networks that were previously ignored. The nature itself of the products transacted is very different. In most cases, the product transacted is informational or intellectual in nature. Hence, the ownership of assets that defines a firm in the traditional literature takes on a

whole new form. The information assets can be reused without diminishing their value. This is because their use does not exclude others from using them simultaneously (Walden 2005). Correspondingly, hierarchies are defined as electronic hierarchies and markets as electronic markets (Malone et al. 1987). To the best of our knowledge, there are limited studies that study the exchange of intellectual assets, with the exception of TCE and patent pools. However the scope of such studies is narrow and very limited in terms of inferences that can be drawn from them.

2.4.8. Summary

The governance form can be viewed as facilitators of smooth transactions between multiple entities. How we structure the transaction will help determine what the transaction costs are. This is because different organizational forms handle different aspects of transactions differently. Hierarchies mitigate the transaction costs by allowing transactions between familiar agents. This reduces the scope of opportunism. Moreover, a firm reduces the bounds on the rationality of individuals by using the collective wisdom of all of the employees. The firms also can reduce the opportunism by owning the assets that are specific to their operations. This can be done by vertical integration with the suppliers or the buyers. Markets, on the other hand, are more efficient. Markets specialize in products and thus can take advantage of economies of scale. Markets, however, are also riskier. With the introduction of technology, the transaction costs go down without increasing the risk unfavorably, making the market form of organization more attractive. Choice of governance form depends on which form better facilitates one form of transaction over the other.

CHAPTER III: THEORY, MODEL DEVELOPMENT, AND RESEARCH HYPOTHESIS

3.1. Overview

We have briefly established earlier that transactions are important for an IT standard setting process. This is because standards are made up of bundles of complementary IP that need to be consumed together for a standard to be valuable. Since the IP is distributed and legally protected, it cannot be used without the permission of the IP owners. The IP rights have to be transferred from the owner to the implementer of the standard. However, transfer of IP rights is only the simplest of the legal hurdles encountered during the standard setting process. The IP rights first have to be identified and negotiated for, a process that is far from perfect. The imperfection in search and contracting results in complications and opportunism in the later stages of standard implementation. Thus, the IP law gives rise to legal risks and transaction costs, which makes transacting for the bundle of rights expensive.

We identify three different forms of transaction costs affecting the standard setting. These are the search costs related to search activities, coordination costs related to contracting activities, and opportunism costs related to IP infringement.

With the conceptualization of the standard as a bundle of IP, it is only natural that the characteristic of the bundle (the standard as we conceptualized) will affect the transaction costs associated with acquiring the bundle. We identify four different characteristics of the IT standard that affect the transaction cost: complexity of the standard or how many different modules a standard has; industry breadth of the standard or how many industries hold the patent used by the standard; geographic

scope of the standard or how many different countries issued the patents required by the standard; and degree of substitutability of an IP in the standard.

These characteristics were identified using different sources. First, I studied the patent portfolios of some major standards like IEEE 802.11, DVD, and PNG. Along with the patent portfolio, I also studied the process, as described in their IP policies, to acquire these patents. Then I followed some popular IP infringement cases as reported in the popular press to identify factors affecting the standards development, what went wrong, and how the cases were resolved. Finally, there is no substitute for experience, so I used expert interviews to determine the antecedents of transaction costs.

The IP-related transactions can be governed in several different ways. A firm can choose to carry out all or part of these activities in-house, collaborate with others to jointly perform these activities, or outsource these activities entirely by using a third party standard. The last is not an option that we explore in this thesis. How the transactions are governed will have an influence on the transaction costs. This is because the governance forms have the ability to influence the transaction costs. However, it is important to note that the choice of governance structure occurs before the transaction occurs and persists during the transaction. It is the central premise of this thesis that different means of governing the standard setting process ameliorate different aspects of the transaction costs by moderating the effect of characteristics of the bundle on the transaction costs. How organizations choose to govern standard setting activities will determine how much they spend on the process of

standardization. Hence, the organizations will choose the governance form that best mitigates these costs.

In this section, we hypothesize on how the characteristics of the standard impact the transaction costs and are mediated by the governance form. For example, as the depth of the IT standard increases, the transaction costs increase, but they increase at a differential rate for different governance forms. The theoretical model is depicted below in Figure 4.

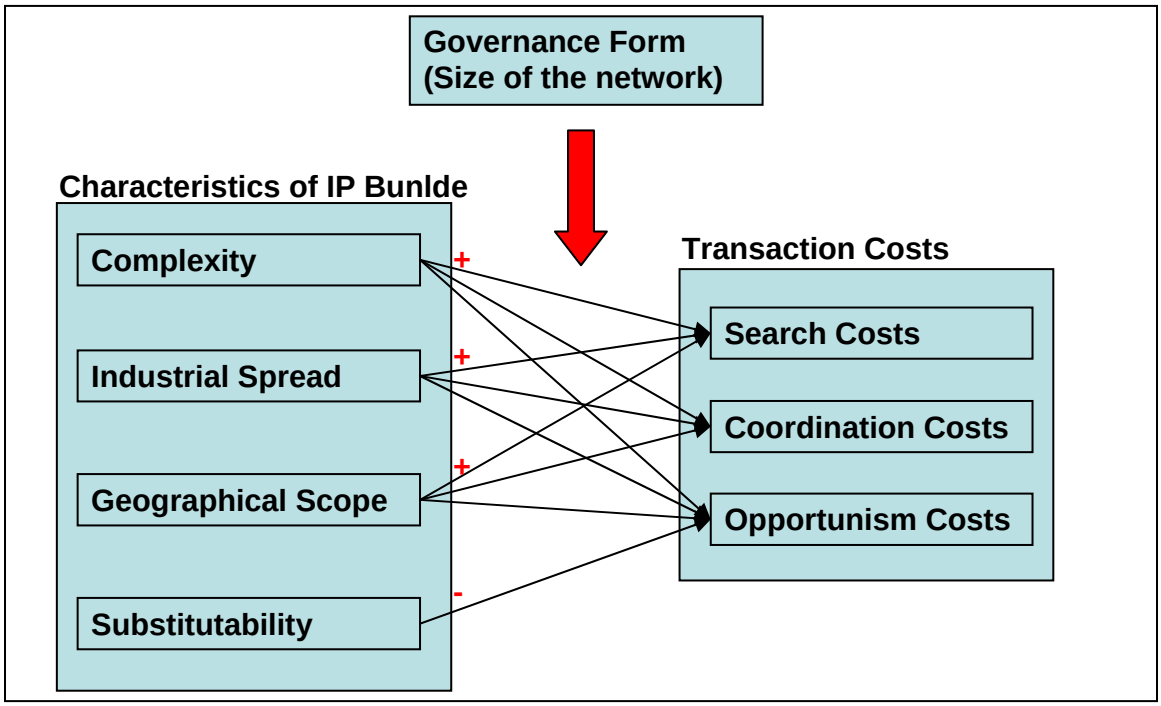

Figure 4: Conceptual Model

Now we proceed to develop the theory in detail.

3.2. Standards as a Bundle of Complementary IP

We conceptualize IT standard as a bundle of complementary IP held by multiple different firms, in multiple different industries, and multiple different countries. In most economic and IS research, IT standards are viewed as a single object that is an input into a technology product (Burrows 1999; Shapiro and Varian 1999a). For example, research in network externalities and IT standards often conclude that only a single standard will survive (Arthur 1990; Arthur 1996; Kauffman et al. 2000). Based on this conclusion, inferences are drawn about a standard owner's monopoly power, ability to lock in, and influence on competition. While this has led to some useful general predictions, it does not give a full view of the complexities in standardization. The truth is that most standards are made up of many unique patents. For example, there are over 500 essential patents owned by nine different entities in 28 different countries that comprise the DVD standard (www.dvd6cla.com). Similarly, the new Microsoft Vista is being built as small modules that, "then fit together like Lego blocks, making development and testing easier to manage" (Lohr and Markoff 2006). We extend the traditional view by recognizing that standards are actually systems of interdependent elements, and these elements have some unique features that must be considered to understand the standard.

3.2.1 Bundle of IP

An IT standard is composed of many smaller elements that we term *intellectual assets*. They are *intellectual* in that they are ideas to solve a problem and they are *assets* because they have value. For example, the MPEG 4 standard is

composed of more than 200 pieces of publicly declared intellectual assets, including a method for media data distribution, method for encoding, and method for decoding. Likewise, 802.11 the wireless standard from IEEE is composed of more than 100 publicly declared intellectual assets. Each asset addresses a specific issue in the technical problem for which the standard is being developed. The assets are the responsibility of the individual team that specializes in that area. The teams may belong to different organizations. For example, more than seven teams worked on different aspects, like delta-filtering, deflating compression, and 24-bit support of the PNG web graphics compression standard (Roelofs 1997). These assets are combined together to form a standard.

3.2.2. Protection

The intellectual assets described above represent ideas that are valuable for the firms. Hence, they are often protected by the granting of IP rights, changing them from intellectual assets to IP. The most common forms of protection under the IP rights framework are patent (for inventions and processes), copyright (for literary works, art and music), trademark (for company and product names and logos) and trade secrets (for recipes, code, and processes). While every type of IP is of interest to the IT community—digital music is concerned with copyrights, online retailers are concerned with trademark, and IT managers are concerned with trade secrets—the principle IP of concern in standard setting is patent. According to Andrew Updegrove, Attorney, Gesmer Updegrove LLP, out of all IP rights issues, patents are the most important to IT standard setting (personnel communication). This is also evident from the IP policies of major standard-setting organizations, which are

basically patent policies; e.g., that of IEEE and ANSI. Therefore, we concern ourselves exclusively with patent issues because they represent the lion's share of IP issues in standard setting.

An organization may protect its assets for a number of reasons such as earning royalties, becoming competitive, or to increase its bargaining power in the market. Jan van den Beld, secretary general, ECMA International, states that, *"IPR is an important aspect (in standard-setting) because many new things are patented and many new things are also appearing in standards, so there is a natural linkage between the two"* (personnel communication). In IT industries, an organization may also protect its assets to block competition, to avoid paying royalties should their competitors apply for IP protection first, and as a bargaining chip for cross licensing (Hanel 2005). Thus, most well-managed high technology firms proactively protect their IP by applying for IP rights, either to gain from future royalties or to avoid future payments.

3.2.3. Complementarity

The complementarity of the IP in a standard means that the bundle of IP has to be consumed together to create value (Gilbert and Katz 2005). This is especially true for IP that is deemed essential for the functioning of the standard. The only choices available to the standard developer, then, is to either use the IP or stop the development process (Lemley 2002). According to ETSI IPR Policy, "*An essential IPR is an IPR which has been included within a standard and which is so essential to the standard that it would be impossible to apply the standard without making use of*

this IPR. The only way to avoid the violation of this IPR in respect to the application of the standard is therefore to request a license from the owner" (ETSI 2001). Similarly, PatCom, the IEEE working group on IP, defines an essential patent (in context of IP), *"…as those patents whose infringement is, or in the case of patent applications, potential future infringement the applicant asserts will be, unavoidable in a compliant implementation of either mandatory or optional portions of a standard"* (IEEE-PatCom 2006). This means to develop a workable standard, it is necessary to acquire the essential IP as a bundle.

For example, a digital content that needs to be protected against piracy has to be digitally signed, encoded, obfuscated, cryptographed, and securely transmitted. The list is not comprehensive, but representative. Each of the requirements listed above addresses a specific task which can be performed without referencing other tasks; e.g., the contents can be digitally signed without being transmitted, and vice versa. Thus, the modules developed for each of the requirements are developed separately. However, to develop any workable DRM standard, each module has to work in sync with other modules. Absence of even one module will weaken the level of protection, making the digital content susceptible to piracy. Unfortunately, each of the modules is also separately protected by IP rights in the form of US patent numbers 6,832,316, 6,785,815, 6,668,325, 6,292,569 and 6,240,185. Any content provider that wants to protect its contents against piracy by way of digital rights management has to contract with Intertrust and other IP holders to obtain necessary licenses.

3.2.4. Multiple Owners

Many different firms can own the IP that makes up a standard. For example, the bundle of IP that went into the development of the MPEG4 standard is held by 22 different firms. Likewise, the IP for IEEE wireless standard 802.11 is held by 91 different firms. There are multiple owners of the IP because different firms, at different times, in different locations, develop workable solutions to common problems and then protect them by applying for patents. These patents are then required as a part of the larger projects such as standard setting. Since the problems faced by organizations are sometimes similar, so are the solutions. However, the law, depending on the country, only grants IP rights to one entity: the first to file or the first to invent, even if two people independently come up with technology.

To summarize, many IT standards can be viewed as bundles of complementary IP that can be owned by multiple entities. This is in contrast to the traditional view of a standard as a single object.

3.3. Implications of the Bundle of Complementary IP View of Standards

Characterizing an IT standard as a single entity results in two difficulties. First, it ignores the fact that different pieces of the standard can be owned by different entities. This leads most research to inappropriately consider only binary ownership of a standard (i.e., either company X owns the standard or it does not). The other difficulty is that the standard is almost always the unit of analysis. Though the standard, as a whole, is important, so, too, are the components of the standard. At the operational level, firms are worried about procuring the patents rather than the

standard. By conceptualizing a standard to be a bundle of more elementary objects, this research allows for more complex ownership of standards. Moreover, it allows for the patent to be the unit of analysis. In this work, to develop or adopt a standard then means developing or transacting for the IP, and the role of the standard setting body is that of managing the use of this IP.

The view of standards as a bundle of IP elucidates a host of legal problems for the standard-setting process never addressed before. This is because each of the building blocks becomes a potential for IP infringement. The penalties for willful misappropriation of IP rights are substantial. Apart from normal damages, the court may award treble damages; that is, the firms must compensate those whom they overcharged three times the amount of the overcharge. Even in cases where misappropriation is not willful, the courts may order normal penalties to cover royalty losses of the IP owner, which can be substantial.

The legal protection provided to intellectual assets warrant that the standards developer be careful while writing the standard. Even a single patent, essential for the standard, can become a bottleneck for the implementation of the standard (Granstrand 1999). Even though IP rights infringement does not occur during writing the standard – the standards developer can use any IP to write standards without infringing upon any of the firm's legal rights – the standard developer needs to be careful. If the implementation infringes on IP rights, there is little chance that the standard will ever be implemented, rendering the entire development effort futile. Thus, it is in the interest of the standards developer to ensure that all IP rights

required for the standardization are in order. This may entail contracting and coordinating with as many entities as the number of IP pieces that go into the standard.

3.4. Conceptualization of the Standard Setting Process in the Context of IP

de Vries (1999) gives a detailed explanation of the standard setting process (de Vries 1999) pp 34-38. However, based on the above conceptualization of a standard as a bundle of IP, we conceptualize the standard setting process a bit differently. With respect to IP, the standardization process consists of three broad phases; the pre-standardization phase, the standardization phase and the post-standardization phase. The conceptualization is important to understanding the origin of various costs described in the next two sections.

3.4.1. Pre-standardization phase

The pre-standardization phase occurs even before any conscious attempt to form standards is initiated. During this phase, firms, as a part of their normal activity, develop and protect their intellectual assets. The development may be a part of a proactive research project undertaken by a firm to keep ahead of competitors; e.g., IBM regularly applies for patents for most of its research. The IP rights so acquired form an asset in the firm's IP bank and are harvested at the appropriate times. The firm holding the IP can license it to other firms for inclusion in their standards or other technologies. For example, the LZW algorithm for loss-less data compression was originally published as a research paper by two Israeli researchers, Jacob Ziv and Abraham Lempel, in 1977. The algorithm was modified and patented by Terry Welch

of Sperry Corporation, which later became Unisys Corporation. The LZW algorithm found widespread application in a variety of web-based standards, such as Acrobat Reader and GIF images (Roelofs 1997).

3.4.2. Standardization Phase

During this phase, a need for a standard is realized and activities are initiated to develop the standard. This phase ends with the workable solution to the technical problem in the form of a written standard. The standardization phase involves gathering IP already available from IP holders in an industry, developing any missing assets that are required to implement the standard, and finally, the integration of existing IP and newly developed intellectual assets, i.e., the writing process itself. According to Jan van den Beld, a number of intellectual assets are developed during the standardization phase (personnel communication). The procedure to combine the intellectual assets into a workable standard is, in itself, an intellectual property of the developer.

3.4.3. Post-Standardization Phase

This is the last stage of the standardization process. In this phase, the specifications are made public and the standard is included in the relevant technology product. This stage can basically be characterized as the implementation and maintenance phase.

3.5. The Case for Transactions, Transaction Costs, and Transaction Cost Economics

The IP rights give the IP holder the authority to exclude everyone else from using or developing similar assets. What this means is that at some point, the firm intending to use the standard must acquire the rights to use the IP in the standard. The IP can be owned by multiple different entities, making multiple interdependent transactions a necessity. The standard developer can choose to ignore the IP and develop the standard in-house, but the infringement can be expensive. As a result, it is in the interest of standards developers to consider infringement issues while writing the standards. This consideration will involve searching for required IP outside of the organization, contracting and coordinating with the IP owners to procure necessary rights, and providing information or access to the rights to the standards implementers. Hence, the transaction of IP is inherent to any standard setting effort.

TCE has been the choice theory to study organization of transactions between economic agents. As discussed, TCE posits that there are considerable costs involved in executing a transaction and that these costs can be moderated by the choice of a governance form. However, this is about as much as there is to the similarity of transactions as studied in the traditional TCE environment and the transactions happening in the standard setting environment. This is because traditionally, the transactions between the economic agents are not interdependent, nor are the agents. The unit of analysis, thus, is a transaction. In other words, a supplier's transaction with entity A does not influence the supplier's transactions with entity B.

In the case of IT standards, the transaction of interest is for the bundle of IP that makes up the standard. Since the IP in the bundle is complementary and held by multiple suppliers, the transactions as well as the agents are interdependent. The complementarity of IP introduces specificity in that the IP is specific to each other. This also introduces externalities so that one firm's use of IP affects trade with all other firms. This means that it is inappropriate to analyze the transactions individually because the value of one transaction depends on access and completion of other transactions. Hence, for the purpose of analyzing transactions in IT standard setting, the unit of analysis becomes the bundle of transactions. While scholars recognize that there are a variety of rights associated with IP that can be transacted (Walden 2005), we restrict ourselves to the right to use and do not consider other rights like the right to exclude or the right to modify.

Now that the unit of analysis has been defined, we highlight some costs involved in IT standard setting. Procurement of IP is not an easy task. Legal implications, multiple owners, and complementarity of IP make the procurement process both necessary and difficult. The consequences of infringement accord that due diligence be performed while setting the standards. This involves searching for IP outside the organization, contracting and coordinating with the IP owners, and providing information or access to the rights to the standards implementers. Since the search and coordination processes are far from perfect, they lead to opportunism in the later stages of standards implementation. Thus, an organization needs to make provisions for legal costs.

3.5.1. Search Costs

This search is commonly referred to as the prior art search in standard setting parlance. Search, in standard setting, is such an important task that Andrew Updegrove suggests that, "just putting together a standard is, in a way, a prior art search" (personnel communication). As a consequence, there are search costs involved in IT standard setting. This is the cost of finding the IP involved in the standard. Ideally, every method used in the standard should be searched against the patent database to ensure non-infringement. Search costs may include lawyer's fees, subscriptions to professional databases, or hiring of technical experts in the domain. A firm may not incur any of these costs if it solely relies on the expertise of its employees to identify patents. This may result in infringement and higher legal costs of opportunism later during standards implementation.

