

MANAGEMENT OF INTELLECTUAL PROPERTY IN
SUPPLY CHAIN OUTSOURCING

A Dissertation

by

RAJORSHI SEN GUPTA

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2012

Major Subject: Agricultural Economics

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Approved by:

Chair of Committee,	H. Alan Love
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ABSTRACT

Management of Intellectual Property in Supply Chain Outsourcing.

(August 2012)

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Firms outsource productive tasks to different locations in order to exploit factor price differentials and gain efficiencies from specialization. However, the benefits of outsourcing come with two risks. The first problem occurs when firms share their pre-existing intellectual property (IP) such as database and trade secrets with contractors. While IP is shared to facilitate the outsourcing project, the contractor may behave opportunistically and misappropriate the IP for its own benefit. Since firms derive significant value from their IP, this can lead to severe economic damages in terms of reduced market share and brand value. The second agency problem arises due to non-contractible effort exerted by the contractor. Depending on the outsourced task, shirking can lead to higher costs and poor quality product. In this dissertation, contractual solutions are developed to mitigate these agency problems associated with outsourcing.

First, several IP misappropriation cases are enumerated in the context of outsourcing. The existing literature is reviewed and the limitations are addressed in the light of these actual cases. Second, theoretical models are developed by considering two

forms of IP misappropriation, depending on whether a R&D contractor emerges as a direct competitor of the principal firm, or the contractor sells the principal's IP to a competitor. Contracts are developed to implement a "carrot and stick" strategy, whereby firms share limited IP with their contractor and also provide incentive payments to deter shirking problem. It is shown that complementary strategies like product differentiation, task modularization, and investment in technological solutions can be useful when legal enforcement is weak. It is also demonstrated that even under the possibility of IP misappropriation; firms may gain from outsourcing if in-house inefficiency is high. However, if legal enforcement is weak, outsourcing would entail higher transaction costs. Finally, an event study is conducted to examine the effect of trade secret misappropriation on the value of Lexar. While Lexar is still outsourcing, it is explored how Lexar survived the IP misappropriation problem through product differentiation and marketing strategies.

DEDICATION

To Santanu Sengupta and Supriya Sengupta for their unconditional sacrifices.

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NOMENCLATURE

AR	Abnormal Returns
CAD	Computer Aided Design
CAR	Cumulative Abnormal Returns
CDM	Contract Design Manufacturer
CLT	Central Limit Theorem
CM	Contract Manufacturer
CRO	Contract Research Organization
CRSP	Center for Research on Securities Prices
DRM	Digital Rights Management
EMS	Electronics Manufacturing Service
FB	First Best Solution
FDA	The Food and Drug Administration
FIPCO	Fully-Integrated Pharmaceutical Company
FIPNET	Fully-Integrated Pharmaceutical Network
FP	Fully Protected Solution
GE	General Electric
GM	General Motors
GPS	Global Positioning System
HP	Hewlett-Packard
ICC	Incentive Compatibility Constraint

IP	Intellectual Property
IPR	Intellectual Property Rights
IRC	Individual Rationality Constraint
IT	Information Technology
LEXR	Lexar ticker symbol
NAND	Not AND (a binary operation in logic)
NASDAQ	National Association of Securities Dealers Automated Quotations
NDA	Non Disclosure Agreement
OEM	Original Equipment Manufacturer
OLS	Ordinary Least Squares
PC	Personal Computer
PD	Product Differentiation
R&D	Research and Development
SAIC	Shanghai Automotive Industry Corporation
S&P 500	Standard & Poor's 500 Index
SB	Second Best solution
SCAR	Standardized Cumulative Abnormal Return
SLA	Service Level Agreement
WFOE	Wholly Foreign Owned Enterprise
WIPO	World Intellectual Property Organization

10-Q Quarterly Report filed with U.S. Securities and Exchange
Commission

10-K Annual Report filed with U.S. Securities and Exchange
Commission

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

1.1 Overview

“It is maxim of every prudent master of a family never to attempt to make at home what it will cost him more to make than to buy. What is prudence in the conduct of every private family can scarce be folly in that of a great kingdom. If a foreign country can supply us with a commodity cheaper than we ourselves can make it, better buy it of them with some part of the produce of our own industry employed in a way in which we have some advantage.” - Adam Smith (1776).

Adam Smith’s explanation of “make or buy” decision is the heart of the phenomenon called outsourcing. It has emerged as a business practice whereby firms contract different tasks or services to outside agents.

In earlier days, coordination of tasks required geographic proximity. Since transportation of intermediate inputs and partially processed goods used to be slow and costly, there used to be agglomeration of production instead of fragmentation. With modern innovations in communication technologies, reduced transportation costs, fragmentation of production became inevitable. As Grossman and Rossi-Hansberg (2006) point out, detailed information about product specifications and the tasks that need to be performed can now be conveyed electronically. Partially processed goods can be transported more quickly and at lower cost than ever before. Modern innovations

This dissertation follows the style of *American Journal of Agricultural Economics*.

in information technology (IT) and communication have enticed firms to exploit the resources distributed across the world. Firms are therefore outsourcing productive tasks to different locations in order to exploit factor price differentials and efficiencies on a world-wide scale.