The search for prior art and its owner in the context of IT standards is very different from the search for suppliers in the traditional context. Because of the legal protection granted to IP and the resulting financial implications, search in the case of IT standard setting is a legal necessity rather than a competitive requirement. In the case of traditional industries, search is mainly related to a firm's need for outsourcing some activity or procuring some assets in order to benefit from the supplier's specialization and economies of scale. If the firm decides to develop the assets in-house, they need not search outside the firm or the search will stop at the first instance of finding a reasonable supplier of the product. This is because production of traditional products is limited by the economies of scale, resulting in multiple suppliers of the same product. However, patent law is designed to do exactly the

opposite - to preclude others from developing and using the similar product. When the product is intellectual property, it does not matter if the assets are developed in-house or procured from outside. IP still has to be searched for possible infringement. Ideally, the search cannot stop until all possible cases of potential IP infringement have been dealt with. Recall that IP is simply an idea with legal rights assigned to it. The problem is that multiple entities may come up with the same idea, and do so *independently*. Thus, when an entity comes up with an idea, it may not know that someone else has already patented the same idea. However, ignorance is not a defense. If an entity already owns an idea, then other entities cannot use the idea without the first entity's permission, even if they came up with the idea on their own.

Search costs arise in the standard setting because there is a lack of information. The details of the IP portfolios and their ownership are not readily available in consumable form. The relevant IP and the firms owning the IP have to be actively searched. This is ironic because the entire basis of IP laws is to promote transparency and disclosure in exchange for monopoly rights over the creation. The IP laws are argued to reduce transaction cost as compared to the non-IP regime because disclosure leads to lower search costs. However, in the case of IT standards, the information asymmetry stems in part from the nature of the IT standard and in part from the differences in the representation of knowledge by the creators. The IP is a knowledge product. It incorporates the ideas and knowledge of the person developing it. It is up to the developer's discretion how s/he wants to represent her idea and what she wants to call it. As long as the idea is unique, innovative, and valuable, the IP rights can be obtained. While there are rules that guide developers of

IP to list their innovation under a specific category where it can be found relatively easily, new technologies often emerge which cannot be easily classified in existing categories. This also increases misclassification, increasing the search costs.

Another reason for the lack of information is the design of IP and the legal system. The published patents are on the same ground in the IP infringement case as are the pending patents or the patents that become pending within a year of development of the technology. Individuals in the firm may be aware of the existing patents in the market; however the information about recent applications or ones that will be applied in the near future may not be as readily available. Unless a firm religiously follows the activities of the IP granting body and follows every application filed for the grant of IP rights in every field, it is nearly impossible to keep track of all the IP. Thus, to develop an IT standard that does not infringe on the IP of others, an extensive search has to be performed.

Usually, the search costs are very prohibitive. According to Jan van den Beld and Andrew Updegrove, standard setting organizations almost never do a comprehensive search because of the prohibitive costs involved in searching (personnel communication). According to Clements, a basic database patent search can cost upwards of $1,000.00 per search, and it does not even guarantee any results (personnel communication). On the other hand, a patent opinion from an attorney is more reliable but can easily cost $50,000.00 for every patent, says Andrew Updegrove. According to Jan van den Beld, most organizations, including

consortiums, conduct only a basic search for available IP and rely mainly on the expertise and experience of professionals working on the standard-setting process.

Academic research provides a good example to illustrate the IP search activity. A researcher sees a problem and proposes a theory to address the issue. The research is presented to the world by way of conferences and journal proceedings. However, before the researcher presents her findings to her peers, she needs to ensure that the work is original. This is done by searching for prior literature on the subject matter and providing citations. The researcher may herself come up with ideas to support the theory. However, if due credit is not given to the original author, the practice is frowned upon. For example, this thesis could have proposed the existence of transaction costs without the author having read Coase or Williamson. However, the reviewers wouldn't have liked that and would have requested the author to read up on the literature. Even when researchers are careful in citing prior literature, reviewers almost always point out an important piece that somehow gets overlooked. Unfortunately, the business world's reviewers are not that forgiving because there are millions at stake. As a matter of fact, oftentimes, the competing firms wouldn't even point out the infringement until later when the IP is extensively in use and claim damages (Kanellos 2001). Thus, a search in the case of IT standards is fundamentally different and a good business practice.

3.5.2. Coordination Costs

Coordination costs refer to the costs involved in communicating and gaining agreement with suppliers. Once the relevant IP has been identified, the next step is to

involve the IP holders in the standard setting process. The IP holders' involvement can be purely commercial where transfer of rights occurs in exchange for monetary consideration. For example, Intertrust, which holds essential patents for any form of the Digital Rights Management (DRM) standard, has signed individual contracts with all major content distributors to license its IP. The terms of the contracts include the license fee, royalties on a per-use basis, the options fee, the maintenance fee, and minimum annual compensation. The involvement can also be in the form of a partnership, where the IP holder receives a part of the royalties generated from the standards sale; e.g., Intertrust recently entered into a consortium of DRM standard developers called the Marlin Joint Development Association (MJDA). The involvement of an IP owner can also be voluntary, where the IP holder grants non-exclusive, royalty-free license to the standards developer, as is the case with most non-commercial standard setting organizations.

In each of the cases cited above, the standards developer will need to coordinate with the IP holder and sign a contract, irrespective of the nature of the involvement of the IP holder. The efforts required to gain the agreement will be different depending on the nature of the agreement. As a result, there will be coordination costs involved in the standards development.

Coordination costs include costs like contracting, maintaining the relationship, and communication costs. Again, these costs are different from the costs incurred in the case of traditional industries. These costs are particularly problematic because standardization involves bargaining for a bundle of goods where each is owned by a

different individual. Ideally, a firm in need for *n* intellectual assets will have to enter into bargaining with however many firms for *n* different times to procure the IP.

Continuing with the example of academic research, imagine a paper with about fifty citations. If the doctrine of fair use didn't exist, a researcher would be required to contact each author, negotiate for the use of his or her research, and sign different contracts with each one. The researcher would also be expected to pay royalties to all authors s/he cites every time someone reads the paper. The scenario becomes even more problematic if the authors of other papers knew that the researcher could not present her research without citing their findings. This increases the complexity of the negotiations and bargaining.

3.5.3. Opportunism Costs

One of the cornerstones of transaction costs is the notion of opportunism, which is defined as, "self-interest seeking with guile" (Williamson 1985) p.30. Given the fact that there are complementarities in the consumption of IP, there is a scope of opportunism. Opportunism costs arise when a party to a transaction charges more than the marginal cost for the item being transacted. The price paid for a patent may be very different than the marginal cost of production of the patent. This is true especially in the case of essential patents. The notion of essentiality and complementarity introduces specificity, in that one firm's IP is specific to other firms' IP. This also introduces externalities, so that one firm's use of an IP impacts other firms. Thus, the complementarity of intellectual property introduces the scope of opportunism in the standard setting process.

Consider the following case to illustrate the scope of opportunism. Assume that the value of the standard to a standard developer (agent) is $v > nc$, where v is the value of the standard, n is the number of patents required, and c is the cost of development of the patent. Thus, the standard is worth more than it costs to make. In such a case the patent owner (supplier) can jointly extract v from the standards developer. This may be done because each supplier individually asks for v/n, or it may occur because the last supplier of the patent asks for v minus the total cost already paid. This is because the standard is a complementary bundle. Without any one patent, the entire standard is useless. Thus, in any bargaining situation, the agent procuring the patents has no credible bargaining situation, other than his threat to exit the market. In fact, it is possible for the patent owners to extract as much as vn for a set of patents that is only worth v.

Imagine that the standard developer approaches the first patent holder. The patent holder then demands v for the patent, arguing that without the patent, the standard developer cannot implement the standard. The agent is indifferent between opting out of the market and getting zero or paying v for a standard that is worth v and getting zero. Assume the standard developer chooses to purchase the patent. The agent then approaches the second patent holder, who demands v, again based on the fact that the standard is worthless without the patent. The agent is then faced with the choice of paying v and having a net gain of –v, or of dropping out of the market and having a net gain of -v. Again, he is indifferent. This can be repeated with all n patent holders for a net loss of nv. In reality, it is not likely that any agent would be so naive. However, the operative word is so. Agents are likely to face this problem

to some degree and to overpay for the standard because of the complementarities of the patents. If each were independent, then the most a supplier could charge would be the value of the single patent. However, with perfectly complementary patents, a supplier can charge the price of the bundle. With less than perfectly complementary patents, a supplier can charge some amount between the value of his own patent and the total value of the bundle. This is still more than the charge for a non-complementary bundle.

However, the scope of opportunism doesn't end with the potential to overcharge for the patents. As mentioned earlier, it has been shown that firms do not patent their technology to protect their R&D investments but to use as a weapon in blocking competition. Thus, the potential for opportunism extends far beyond the standards development phase into the standards implementation. Interestingly, a standard cannot infringe upon a patent until it is implemented in a product. However, once a product has been designed and produced, the producer is at the mercy of the patent holder. The patent holder can sue to recover the value they would have received in a licensing arrangement, which is costly. But, they have a much more powerful weapon. They can seek an injunction against the infringing firm, as NTP did against RIM's Blackberry (Wong 2006). The injunction means that the infringing company must stop using the patent, not simply pay for its fair value. In the case of essential IP, it allows the patent owner to appropriate *all* of the profits from both the standard and the product containing the standard. Thus, opportunism costs can be huge.

The essence of the argument is captured in the following statement: "Single patents with great blocking power could be an expensive nuisance to a large company, especially if held by inventors with no manufacturing capacity, who are thus invulnerable to retaliation through counter-blocking" (Granstrand 1999). For example, Microsoft settled a legal dispute with Intertrust involving patent infringement of Intertrust's DRM technology for $440 million. Intertrust argued that the anti-piracy mechanism of Microsoft video and audio software (media player) was similar to Intertrust's patent-protected technology. From the above case, it can be concluded that either Microsoft did not perform an adequate search before incorporating digital rights standards in its media player, or it deliberately chose to ignore the IP of Intertrust. The latter case seems unlikely because of the high visibility of the media player and public announcement by Microsoft about new anti-piracy features and their media player. Opportunism may seem trivial at first, but as can be seen from Table 4, the costs associated with missing an IP are substantial.

Case	Plaintiff	Defendant	Settlement
IE Plug-ins (Ackman 2003)	Eolas	Microsoft	$521 million
Blackberry (AssociatePress 2006b)	UT-Austin/NTP	RIM	$1.8million/$612 million
DRM (PressPass 2004)	Intertrust	Microsoft	$ 440 million

Table 4: Opportunism Cost

Even if a company wins a legal dispute over a patent, the costs involved in litigation are still substantial—$3 million by some estimates (AssociatePress 2006b).

Thus, necessary steps must be taken during the standardization phase to avoid opportunism in the post-standardization phase.

To summarize, the conceptualization of IT standards as a bundle of complementary IP held by multiple firms gives rise to transaction costs of the type search cost, coordination cost, and opportunism cost. Even though opportunism may arise during the later stages of standards implement, the standards development organization needs to take precautions beforehand to avoid expensive mistakes. The differences in the traditional treatment of transactions and IP transactions are highlighted below.

FEATURE	TCE	STANDARD TCE
Focus	Transactions and the choice to govern transactions by one institutional mode rather than another	Bundled transactions and the choice to govern the transactions by one institutional mode rather than another
Unit of Analysis	Independent transactions	Interdependent transactions
Outcome	Transfer of a good or service	Transfer of bundle of IP
Nature of the product transacted	Physical transfer of goods required	Only information is transferred
Claim	Transaction will be governed so as to minimize the costs involved in carrying them out.	Transaction will be organized in a way as to minimize the cost involved in transacting the bundle; i.e., individual transactions don't matter as long as the bundle is the cheapest
Economic agents involved	Suppliers, Manufacturers, Customers	Standard development organization, Participants, IP holders, Implementers, End users
Governance Structures	Market, Hierarchy, Hybrid	Markets, Hierarchies, Networks, Hybrids
Antecedents	Asset Specificity, Uncertainty, bounded rationality	Complexity, Industrial spread, Geographical scope, Substitutability
Asset Specificity	Defined as the value of the asset in its current use and	Does not apply as assets can be used

	next best use.	simultaneously in multiple locations. However there is some specificity of IP with respect to each other in the bundle.
Search Costs	Minimal for hierarchies, moderate for hybrids and high for markets.	Same and high for given number of patents for all governance forms.
Coordination Costs	By fiat, low for hierarchies, moderate for hybrids and high for markets.	Same and high for given number of patents for all governance forms.
Opportunism	Is in the form of shirking, but low because of fiat for hierarchies, moderate for hybrids, and high for markets.	High for hierarchies because of issues like submarine patents, high for markets.
Alternates	In the long term, any transactor can be replaced by another; i.e., long term lock-ins not possible	Because of the nature of essential IP, the transactor may never be replaced

Table 5: Differences between traditional treatment of transactions (TCE) and bundled treatment of transactions.

3.6. Characteristics of the Bundle and Factors Affecting the Transaction Costs

The fact that technology is made up of bundles of complementary IP is now recognized by both scholars and practitioners (Gilbert and Katz 2005; Lohr and Markoff 2006). However, not every bundle is made the same. The characteristics of the bundle depend on the specifics of the problems for which it was assembled.

These characteristics of the bundle will have implications for the transaction costs associated with assembling the bundle, a.k.a. the standard setting. We have identified four characteristics that define the bundle of IP.

3.6.1. Complexity of the Standard

All standards are not made equal. Some are more complex than others because they address a more complicated problem. Standards that address complex issues will have a large number of modules that interact with each other as compared to standards that address simple issues. This is because the complexity of standards is reflective of the complexity of the problem that it is addressing. One cornerstone of effective problem-solving in IT is to break 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. This is also the basis for the object-oriented programming and design and software reuse where each module is developed independently. The same is the case with IT standards. Each smaller problem is addressed independently by developing a specific solution. The solution so developed is an intellectual property in itself and can be used to address similar problems elsewhere.

Thus, complex problems require breaking down the problem into many smaller, more manageable sub-problems. Solution to each sub-problem will be an intellectual asset that can be owned by a different entity and will result in a large number of infringable modules. It is important to note that complex and simple are relative to each other and cannot be defined in an absolute sense. For example, the

wireless 802.11 standard requires more than 200 patents (http://standards.ieee.org/db/patents/pat802_11.html) held by more than 100 different organizations in many different countries, as compared to the 802.1 standards for LAN/MAN architecture that only has approximately 40 patents held by about 20 different organizations (http://standards.ieee.org/db/patents/pat802.html). It can be argued that the wireless standards are more complicated than the LAN standards because they have to address additional problems, like the hidden node problem and wireless data security specific to the wireless transmission of data apart from ones already addressed by LAN standards. Hence, complex standards will have a higher number of patents than simple standards.

Since each module in the standard can be independently protected by anyone in the industry, there is a higher chance that the modules may infringe upon several of the externally held IP. To avoid infringement or potential infringement, IP rights have to be searched externally. Note here that even if the standard developer concludes that no IP needs to be procured, they still have to do a search to avoid potential infringement. The level of effort required and the cost involved for this activity will be proportional to the number of searches undertaken by the standard developer. In other words, n modules will require n number of search efforts, even if the actual number of patents required may be less. The standard developer in each case will have to search a potentially large market in order to ensure that no part of the standard infringes on any external patent. The amount of communication and repetition involved will increase as the number of modules in the standard increase.

In mature markets like telecom, most of the sub-domain problems already have been identified, defined and solutions protected by way of IP rights. This is not to say that new problems do not emerge; merely that the telecom industry is highly mature in terms of patents. Thus, it is frequently the case that the IP search will result in a list of IP rights that have to be procured from the external entities. As Chiariglione notes, *"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" (Chiariglione 2002).* Even in the case of emerging markets, like that of IT, there are increasing instances when a standard requires external IP to be procured. This will incur coordination costs. The coordination costs will be dependent on the number of patents that are identified in the search process. Ideally, a firm in need for *n* patents will have to enter into bargaining with however many firms for *n* different times to procure the IP. The coordination efforts will include coordination and negotiation with all of the patent holders, maintaining a separate account of the usage and reimbursing them separately, a process that adds substantially to the overhead costs of using the patents. These costs are also particularly problematic when bargaining for a bundle of goods, where each is owned by a different individual.

The complexity of an IT standard will also have a bearing on the opportunism cost. This is because as the number of patents required increases, the probability that the standard developer will miss out on some prior art increases. This may be because the standard developer may overlook some standard IP being a part of the solution, or if the problem in the sub-domain is not stated properly. Moreover, with

the increase in the number of patents required to write the standard, there will be more entities which can potentially take advantage of the standard setting body, thereby increasing the opportunism costs.

Thus, we hypothesize:

Hypothesis 1a: As the complexity of the IT standard increases, the search cost increases.

Hypothesis 1b: As the complexity of the IT standard increases, the coordination cost increases.

Hypothesis 1c: As the complexity of the IT standard increases, the opportunism cost increases.

3.6.2. Industry Breadth of an IT Standard

The IT industry has had, and continues to have, a profound impact on both the personal as well as professional lives of the people involved. The results of the development in IT are felt across a wide range of industries. The IT is leading a revolution where products from different industries are fast converging, increasing the need for interoperability. For example, a cellular telephone is now also a personal storage device and a hand-held personal entertainment device with portable music and videos. These functionalities, however, come from different industries. The simple looking device combines technologies from the telecommunications, computer, entertainment, and graphics industries to perform its job. In light of this rapid convergence, the importance of IT standards cannot be overstated. Naturally, a standard that makes interoperability possible within products of multiple industries will draw upon the intellectual property spread across these industries, due to the fact that the standard may require new functionalities and additional modules for new

products to interoperate. These additional modules can be held by firms in any of the industries affected by the standard. A standard developer operating in an industry may have a good knowledge about their industry. However, as the boundaries extend, the standard developer will have to consider the infringement implications from the IP owners from other industries. This will also be the case if the standard developed in one industry can be used or will have applications in other industries, as well.

If the standard has implications or application in multiple industries, it is necessary for the standard developer to search the IP available in these industries for possible infringement. A simple analogy for this would be that of a researcher writing an interdisciplinary research paper having to review the literature for both disciplines. The search for IP will be difficult because different industries may use different terminology to represent their IP. For example, joint product development in case of economics is called coalition formation; in case of management, it is called coopetition; in case of finance, it is called joint venture; and in case of marketing, it is called cooperative alliance. A standard developer will have to learn about as many different industries' terminology or hire as many experts as the standard has implications upon.

Once the IP has been identified, the coordination efforts with IP owners in different industries will start. Different industries operate differently and have different sets of rules, reporting procedures, protocols, motivations, and expectations

that will guide their negotiating and contracting procedures. As a result, IP spread over different industries will have implications on the coordination costs.

Finally, the absence of familiarity with the other industry can result in negotiation holdups and greater opportunism problems. This is the case because the organizations in the other industry are not as likely to provide concessions in the case of infringement as would the firms in the same industry. Firms in the same industry may be interdependent on each other or may stand to benefit from each other by cross-licensing in the long run and hence, may be more forgiving in the case of IP infringement. Sometimes, the firm developing IT standards will have to negotiate with entities which do not operate in the industry but whose sole mission is to hoard IP, increasing the scope of opportunism.