In this section, some operational definitions are introduced to facilitate discussion. The existing literature uses different nomenclatures for the parties involved in outsourcing relationships. Here the terms “principal” and “agent” in are used to delineate the contracting party and contractor. Alternative interpretations of principal and agent are as follows:

Table 1. Different Interpretations of Principal and Agent

Principal	Agent
Product company/ Original Equipment Manufacturer (OEM)	Contract Manufacturer (CM), Contract Design Manufacturer (CDM)
Pharmaceutical or Biotechnology company	Contract Research Organization (CRO)
Customer	Supplier
Client	Vendor/ Service Provider
OEM	Electronics Manufacturing Service provider (EMS)
Outsourcer	Outsourcee

Outsourcing occurs when a principal delegates operations/tasks that it could have done in-house to an independent agent. As a firm outsources, it enters into a contractual relationship with the contractor. Offshore outsourcing occurs when a principal moves part of the production process or services to an agent located in a foreign country. Thus

the geographic location of the principal's headquarter is different from the location of the agent. Onshore outsourcing occurs when the location of the agent is same as the location of the principal's headquarter.

1.2 Factors Contributing to R&D Outsourcing

R&D used to be looked upon as a sacrosanct core area for the companies. While the trend of outsourcing non-core support functions such as Information Technology (IT) has been common, outsourcing has not remained confined to low skilled tasks. These days, companies have been looking to outsource core activities like R&D as well. Companies like Dell, Motorola, and Hewlett-Packard (HP) are outsourcing complete designs from outside developers. Likewise, Boeing Co. has been working with HCL Technologies of India to co-develop software for everything including navigation systems and landing gear to cockpit controls for the 787 Dreamliner jet (Businessweek, 2005b). Previously, pharmaceutical companies used to outsource routine tasks like clinical trials and low cost manufacturing of established drugs. More recently, these companies have begun to outsource R&D services like drug discovery to Contract Research Organizations (CRO). Evidently, the importance of R&D outsourcing is ever increasing. In 2010, \$42 billion out of the \$105 billion global drug development spending was through outsourcing contracts (www.prleap.com). According to Gartner, worldwide semiconductor outsourcing services revenue is estimated to grow to \$66.8 billion in 2012 (www.gartner.com).

Yet, the approaches and extent of outsourcing has been quite different among companies. While Dell outsources most of the design for notebooks, Apple does the design in-house to the extent that it specifies “Designed by Apple in California” on each iPod and iPad. Motorola outsources complete design for its cheapest phones, but controls all of the development of high-end phones like Razr (Businessweek, 2005b). These alternative approaches may be understood in terms of the following example. Hypothetically, let us consider a researcher who wants to write a research paper. When would that researcher want to do the research and write a paper herself and not collaborate with others? Generally speaking, if: a) the researcher is confident that her own ability is sufficient for the project; b) there is low project uncertainty, i.e. the goals are well defined; and, c) time is not an issue, then the researcher can accomplish all tasks like data collection, data analysis, and interpreting the results herself. In other words, the researcher will pursue an in-house approach to write the paper.

On the other hand, if the researcher knows that there is: a) a chance that she might not be able to accomplish all the tasks herself; b) there is huge uncertainty in the project; and, c) the project may require more time to complete than what is available; the researcher might outsource some R&D tasks to her peers. For instance, data collection or the literature review might be outsourced to someone else. Accomplishing these tasks involves time, which may be reduced by outsourcing and thus the researcher can concentrate on core competence, like conducting data analysis and interpreting the results.

The above description fits quite well with R&D done by firms. For biotech and pharmaceutical companies, the cost of conducting R&D is extremely high. The cost of bringing a drug to market from concept stage is approximately \$1 billion and can take 10-15 years. There is huge uncertainty in drug development; out of 5,000 drugs tested, about five reach the clinical trial stage and typically only one is approved by the FDA. Likewise, for semiconductor chips, it costs \$1-2 billion in leading edge process technology development, \$40-\$50 million in chip design and \$5-7 billion for an advanced fabrication facility (Chip Design, 2011). Thus we observe that biotechnology, pharmaceutical and semiconductor companies have been outsourcing innovation more extensively.

In contrast, innovation in the food and beverage industry is typically incremental. For example, new flavors may be introduced in existing products lines or product shapes or colors may be changed. These innovations are generally characterized by lower cost and less uncertainty. Thus most food and beverage companies prefer to conduct R&D in-house. Generally, in these cases, the companies maintain internal expertise and keep R&D in-house. For instance, H-E-B, the supermarket chain maintains a new product development staff and develops private label products in-house.

1.3 Benefits of Outsourcing

Before discussing the problems of outsourcing, a brief review of the benefits of outsourcing is warranted. It may be argued that lower cost has been the primary motivating factor behind outsourcing. Figure 1 is useful to comprehend the factor

price differentials in offshore outsourcing.

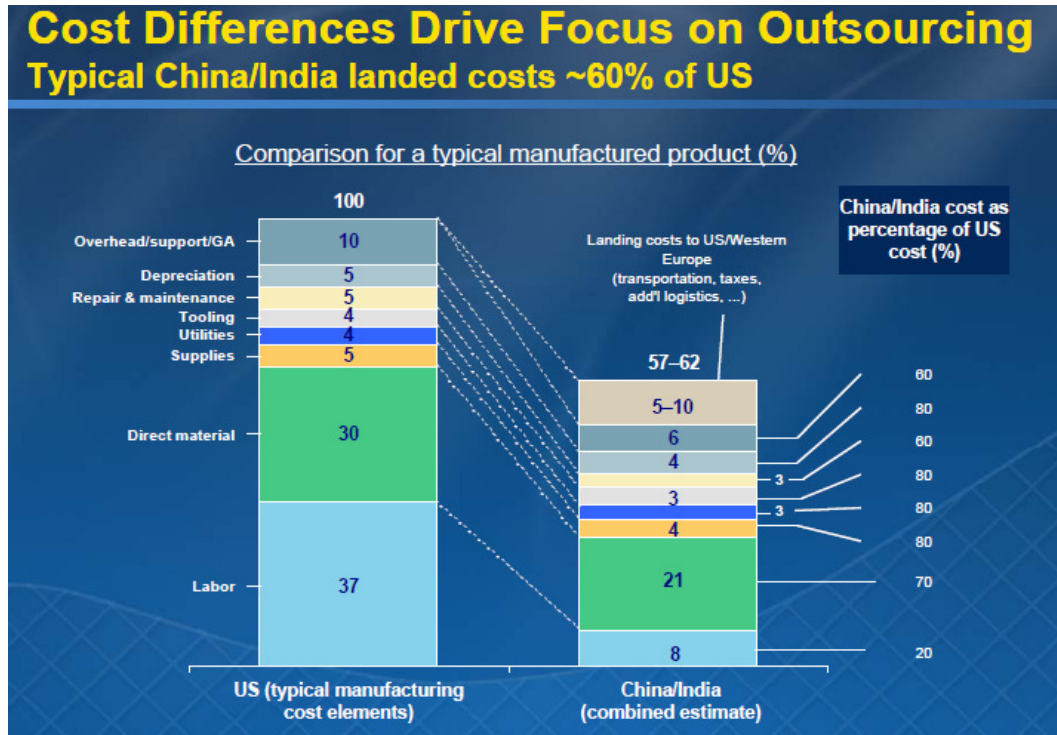


Figure 1. Comparison of Costs in U.S. and China and India

Source: Stevenson (2008)

The wage rate for an offshore Java developer ranges from \$20-\$40 per hour, compared to \$150 per hour for a U.S. based developer and the average annual salary of an engineer in U.S. is \$70,000 compared to \$13,580 in India (Vogel and Connelly, 2005). In software development and IT related industries; outsourcing driven by a cost cutting rationale is hard to escape. According to McKinsey Global Institute (2003) estimates, in 2010, the U.S. IT industry saved \$390 billion through offshore outsourcing of software development.

Motivations behind outsourcing R&D to offshore locations extend beyond cost. General Motors (GM), for example, uses its design studio in Bangalore, India to develop blueprints for new models. As pointed out by Darwin Allen, director of product communication with GM, "Obviously you are aware of [cost savings], but the real motivation is to find people with expertise" (Yee, 2008). Similarly, the drug giant Bristol-Myers Squibb notes, outsourcing has become so vital in the pharmaceutical company's infrastructure and drug discovery strategy that it can no longer be considered an option, but has become a strategic asset. Cost savings is no longer the only factor (www.outsourcing-pharma.com). Pharmaceutical companies outsource clinical trials to CRO in order to reduce testing time and hence overall costs. Essentially, outsourcing enables companies to access external expertise that is unavailable or too costly to do in-house. The following examples demonstrate this point.

- a) Nokia was facing increasing pressure for not having the popular 'clamshell' designed phone in its product range, thereby limiting its scope in Asian markets. Nokia decided to outsource the complete product design from BenQ, a Taiwanese original design manufacturer (ODM). This enabled Nokia to reduce the capital required to do the R&D in-house (Himola et al., 2005).
- b) The Volvo 850 model required an extremely narrow, short gearbox for automatic transmission. But Volvo lacked internal expertise to produce such a complex design in time to meet its product launch deadline. Hence it contracted the gearbox design to the outside supplier Aisin Seiki (Novak and Stern, 2009).

c) Eli Lilly transformed itself from a fully-integrated pharmaceutical company (FIPCO) into what it refers to as a fully-integrated pharmaceutical network (FIPNET). The company outsources in order to increase capacity and get access to external capabilities. This organizational transformation has been realized through outsourcing of early-stage development works to ChemExplorer and PharmExplorer in China and discoveries to Jubilant in India (PricewaterhouseCoopers, 2008).

d) Designs are becoming complex and products are having shorter lifecycles. Many computer companies like Dell and Sony are outsourcing design and manufacturing to contract agents. Motorola outsources design of lower priced phones.

All of the above examples concur with Adam Smith's basic idea that a task may be outsourced when it cannot be done with one's own internal resources at sufficiently low cost. However, it is important to note that the benefits of outsourcing come with several problems like loss of control, quality deterioration, and issues related to IP. This dissertation addresses the problem of IP protection in outsourcing.