Thus, we hypothesize:

Hypothesis 2a: As the industry breadth of the IT standard increases, the search cost increases.

Hypothesis 2b: As the industry breadth of the IT standard increases, the coordination cost increases.

Hypothesis 2c: As the industry breadth of the IT standard increases, the opportunism cost increases.

3.6.3. Geographical Scope of the Standard

The arguments here are similar to the industry breadth of an IT standard except more profound. With the emergence of the global markets, there is an increased need for communications across borders. IT has enabled businesses across geographic boundaries to communicate in real time. There is an inherent

interdependence in the global supply chain. For this, it is important for businesses in different countries to follow the same standards. But this also increases the scope of the standard to international domain. To successfully implement standards that are used globally, the standard needs to be in compliance with each and every country's local IP laws. Traditionally, IP rights issued in one country had few legal implications for the business in the other countries. But IT standards have global impact. The businesses cannot simply ignore the IP rights issued in other countries because of the global interdependence of businesses.

Thus, for a standard that has implications in multiple countries, it is necessary for the standard developer to search the IP available in these countries for possible infringement. Moreover, different countries have different ways of maintaining their patent databases. Most developed countries provide online searchable databases which makes the search easier. However, most third world countries still rely on paper documents, which make the search difficult. Moreover, there are language and cultural barriers that may affect the search process. Thus, for IT standards, it is not only necessary to search within the industry and within the country, but also across industries and countries.

Likewise, the coordination efforts will include understanding new legal norms, complying with local rules and regulations, and accommodating the local business and cultural values in the contract. This will affect the coordination costs. An example of how different laws affect the business operations of an organization can be seen by comparing the outcomes of the Microsoft antitrust lawsuit in the

United States of America and Europe in the case of Windows Media Player bundling. While in the US, Microsoft was not held accountable in the antitrust lawsuit, European countries held Microsoft responsible and forced them to pay a heavy penalty for bundling the media player with their operating system.

Finally, a standard with global implications that infringes upon a country's patent will not be implemented in the infringed country. Organizations outside the country have little incentive to cooperate in the case of infringement, increasing the scope of opportunism.

Thus, we hypothesize:

Hypothesis 3a: As the geographic span of the IT standard increases, the search cost increases.

Hypothesis 3b: As the geographic span of the IT standard increases, the coordination cost increases.

Hypothesis 3c: As the geographic span of the IT standard increases, the opportunism cost increases.

3.6.4 Degree of Substitutability of an IP in the Bundle

Substitutability is a concept related to the complementarity described earlier. We argued that a standard is valuable only when all the essential IP is contained in a bundle. Absence of even a single IP can make the entire standard redundant. This notion is slightly different from substitutability. Substitutability, as conceptualized here, is the ability of the standard developer to substitute one piece of IP with another to achieve similar functionality in the standard. A substitute is desired when the original IP is not available on reasonable terms. For example, there are a number of

IPs available for data compression. Each uses a different algorithm to do the same thing; compress the data. Even though each will produce the desired objective of compressing the data, the outcomes and the performance may not be similar. For small files, the compression requirements may be different than the compression requirements for pictures and will be different than the compression requirements for movies. Nevertheless, there may be some amount of substitution possible under certain cases. The substitutability will affect the transaction costs because it provides alternatives to the standard developer. An ideal standard will not settle for anything less than a perfect technical solution, but commercially, if the best IP is not easily available or affordable, the developer might have to settle for the second best.

Substitutability of a patent will not have any effect on the search cost. This is because the standard developer will still have to search through a potentially large database for all modules, even if substitutes are available. Likewise, substitutability will not have any effect on the coordination costs, as the standard developer will still have to enter into a contract with the IP owners and maintain a payment account for the royalties. Substitutability will affect the opportunism cost as it reduces the bargaining power of the IP owner. If a standard infringes on a patent and there are substitutes available, the IP owner will have little credibility in a threat to shut down the standard. Conversely, if the IP owner is aware that there are no substitutes available, the threat of opportunism will greatly increase. For example, one reason why the initial negotiations between the RIM and NTP for the proposed $415 million failed was because NTP knew that RIM did not have a workable substitute available for their infringed email patent. Finally, after lengthy legal proceedings and extensive

negotiations, the case was settled for $615 million. Unfortunately, this settlement amount does not include lost sales that NTP suffered during the litigation process. The NTP-RIM case illustrates how non-existence of substitutes can increase the opportunism cost - $200 million in this case. NTP did announce eventually that they were working on the substitute technology and will implement it in the case of the court injunction on the Blackberry; however, that was more of a last-minute desperate effort to get NTP to agree to settle. Moreover, substitutability increases the competition, thereby allowing the standard developer to extract more value from the IP owner.

Thus, we hypothesize:

Hypothesis 4: As the degree of substitutability of an IP increases in a standard, the opportunism cost decreases.

3.7. The Role of Governance Structure

The governance structure plays an important role in moderating the transaction costs (Coase 1937; Williamson 1985; Williamson 1991). How transactions are governed will influence the transaction costs. Different governance forms are good at managing different characteristics of the transaction and hence, mitigate the costs differently. This is because different governance forms have different coordination and control mechanisms that influence the transactions. For example, TCE posits that if the frequency of transactions is high, it makes sense to invest in specialized structures to save on the recurring coordination and contracting costs (Williamson 1985). Likewise, if an organization envisions hold-up problems with the transactions, they should organize the transactions in-house. The

coordination in such a case is hierarchical and control is by fiat. There are no contracts, and disputes are resolved internally. Similarly, market governance of the transactions is controlled by the price mechanism. However, it is important to note that the decision to govern the transaction in a particular fashion occurs before the transaction occurs and then persists for the duration of the transaction. Thus, the choice of governance form can be viewed as making an ex-ante decision about governance to mitigate ex-post problems with transactions.

This worked well with the transactions involving traditional products. The complex governance forms, such as the network form of governance that is so common for standard setting, did not exist or was not preferred because they were not required, as Williamson suggests, "[*m*]*any hypothetical forms of organization never arise, or quickly die out, because they combine inconsistent features* (Williamson 1991, p 271)." The control and coordination mechanisms were designed to address problems associated with the physical products and thereby reducing transaction costs. For example, hierarchical control over a relation-specific asset reduces opportunism by acquiring the ownership of the asset. However, ownership of an intellectual asset is very different from ownership of a physical asset. In most cases of physical assets, mere possession of an asset gives the owner the right to use, which in turn excludes everyone else from using the asset. Conversely, in the case of intellectual assets, the right to use and right to exclude are alienable, and multiple different entities can use the assets simultaneously without diminishing the value of the asset (Walden 2005). Likewise, hierarchical control over frequent transactions helps avoid coordination costs by eliminating the need for negotiations and

contracting. If the market mechanism is favored purely based on price, then there is a need for repeated coordination because there is a transfer of physical goods involved. Physical goods tend to diminish with consumption and hence, the need for continuous supply. However, intellectual assets have no such constraints. But because of the legal protection accorded to the IP, one-time negotiation and contracting is necessary, and there is no need for repeat transfers.

Once the rights to use the IP are transferred, there need not be any further coordination for the supply. The IP can be used as many times as need be. Thus, a different breed of governance forms emerged to address uniqueness in the IP transactions. As Powell argues persuasively, other hypothetical forms beyond the market-hierarchy continuum do exist (Powell 1990).

Furthermore, the hierarchical control and coordination for intellectual assets may not always be possible. This is because the traditional production is not always protected. The entire premise underlying market hierarchy governance as envisioned by TCE is that there are multiple suppliers of a similar product in a market, and hierarchies can do the same job at an additional production cost, albeit a lower transaction cost. However, the same is not true for IP where there can only be one supplier. It doesn't matter if the organization wants to do it in-house or procure it from some other entity. Their only choice is to procure the IP from the legitimate IP owner or discontinue production in case they don't agree to the terms.

Thus, hierarchies or markets, in the pure sense, are most likely to be non-existent in the IT standard setting environment. Moreover, hierarchies and markets in

the IT standard setting don't serve the same purpose of reducing the transaction costs as described in the TCE. This is because for traditional products, hierarchies reduce search costs by eliminating the need to search. Once a hierarchy decides to govern the transaction in-house, there is no legal requirement to search. The same is not true for IT standards that are made up of IP. Irrespective of whether IP is developed in-house or procured from outside, it has to be searched. Similar arguments can be made for the coordination costs and the opportunism costs. Hierarchical control over the transactions eliminates the need to coordinate with an external entity. Since there is no external entity involved, there is no scope of opportunism.

However, in the case of IT standard setting, if the search results in externally held IP, coordination costs cannot be avoided. As a matter of fact, since the transaction is for a bundle of IP, the coordination efforts will involve negotiations and contracting with multiple monopolists that are well aware of their power, a position that will add substantially to the coordination costs and opportunism costs.

3.7.1. Different governance forms observed in the IT standard setting

Governance of the standard setting process means defining and committing to a process of acquiring the necessary IP. While we still observe governance forms resembling hierarchy, network, and markets, we do not consider markets in our analysis. This is because the IP is required to be in bundles. The market form of governance will then represent using a third party standard. Even though the standard user will still be responsible for all of the legal liabilities arising out of the use, most often, the seller of the standard assumes these liabilities on behalf of the standard

user. Moreover, a pure market can be analyzed as a hierarchy from the seller's perspective. Broadly speaking, any transaction in an IT standard setting can be governed either by the hierarchy or by the network. A hierarchy is where the majority of the transactions – development of IP – are managed in-house using internal resources. The network form of organization is one where more then two entities pool their resources to jointly develop and administer the standard. Obviously, there is no fixed number of firms in the network, so we discuss small networks and bigger networks. Hierarchy can be considered as the smallest network of one firm.

To understand the governance forms in the IT standard setting, we need to understand the organization of the industry and the actors involved in the transactions. In the case of a brick and mortar economy, the main entities involved are the suppliers, the manufacturers, and the customers. There are other entities like shareholders and the government, but they are inconsequential to our analysis, so we ignore them. Between the suppliers, manufacturers, and the customers, there is only a bilateral mutual dependence. The higher order interdependence does not exist. For example, the manufacturing firm is dependant on its supplier for the raw material or on its customers to buy their product. The manufacturer's relation with its suppliers and customers is the least dependent on other manufacturers in the economy or other manufacturers' relations with their suppliers and customers. Moreover, since there are many suppliers of the same raw material and many customers, the overall relative bargaining power of any entity is low with respect to any other. Thus, the possibility of a pure hierarchy exists by way of vertical integration with either the suppliers or

the customers. Similarly, the possibility of pure markets exists because the boundaries of the suppliers and customers are distinct from that of the firm.

Finally, hybrids exist because a firm chooses to selectively enter into a deep relationship with a few of its customers or a few of its suppliers, but again, this is at a bilateral level.

In the case of IT standards, there are more entities than those conceptualized by the TCE. Specifically, the IT standards environment has five different kinds of stake holders: a standards development organization, participants who have some interest in the standard, patent owners, the implementers of the standard, and the end customers. Of course, the roles of these entities may overlap, but for now we assume that they are distinct. The standard setting process is the complex balancing procedure with respect to these stake holders because all of them are mutually dependent on each other. A standards development organization, which could be a firm or a network, is one that actually writes the standard based on the inputs and recommendations it receives. The participants in the standard setting process are the individuals and/or organizations that participate because of their knowledge or interest in the technology. The patent holders are the owners of the essential IP needed to implement the standard. The implementers are the firms that use the standard as one of the inputs in the manufacturing process of the final product. Finally, end users are the ultimate consumers of the standard. The relation of the different entities to each other is depicted in Figure 5:

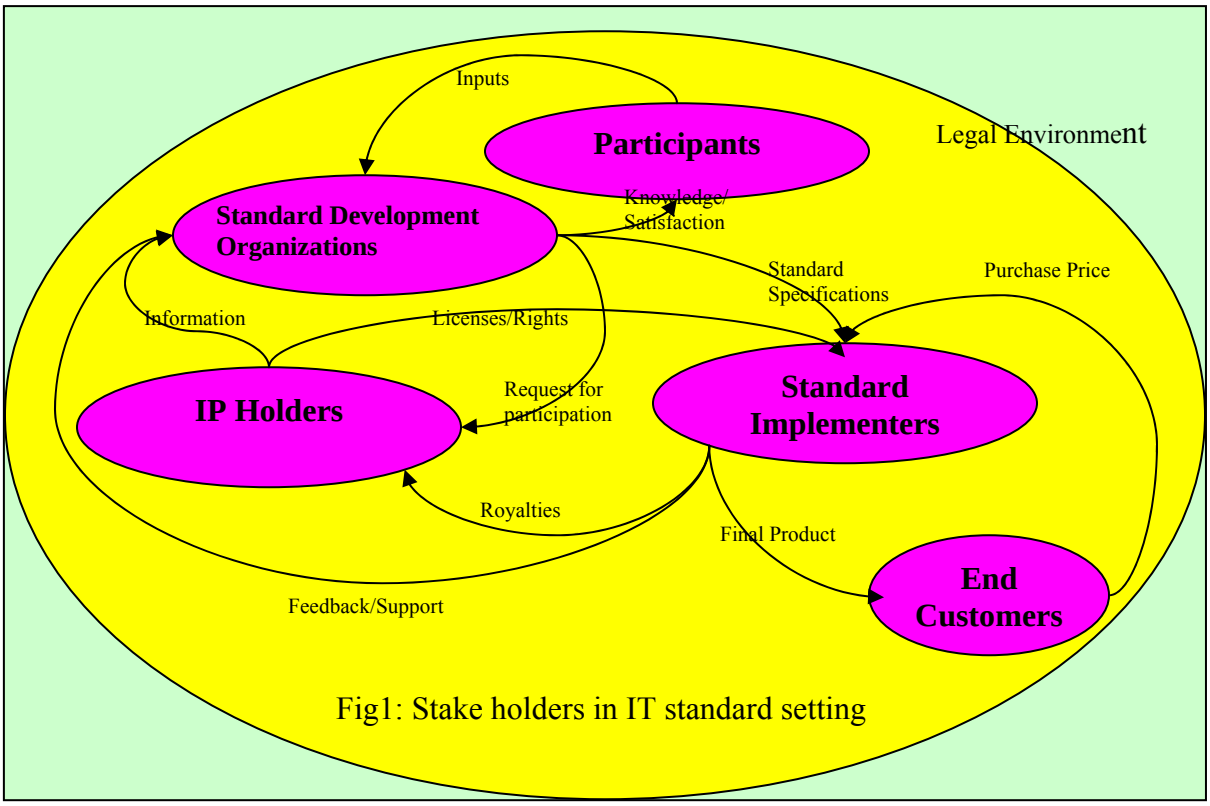

Figure 5:Relation of Different Entities to Each Other

As is evident from the complex set of relationships depicted in Figure 1, the emergence of hierarchy, markets or hybrids as conceptualized by TCE is nearly impossible. To explain the governance forms in the IT standard setting, we look at the roles of various stake holders.

Standard development organization: In the role of the standard development organization, the agent's main job is to set the standards. This involves identifying a problem, developing a technical solution to the problem, identifying the relevant IP, procuring the necessary assurances from the IP owners, writing the standard and distributing the standard. The standard development organization's role can be played by a single firm, a group of firms, or by a group of firms and individuals.

IP owners: IP owners are the holders of the intellectual property rights. The IPR are acquired as a result of original creation or as a result of acquisition from the original creator. In this thesis, the IP holders are central to the premise of identifying the structural forms in the IT standard setting. IP owners can be firms or individuals.

Participants: Participants are firms or individuals who participate in the standard setting process because of their interest in the field. The interest may be commercial in nature where the standards being developed will impact the industry in which the participant operates or non-commercial in which the participant has other interests such as research, e.g., universities, in the standard.

Standard implementers: Standard implementers are the entities which incorporate the standard developed by the standard development organizations into their products and services. Again, the patent holders and the standard development organizations can play the role of standard implementers.

End users: End users are the consumers of the standards who consume the standard by way of purchasing the products manufactured by the standards implementers. We deliberately exclude the end customers from our analysis as they are numerous individuals who have little bargaining power alone. This will not affect the governance form anyway because the end customers are outside the boundaries of the governance structure. Even if some technology-savvy customers do wish to contribute to the standardization process, they will be doing so as participants.

The above roles are not distinct. If we keep the standards development organization as our reference point, then any of the entities can play the role of the standards development organizations. For example, the patent holders can get together and develop a standard, or the product manufacturers (implementers), recognizing the need for the standard, can play the role of standard development organizations, or the patent holders can also be the implementers and they can come together to jointly develop the standard. Alternately, if all of the IP is owned by a single entity, that entity can play the role of standard developer. The various relevant cases are summarized below in Table 6. The cases are not comprehensive but representative.

Case	Examples
All roles are played by a single organization, i.e., standard development, IP holder, standards implementer, participant	Proprietary standards such as the IBM AS400 server platform, Apple Macintosh OS
IP holders jointly develop the standard but leave the implementation to external entities.	Consortium standards like DVD
IP holders are the same as implementers but leave the standard development to the third party.	ECMA, which wrote the standard for IOMEGA zip drives which holds all the IP and also manufactures the ZIP
IP holders are distinct from standard development organizations, are distinct from participants, and are distinct from standard implementers.	Standard Setting Organizations like the RosettaNet and IEEE
The manufacturers (implementers) get together to develop standards but need to acquire patents from the external entities. The interesting point to note is that some of the IP may be held by the implementers.	Consortium standards like Marlin Joint Development Association which develops standards for digital rights management. InterTrust was included in the consortium simply because it held the essential IP required for implementing the DRM standard.
Participants develop the standard and leave the acquisition of the IP to the implementers.	IEEE for some time only allowed individuals to participate in the standard- setting process. Open source movement falls into this category.
Standard development organizations, implementers and participants are one entity, but IP is procured from an external entity.	Proprietary DRM standards will fall into this category, where every standard developer procures IP from the external agent.

Table 6: Examples of Possible Governance Forms

As described above in Table 6, there are numerous governance forms that look like networks or hierarchies. It is nearly impossible to consider all of these forms in one study. Hence, in the name of parsimony, we restrict ourselves to considering only two governance forms; hierarchies and networks. We do consider the varying sizes of networks; i.e., we distinguish between small networks and bigger networks.

3.7.1.1. Hierarchies: The hierarchical governance is when a single firm – the promoter – develops the standard and all the IP using in-house talent and resources. The transactions are organized in-house and external dependence is minimal. However, as mentioned earlier, organizing transactions in-house does not preclude the hierarchies from performing external searches for the external IP, coordinate with external entities, or deal with opportunism due to infringement.

3.7.1.2. Network Form of Governance: Scholars began to recognize another ideal form of governance called network governance (Granovetter 1995; Powell 1990). A network can be defined as, "… *a select, persistent and structured set of autonomous firms (as well as non-profit agencies) engaged in creating products or services based on implicit and open-ended contracts to adapt to environmental contingencies and to coordinate and safeguard exchanges* (Jones et al. 1997) p.914." The desirable aspect of network governance is that it already recognizes a group of firms and a bundle of resources; thus, we can use the definition without modification. Below, we describe three network forms of organizations that we include in this study.