1.4 Problems Related to Intellectual Property

1.4.1 IP Ownership

Firms can achieve sustainable competitive advantage from creation, ownership, protection, and use of difficult to imitate IP/ knowledge assets (Teece, 2000b). Modern enterprises derive significant value from their IP. There have been suggestions that as much as 75 percent of the market value of a typical U.S. company resides in IP assets (ASIS International Report, 2007). The World Intellectual Property Organization

(WIPO) emphasizes two critical IP related concerns in offshore outsourcing: ownership of IP and inadvertent, accidental or willful disclosure of confidential information and trade secrets that result in IP loss. Companies risk IP and business knowledge loss when they outsource tasks to suppliers. Further, when IP development involves offshore outsourcing, the problem becomes even more serious because of cross country differences in IP protection. Specifically, R&D outsourcing can be riddled with several risks related to IP:

- Principal may become dependent on outsourcing agent because she did not invest to develop internal resources for new knowledge creation on her own. This may ultimately result in supplier lock-in, where the principal suffers economic loss from terminating the relationship with the outsourcing partner.
- The principal could jeopardize core competencies by sharing proprietary knowledge with the agent.
- As the principal outsources R&D, know-how is transferred to the agent. In the extreme, this can lead to irreversible loss of the principal's core competence to the agent.
- Failed outsourcing relationships might lead to leakage of proprietary technology to rival companies.

Suppose a principal outsources a software writing task to a contract agent. The IP created within an outsourcing relationship is referred to as foreground IP. If the IP created from the outsourcing relationship is protected, then the company can earn rents from that IP. However, in certain situations the agent can leak the IP to competitors of

the company and, in that case, the rents will be dissipated. Another key concern for a principal is ownership of IP developed by the agent. Even when ownership is clearly specified in the contract, the vendor may behave opportunistically ex-post. For example, in the 1990s, Borden Foods Corp. developed a fully cooked, shelf-stable pasta and meat sauce meal. To do so, unique software driven system was outsourced from a developer, which eventually led to IP ownership problem between the manufacturer and the developer (Higgins, 2009).

The existing literature acknowledges this type of ex-post opportunism problem in outsourcing and offers suggestions to mitigate them. As pointed out by Clemons and Hitt (2004), software development contracts are incomplete, implying that it is impossible to specify all future contingencies that might arise. Incompleteness of contracts leads to the hold-up problem. One way to solve the hold-up problem is to allocate the property rights appropriately, as suggested by the theory of Property Rights (Grossman and Hart, 1986; Hart and Moore, 1990). Using this theory, Aghion and Tirole (1994) argue that property rights should be owned by the party whose effort is most critical to an innovation project. More recently, Walden (2005) argued that in software outsourcing contracts, the client should give some share of the benefit to the vendor when there is a possibility of knowledge spillover.

In an outsourcing relationship, bilateral hold-up problems can occur. After the agent sinks a (non-contractible) relationship specific investment, the principal can hold up the agent by demanding a share of rents resulting from the investment made by the agent. On the other hand, under certain circumstances, the principal may also be subject

to a hold up problem. As Clemons and Hitt (2004) point out, in the outsourcing literature the imposition of unplanned, higher fees, vendor's threats to discontinue service or by other unmanageable threats is frequently termed as vendor hold-up (Aron et al. 2005). One way to prevent hold-up problems is to use contractual safeguards. Many U.S. companies accomplish this by including a "work for hire" clause in software development contracts to ensure that the principal retains the copyright for the work being done by the agent. It should be noted that "work for hire" clause is based on the U.S. copyright law concept, which may be ineffective in offshore outsourcing locations. For instance, under the Indian law, the "work for hire" concept does not apply to a situation where the author is independent party; it applies only in an employer-employee situation. Thus an Indian software company that develops software for a U.S. company would own the software. Similarly, when companies outsource tasks to China through Wholly Foreign Owned Enterprise (WFOE), unless specified in the R&D contract, the parent does not have ownership of IP just because it owns the WFOE. Therefore outsourcing contracts must clearly specify the ownership of IP. Following the incomplete contracting literature, property rights should be assigned to the party whose investment matters most in the project under consideration.

1.4.2 IP Protection in Outsourcing

In addition to ownership of foreground IP, the protection of pre-existing or background IP of the principal is also a key concern in outsourcing. Companies usually possess a portfolio of pre-existing IP comprised of technological know-how, software,

database, technological process, and trade secrets. As companies outsource tasks, they need to share pre-existing IP with their contract suppliers. Under certain circumstances, the supplier can misuse this information for its own benefit. It can use the shared IP to create knockoffs that are cheaper substitutes of the original product, or sell the shared IP to a competitor.

Before discussing how the extant literature addresses the problem of IP protection in outsourcing, it is worthwhile to examine some real life cases of IP misappropriation that occurred in outsourcing. There are three objectives in enumerating these cases. First, actual examples of IP misappropriation are not identical. It is important to understand the intricacies of the cases before any meaningful suggestions might be offered. Second, these examples are used to build up several assumptions of the analytical models developed in Chapter II and Chapter III. Finally, in light of these examples, shortcomings of the existing literature on IP protection in outsourcing are uncovered. Further, the examples help identify how this dissertation contributes to the literature in terms of offering unique solutions to the problem of IP protection in outsourcing.

1.4.3 Examples of IP Violation in Outsourcing

Example 1: Motorola had outsourced design and manufacturing of mobile phones to BenQ, a contract manufacturer in Taiwan. Eventually BenQ started selling its own brand of mobile phones in China (Businessweek, 2005b). The contract was consequently cancelled by Motorola.

Example2: Boston based shoe manufacturer New Balance outsourced manufacturing to a supplier located in China. After the end of contract, the manufacturer did not return IP owned by New Balance, including molds, product specifications, signs, labels, and marketing information. The outsourcing supplier launched a competing line of shoes under his own brand. Eventually, New Balance was awarded \$9.9 million in damages for the 200,000 shoes that the agent sold after termination of contract. In an effort to reduce such risks going forward, New Balance reduced the number of outsourcing suppliers, increased monitoring effort to control production, and changed to a high-tech label that was more difficult for counterfeiters to copy (Kahn, 2002).

Example 3: Tiwana et al. (2008) point out that offshoring can expose core technologies and business processes of clients to offshore vendors. IBM had outsourced manufacturing of personal computers to Lenovo, who later emerged as a competitor (Arruñada and Vázquez, 2006). Similar to the IBM-Lenovo case, General Electric (GE) had outsourced production of microwaves to Samsung. Eventually, the latter became major manufacturer of microwaves. Automobile companies extensively outsource parts from component suppliers, who often develop to a stage where they are capable of becoming producers of entire vehicles. The component suppliers can eventually enter the market with their own vehicles (The Economist, 1998). These are examples of how an Original Equipment Manufacturer (OEM)'s outsourcing strategy can give rise to competing firms. The OEM shares proprietary pre-existing IP including production know-how and design, with its contract manufacturer (CM), who then uses the information to become an independent firm competing with the OEM. Essentially, by

virtue of manufacturing products for an OEM, the CM gains enough information and expertise that it becomes successful in launching its own brand eventually.

Example 4: General Motors's (GM) local partner in China is Shanghai Automotive Industry Corporation (SAIC). Chery, a Chinese carmaker was owned in part by SAIC. In 2003 Chery launched a mini car model (QQ) seven months earlier than the launch date of GM's Chevrolet Spark. The QQ and Spark were very similar in design and later investigations revealed that the two vehicles share almost identical body structure, exterior design, interior design and key components. Not only was QQ introduced earlier than Spark, it was also cheaper than Spark by \$1500 (Liu and Fernandez, 2007). In December 2004, GM Daewoo sued Chery for unfair competition in the Second People's Court in Shanghai. GM claimed that QQ was a knock off of Matiz, a model owned by GM Daewoo. It was found that proprietary information like product specifications and formulae were indeed compromised during the development of Spark (www.autoweb.net, Businessweek, 2005a). Chery used the stolen information to build QQ without investing the time and money. QQ was favorably accepted by the consumers and sales of Spark were much lower than expected. The case was finally settled privately with an undisclosed amount.

Example 5: Novak and Stern (2009) point out that when a system is outsourced it is likely that trade secrets will leak. Knowledge about new innovations or designs may inadvertently be revealed to competitors when outsourcing suppliers exploit knowledge gained in one partnership in bidding on future projects. The 2001 lawsuit between DaimlerChrysler and GM was based on the argument that Chrysler had outsourced Jeep

grilles to AM General and eventually the design was passed on to GM. Daimler charged that the GM Hummer H2 grille was “borrowed” from the Jeep grille design.

Example 6: Software companies share their IP (e.g. source codes¹ for testing and debugging) and sensitive systems designs (for applications development) with their contractors. By doing so, they face the risk of losing their IP. For example, SolidWorks Corp., a U.S. based software company had outsourced debugging tasks of its 3D computer aided design (CAD) to Geometric Software Solutions Ltd. in India. An employee of the offshore company stole the program source code and tried to sell it to SolidWork’s competitors. The employee was charged with theft but he might win the case since the source code did not belong to Indian company and therefore the Indian laws would not be applicable (Fitzgerald, 2003). Jolly Technologies, a California based software manufacturer had similar adverse experience when it offshored R&D to an Indian company (Frank, 2005). It has been suggested that lack of legal enforcement is the root cause of these misappropriation cases.

Example 7: Chen and Bharadwaj (2009a) cite the case of Point Solutions Ltd. vs. Focus Business Solutions Ltd. In 2001, Focus had outsourced software development and review task to Point. Focus shared some of its proprietary codes with Point so that the latter can accomplish the task. After Point had received the contract, it began to develop its own competing software. The rapid development of the competing software by Point was possible because it had access to source code shared by Focus. Focus claimed that it had lost competitive advantage due to the IP misappropriation problem.

¹ Source code is a blueprint that specifies the functionality of a computer program.

Example 8: Lexar Media shared its IP with Toshiba under a Non Disclosure Agreement (NDA) before engaging in a joint development project. Later, Toshiba and SanDisk announced joint development of similar technology. Lexar alleged that Toshiba had utilized Lexar's trade secrets in Toshiba's product line, like NAND flash chips, Compact Flash cards, XD-picture cards, Secure Digital cards. Not only was Toshiba a significant partner of Lexar in several joint development projects, Toshiba had placed a member in the board of directors of Lexar. This left Lexar's IP (Multipage Write Technology) and trade secrets exposed to Toshiba and led to the eventual leakage to its competitor SanDisk (Burgess and Power, 2008, pp.24).