3.7.2. Benefits and Advantages

TCE recognizes that markets and hierarchies exist because they provide certain exclusive benefits that the other governance structure cannot provide. Markets provide price efficiency, and hierarchy economizes on transaction costs. How a transaction will be governed depends on whether the transaction costs outweigh the price efficiency. Likewise, in IT standard setting, the choice of governance form will depend on exclusive benefits that each governance structure provides that cannot be achieved by the other form. One of the tradeoffs between the hierarchy and network forms of governance is that the hierarchy is fast to respond to the market needs as compared to networks that are more comprehensive. However, specific to IP, there are different advantages that each governance form grants to the IP holder. Since standards form natural monopolies, a hierarchy that has access to all IP in-house stands to benefit greatly from royalties over the life of the standard. This is the also the basis of the standards war that has been extensively studied in the literature (Shapiro and Varian 1999a; Shapiro and Varian 1999b).

The basic ideology of the hierarchy is to fight for the market. The view is summarized by the following statement, "A monopoly in the bush may be worth more than an oligopoly in the hand" (Dranove and Gandal 2003) (pg. 10). Thus, it makes sense for hierarchies to take risks and develop standards for market dominance. However, more often than not, IP is held by multiple firms outside the firm. In such a case, there is a deadlock situation where a standard cannot be established without the cooperation of all IP owners. The network form of governance allows multiple entities to pool their resources and establish a standard which otherwise would not be

possible. Moreover, since the competition in network standards is limited, it leads to faster adoption. Because of this, the total size of the market increases and different organizations compete in the market rather than for the market.

3.7.3. Governance forms, Characteristics of the Bundle, and the Transaction Cost

TCE suggests that different governance forms mediate the costs in a different way. In this section we analyze how the governance of a transaction moderates the effect of characteristics of the bundle on the transaction costs.

3.7.3.1. Complexity, Transaction Costs, and the Governance Form: As established earlier, complexity of an IT standard represents the number of modules that interact with each other. As the number of modules increase, so does the potential for infringement. As a result, for a large number of modules, greater search and coordination efforts are required, resulting in higher search and coordination costs. For example, search efforts depend on how many ideas go into a standard. One with only ten patentable ideas will have lower search costs than one with 100 patentable ideas. The same holds true for the coordination efforts. The more patents that are identified, the higher the coordination efforts are that are required. However, given a baseline need to search and coordinate, different governance structures moderate the actual cost of these activities. This is because different governance forms have different mechanisms that facilitate search and coordination. The hierarchy mainly relies on in-house expertise – the knowledge of engineers working on the standard and the skills of the legal department in identifying the external IP. Since the promoters group has only limited resources and people working on the

standard, it is less likely that the knowledge of all necessary IP will reside with the engineers in charge of developing the standard. As a result, the search will have to go to expensive lawyers who will use formal methods, rather than simply retrieving the information from memory. Moreover, search by lawyers in itself is not foolproof because of limited domain knowledge. This is also true because the employees of a single company are usually trained using similar methods, subscribe to the same databases, share similar technology and resources in developing the standards, and as a result, can systematically overlook an important piece of IP.

Similarly, the coordination efforts will require independent negotiations, and the contracts will be specific to that piece of IP. Separate accounts will need to be maintained with the contracted terms and conditions for reimbursing the IP owners.

Also, since there is only a single firm involved, the entire cost of search and coordination is borne by it. If an IP is found outside the organization, then a workaround must be developed and search conducted on the workaround idea. Thus, an IP hierarchy must search more than the total number of patentable ideas.

However, networks are structurally different. Networks draw expertise and support from multiple sources. Different firms contribute experts and monetary resources in the development of the standards. The networks have formalized procedures to identify IP required for the standards development. This includes dedicated time in meetings aimed to identify potential IP infringements where the attendants of the meeting have to make the working committee aware of potential IP that may be infringed upon during the course of the development. Since the people

working on the standards come from different industries, backgrounds, cultures, and countries, the likelihood that an infringing patent will be identified during one of the meetings is higher. Just the fact that there is diversity in the standard setting process eliminates a lot of search costs. To take an example from the academic community, an IS researcher writing a research paper alone will have to spend more time on literature review than if the efforts are shared by co-authors. Also, the likelihood that one of the co-authors might be aware of a study that addressed a particular issue is higher in case of multiple authors than in the case of a single author. This will dilute the equity for the IS researcher, but if the objective is to write a quality paper that is read by a wider audience, it is more desirable.

Moreover, some of these firms are also the patent holders of the patents that are required in developing the standard, making the search easier and less expensive. It is also in the interest of the members of the network to make the committee aware of the patents that they hold themselves lest they will be deemed invalid later, as happened in the case of Rambus and Infineon (Consortiuminfo.org 2006). The network members also have incentives to disclose their patents because it creates a market for their technology (Dolmans 2002). It is in the interest of the members of the network to make the standard successful. As a result, due diligence is accorded to the search process before the actual standard is set. Finally, the network form of governance is viewed as socially desirable; hence, they can make a public appeal for requests for disclosure, requests for comments, and invite letters of assurance from potential infringees to come forward and disclose their patents. This privilege is not available to proprietary standards developers because even if they make a public

appeal for patent holders to come forward and disclose their patents, it is highly unlikely that the real patent holder will come forward and disclose, for commercial reasons.

Having multiple firms as members also helps in reducing the coordination costs required to develop the standard. Since the IP holders are also the members of the network, the negotiations and the contracting are based on pre-specified standardized terms and conditions that were agreed upon by every member before joining the network. This greatly reduces the need to coordinate. Moreover, the networks are governed by anti-trust laws in most industrialized nations. Contracting and licensing of the IP compulsorily follows reasonable and non-discriminatory terms; otherwise it is deemed as anti-competitive.

Even though the networks have to incur the search and coordination costs like the hierarchies, the difference is that these costs are greatly reduced and have to be incurred only once. The costs themselves are shared by multiple entities. Hierarchies, on the other hand, have to incur the cost as many times as the number of proprietary standards developed. Thus, the social benefits of saving on the search and coordination costs over the entire economy are substantial.

Thus, we hypothesize:

Hypothesis 5a: As the complexity of the IT standard increases, the search cost increases but it increases more for hierarchies than for networks.

Hypothesis 5b: As the complexity of the IT standard increases, the coordination cost increases but it increases more for hierarchies than for a networks.

The opportunism cost increases as the number of modules in a standard increase. A governance form has the ability to moderate these costs for legal, social, and economic reasons. Legal reasons include the requirements of anti-trust guidelines that are applicable for networks but not for hierarchies. Anti-trust laws are in place to preserve and promote competition and to preserve the free enterprise system. The legal system follows the ideology that competition is good and can be best achieved if the licensor and licensee of the IP make decisions independent of each other. However, networks, because of their collusive nature and membership, can be easily construed as anti-competitive. As a result, networks have to follow strict anti-trust guidelines to stay in operation. Violation of such guidelines has penalties ranging from stiff fines, disbanding the network, and even jail terms for participating individuals (Consortiuminfo.org 2006). The anti-trust guidelines require members of networks to make available their IP on reasonable and non-discriminatory terms which greatly reduces opportunism. Social reasons that reduce opportunism arise because firms operate in the societal ecosystem. The general perception of a firm suing another firm for IP infringement is more favorable than a firm suing a member of a network for IP infringement. This is because the networks are deemed to work towards societal good as compared to hierarchies, which are deemed to work in self-interest. Moreover, individuals and firms are more likely to voluntarily grant IP licenses to a network than to a hierarchy. Even if a dispute arises that leads to opportunism, there is a greater opportunity for mediation in the case of a network than in the case of a promoters group. This is because the likelihood of a

member of a network having some relationship with the IP owner, and hence, the possibility of mediation, is higher.

Finally, the economic reasons also reduce the scope of opportunism. A firm suing a hierarchy can expect retaliation in the form of counter- suing. With minimal bilateral dependence, the scope of this happening is limited. However, if a firm sues over a standard implementation that is developed by a network, the retaliation can be from multiple firms and the impact can be more severe, as was the case against SCO with IBM countersuing SCO for Linux.

Networks also differ in their objectives. In the absence of commercial interests, a network can simply abandon the standard in case an essential IP is not available on reasonable and non-discriminatory terms, thereby greatly reducing the bargaining power of the IP holder. A hierarchy, on the other hand, stands to benefit greatly if the standard is widely adopted. Since all of the benefits accrue to a single entity, the IP holder is in a much stronger bargaining position and can negotiate for slightly less than the entire surplus from the standard.

To summarize, as the complexity of IT standards increase, the scope of opportunism increases. However, network forms of governance are able to mitigate these costs because of the membership structure and requirements of reasonable and non-discriminatory terms. Hierarchies, on the other hand, have no such social, economic, or legal recourse to mitigate these costs. Hence, we hypothesize:

Hypothesis 5c: As the complexity of the IT standard increases, the opportunism cost increases, but it increases more for hierarchies than for a networks.

3.7.3.2. Industry Breadth of an IT Standard, Transaction Costs, and Governance Form

As established earlier, the industry breadth of an IT standard increases the search, coordination, and opportunism costs. As the number of industries represented in the standard increases, so does the potential for infringement and hence, the need to search. The coordination efforts now involve interaction with firms in different industries who may follow different guidelines, thereby increasing the coordination costs. Since the firms are no longer in the same industry, there is less bilateral dependence, thereby increasing the scope of opportunism. Governance forms moderate these costs because they follow different mechanisms to administer the standard. As described previously, the hierarchies mainly rely on in-house expertise – the knowledge of engineers working on the standard and the skills of the legal department - in identifying the external IP. The engineers and lawyers will have to learn about a whole new domain and nomenclature to search for the IP in a different industry.

Since the hierarchies have limited resources and people working on the standard, it is less likely that the knowledge of all necessary IP will reside with the engineers in charge of developing the standard. Even if the hierarchy decides to hire experts from a different industry, there is a limit to the number of people it can hire without overshooting its budget. Specialized lawyers from other industries can be hired, but again, their involvement is expensive. Coordination efforts for a hierarchy will require independent negotiations and contracts with firms in different industries.

The industries may have different procedures and guidelines that they follow which will influence the contracts. Negotiations will be difficult across industries because they don't share common interests. Moreover, the entire cost of search and coordination and implications of opportunism is borne by a single firm. Hierarchy will also be susceptible to higher opportunism costs. Since the search across industries is not perfect, the likelihood of omission of an important piece of IP is more likely than if the search were restricted to a single industry. In the absence of common interest and bilateral dependence, there is no incentive for firms outside the industry to cooperate with the promoters group in case the infringement occurs.

Networks draw their members from different industries who are experts in their own domain. Obviously, these firms will be more aware of the IP and the business practices in their respective fields. As a result, search and coordination will be much easier for networks. Continuing with the example from the academic community, an IS researcher writing a research paper that has implications for marketing and IS can greatly reduce the search cost of literature review by collaborating with a marketing researcher. This will ensure that the IS professional gives due credit to the literature in the marketing area. Moreover, network members are also the patent holders from the different industries, which reduces the search and coordination costs for the network more than it would for a hierarchy. Since the member firms in the network are also the patent holders, search and coordination is relatively easier and less expensive. This is not to say that all patents are accounted for by the members; it only signifies that the search cost is eliminated to the extent of number of patents already held by the member firms and is greatly reduced for other

patents held outside the firm. The coordination efforts are further benefited by the standardized contracts across the industries and the requirements of reasonable and non-discriminatory terms by networks.

Finally, networks attract members who stand to benefit by the standards developed by the network. One of the benefits is inclusion of their IP in something that is important, and hence, networks attract IP holders, unlike hierarchies, where an IP holder would be better off not disclosing its patents.

The opportunism in the case of patents spread across industries is influenced by the governance form in the same method as described in the previous section. Anti-trust laws are in place to avoid collusion; however, government recognizes the importance of collaboration, particularly in technology standard setting. Thus, technology standard setting networks often pre-approve and register with the governmental agencies like the US DOJ by way of Business Review Procedure. This requires that the network follows certain guidelines, like making the standard available on a non-discriminatory basis; i.e., charging a fair, usually equal, price to anyone who wants to use the standard.

Registering the network and making the standard available at a fair price greatly reduces the chance that the court will find the network's activities illegal. Thus, plaintiffs can only sue the user of the standard for damages rather than treble damages, and plaintiffs are much less likely to win. Therefore, technology networks are by and large governed by these legal guidelines. By design and by law, consortiums are constructed in such a way as to guarantee the members a fair price.

Because anti-trust laws require a fair price, there is incentive not to overcharge. Other social and economic factors that reduce the opportunism for networks are similar to the ones described above.

To summarize, as the industry breadth of IT standards increases, the transaction costs increase. However, the network form of governance is better able to mitigate these costs because of the membership structure and requirements of reasonable and non-discriminatory terms. Hierarchies, on the other hand, have no such social, economic, or legal recourse to mitigate these costs.

Thus, we hypothesize:

Hypothesis 6a: As the industry breadth of the IT standard increases, the search cost increases, but it increases more for hierarchies than for a networks.

Hypothesis 6b: As the industry breadth of the IT standard increases, the coordination cost increases, but it increases more for hierarchies than for a networks.

Hypothesis 6c: As the industry breadth of the IT standard increases, the opportunism cost increases, but it increases more for hierarchies than for a networks.

3.7.3.3. Geographic Span of the Standard, Transaction Costs, and Governance Form.

The arguments here are similar to the industry breadth of an IT standard except more profoundly. Different countries maintain their IP databases differently, use different nomenclature and language, have different cultural, social, political and legal environments. These factors make the search and coordination activities difficult and opportunism more intense. IT standards span geographic boundaries; however, if a standard infringes on a local IP, the standard cannot be implemented in

that country. This renders the entire standard useless, even in countries where its implementation does not infringe any IP. Moreover, most countries that are active in international trading are also the signatories of the World Intellectual Property Organization (WIPO), which lays down specific guidelines for IP protection for member countries. Thus, infringement in one country can have consequences in other countries, as well. Different governance forms, although unable to mitigate the costs entirely, substantially influence these costs. The mode of influence is relatively similar to that described in the complexity of IT standards and industry breadth of IT standards. The hierarchies, because of their limited resources, cannot conduct extensive searches across all countries. Moreover, hierarchies may not have presence in all of the countries, making the search and coordination process even more expensive. Hierarchies have to invest a great deal in coordinating with international IP owners because of different laws. Similarly, the scope of opportunism is expected to be higher because of an absence of common interests or bilateral dependence between the IP holders across boundaries. There have been instances where foreign companies have successfully sued American corporations in the US courts over patent infringement; e.g. Apple was sued by Singapore-based Creative Technologies in the U.S. District Court in California in May 2006 for a patent granted in August 2005, long after ipod had become a revolution.

Networks are able to mitigate these costs to a large extent because of diversity in the membership and the governance structure. Membership in the network is usually not restricted by country, and as a result, firms in other countries which are also IP owners find it beneficial to participate in the global phenomenon, increase

their visibility, and in turn, reduce the transaction costs for the standards development. Firms in many different countries participate by contributing IP, knowledge, and financial and other resources. The local firms are expected to be more aware of the local IP and other legal issues. This not only facilitates the search process but also helps in coordination and reduces opportunism.

Thus, we hypothesize:

Hypothesis 7a: As the geographic span of the IT standard increases, the search cost increases, but it increases more for hierarchies than for networks.

Hypothesis 7b: As the geographic span of the IT standard increases, the coordination cost increases, but it increases more for hierarchies than for networks.

Hypothesis 7c: As the geographic span of the IT standard increases, the opportunism cost increases, but it increases more for hierarchies than for networks.

3.7.3.4. Degree of Substitutability of an IP in the Bundle, Transaction Costs, and Governance Form.

It was argued that the substitutability of an IP in the bundle will not have any effect on the search and the coordination costs. This is because the standard developing organization will still have to search potentially large databases to ensure that substitutes don't infringe on any IP. Substitutability affects opportunism costs because it provides options to the standards developer, thereby reducing the bargaining power of the IP holder.

Discussion about substitutability of an IP is relevant both before the standard is specified and after the standard is implemented. If an infringing IP is not available on reasonable terms during the standard setting process, implementing substitutes is

relatively easier than if the infringing IP is discovered after the standard is already implemented. This is because early identification of the infringing IP gives the standard developer enough time to develop workarounds in case the substitutes are not available. However, in case the infringement is discovered after the fact that the standard has already been adopted, substitutability can be expensive. Even if the substitute is available, the cost of implementing the substitute can be enormous, both in terms of restructuring the standard, as well as lost business due to uncertainty surrounding the standard.

Hierarchies are affected by substitutability in two ways. First, if the substitute is not available, there is little concession that the hierarchy will get from the IP owner whose IP has been infringed. As a result, the opportunism costs will be high. Second, if the substitute is available, the retooling cost for the hierarchy will be high. As a result, ideally, the IP owner of the substitute will be able to extract the entire surplus that the hierarchy expects to save by using the substitute. The hierarchy even stands to lose more in terms of lost sales and customer confidence. The problem arises because the hierarchies do not have a credible threat to abandon the standard if the standard is profitable. Networks have a credible threat to abandon the standard and hence, the scope of opportunism is low. As a matter of fact, most IP policies of networks clearly specify that the network will abandon the standard in the case that they are not able to procure the IP on reasonable and non-discriminatory terms. While the diversity in the membership of the network and their business relationship with one another and others in the industry lowers the scope of opportunism by allowing the substitute IP holder to participate in the standard setting process, its

commercial nature leaves it susceptible to some degree of value extraction by the IP owners.

Another important aspect of a network that is absent in the hierarchy is the courts' view about IP infringement. If the relevant IP is not available to the hierarchy on reasonable terms, courts are not expected to take a lenient view towards it, categorizing the losses arising out of infringement as a business risk. However, in the case of networks, courts and the government have historically intervened and sometimes can force the IP holder of the infringed IP to license it on reasonable terms for the sake of societal good.

Thus, we hypothesize:

Hypothesis 8: As the degree of substitutability of an IP increases in a standard, the opportunism cost decreases; however it decreases more for networks than for hierarchies.

Thus to summarize, we test for the following hypothesis:

	Search cost		**Coordination cost**		**Opportunism cost**	
Governance Form Characteristic of the bundle	Hierarchy	Network	Hierarchy	Network	Hierarchy	Network
Complexity	↑ at a higher rate	↑ at a lower rate	↑ at a higher rate	↑ at a lower rate	↑ at a higher rate	↑ at a lower rate
Industry Breadth of an IT standard	↑ at a higher rate	↑ at a lower rate	↑ at a higher rate	↑ at a lower rate	↑ at a higher rate	↑ at a lower rate
Geographic Scope of an IT Standard	↑ at a higher rate	↑ at a lower rate	↑ at a higher rate	↑ at a lower rate	↑ at a higher rate	↑ at a lower rate
Degree of substitutability	X	X	X	X	↓ at a lower rate	↓ at a higher rate

Table 7: Summary of Hypothesis

CHAPTER IV: RESEARCH METHOD

4.1. Overview

The conceptual model is used to derive the measurement model. The measurement model was empirically tested by administering the web- based survey to the key informants directly involved in IT standard setting. As per my knowledge, this is the first study that conceptualizes a standard as a bundle of IP and studies the role of IP in IT standard setting. Survey methodology allows us to explore as well as confirm our beliefs about the system in place. Before the web survey, in-depth interviews were conducted with the industry participants to understand the nature of the problem and to come up with key constructs. In my conversation with the industry experts, I observed a great deal of confusion about the IP policies of several organizations. While some people reported that IP was not such a big issue, others reported that it was definitely becoming something to be concerned about. Moreover, most organizations do not conduct searches or at least do not require searches of IP or disclosure of IP while standard setting; nevertheless, they take affirmative actions to not infringe on a patent.

During the study, I had two choices to test the theory; case study and survey methodology. Experimental design was outright ruled out because it is impossible to replicate the real-world costs and benefits in the simulated environment. As a result, the choice was narrowed down to case study or survey methodology. Eventually, we settled for the survey methodology for several reasons: first, we wanted the study to have more generalizability across governance forms, across countries, and across

industries. A case study would have limited our results to a particular type of a governance form or constrained our findings to a particular type of an industry, or a country. Moreover, there are several case studies which briefly address the issue in a specific industry. Second, we wanted to incorporate the beliefs of a large number of industry experts, thereby getting an overall feel for the problems faced by IT professionals in general. Third, due to the fact that standards have profound impact across industries and across countries, it makes sense to include as much variability in the study as possible. I believe that the survey methodology is best suited to measure the belief of the people about IP issues.

4.2. Sample and Data Collection

The first attempt for data collection was unsuccessful. The survey questions were developed using discussion with key informants, reading newspapers, IPR documents of major standard-setting firms, and navigating through IP portfolios of some major standards. Due to the limited population of people participating in the standard setting, the survey was only tested for face validity by sending it to some lawyers and top executives of major standard setting firms. The final questionnaire was administered to the participants of an internet request for comments group. The list of key informants was compiled using email harvesting of internet requests for comments maintained by http://www.faqs.org. Internet requests for comments (RFC) is a public database of technical and organizational notes related to different aspects of computer networking, including protocols, procedures, programs, and concepts. The database is available on several websites. People from diverse background and fields contribute to the RFC database in the form of discussions on research concepts

and status memos about the internet. The contacts found in the RFC were deemed ideal for our questionnaire, as they are active participants in the internet standard setting process. Since these respondents are listed as key contact authors for that particular RFC, it was assumed that they will be well aware of the IP issues facing them in the standard setting process. This attempt failed miserably, and we only received a response rate of 1%.

Post-survey analysis on why the survey failed highlighted some key shortcomings. RFC's have been maintained online, even before the start of the internet, since 1969. A lot of people had moved or were not associated with their current jobs anymore. As a result, it is highly unlikely that the survey reached its targeted audience. Second, most people working on open internet RFC work on open standards and would not respond to the HTML-formatted emails that the Texas Tech servers supported. As a matter of fact, some of the individuals replied to the email request displaying all garbled text. Third, the internet by and large is developed on open philosophy; hence, the respondents, in their emails, mentioned that they don't consider patents as something that the internet community is concerned about or would respond to. Fourth, the email was sent as a general request to fill out questionnaires by spending 30-45 minutes of their time. The amount of time required to fill out the questionnaire was not acceptable to most of the respondents. Fifth, a lot of people were concerned about pfishing and spamming activities and were hesitant to respond without verifying the identity of the sender. Finally, a small but unfortunate incident made the respondents very upset. People move across organizations but they continue to participate in standard setting activities. As a

result, there were multiple duplicate emails listed for some people which were hard for me to identify. This resulted in some respondents getting multiple requests, which didn't set very well with them.

4.3. Sampling and Data Collection – Attempt 2.

Even though the first survey failed miserably, we got a wealth of information about how to administer the second survey. To start, we simplified the survey and pilot tested it with 20 respondents for face validity, content validity, and response rate. The respondents were industry experts actively engaged in IT standard setting activities for organizations like IEEE, OMG, and OASIS. The designation of the experts included directors of standard-setting bodies, general counsel and attorneys-at-law engaged in consulting with standard setting bodies, team leaders, and participants in standard setting committees. The experts were asked to evaluate the survey based on clarity, ambiguity of items, relevance to the construct, length of the questionnaire, time required to complete, and understandability. Based on the recommendations, some items were modified or dropped, while others were left as is. The response rate for the revised pilot test was considerably better. Once again, a list of email was compiled, this time manually, to have the most up-to-date list of people working on standards. Numerous email archives were browsed and email addresses were collected of people who were actively responding to standard-setting activities of popular standards.

4.3.1 Subjects

The targets for this research are the participants in the various standard-setting processes. For a respondent to be included in the survey list, s/he should have been an active contributor to the standard setting process as determined by their participation in the online archived discussions about the development of a standard. The profile of the respondents included in the study range from team member to project leader and chairman of the working groups. The targeted subjects are ideal for our study because they are the ones who make decisions about what gets included in the standard and what gets left out. Law penalizes the implementers of the infringed standard and not the developer; as a result, the targeted group sometimes may not bear the direct consequences of infringement. However, there are at least two reasons why this will not affect our study. First, some participants in the standard-setting process are also employees of the firm that do intend to implement the standard and thus are direct stake holders in the risks associated with them. Second, standard setting requires considerable upfront costs, resources, and efforts. It is hard to envision that someone will go through all these efforts just to see their standards not being implementable.

The list of archives that we considered included standards set by OASIS, IEEE, GridForum, T11, EICTA, MFAForum, DAML, and several others.

We wanted to target both hierarchies and networks. However, because of the proprietary nature of hierarchies, there is almost negligible information available online about the participants involved in hierarchical standard setting. To address this

issue, we sent emails to corporate accounts of people working on standards without identifying where we obtained their information. We requested the respondents to think about any standard that they have worked on in last few years and respond accordingly in the hope that we will get mixed responses about proprietary and hierarchical standard setting.

4.3.2. Sampling Procedure

We identified a list of about 900 standard-setting bodies as listed on www.consortiuminfo.org. Not all 900 standard-setting bodies are involved in IT standard setting. We used convenience sampling to select about 300 standard-setting bodies from which we can collect email addresses. Since all standard-setting bodies do not publish their archives online, the contact information collection was limited to only those bodies which made their archives available online. These are usually organizations which follow open standards development. The email archives were carefully browsed to obtain a list of people who actively responded to the listserv requests.

4.4. Operationalization of the Constructs and Instrument Development

Since this is the first such study that addresses IP issues in the IT standard setting, pre-validated measurement instruments were not available to use. As a result, new single item instruments were developed for every construct specific to this research. This is consistent with other transaction cost studies where no preexisting measures are available. The reason for this is that transaction costs are situation-specific and hence, it is unlikely that standardized measures are available. However,

efforts were made to closely match the new instrument with existing literature. For example, complexity in software is usually measured as number of lines of codes (Banker et al. 1993). Taking a cue from this, we measured complexity of the standard with the number of pages since the number of lines of codes will be irrelevant. Similarly, industrial spread and geographical scope of IT standards were measured by asking questions about how many industries and how many countries are represented in the standard. This is consistent with other transaction cost studies where distance of a facility from the factory is used as a measure of asset specificity. Substitutability was measured by asking the relative ease of finding substitutes on a five-point Likert scale. Search costs and coordination costs were determined in terms of man-months by multiplying the percentage of time spent on search and coordination activities with the number of people involved in standard setting and the number of months it took to develop the standard. Opportunism cost was measured as likelihood of getting sued. Finally, the governance form was measured by asking the number of firms participating in the standards development.

4.4.1. Complexity of the IT standard

Complexity in the IT standard refers to the number of methods interacting with each other in the standard. As we argued earlier, complex problems are solved by breaking down the problems into smaller modules and addressing them individually. In the case of IT standards, each of these modules can be protected separately as the IP of their respective owners. A module is defined as a named sub-function or a sub-routine in the standard (Basili and Perricone 1984). In the software field, complexity is most often measured using number of lines of codes in the

software or a specific module (Basili and Perricone 1984), or number of operators or operands in the program, and other similar measures. Taking a cue from measuring software complexity, this construct is operationalized as number of pages in a standard. We earlier tried to measure this construct as the number of methods in the standard; however, there was a lot of ambiguity in the measurement, as most people are not aware of how many methods went into the standard over time or had difficulty in recalling. As a result, number of pages was deemed as an appropriate measure since a complex standard will have more methods and thus will require more detailing, thereby increasing the number of pages. Thus, number of pages is an appropriate measure of complexity of the IT standard. The operationalization of complexity is presented below.

Complexity: How many single-spaced pages are there in the final specification? (An estimate is fine.)

4.4.2. Industry Breadth of IT Standard

This construct is operationalized in a manner similar to the complexity of the IT standard. This is because the industry breadth of an IT standard also represents complexity, albeit of a different kind. A standard will have an impact on different industries or build on IP held in other industries. It is essential that a standard does not infringe on the IP of any industry that is remotely associated with the standard. A reasonable proxy for this is the number of technical areas from which the methods came. A technical area is a widely understood term that we picked up while browsing through the US patent and trademark office. Firms applying for patents have to

classify their patents in one of the many technical areas specified in the USPTO website. Hence the construct is operationalized as follows:

Industry Breadth: How many different technical areas are represented in this set of specifications (or the standard)?

4.4.3. Geographic Scope of IT standard

The geographic scope of the IT standard measures the number of countries where the patents might be held. Thus, the construct is operationalized as:

Geographic Scope: How many different countries are represented in this set of specifications (or the standard)?

4.4.4. Degree of Substitutability

Substitutability is basically measuring the ability of the standard developer to replace an essential IP with an alternative. It is measured on a five-point scale as an answer to the following question:

Substitutability: How easy would it be to find substitutes for methods already chosen?

All methods have easily available substitutes.	1
Most methods have easily available substitutes.	2
About as many methods have substitutes as don't.	3
Few methods have easily available substitutes.	4
No method can be easily substituted.	5

4.4.5. Search Costs

Search costs are measured as total time spent in man months on all search-related activities. This construct is a product of three separate questions:

1. On a scale of 0-100, what percentage of time did everyone involved in [Nickname of the Standard] spend in identifying, discussing, finding and considering the pre-existing methods? (0 for none) Estimates are fine.

2. Approximate number of people in your working group?

3. How many months did it take to write this set of technical specifications (or the standard)?

Total search costs, then, are the product of 1, 2, and 3.

4.4.6. Coordination Costs

Coordination costs are measured as total time spent in man months on all coordination-related activities. This construct is a product of three separate questions:

1. On a scale of 0-100, what percentage of time did everyone involved in [Nickname of the standard] spend in procuring permission (negotiating, contracting, and coordinating) to use the pre-existing methods? (0 for none) Estimates are fine.

2. Approximate number of people in your working group?

3. How many months did it take to write this set of technical specifications (or the standard)?

Total coordination costs, then, are the product of 1, 2, and 3.

4.4.7. Opportunism

Opportunism is the degree of vulnerability of the standards developer with regards to non-availability of essential patents on reasonable and non-discriminatory terms. Basically, opportunism arises because there is a risk of getting sued. If there were no risk, the transaction costs or problems would not exist. As a result, we measure opportunism as the likelihood of getting sued on a five-point scale. Thus, we measure opportunism as:

Opportunism: What is the likelihood that one of the specification users may become a target of patent litigation?

Highly likely	1
Somewhat likely	2
Maybe (neutral)	3
Less likely	4
Not likely at all	5

4.4.8. Governance Form

Earlier, we described two stylized governance forms; namely, hierarchies and networks. We defined hierarchy as a single firm or one dominant firm and a few smaller firms developing standards. We defined networks as a group of equals. Networks can range all the way from two firms to several thousand firms participating in the standard-setting process. As a result, we measure governance

form on a continuum. We measure governance form as the number of companies participating in the standard-setting process.

Governance form: How many different companies are represented in this set of specifications (or the standard)?

4.5. Data Analysis Method

The research model is tested using regression analysis. Two types of regression are used; OLS and logistic regression. Regression analysis is used to analyze the strength of the relationship between a random response variable and one or more explanatory variables. Regression analysis is one of the oldest statistical techniques used to study relationships amongst variables. Regression analysis has been used in research to describe strength and direction of relationships, importance of a variable in the model, and form of relationship (Gilmartin and Hartka 1992).

There were several choices for data analysis that we considered. Initially, we wanted to use structural equation modeling (SEM) to test our theory. However, due to complexity in data collection and difficulty in interpreting the loadings of independent latent variables, we selected regression as our final choice. Regression analysis offers a simple and robust way to model complicated relationships if the relationships are pre-defined and well-understood, sample size is large enough, and assumptions are not badly violated. Regression is particularly suited for our analysis because regression allows making predictions for scenarios that do not currently exist.

4.6. Basic Notations and Guidelines of the Measurement Model

The measurement model specifies the relationships between the response variable and several explanatory variables. There are two different regression equations that we consider; we consider OLS regression where the response variable is continuous; e.g., for search costs and coordination costs, and logistic regression, where the response variable is ordinal for opportunism cost.

OLS Multiple Regression Model

$$Y_i = \beta^*_{k0} + \beta_k (X_{ki} - \overline{X_k}) + \beta_{jk} (X_{ki} - \overline{X_k})(X_{ji} - \overline{X_{ji}}) + \varepsilon_{ki} \quad (1)$$

Logistic Regression Model.

$$Y_i = \frac{e^{\beta^*_{k0} + \beta_k (X_{ki} - \overline{X_k}) + \beta_{jk} (X_{ki} - \overline{X_k})(X_{ji} - \overline{X_{ji}}) + \varepsilon_{ki}}}{1 + e^{\beta^*_{k0} + \beta_k (X_{ki} - \overline{X_k}) + \beta_{jk} (X_{ki} - \overline{X_k})(X_{ji} - \overline{X_{ji}}) + \varepsilon_{ki}}} \quad (2)$$

Where,

Y = response variable,

X = explanatory variables.

β = regression coefficient and measures the effect size of X on Y. The coefficient sign determines the direction of the relationship.

CHAPTER V: DATA ANALYSIS AND RESULTS

5.1. Overview

This section describes the data collection process and the outcomes of the process. The section starts by describing the sample characteristics, summary statistics, and finally, the results.

5.2. Sample characteristics

Final surveys were sent to 1,671 people whose email addresses were obtained by browsing through standard setting archives of organizations found on the list maintained by www.consortiuminfo.org. Since there is a great deal of movement of personnel in the technology sector and because we only wanted recent standard setting activities, efforts were made to only include active or recently defunct archives. Out of 1,671 emails, 346 bounced; thus, it can be expected that the survey reached, at most, 1,325 respondents. Out of 1,325 respondents, 56 replied to the email stating their unwillingness to participate and did not take the survey. A total of 436 people responded to the online survey, equaling a response rate of 33.0%. If we include the respondents who did not wish to participate, the response rate becomes 37%. Of the 436 responses received, 55 respondents had not participated in a standard setting activity, or the standards they participated in did not have distinct methods in them. Thus, the number of usable responses dropped to 381. Out of 381 responses, the observations where search costs, number of companies, and number of pages were reported to be zero were deleted and data with outliers were removed. As a result, we were left with 345 responses for our model testing.

The profile of the respondents is presented in the Table 8 below:

Designation	**Respondents** **N=345**	**Percentage**	**This standard Experience (AVG)**	**Total Standards Experience (AVG)**
Project leader or chairman	164	47%	57 Months	121 Months
Legal	0	0%	-	-
Administrative	6	2%	96 Months	214 Months
Working group member	127	37%	45 Months	91 Months
Individual	13	4%	35 Months	73 Months
Others	35	10%	38 Months	102 Months

Table 8: Profile of the respondents

Respondents were allowed to write comments on the responses they provide. This allowed us to manually scrub the data and remove responses where the respondent expressed doubt about his or her responses. This allowed us to remove outliers, abnormal values and incorrect data. The characteristics of the standard are presented below in Table 9:

Characteristic	Response	N=345	Percentage
Patent/Copyrights and other IP involved	Yes	130	39%
	No	131	37%
	Maybe	84	24%
Methods Pre-existing or original	All Original	16	5%
	Mostly Original	106	31%
	Few Original	78	23%
	Mostly Pre-Existing	127	37%
	All Pre-existing	18	5%
Standard Age (Project started during)	>=2001	204	59%
	1996-2000	81	23%
	1991-1995	25	7%
	1986-1990	15	4%
	<=1985	20	6%
Organizational Spread	Multinational	290	84%
	National	44	13%
	Regional	5	1%
	Others	6	2%
Continent where standard was developed	Mainly North America	193	56%
	Mainly Europe	23	7%
	N. America & Europe	60	17%
	N. America & Asia	5	1%
	Europe & Asia	2	1%
	Multiple Continents	60	17%
	Mainly Asia or Australia	2	1%

Table 9: Characteristics of the Standard

The summary statistics of the constructs are presented below in Table 10.

Variable	N	Mean	Std Dev	Minimum	Maximum
No. of Tech Areas	345	9.28	27.35	1.00	300.00
No. of Countries	345	11.26	19.70	1.00	191.00
No. of Pages	345	504.77	1387.54	2.00	10000.00
No. of Companies	345	59.89	177.87	1.00	2000.00
Substitutability	345	3.39	0.98	1.00	5.00
Total Months	345	30.31	27.36	1.00	240.00
Psearch (% time)	345	36.06	26.18	1.00	100.00
Pcoordination (% time)	345	8.79	13.59	0.00	95.00
Likelihood Sued	345	4.20	1.11	1.00	5.00
No People	345	49.70	81.22	2.00	600.00
LogNoTechAreas	345	1.63	0.86	0.69	5.71
LogNOCountries	345	1.98	0.91	0.69	5.26
LogNOPages	345	5.03	1.48	1.10	9.21
LogNOCompanies	345	3.04	1.23	0.69	7.60
LogTCSearch MM	345	5.10	1.65	0.69	11.08
LogTCCoordinationMM	345	2.53	2.25	0.00	9.39

Table 10: Summary Statistics

5.3. Regression Analysis

The list of variables considered and their relationships with one another is presented in Table 11.

Variable Name	Classification	Search cost	Coordination cost	Opportunism cost
Search Costs (TCSearchMM = PSearch*NoPeople*Months)	Response variable	-	-	-
Coordination Cost = (TCCoordinationMM =Pcoordination*NoPeople*Months)	Response variable	-	-	-
Opportunism Cost = Likelihood of being sued	Response variable	-	-	-
Complexity= LogNoPages = Log (No. of pages)	Predictor variable	X	X	X
Industrial Spread=LogNoTechAreas = Log (No. of Technical Areas/Industries)	Predictor variable	X	X	X
Geographical scope=LogNoCountries = Log (No. of countries)	Predictor variable	X	X	X
Substitutability	Predictor variable	-	-	X
Governance Form=LogNoCompanies = Log (No. of companies)	Moderator	X	X	X
Interaction Governance Form and Complexity = OF*Complexity	Interaction term	X	X	X
Interaction Governance Form and Industrial spread = OF*LogNoTechAreas	Interaction term	X	X	X
Interaction Governance Form and Geographical Scope = OF*LogNocountries	Interaction term	X	X	X
Interaction Governance Form and Substitutability = OF* Substitutability	Interaction term	-	-	X

Table 11: List of variables and their interrelationship

The above table represents three models that are of interest in the thesis. We take individual models and discuss the results below.

5.3.1. Correlation Matrix

Pearson correlation matrix was examined for the extent of multicollinearity problems (Table 12). The highest squared correlation (coefficient of determination) among the independent variables was 0.49 between the measure of substitutability and lognopages. All squared correlations were much less than 0.80 suggesting no significant multicollinearity problems (Hair et al. 1995).