Example 9: Danone and Wahaha established a joint venture contract in 1996. In 2007, Danone pulled out of the joint venture alleging that Wahaha was selling a competing line of soft drink products using an outside network of operations. This parallel business was a breach of the joint venture contract. Danone estimated the losses to be \$100 million (Wall Street Journal, 2009).

Example 10: This exemplifies the problem of IP protection in R&D outsourcing. In order to maintain anonymity, the principal is denoted as P and agent as A. P had a unique idea and outsourced the task of writing software code for the envisaged project to A. Eventually A had developed a competing product while he was still working on the P's project. A had successfully launched his product much earlier than P was able to. P sought legal means and the case was settled privately. This case provides several valuable insights for companies willing to outsource. First, the reasons for outsourcing matches those described earlier in section 2.1: P did not have the internal expertise to

write the code in-house. The task of writing codes is subject to uncertainty and tight time constraint. Thus P had outsourced the R&D task to A, who had better expertise in code writing. Secondly, the main problem in this example is that no formal contract was written between the P and A. If a company outsources the development of software it needs to ensure that it owns the IP on the developed software. But in real life, as in this case, it is difficult to delineate the ownership of IP in the first place. Thus the knowledge shared by the P was difficult to verify by the court. These cases are summarized in Table 2 in terms of common characteristics.

Table 2. Actual Cases of IP Misappropriation in Outsourcing

Principal (P) Agent (A)	Outsourced task	Nature of knowledge sharing	Type of IP violation	Outcome
P: Motorola A: BenQ	Design		Set up competing brand	Contract was cancelled
P: New Balance A: Contract manufacturer	Manufacturing	Product specifications, molds, signs, labels, marketing information	Set up competing brand	P was awarded \$9.9 million in damages, P changed to a high-tech label that was difficult to copy
P: IBM A: Lenovo	Manufacturing	Product specifications	Emerged as competing brand	IBM sold PC business to Lenovo
P: GE A: Samsung	Manufacturing	Product specifications	Emerged as competing brand	

Table 2 Continued

Principal (P) Agent (A)	Outsourced task	Nature of knowledge sharing	Type of IP violation	Outcome
P: GM Daewoo A: SAIC	Joint development project	Product specifications and formulae	Set up competing firm	Spark's design was unpatented in China. Therefore GM could not seek patent protection. Privately settled
P: Daimler Chrysler A: AM General	Jeep grille		Used IP to create grilles for GM	
P: SolidWorks/Jolly A: Geometric Software Solution Company/contract R&D center	Debugging software codes	Source code	Intended to sell source code to competitor	Legal enforcement problem; prosecution was difficult as IP did not belong to Indian company. Jolly pulled out R&D activities from India.
P: Focus Business Solutions A: Point Solutions	Software development and review of product	Source code	Developed competing software	Focus lost competitive advantage
P: Lexar A: Toshiba	Joint development project	Multipage write technology	Shared IP with Sandisk, a competitor of Lexar.	Settled for \$465million
P: Danone A: Wahaha	Manufacturing		Established parallel business that competed with the joint venture.	Privately settled
P: Anonymous A: Anonymous	Software coding	Business plan and codes	Set up competing firm	Privately settled

The following commonalities are identified across these cases.

- i. The principal shares its IP with the agent. This IP is pre-existing or background IP owned by the principal.
- ii. After the principal shares its IP with the agent, the latter learns the technology.
- iii. The agent behaves opportunistically. In particular, the agent misappropriates the technology towards its own benefit.
- iv. The misappropriation of IP can take various forms. After the principal discloses its pre-existing IP with the agent, the latter may
 - a) use the information to learn the technology and eventually set up an independent competing firm, or
 - b) sell the IP to a competitor of the principal firm.
- v. Legal enforcement of contracts may be difficult. The agent can continue selling the counterfeit/knock-off product even after injunction is imposed. This is irrespective of the geographic location of the agent.
- vi. While litigation is an option, it can be extremely costly with uncertain outcomes.

It is evident from the above examples that knowledge sharing by the principal is necessary in outsourcing projects. However, this is also the source of the IP misappropriation problem. Thus information sharing precedes information leakage. We discuss this aspect in details below.

1.5 Knowledge Sharing by Principal

Earlier, integrated circuit chip design companies used to be large and vertically integrated. Later they began to move chip manufacturing to offshore fabrication facilities (called “fabs”) that leveraged economies of scale to produce large volumes of chips for many chip companies. Thus the chip companies did not have to raise capital to establish their own manufacturing capabilities. Today, almost every U.S. chip company is “fabless”, meaning that they do not have manufacturing facilities. These companies design their semiconductor products and contract chip production from their designs to offshore fabrication facilities (Patel and Pais, 2004). Two things are noteworthy here. First, chip manufacturing is not a core competency of these companies and hence it is outsourced. On the other hand, chip design being a core competency for these companies is not outsourced. Although chips sold by Texas Instruments and its rivals are manufactured in the same foundries, the product differentiation can be attributed to chip design (Boehner, 2008). Second, the outsourcing arrangement requires the chip design companies share their proprietary technology with the fabrication facilities. This is an example of knowledge sharing by the principal.