	LogNoPages	LogNoTechAreas	LogNoCountries	LogNoCompanies	Substitutability
LogNoPages	1	0.25431 <.0001	0.30137 <.0001	0.35804 <.0001	0.02028 0.7073
LogNoTechAreas		1	0.20322 0.0001	0.40736 <.0001	0.11520 0.0324
LogNoCountries			1	0.35102 <.0001	0.06026 0.2644
LogNoCompanies				1	0.16681 0.0019
Substitutability					1

Table 12: Correlation Matrix

5.3.2. Regression Analysis – Search Costs

5.3.2.1 Model

The model for search cost is:

$$\text{TCSearchMM} = b_0 + b_1 LogNoPages + b_2 LogNoTechAreas + b_3 LogNoCountries + b_4 LogNoCompanies + b_5 LogNoPages * LogNoCompanies + b_6 LogNoTechAreas * LogNoCompanies + b_7 LogNoCountries * LogNoCompanies + e$$

Where,

b_0: is the intercept term and interpreted as search cost when all other variables are set at their mean.

b_1-b_8: are estimated regression coefficients and measure the size of the effect of predictor variable on the response variable.

e=error term

Since the data is highly skewed with some outliers, we took the log transformation for both the dependent and the independent variables. We centralized the data as it makes the parameter estimates more interpretable. For measuring governance form, we used a continuous scale to measure how many companies participated in the standard development activity. Smaller numbers reflect hierarchical governance and larger numbers reflect network governance.

5.3.2.2. Estimate interpretation.

b_1 : We expect a positive sign for this estimate, as that would suggest that with the increase in number of pages (complexity), the search cost goes up.

b_2 : We expect a positive sign for this estimate, as that would suggest that with the increase in the number of industries (industrial spread), the search cost goes up.

b_3 : We expect a positive sign for this estimate, as that would suggest that with the increase in number of countries (geographical scope), the search cost goes up.

b_4 : This is an interaction variable; hence, a significant result for this would indicate that there are differences between the search costs incurred by any two different governance forms.

b_5 : This is a parameter estimate of the interaction term. As such, the sign of this estimate is difficult to interpret, but a significant estimate would indicate that the increase in search costs due to complexity will be moderated by the governance form. We will interpret these results using graphs.

b_6 : This is a parameter estimate of the interaction term. As such, the sign of this estimate is difficult to interpret, but a significant estimate would indicate that the increase in search costs due to industrial spread will be moderated by the governance form. We will interpret these results using graphs.

b_7 : This is a parameter estimate of the interaction term. As such, the sign of this estimate is difficult to interpret, but a significant estimate would indicate that the increase in search costs due to geographical scope will be moderated by the governance form. We will interpret these results using graphs.

The regression results are presented in Table 13:

Table 13: **Log Search Cost (Man-months) Log(% effort search*no. of people*no.of months) N=345**				
Variable	**Model Name**	**Coeff.**	**t-stat**	**p-value**
LogNoPages	Complexity	0.22166	3.93***	0.0001
LogNoTechAreas	Industrial Spread	0.09594	0.91	0.3618
LogNoCountries	Geographical Scope	0.38520	4.01***	<.0001
LogNoCompanies	Governance Form	0.35441	4.67***	<.0001
LogNoPages*LogNoCompanies	Interaction of Complexity and Governance Form	-0.00948	-0.24	0.8082
LogNoTechAreas*LogNoCompanies	Interaction of Industrial Spread and Governance Form	0.06636	1.19	0.2333
LogNoCountries*LogNoCompanies	Interaction of Geographical Scope and Governance Form	-0.12447	-2.01**	0.0453
Intercept		5.17073	62.76	<.0001
F-statistic		20.27***		
R^2		.2963		
*Note: Significance level: *** = 0.01; ** = 0.05; * = 0.10*				

Table 13: Regression results for the search cost

The R^2 of the model is 0.29. The highly significant model p-value shows that overall, there is some correlation between each independent variable and the dependent variables.

5.3.2.3. Discussion of the results for search cost

The results show that complexity and geographical scope significantly affect the search costs in IT standard setting. As hypothesized, with the increase in complexity, the search cost goes up, and the same is true with the increase in number of countries. The positive and significant LogNoCompanies suggests that different governance forms incur different transaction costs. Finally, the results also show that

the governance form has the ability to moderate the effect of geographical scope on the search cost.

A unit increase in the complexity (log of number of pages ~2.7 pages) increases the log of total search cost by 0.22166 (~1.24 man months), holding all other variables at their means. Similarly, with every unit increase in the log number of countries (~2.7 countries), the search cost goes up by 0.38 (~1.46) man months. Finally, to interpret the interaction term, we plot the graph of the estimated regression function. We select two values of the governance form, a low value (LogNoCompanies=0 or a network with one firm), and a high value (LogNoCompanies=2, or a network of about seven firms), to show differences between the two governance forms. The graph is presented as Figure 6:

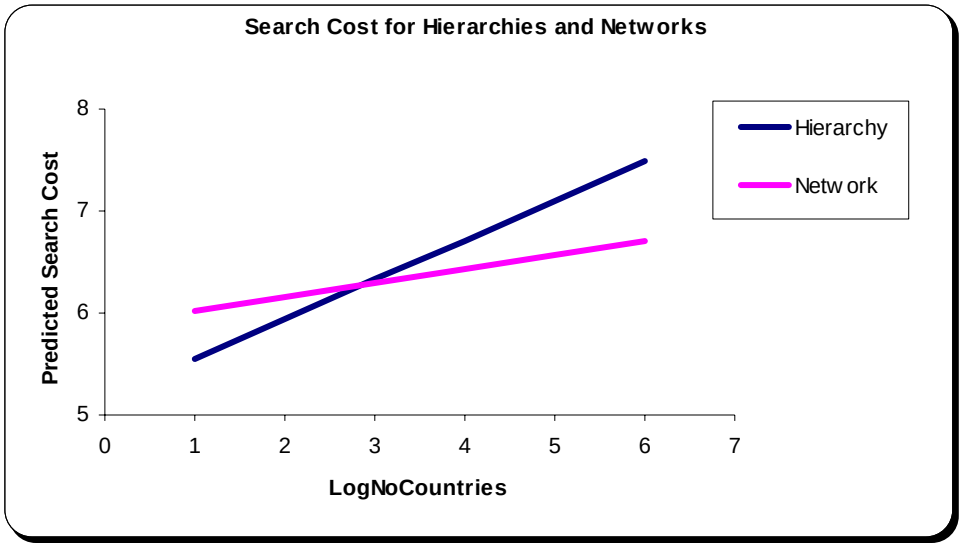

Figure 6: Governance form and search cost with the increase in geographic span

The graph suggests that for a few countries, the hierarchies (or smaller networks) incur a lower search cost. This may be because hierarchies may already

hold all of the patents in their home country where they are developing the standard and, as a result, do not invest in searching. Networks, on the other hand, have to follow formal procedures and thus are more expensive to start with. However, as the number of countries increases, hierarchies have to incur more costs because now, they have to formally search for patents in other countries. Networks benefit because they have members from other countries which help in the search process and thus, the cost goes up much more slowly than it does for hierarchies.

We do not find any support for the effect of industrial spread on search costs, and we also did not find any evidence that the governance form plays any role in it. While the exact reason why this may be the case is unclear, I suspect that the different industries in IT standard setting may be very similar to each other, thus sharing common databases, making the search cost the same as searching a single industry. We also do not find any evidence for the role of governance form in moderating the effect of complexity on search costs. What this suggests is that as the complexity increases, the search costs may be going up at the same rate for both hierarchies and networks. Thus, if both hierarchies and networks require 100 patents, then they are both spending equal time searching for 100 patents. However, since we argued that the diversity in the governance form should help reduce the search costs, we don't see that happening. One possible explanation for this could be that the networks incur a lower search cost because they benefit from the diversity of the people working for them. At the same time, it is also possible that hierarchies save an equal amount by not searching at all. This is a plausible explanation, given the fact that many of people we spoke with advised that the search costs are so high that they rarely search.

Of course, hierarchies may have to pay for this oversight in the future by incurring higher opportunism costs.

Thus, with regards to the search costs, we find that the following hypotheses are supported:

Hypothesis 1a: As the complexity of the IT standard increases, the search cost increases.

Hypothesis 3a: As the geographic span of the IT standard increases, the search cost increases.

Hypothesis 7a: As the geographic span of the IT standard increases, the search cost increases, but it increases more for hierarchies than for networks.

We did not find any support for the following hypotheses:

Hypothesis 2a: As the industry breadth of the IT standard increases, the search cost increases.

Hypothesis 5a: As the complexity of the IT standard increases, the search cost increases, but it increases more for hierarchies than for networks.

Hypothesis 6a: As the industry breadth of the IT standard increases, the search cost increases, but it increases more for hierarchies than for networks.

5.3.3. Regression Analysis – Coordination Costs

5.3.3.1 Model

The model for coordination costs is:

$$\text{TCCoordinationMM} = b_0 + b_1 LogNoPages + b_2 LogNoTechAreas + b_3 LogNoCountries + b_4 LogNoCompanies + b_5 LogNoPages * LogNoCompanies + b_6 LogNoTechAreas * LogNoCompanies + b_7 LogNoCountries * LogNoCompanies + e$$

Where,

b_0: is the intercept term and interpreted as a coordination cost when all other variables are set at their mean.

b_1-b_8: are estimated regression coefficients and measure the size of the effect of the predictor variable on the response variable.

e=error term

We did a log transformation for both dependent and independent variables so that we satisfy the regression assumptions. We also centralize the data so that we can better interpret our results.

5.3.3.2 Estimate interpretation.

b_1 : We expect a positive sign for this estimate as that would suggest that with the increase in number of pages (complexity), the coordination cost goes up.

b_2 : We expect a positive sign for this estimate as that would suggest that with the increase in the number of industries (industrial spread), the coordination cost goes up.

b_3 : We expect a positive sign for this estimate as that would suggest that with the increase in number of countries (geographical scope), the coordination cost goes up.

b_4 : This is an interaction variable; hence, a significant result for this would indicate that there are differences between the coordination costs incurred by any two different governance forms.

b_5 : This is a parameter estimate of the interaction term. As such, the sign of this estimate is difficult to interpret, but a significant estimate would indicate that the increase in coordination costs due to complexity will be moderated by the governance form. We will interpret these results using graphs.

b_6 : This is a parameter estimate of the interaction term. As such, the sign of this estimate is difficult to interpret, but a significant estimate would indicate that the increase in coordination costs due to industrial spread will be moderated by the governance form. We will interpret these results using graphs.

b_7 : This is a parameter estimate of the interaction term. As such, the sign of this estimate is difficult to interpret, but a significant estimate would indicate that the increase in coordination costs due to geographical scope will be moderated by the governance form. We will interpret these results using graphs.

The regression results are presented in Table 14:

Table 14: **Log Coordination Cost (Man Months) = Log(% effort coordination*no. of people*no.of months)**				
Variable	**Model Name**	**Coeff.**	**t-stat**	**p-value**
LogNoPages	Complexity	0.10785	1.24	0.2170
LogNoTechAreas	Industrial Spread	0.43346	2.67***	0.0080
LogNoCountries	Geographical Scope	0.27689	1.87*	0.0630
LogNoCompanies	Governance Form	0.18808	1.60	0.1097
LogNoPages*LogNoCompanies	Interaction of Complexity and Governance Form	-0.10095	-1.67*	0.0952
LogNoTechAreas*LogNoCompanies	Interaction of Industrial Spread and Governance Form	-0.05844	-0.68	0.4969
LogNoCountries*LogNoCompanies	Interaction of Geographical Scope and Governance Form	0.15752	1.65	0.1009
Intercept		2.58211	20.27***	<.0001
F-statistic			5.57***	
R2			0.1037	
*Note: Significance level: *** = 0.01; ** = 0.05; * = 0.10*				

Table 14: Regression results for the coordination costs

The R^2 of model is 0.10. The highly significant model p-value shows that overall, there is some correlation between each independent variable and the dependent variables.

5.3.3.3 Discussion of the results for coordination costs

The results show that industrial spread and geographical scope significantly affect the coordination costs in IT standard setting. As hypothesized, with an increase in the number of industries represented in the standard, the coordination costs go up, and the same holds true for the increase in the number of countries; the search cost goes up, and the same is true with the increase in number of countries. The LogNoCompanies misses the significant mark by 0.0097. While this means that we failed to find evidence of difference in coordination form between different

governance forms, there is mild evidence that there may be some differences. The reason for these weak results may be similar to what we discussed in the search costs section. Hierarchies and networks may be achieving similar coordination costs by doing (or not doing) some activities.

A unit increase in the industrial spread (log number of technical areas ~2.7 pages), increases the log of total coordination costs by 0.43346 (~1.54 man months), holding all other variables at their means. Similarly, with every unit increase in the log number of countries (~2.7 countries), the coordination costs go up by 0.27689 (~1.31) man months.

Finally, to interpret the significant interaction term, we plot the graph of the estimated regression function. The interaction between the effect of complexity and coordination costs is significant at $p < .10$. This suggests that the effect of complexity on coordination costs is dependent on the governance form. We select two values of the governance form, a low value (LogNoCompanies=0, or a network with one firm) and a high value (LogNoCompanies=2, or a network of approximately seven firms), to show the differences between the two governance forms. The graph is presented as Figure 7:

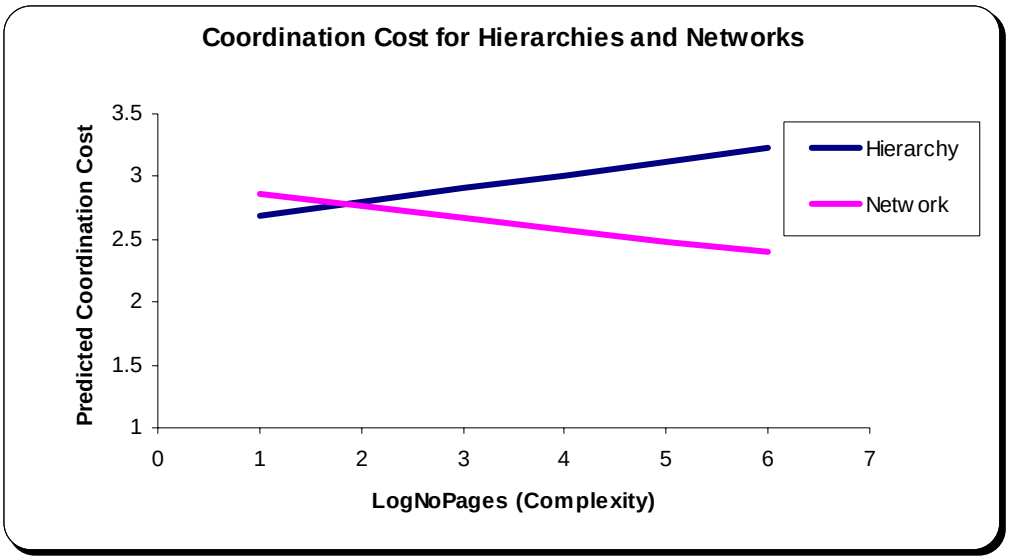

Figure 7: Governance form and coordination costs with the increase in complexity

Figure 7 suggests that for low complexity, the hierarchies (or smaller networks) incur a lower coordination cost. In other words, to start with, hierarchies are better off than networks. However, as the complexity increases, the bigger the network, the better it is in terms of managing coordination costs. As a matter of fact, after some level of complexity, the coordination costs for bigger networks go down. This is because for lower complexity, hierarchies are quick to write up contracts, but networks have to go through many formal processes to get everything in place. Once the systems are in place, the contracting costs for networks are negligible as compared to hierarchies, which have to write up new contracts every time.

We do not find any support for the effect of complexity on the coordination costs, even though the interaction term was significant. What this suggests is that with the increase in complexity, the coordination costs do not go up. However, given the level of complexity, different governance forms are able to mitigate some of these

costs. This can occur if most of the patents are held by a few firms. In that case, the increase in complexity will not increase coordination costs, but for networks, each additional member follows the same contracts, thereby reducing costs for the networks. We also did not find any support for geographical scope affecting the coordination cost. If the number of countries where the patents are held increases, the corresponding increase in coordination costs is not significantly different from zero. This is surprising, and we are unsure as to why this may be the case. The only conclusion we can reach is that if multinational firms across the boundaries hold the majority of the patents, it would thereby reduce the costs for hierarchies. Networks, at the same time, do not incur coordination costs because the members of the network may be holding the majority of the patents.

We also do not find any evidence in support of governance form moderating the relationship between geographical scope and coordination costs or governance form moderating industrial spread and coordination costs. Again, the exact reasons why this may be the case is unclear, but the likely reason could be that few firms own all the patents, thereby making the role of governance form iffy.

Thus, with regards to the coordination costs, we find that the following hypotheses are supported:

Hypothesis 2b: As the industry breadth of the IT standard increases, the coordination costs increase.

Hypothesis 3b: As the geographic span of the IT standard increases, the coordination costs increase.

Hypothesis 5b: As the complexity of the IT standard increases, the coordination costs increase, but they increase more for hierarchies than for networks.

We did not find any support for the following hypothesis:

Hypothesis 1b: As the complexity of the IT standard increases, the coordination costs increase.

Hypothesis 6b: As the industry breadth of the IT standard increases, the coordination costs increase, but they increase more for hierarchies than for networks.

Hypothesis 7b: As the geographic span of the IT standard increases, the coordination costs increase, but they increase more for hierarchies than for networks.

5.3.4. Logistic Regression Analysis – Opportunism Cost

5.3.4.1 Model

Since the dependent variable (TCOpportunism) is an ordinal categorical variable with five levels (1=high likelihood of getting sued and 5=no likelihood of getting sued), we use ordinal logistic regression to model opportunism cost.

Logistic regression uses maximum likelihood estimation to calculate the probability of being in a particular category. It calculates the change in log odds of being in one category over the other. Logistic regression is particularly suitable in this cases since it does not assume linearity amongst the dependent and independent variables and is robust when the assumptions are violated.

The model for opportunism cost is:

$$TCOpportunism = \frac{e^{\begin{array}{l}b_0+b_1 LogNoPages+b_2 LogNoTechAreas+b_3 LogNoCountries+b_4 Substitutability+b_5 LogNoCompanies+\\ b_6 LogNoPages*LogNoCompanies+b_7 LogNoTechAreas*LogNoCompanies+b_8 LogNoCountries*LogNoCompanies+\\ b_9 Substitutability*LogNoCompanies+e\end{array}}}{1+e^{\begin{array}{l}b_0+b_1 LogNoPages+b_2 LogNoTechAreas+b_3 LogNoCountries+b_4 Substitutability+b_5 LogNoCompanies+\\ b_6 LogNoPages*LogNoCompanies+b_7 LogNoTechAreas*LogNoCompanies+b_8 LogNoCountries*LogNoCompanies+\\ b_9 Substitutability*LogNoCompanies+e\end{array}}}$$

Where,

b_0: are the estimated log odds of the left out category versus cumulative probabilities of all other categories when all other variables are set at mean.

b_1-b_8: are the increase in the log odds ratio for a unit increase in the corresponding independent variable.

e=error term

5.3.4.2 Discussion of the results for opportunism cost

The logistic regression results are presented Table 15:

Table 15**. Logistic Regression Results Interaction with Orgn Form as measured by number of companies**

Opportunism Cost (Likelihood getting sued) 1=not likely at all 5=highly likely			
Variable	**Model Name**	**Coeff.**	**Chi-Sq**
LogNoPages	Complexity	-0.1930	5.7067**
LogNoTechAreas	Industrial Spread	-0.1776	1.4771
LogNoCountries	Geographical Scope	-0.1900	1.9480
Substitutability	Substitutability	0.1105	1.0005
LogNoCompanies	Governance Form	-0.1061	0.9140
LogNoPages*LogNoCompanies	Interaction of Complexity and Governance Form	0.1126	3.5902*
LogNoTechAreas*LogNoCompanies	Interaction of Industrial Spread and Governance Form	0.0134	0.0285
LogNoCountries*LogNoCompanies	Interaction of Geographical Scope and Governance Form	-0.2733	8.7835***
Substitutability*LogNoCompanies	Interaction of Substitutability and Governance Form	0.2104	4.8505**
Intercept 5		3.0750	142.5229***
Intercept 4		2.5387	145.9947***
Intercept 3		1.3806	89.2861***

Intercept 2	0.1454	1.4264
Chi-Square	38.8618***	
*Note: Significance level: *** = 0.01; ** = 0.05; * = 0.10*		

Table 15: Regression results for the opportunism cost

The pseudo R^2 of the model is 0.1065. The highly significant model χ^2 for the likelihood ratio and wald test shows that overall, there is some relationship between at least one independent variable and the dependent variables.

The score test for proportional odds assumption is significant at the $p < 0.01$ level, suggesting that there is a violation of parallel slope assumption. As a result, we should be careful in using the ordinal logit model which makes the parallel slope assumption. However, as all models are a simplification of reality and often violate assumptions, this model too, is a simplification of what is happening in the real world. There are alternate models that we can use which are less susceptible to violation, such as multinomial logit regression; however, we stick to ordinal logistics for the following reason. Multinomial regression does not assume ordering in the categorical variable. As a result, there is considerable information that is lost. In our dependent variable, there is a definitive ordering of responses, and there is no reason a priori to believe that the categories do not make sense. Furthermore, we would like to be able to make predictions about the increase in likelihood of being in the riskier category, given the increase in variables of interest. This cannot be achieved using multinomial logit regression. Moreover, we wanted to retain the ability to be able to calculate the expected value of the likelihood of getting sued and how it changes with the change in variables, and for this, it is important that we retain the ordinal nature of the response variable.

To evaluate the results, the left-out category is the lowermost (or category 1), which corresponds to the least likelihood of getting sued. The positive significant coefficient of lognopages suggests that with the increase in complexity, the likelihood of being in a higher category (or likelihood of getting sued) goes up. Specifically, a unit increase in the complexity of the standard (~2.7 pages) decreases the odds of being in the next higher category by $e^{-0.1930} = 0.8244$ or 17.56%, holding all other variables at their mean.

Finally, to interpret the significant interaction term, we plot the graph of estimated logit regression functions. We calculate the expected value of the likelihood of getting sued to make the graphs. The expected value is calculated using the following procedure:

There are five levels of dependent variable 1 (no likelihood of getting sued) – 5 (highly likelihood of getting sued). Corresponding to five levels, we calculate the probabilities (P_1, P_2, P_3, P_4, P_5) of being in a particular category using the following logit function.

The logit function is defined as:

$$\log\left(\frac{p_1}{1-p_1}\right) = b_{01} + b_i X_i \Rightarrow p_1 = \frac{e^{b_{01}+b_i X_i}}{1+e^{b_{01}+b_i X_i}}$$

$$\log\left(\frac{p_1+p_2}{1_1-p_1+p_2}\right) = b_{02} + b_i X_i \Rightarrow p_2 = \frac{e^{b_{02}+b_i X_i}}{1+e^{b_{01}+b_i X_i}} - p_1$$

Finally,

$$\log(\frac{1-p_5}{p_5}) = b_{04} + b_i X_i \Rightarrow p_4 = \frac{e^{b_{04}+b_i X_i}}{1+e^{b_{01}+b_i X_i}} - p_1 - p_2 - p_3$$

Once we have the probabilities of being in a particular category, we multiply it by the value of the category to get the expected value for a particular set of independent variables.

The following graph (Figure 8) shows the change in the expected value of opportunism with increased complexity. The graph suggests that with the increase in complexity, the expected value of opportunism cost goes up for hierarchies or smaller networks, but not for bigger networks. For two large networks, the cost goes down more for a bigger network than a relatively smaller network. Thus, with an increase in complexity, hierarchies are more likely to get sued than networks. As a matter of fact, the opportunism costs for a network even go down. This may be due to the fact that when more firms join the network, it increases the bargaining power or influence of the network over other entities, which substantially reduces the opportunism cost.

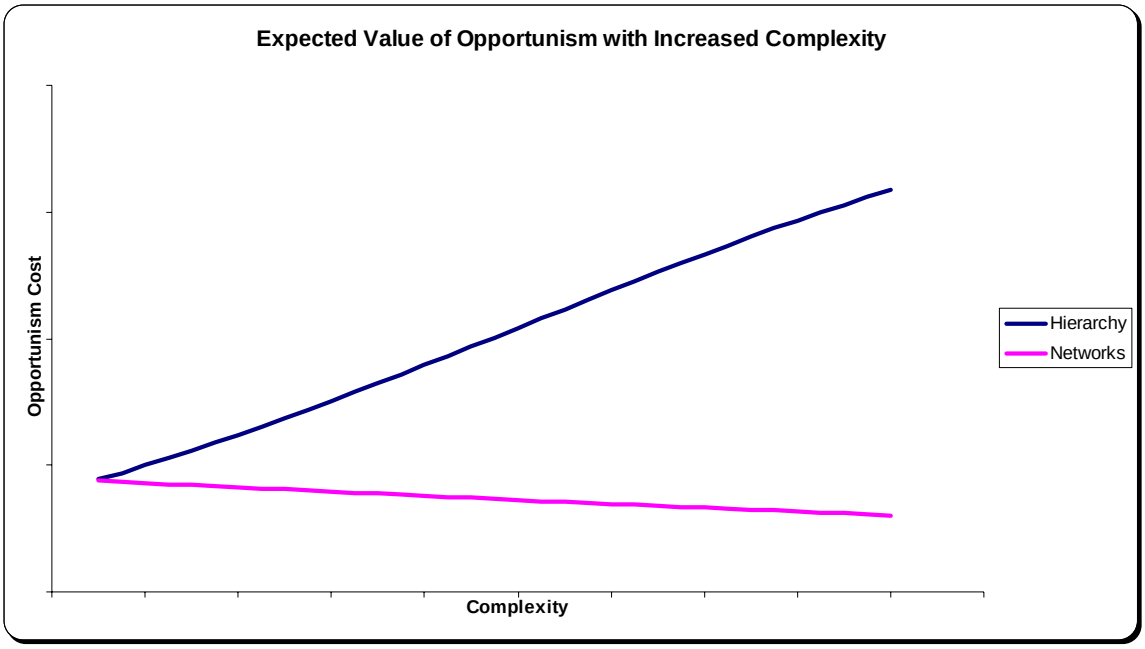

Figure 8: Governance form and opportunism cost with the increase in complexity

The following graph (Figure 9) shows the change in expected value of opportunism with increase in the geographical scope. The results here contradict our hypothesis that with the increase in geographical scope, opportunism increases more for hierarchies than for networks. This graph suggests that with the increase in geographical scope, the opportunism increases more for networks than for hierarchies. Why this may be the case is an interesting question that needs further exploration. However, to argue, this can be the case if the firms involved in hierarchical standard setting are very large multinational firms with patents all over the world, and firms involved in network standard setting are small firms limited to a geographical region. The large multinational firm can leverage their global patent portfolio to develop hierarchical standards as compared to small firms which rely on external sources.

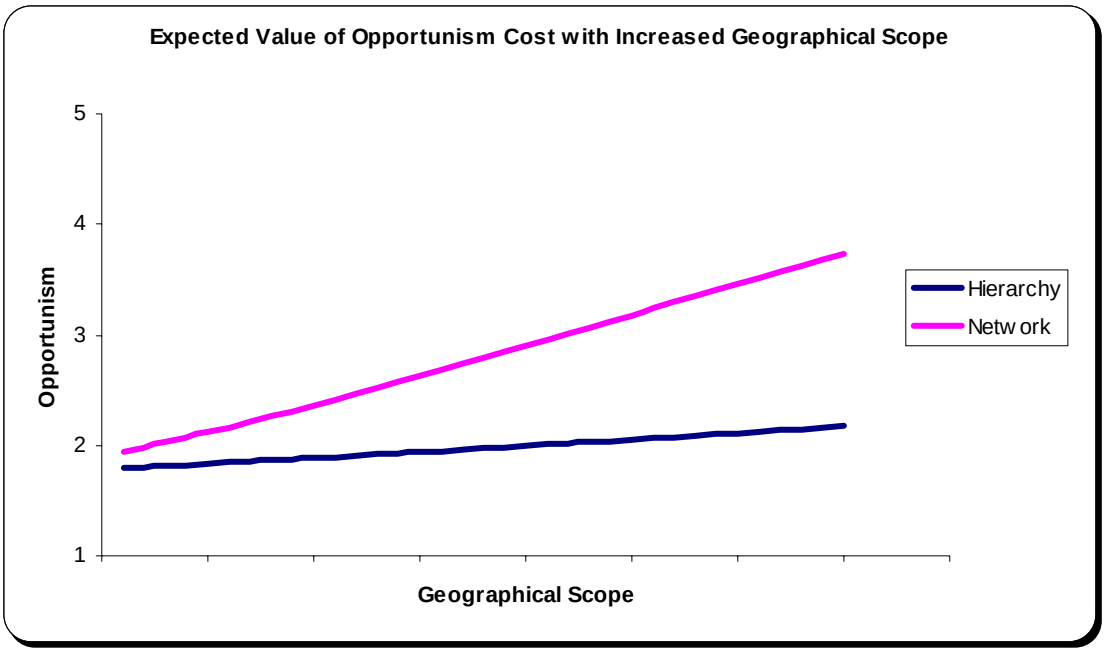

Figure 9: Governance form and opportunism cost with the increase in geographical scope

Finally, the last significant interaction terms shows the change in expected value of opportunism with the change in the substitutability of patents in the standard. The results (Figure 10) show that with the decrease in substitutability, the opportunism cost almost remains the same for hierarchies, but decreases for networks. The decrease in substitutability means that the standard is less useful in the absence of the patent. For hierarchies, the opportunism is higher, signifying that they are more susceptible to opportunistic behavior of the patent holder than networks.

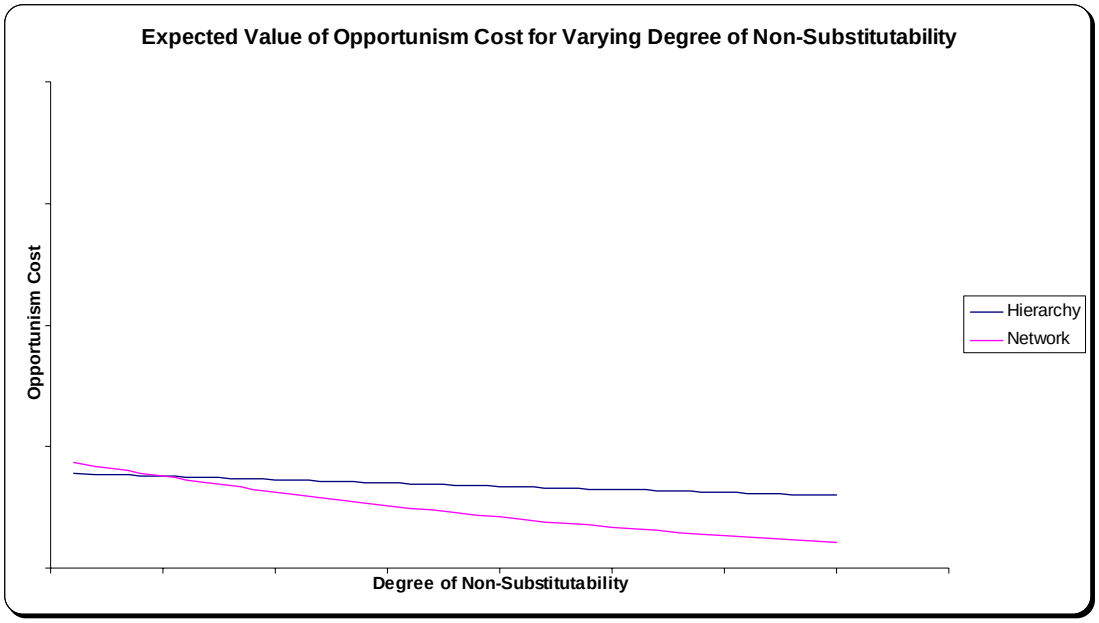

Figure 10: Governance form and opportunism cost with the decrease in substitutability

We do not find any support for the effect of industrial spread and geographical scope on opportunism cost. This can happen if the industries are closely related and there are multinationals involved in the standard setting. We also do not find any support for governance form moderating the effect of industrial spread on opportunism cost. This again can be due to the fact that the industries involved in the standard setting are closely related.

Thus, with regards to the opportunism cost, we find that the following hypotheses are supported:

Hypothesis 1c: As the complexity of the IT standard increases, the opportunism cost increases.

Hypothesis 5c: As the complexity of the IT standard increases, the opportunism cost increases, but it increases more for hierarchies than for networks.

Hypothesis 7c: As the geographic span of the IT standard increases, the opportunism cost increases, but it increases more for hierarchies than for networks.

Hypothesis 8: As the degree of substitutability of an IP increases in a standard, the opportunism cost decreases; however, it decreases more for networks than for hierarchies.

The following hypotheses were not supported:

Hypothesis 2c: As the industry breadth of the IT standard increases, the opportunism cost increases.

Hypothesis 3c: As the geographic span of the IT standard increases, the opportunism cost increases.

Hypothesis 4: As the degree of substitutability of an IP increases in a standard, the opportunism cost decreases.

Hypothesis 6c: As the industry breadth of the IT standard increases, the opportunism cost increases, but it increases more for hierarchies than for networks.

5.4. Summary of Discussion.

Overall, we find support for nine of our hypotheses and did not find support for ten. One of the hypotheses was supported in the opposite direction. The results are presented in the Table 16:

No	Hypothesis	Results	p-value
1a.	As the complexity of the IT standard increases, the search cost increases.	Supported	0.0001***
1b.	As the complexity of the IT standard increases, the coordination cost increases.	Not Supported	0.2170
1c.	As the complexity of the IT standard increases, the opportunism cost increases.	Supported	0.0169**
2a.	As the industry breadth of the IT standard increases, the search cost increases.	Not Supported	0.3618
2b.	As the industry breadth of the IT standard increases, the coordination cost increases.	Supported	0.0080***
2c.	As the industry breadth of the IT standard increases, the opportunism cost increases.	Not Supported	0.2242
3a.	As the geographic span of the IT standard increases, the search cost	Supported	<0.0001***

	increases.		
3b.	As the geographic span of the IT standard increases, the coordination cost increases.	Supported	0.0630*
3c.	As the geographic span of the IT standard increases, the opportunism cost increases.	Not Supported	0.1628
4.	As the degree of substitutability of an IP increases in a standard, the opportunism cost decreases.	Not Supported	0.3172
5a.	As the complexity of the IT standard increases, the search cost increases, but it increases more for hierarchies than for networks.	Not Supported	0.8082
5b.	As the complexity of the IT standard increases, the coordination cost increases, but it increases more for hierarchies than for networks.	Supported	0.0952*
5c.	As the complexity of the IT standard increases, the opportunism cost increases, but it increases more for hierarchies than for networks.	Supported	0.0581*
6a.	As the industry breadth of the IT standard increases, the search cost increases, but it increases more for hierarchies than for networks.	Not Supported	0.2333
6b.	As the industry breadth of the IT standard increases, the coordination cost increases, but it increases more for hierarchies than for networks.	Not Supported	0.4969
6c.	As the industry breadth of the IT standard increases, the opportunism cost increases, but it increases more for hierarchies than for networks.	Not Supported	0.8660
7a.	As the geographic span of the IT standard increases, the search cost increases, but it increases more for hierarchies than for networks.	Supported	0.0453**
7b.	As the geographic span of the IT standard increases, the coordination cost increases, but it increases more for hierarchies than for networks.	Not Supported	0.1009
7c.	As the geographic span of the IT standard increases, the opportunism cost increases, but it increases more for hierarchies than for networks.	Opposite support for hierarchies	0.0030***
8.	As the degree of substitutability of an IP increases in a standard, the opportunism cost decreases; however, it decreases more for networks than for hierarchies.	Supported	0.0276**
Total	**Supported**	9	
	Not Supported	10	
	Supported in opposite direction	1	
*Note: Significance level: *** = 0.01; ** = 0.05; * = 0.10*			

Table 16: Hypothesis and Results

The mixed results from our analysis paint a very interesting picture of the state of standard setting under the current patent regime. Support of nine of our hypotheses and one hypothesis in the opposite direction suggests that there are significant transaction costs of the nature of search, coordination, and opportunism. At the same time, failing to find evidence for the other ten hypotheses suggests that there is a great deal more going on that needs further investigation.

The interpretation for the first four sets of hypotheses is simple and straightforward. With one unit of increase in the measure of response variables, holding the moderator (the number of companies) and other variables at their mean, the transaction cost (search or coordination cost) goes up by the estimated coefficient of the predictor variable. For the opportunism, we are using logit function and hence, we do not discuss means but the likelihood of being in the higher category. So in the case of opportunism, with one unit of increase in the measure of predictor variables, holding everything else at the mean, the likelihood of being in the higher category is given by logit odds, which is equal to e^{β_k} where β_k is the parameter estimate for the response variable.

The more interesting findings are in the interaction terms, which also form the core of this thesis. Do governance forms matter? The results show that how the transactions are governed makes a difference in how much cost is incurred. With respect to the search cost, we find that hierarchies are better than networks when the number of countries where patents are held is small; i.e., the geographical scope is limited. However, this advantage is soon lost when the geographical scope expands

and the network becomes more attractive. We do not find evidence for the governance form moderating the effect of complexity and industrial spread on the search cost. We attribute this to the following. Since the search costs are so high, it is possible that hierarchies do not perform any searches, saving themselves the search costs. As a result, they are able to match the costs incurred by the networks. However, this can result in opportunism later for a hierarchy, which is evident from the support for our hypothesis 5c, which states that as the complexity increases, the opportunism increases more for hierarchies than for networks.

With regards to the coordination costs, we find that hierarchies are again better than networks for simpler standards with fewer methods. Again, this advantage is lost as the complexity of the standard increases and networks become more attractive. We do not find evidence that the governance form moderates the effect of industry breadth and geographical scope on the coordination costs. This is to say that there are no differences in the transaction costs incurred by hierarchies or by networks. Again, this could be because hierarchies avoid coordination costs by deliberately ignoring the patents in their search process and thus avoiding the cost to negotiate and contract, and networks avoid these costs by standardizing on contracting terms and forming patent pools.

Another instance where hierarchies and networks incur similar coordination costs across industrial spread and geographical scope are when the majority of the patents are owned by the hierarchy across the vertically integrated company or across its various subsidiaries across the world. This helps hierarchies to reduce their

coordination costs. Networks achieve the same results by having participants from these different industries or different countries.