Likewise, in software development outsourcing, the principal needs to share critical information in the form of source codes with the agent. The vendor gets access to this IP in order to accomplish the outsourcing task. Similarly, companies selling electronic products need to share product designs and specifications with their agents. In both cases, the shared IP becomes vulnerable to supplier opportunism and misappropriation.

1.6 IP Theft by In-House Employees

It is important to note that the risk of IP theft is a not unique feature of outsourcing. In principle, employers can exercise higher control and monitoring to check for opportunistic behavior of their employees. Also, career concerns of employees may mitigate information leakage by in-house employees (Baccara, 2007). However, there are numerous instances where opportunistic in-house employees have tried to sell company IP to competitors. Interested readers may follow Rajan and Zingales (2001) to see how employees can leak information to rivals. Companies like Ford, Gillette, and Cargill have all faced this problem. The employees gain access to company IP and either sell the IP to a competitor, or take these IP with them when they join a competitor company.

From the various examples cited above, it is evident that the problem of IP misappropriation is universal. Companies that outsource are aware of potential problems like counterfeit, knock-offs or third shift when they outsource production to contract manufacturers. Yet, they cannot ignore the benefits that outsourcing provides. As Rick Wagoner, CEO of GM remarks:

“There is always risk when you’re investing in an emerging market. But the bigger risk is not being there” (Businessweek, 2004).

Given that most companies acknowledge the IP theft problem as inevitable, it is important for economists and practitioners to understand how firms protect their IP when they outsource supply chain activities to contractors. In the next section these strategies are discussed.

1.7 Strategies to Protect IP in Outsourcing

In order to protect their IP, companies have been using various kinds of protection mechanisms and strategies. The effectiveness and limitations of these approaches are discussed in the following sections.

1.7.1 Legal Remedies

Legal tools like patents, trade secrets exist but often they are ineffective. It has long been known that patents do not work in practice as they do in theory (Teece, 1986). Moreover, IP laws vary across countries and enforcement is difficult. IP protection has remained an important policy issue between developed countries and developing countries where tasks are outsourced. While developed countries insist that developing countries must tighten their IP protection laws, the latter resist such pressures on the ground that IP protection is a means of rent transfer to developed countries (Markusen, 2001).

It is important to note that when companies outsource tasks to offshore locations, any kind of IP disputes are likely to be governed by the laws of the country where the supplier is located. The more severe problem with outsourcing is enforcement, especially when tasks are sent offshore. Due to inefficiencies in legal systems in offshore locations a company that is outsourcing to these locations may not expect significant monetary recovery.

In spite of the problems with legal enforcement of contracts, it is advisable to write a proper contract to begin with. A Non Disclosure Agreement (NDA) is often a key step to protect IP shared in an outsourcing relationship. When the principal wants to

outsource production to a contract manufacturer, valuable information like product specifications should be shared only after signing a NDA. Also, when possible, the principal ought to apply for a patent. For example, in case of a medical device company, utility patents are most important form of IP protection. Utility patents protect the functional aspects of a technology like the components, composition of the device, manufacturing techniques and software processes. Another type of patent protection that is less costly and generally less useful is design patent. A design patent does not protect any functional aspect of the medical device but only covers the appearance. In certain countries outside U.S., protection of manufacturing designs may be obtained by using “utility designs” or “utility models.” These are cheaper than utility patents and offer weaker protection than utility patents (Chesser and Cohen, 2005).

Given the weak protection available through legal means, companies use a rich variety of strategies to combat the IP theft problem. These strategies are discussed below using real life examples in each case. The objective is to understand these strategies and examine their relative effectiveness in the analytical models presented in Chapter II and Chapter III.

1.7.2 Limited Knowledge Sharing

Companies often use less than full information sharing strategy. In building the Boeing 777, both Boeing and outsourced Japanese engineers shared proprietary information. However, to deter espionage by the Japanese engineers, their access to Boeing’s secure areas was limited (Lewicki et al., 1998).

Secrecy is one of the ways that companies use to protect their IP while engaging with suppliers. Thus automobile manufacturers try to keep design and technology choices as trade secrets during the product development stage. As Novak and Stern (2009) point out, most product development for each system occurs within secured facilities and system-specific or even component-specific access codes are required to access specific areas or computer databases. In order to maintain trade secrecy, companies often need to limit coordination efforts across different components of automobile production.

1.7.3 Modularization of Tasks

Task modularization is a useful strategy to secure IP from being misappropriated. Companies create sealed modules for selectively sharing their IP without exposing it too much. Then the companies send these modules to contract agents to perform the specific tasks. The modules give partners enough contexts for completing their specific task without revealing enough IP for duplicating designs or processes. For example, an automotive parts company wanted to cut the cost of developing sunroof product. Since creating CAD geometry for fitting sunroofs to car models was not a core competency of the company, it decided to outsource that task. The contractors had enough contexts to complete their tasks of modifying sunroof parts, but not enough for them to learn to duplicate the design without extraordinary effort (Brincheck, 2008).