With regards to opportunism, we find that networks overall are better when dealing with the complexity and non-substitutability of the patents, and hierarchies are better when dealing with the geographic span of the standard. We do not find support for governance form affecting the impact of industrial spread on the opportunism cost. A summary of which governance form is better in which case is summarized in Table 17:

Advantage		**Search cost**	**Coordination cost**	**Opportunism cost**
Complexity	**Low**		Hierarchies	Networks
	High		Networks	Networks
Industrial Spread	**Low**			
	High			
Geographical Scope	**Low**	Hierarchies		Hierarchies
	High	Networks		Hierarchies
Substitutability of patent	**Low**			Networks
	High			Hierarchies

Table 17: Relative advantage of Hierarchy and Network

Thus, we see that hierarchies are better than networks in some cases, and vice versa.

CHAPTER VI: CONCLUSION, LIMITATIONS, AND DIRECTIONS OF FUTURE RESEARCH

6.1. Overview

In this chapter, we conclude the study by discussing our findings. We also provide limitations and directions of future research.

6.2. Conclusion

Our analysis shows that both hierarchies and networks offer some benefits over each other under the given circumstances. These differences are very important and have both theoretical and practical implications. This is because the firm developing the standard cannot control the characteristics of the bundle, but what they can control is the governance form. By selecting an appropriate governance form for their standards, the firms cannot only avoid costly patent litigation, but also, standard wars. Of course, the firms can also use this model to calculate their costs and their likelihood of getting sued and decide, based on their cost benefit analysis that they still want to develop the standard hierarchically. As Dranov and Gandal put it, "A monopoly in the bush is often worth more than an oligopoly in the hand" (Dranove and Gandal 2003).

Our model also explains why we still see both hierarchies and networks in the standard-setting environment. We show that hierarchies are particularly beneficial if the standard is not very complicated, both in terms of number of methods and the geographical scope. However, with time, the standards are becoming more complicated, and IP issues are becoming more prominent. Under such circumstances, networks are preferred over hierarchies. Out of the three costs identified, I believe that the opportunism cost is the most problematic. If there were no opportunism, the

search and coordination would be redundant. As a result, more weight should be provided to opportunism when we evaluate our models. Thus, we conclude that hierarchies are preferred when the geographical scope of the standard is high and the substitutability of the patents in the standard is high. For cases where standards are complex and there are no easily implementable substitutes available, networks are almost always preferred.

One conclusion that comes out of the analysis is that to begin with, hierarchies are cheaper than networks. Since we measure transaction costs in terms of time required to develop the standard, this means that for lower levels of complexity, industrial and geographical scopes, hierarchies are much faster than networks. This is because hierarchies work with the same objective and the differences are resolved by fiat. Thus, the initial coordination and opportunism costs are low, which results in faster standards development. Moreover, the standards initiative may start with pieces of technology that the hierarchy already owns, which reduces the search cost for small, less complex standards. Networks, on the other hand, have participants with differing objectives coming from different industries and different countries. However small the standardization effort may be, there will always be an initial cost incurred in organizing the group, standardizing the contracts, getting the regulatory approvals, and agreeing upon the standard. Once the systems are in place, this initial investment greatly enhances the ability of a network to mitigate future occurrences of these costs. For example, once the contracts are standardized, no further negotiations occur for additional firms that want to join the network. This substantially reduces the marginal costs of increasing complexity, industrial spread, geographical scope,

and substitutability. This outcome of our analysis has been presented often in various papers and books on standard setting. However, such papers have only provided anecdotal evidence. This research provides empirical evidence for the same.

Another conclusion that came out of our analysis is the lack of support for the hypothesis that the governance form influences the impact of the complexity of the standard and the geographical scope on search and coordination costs. While the exact reasons for this are unknown, based on our conversations with industry experts, it seems likely that the search costs and coordination costs are so high that some firms chose to ignore this entire step altogether. This can be a costly mistake for the future and may result in expensive lawsuits. Further support to this argument is visible in the support for our hypothesis on opportunism.

Legal IP issues are fast becoming a major concern of most IT departments. There is a conscious and deliberate move towards IP harvesting within companies big and small. This is because IP represents hidden treasure for the firms holding it which, if harvested properly, can result in substantial profits for the firms (Rivette and Kline 2000). But apart from legitimate use and licensing, there are firms that exist whose sole purpose is to create a technology-blocking patent portfolio which then can be enforced to drive revenue. Firms like Acacia, Intellectual Ventures, NTP and Forgent are said to pursue an activity called patent trolling (AssociatePress 2006a; AssociatePress 2006b; Orey 2006), which means that they acquire patents which they do not use themselves - in fact, they frequently produce no product whatsoever and own no assets other than patents - and sue other firms for royalties. Firms settle,

often without a fight, because patent litigation costs several million dollars. The returns can be huge. Forgent makes over $100 million in revenues from royalties, and NTP recently settled a suit for $600 million. Patent trolls cause serious problems for technology developers because they have no production that can be held hostage, so there is no ability of other patent owners to exercise power over them. "Single patents with great blocking power could be an expensive nuisance to a large company, especially if held by inventors with no manufacturing capacity who are thus invulnerable to retaliation through counter-blocking" (Granstrand 1999).

Search is also becoming more complicated. As the number of patents granted increased from 60,000 in 1980 to 165,000 in 2005 and close to a million applications pending as of Sept. 30, 2005 (Source: USPTO), the difficulty in locating relevant patents has also increased. On top of that, as the volume of relevant information has increased, due, in large part, to the internet, searching prior art has become more difficult. In addition, the international nature of technology and IP is coming into play, making search much more global. We recently spoke to a technology developer group which was busy trying to track down the owner of an Australian patent. Moreover, given the potential gains from having a technology implemented which contains a submarine patent, patentees have an incentive to obfuscate their patents.

The Supreme Court and the United States Congress have taken notice of the extreme implications and the cost of the IP infringement on businesses and the society. The Supreme Court has admitted cases and issued guidelines with respect to two highly controversial aspects of IP infringement: the issue of obviousness, and the issue of permanent injunction.

On the issue of obviousness, the Supreme Court issued a judgment in the case of *KSR v. Telefax (April 30, 2007)* that will potentially set precedence in evaluating and even challenging the obviousness of all current and future patents. The Supreme Court ruled in the favor of KSR and loosened the test of obviousness as interpreted by the circuit court of appeals for patents. It will now be difficult to apply for patents or easier to challenge patents granted on inventions that are mere combination of existing technologies. This will effectively reduce the problems of patent thickets and patent trolling where small increments in technology were patented to surround the original patent making it useless.

On the issue of permanent injunction, the Supreme Court in a case related to *eBay v. MercExchange,* passed a landmark judgment on May 15, 2006, making permanent injunction a thing of passé. Traditionally, the circuit court of appeals has issued an automatic injunction on the technology infringing on a patent. However, the Supreme Court ruled that the injunction should not be automatically issued in the case of patent infringement but should be based on the four factors traditionally used to determine the appropriateness of the infringement. As a result of this judgment, the negotiating power of the, so called patent trolls, will be greatly diminished.

U.S. Congress, on its end, has introduced the, "Patent Reforms Act of 2007", to update the current patent laws. The bill, if passed, would change the U.S. patent system from the current "first to invent" system to the "first to file" system. It would also make changes in how damages are calculated incase of infringement. Critiques however argue that first to file will start a new race for filing patents and will

diminish the quality of patents applied. This is because, in the race to apply for patents, the patentees will ignore the prior art resulting in lower quality applications.

One other observation we can offer is that technology firms are patenting more now than they have in the past (Bessen and Hunt 2004; Kortum and Lerner 1999; Rivette and Kline 2000). For example, Microsoft only had one patent in 1990, close to 800 patents in 2000 (Rivette and Kline 2000) p.4, and 3,955 patents in 2005, with another 3,400 patents pending (Stross 2005). The more patents there are, the more potential for infringement there is. This notion of patent thicket is becoming increasingly important in law and economics (Shapiro 2001). Our analysis suggests that this should increase the relative benefits of using networks over hierarchies. This observation seems to be borne out by the rise of networks.

We hope that both practitioners and researchers will consider the legal aspects of the technology development process and recognize that a bundle of IP has unique characteristics which are different than either physical property or single instances of IP. In the coming years, these issues will move to the fore in technology development, and we need to be prepared.

6.3. Limitations

Like every other study, the current study was done under the constraint of several limitations. First and foremost is the generalizability of the findings. Since IP issues are very near and dear to a firm's strategic plans, it was hard to collect data for proprietary standards. We were only able to target the people who listed their contact information online through public archives of standard setting. These are the people

who actively participate in open or network standard setting. As a result, our data was skewed towards responses from networks more so than hierarchies.

Second, since the participation in the survey was purely voluntary, there may be some response bias, especially from people who feel strongly about the patents issue in the IT standard setting.

Third, the study is the first of its kind, and there is much room for improvement in terms of defining constructs and their measures. There exists no standard terminology for methods that exist in the standards. Since the data for this study is collected using respondents' subjective measures, any shortcomings in defining the measuring of the construct will be reflected in the subjective interpretation of respondents. While every effort was made to avoid this problem, we believe there is still room for improvement.

Fourth, since the responses were anonymous, there is no way for us to find out if multiple people working on the same standard responded, creating the problem of repeated measure. To avoid this, we selected as many different standards as possible and did not identify to the respondent the standard that we selected.

6.4. Directions of Future Research

This is one of the first researches in the field of information systems that considers the intellectual property issues in technology standard setting. As a result, there is a tremendous opportunity for expanding the current research and new research. First and foremost, the current research raises more questions, such as how opportunism is affected by search and coordination efforts.

The second is to extend this research by studying other factors in standards development. The coordination costs themselves can be divided into two – external coordination costs with patent holders and internal coordination costs of organizing the network. It will be interesting to see if one is more significant than the other in determining the governance form.

Finally, in this research, we only consider two ideal forms of governance in very simple terms; hierarchies and networks. Future work should consider more characteristics of the ideal types, thereby creating more ideal types. Networks in particular can be divided into several sub-forms. There are consortia, which may include only the IP holders, and there are technology development authorities, like IEEE, who may include other interested parties. Moreover, the motivations may be different among different organizations. For example, a government body may want to develop fair technologies, while an engineering body may want to develop high-quality technologies, and a consortium may want to develop profitable technologies. These different motivations can severely modify the costs associated with each form. We offer a basic model from which this analysis can proceed.

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APPENDIX A

Complete Survey

1. Email sent to respondents.

Dear Mr./Ms./Dr. (Respondent's Last Name),

My name is Nitin Aggarwal, and I am a Ph.D. student at Texas Tech University. As a part of my thesis, I am trying to study the antecedents of a successful standard setting process. For this, I request you to kindly take a short survey that should not take more than 4-5 minutes of your time. Your responses will be anonymous. There is a progress bar at the bottom of the survey which will show you how much of the survey is finished.

You can access the survey by following this link:
http://surveys.irim.ttu.edu/surveys/EEJNBN

If you decide to participate or not to participate in this survey, please reply to this message once so that I don't send you any reminders. As the responses are anonymous, there is no way of finding out who participated in the survey.

I know you are very busy and that you must be getting a lot of requests like this, which sometimes can be annoying. However, the nature of good research is such that it can only be useful if it is validated by industry experts such as yourself. This research is very important to me and hopefully to my peers in the industry and academics. I sincerely request you to give me 5 minutes of your time and complete this survey. It will mean a lot to me.

Also, as an active participant in the standard setting process, you might be interested in a short summary of the results and what they mean. I will be happy to provide those to you.

There are only few people knowledgeable enough to answer these questions. It is important that I get as many responses as possible. If you have any questions or concerns, please do not hesitate to contact me on my cell at 806.928.1609 or email me at nitin.aggarwal@ttu.edu. I will try to answer them to the best of my ability.

Once again, thanks for taking time out and considering my request.

Best regards,

Nitin Aggarwal | Ph.d. student
Information Systems and Quantitative Sciences
Rawls College of Business | Texas Tech University
P.O. Box 42101 | Lubbock | TX 79409-2101
office: 510 | email: naggarwal@ba.ttu.edu
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2. Reminder email sent to respondents.

Dear Mr./Ms./Dr. (Respondent's Last Name):

About a month ago, I sent out a request to participate in my thesis survey. I noticed that I haven't heard back from you. I sincerely request you to kindly spare five minutes of your time to fill out the survey. If you have already filled out this survey, I apologize for the reminder. Kindly disregard this email. I will not send out any more reminders for this batch, unless I make a horrible error.

You can fill out the survey by following the link below.

I have also enclosed the original email below for your reference. I greatly appreciate your time and effort..

<Original Message>

Dear Mr./Ms./Dr. (Respondents Last Name):

My name is Nitin Aggarwal, and I am a Ph.D. student at Texas Tech University. As a part of my thesis, I am trying to study the antecedents of a successful standard setting process. For this, I request you to kindly take a short survey that should not take more than 4-5 minutes of your time. Your responses will be anonymous. There is a progress bar at the bottom of the survey which will show you how much survey is finished.

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I know you are very busy and that you must be getting a lot of requests like this, which sometimes can be annoying. However, the nature of good research is such that it can only be useful if it is validated by industry experts such as yourself.. This research is very important to me and hopefully to my peers in the industry and academics. I sincerely request you to give me 5 minutes of your time and complete this survey. It will mean a lot to me.

Also, as an active participant in the standard setting process, you might be interested in a short summary of the results and what they mean. I will be happy to provide those to you.

There are only a few people knowledgeable enough to answer these questions. It is important that I get as many responses as possible. If you have any questions or concerns, please do not hesitate to contact me on my cell at 806.928.1609 or email me at nitin.aggarwal@ttu.edu. I will try to answer them to the best of my ability.

Once again, thanks for taking time out and considering my request.

Best regards,

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3. Questionnaire.

Welcome to the research project on IT standard setting. This short survey will only take 4-5 minutes of your time. If you have questions before or after the survey, please feel free to send us an email. We want to thank you for taking time out and filling out our survey.

We are interested in understanding the process that goes on behind the writing of technical specifications. Your individual responses will be kept confidential and used as an aggregate with all other responses.

If you would like to get a summary of the results of the survey, please check the boxes below.

☐ I want to get a summary of the results.

Email Address: _____. This will be stored in a separate database to maintain anonymity.

Note: Please note that this is academic research done as a part of my Ph.D. thesis at Texas Tech University. It is not a marketing survey or a prologue to a sale. You are not a part of any database that was bought by me. You may get another reminder (or two at most) to complete this survey, and that is it. Your 4-5 minutes are very valuable to me and can make the difference between getting good results or no results at all. Your responses are confidential and will be used in aggregate. No identifying information will be released or published. Again, please let me emphasize that this is an academic research project and should only take 4-5 minutes to complete. Your help is greatly appreciated in completing this important study.

For questions and comments, please contact:

Nitin Aggarwal, Ph.D. Student
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Are you participating, or have you participated, in any standard-setting activity that involves writing or specifying technical specifications?

☐ Yes ☐ No

---------- Page Break ----------

Please think of a set of technical specifications (or a standard) that you worked on, either in your company or as a representative of your company and answer the questions in its context.

Please give a name (or a nickname) to the specification that you worked on _<default this_.

Are there different methods, parts, or sections in this <nickname> standard?	☐ Yes	☐ No	
Are any of the methods or parts covered by patents, copyrights, or trade secrets?	☐ Yes	☐ No	☐ Maybe

1a. Were the people working on <nickname> set of technical specifications all working for the same company or different companies?

All work for the same company.	1
Mostly work for the same company.	2
More work for some companies than others.	3
Mostly work for different companies.	4
All work for different companies.	5

1b. Who has the power to make decisions regarding this standard?

One company has all the power.	1
One company has most of the power.	2
Few (two or three) companies have most of the power.	3
Every company has some power but some have more power than others.	4
The power is equally distributed amongst multiple companies.	5

2. How many methods (distinct components) are there in the technical specification <nickname>? _____

3. How many (estimated) single-spaced pages are there in the final specification? _____

4. Were the methods in this standard your original creation or were they pre-existing?

All Original	1
Mostly Original	2
Few Original	3
Mostly pre-existing	4
All pre-existing	5

5. With regards to various methods used in the standard:

All came from the same industry	Mostly came from the same industry	More came from some industries than others	Mostly came from different industries	All came from different industries
☐1	☐2	☐3	☐4	☐5
All came from the same company	Mostly came from the same company	More came from some companies than others	Mostly came from different companies	All came from different companies
☐1	☐2	☐3	☐4	☐5
All came from the same country	Mostly came from the same country	More came from some countries than others	Mostly came from different countries	All came from different countries
☐1	☐2	☐3	☐4	☐5

6. How easy would it be to find substitutes for methods you already chose?

All methods have easily available substitutes.	1
Most methods have easily available substitutes.	2
About as many methods have substitutes as don't.	3
Few methods have easily available substitutes.	4
No method can be easily substituted.	5

7a. How many different countries are represented in this set of specifications (or the standard)? _____

7b. How many different technical areas are represented in this set of specifications (or the standard)? _____

7c. How many different companies are represented in this set of specifications (or the standard)? _____

7d. Technology references from how many distinct industries were helpful in developing [Nickname]? (For example, modern cell phones may use technology

references from the wireless, hardware, telecom, security, and entertainment industries.) _____

8a. How many months did it take to write this set of technical specifications? _____ months

8b. On a scale of 0-100, what percentage of time did everyone involved in [Nickname] spend in identifying, discussing, finding and considering the pre-existing methods? (0 for none) Estimates are fine. _____

9. On a scale of 0-100, what percentage of time did everyone involved in [Nickname] spend in procuring permission (negotiating, contracting, and coordinating) to use the pre-existing methods? (0 for none) Estimates are fine. _____

9b. On a scale of 0-100, what percentage of TOTAL TIME did everyone in [Nickname] spend on activities OTHER THAN defining and writing the actual technical specifications? (0 for none) Estimates are fine. _____

9c. If everything had gone smoothly (you did not face any political, legal or social barriers), what percentage of original time would have been enough to do a similar job? Estimates are fine. _____

10. What is the likelihood that one of the specification users may be a target of some patent litigations?

Highly likely	1
Somewhat likely	2
Maybe (neutral)	3
Less likely	4
Not likely at all	5

11. Internal Coordination:
On a scale of 0-100, what percentage of total time, of all standard-setting activities, was spent on coordinating and negotiating with MEMBERS INTERNAL to your working group? Estimates are fine. _____

12. External Coordination:
On a scale of 0-100, what percentage of total time of all standard-setting activities was spent on coordinating and convincing parties (NON PRIMARY MEMBERS) EXTERNAL to your working group?_____

13. Has your company/organization or any of the standard's users ever been involved in litigation with regards to [Nickname]?

Are any of the methods or parts covered by patents, copyrights, or trade secrets? ☐ Yes ☐ No ☐ Don't know

The following questions are for classification purposes only.

1. How long have you worked with the technical specification (or the standard) [Nickname]? _____ (months)

2. Total experience with all standard setting activities? _____ (months)

3. Nature of your association with the committee.

☐ Project leader or chairman ☐ Legal

☐ Administrative ☐ Working group member

☐ Others (Please describe) _____ ☐ Individual

4. Approximate number of people in your working group? _____

5. Which continent was this standard developed in?

Europe and Asia	1
Mainly Asia	2
Mainly Australia	3
Mainly Europe	4
Mainly North America	5
Multiple Continents	6
N. America and Asia	7
N. America and Europe	8

6. In which year was this standards project started? _____
7. How large (widespread) is the organization developing the standard?

Multinational	1
National	2
Regional/Local	3
Others	4

8. Was this standard primarily developed by:

A company (1 or 2)	1
A consortium or a standard setting organization	2