Tiwana et al. (2008) point out that Japanese companies consistently use modularization strategy to mitigate IP risk. They decompose an outsourced project into

smaller pieces and outsource the tasks to different vendors. The decomposition of tasks is done in such a way that only the client can assemble them back together. The authors argue that in contrast to Japanese manufacturers, most Western companies try to protect their IP through legal contracts, which are frequently unenforceable across national boundaries.

HP outsources design of boards and systems from its electronic manufacturing services (EMS) partners, who are often recognized as contract design manufacturers (CDM). When HP outsources design from its CDM, it makes sure that its IP is protected. In particular, the CDM need to have separate labs for HP products (Carbone, 2007). Also, HP uses the threat of terminating business with a CDM if any IP is compromised. This strategy works well since agents do not want to lose HP as their key customer.

Fine and Whitney (1996) explain how HP implemented successful outsourcing strategy and protected its IP while designing disk-drives. HP found that it would not be able to keep up with all the elements of disk drive technology. So it designed the disk operating system software, the read/write control system and contracted out the design to Citizen Watch to manufacture the disk drive. Each element in the product was made by a different company. Fine and Whitney (1996) argue that there were several factors that prevented Citizen from assembling the same set of suppliers and going into the disk drive business itself. HP's skill lies in the ability to forecast price and demand in the future and then to convert those requirements into engineering specifications. The two vital skills, market knowledge and system engineering were HP's core competency. It would be hard for Citizen to replicate these core competencies and hence it never

emerged as a competitor of HP in disk drive business.

Car manufacturers need to disclose their valuable IP (e.g. designs) with their external suppliers. Thus they face the risk of innovations being revealed to their competitors before vehicles are introduced in the market (Novak and Stern, 2009). In this case, a modular system can be beneficial in protecting IP. A design challenge in the luxury car market has been the integration of cellular phone subsystem into the audio system. If these were integrated design then the cellular phone would share a circuit board and control panel with the audio system. In contrast, a modular design would allow the cell phone's circuit to be separate from the audio system. Thus design modularity can facilitate outsourcing of cellular phone components with little overlap between manufacturer and the supplier during product development. Instead, an integrated design would require extensive disclosure of designs to the phone supplier. For example, an integrated design would reveal to the supplier whether a global positioning system (GPS) was also included, while a modular design can avoid this disclosure.

1.7.4 Technological Solution

One effective way of protecting IP while outsourcing is to use technological solutions. For instance, advanced encryption, watermarking, digital rights management (DRM) technologies provide inexpensive ways to protect IP. Consider the example of PTC, a provider of product development software. It incorporated protective measures in its software that would prevent IP theft during design collaboration. When designers

share product data with suppliers, they can de-feature the product models. This enables that only the needed data is shared with the suppliers (Teresko, 2008). Often companies differentiate products by using authenticity measures. Anheuser Busch was facing the problem of counterfeit Budweiser beer products in China. The company started importing unique foil (that turns red when cold) for packaging which is difficult for counterfeiters to obtain (Businessweek, 2005b).

1.7.5 Demand-side Strategies

In addition to the supply side strategies of managing the agent or modularizing the architecture of the tasks, there is another useful strategy that companies use to protect their IP. Product differentiation is one such effective strategy. If there is IP theft, the competing products will have similar features. If the products are too similar, then the consumers will prefer the one that is cheaper. Therefore a company must ensure that its product has certain unique features or services that are valuable to the customers. Providing complementary services like product support can be used to introduce a switching cost among the customers. To the extent that customers value the service provided by the company, they will be reluctant to switch to competing products. Companies have often bundled their products with customer services and hence, if the customer is purchasing counterfeit products then she would not get the valuable service. Microsoft, for instance, provides regular product updates to genuine software owners. Pirated software owners do not get this service. Thus we see how product features and/or services may be used to deter sale of pirated products.

The above cases illustrate that companies resort to different kind of strategies in order to protect their IP while engaging in outsourcing. Companies willing to outsource should assess the relative costs and benefits of these alternative solutions.

1.7.6 What (not) to Outsource?

“We will push some product development projects to India and China, but the lion's share will stay where it is.”- Bill Gates (CNET News, 2004).

The existing literature contends that companies must keep core competency tasks in-house and not outsource them (Prahalad and Hamel, 1990; Lacity and Willcocks, 1998). Thus it is important to identify the core competencies in the first place. Core competencies are the tasks that a firm can do better than others. Prahalad and Hamel (1990) suggest several tests to identify whether a task is core competency or not. A core competency should provide potential access to a wide variety of markets, a significant contribution to the perceived customer benefits and must be difficult for competitors to imitate. These tasks are also sources of comparative advantage to the firm. Examples of core competencies are ‘miniaturization’ at Sony, ‘small engine design and manufacture’ at Honda, ‘measurement technology’ at HP (Leonard-Barton, 1992).

Clemons and Hitt (2004) provide valuable insight on how to decide which activities to outsource and which to keep with the firm. According to their suggestion, a risk based screening must be done for each of the candidate tasks. Once the risks are listed, the management needs to see if these risks are manageable by designing contract. The authors suggest that a firm should consider keeping an activity in-house if the size

of the expected economic loss that can result from an outsourcing contract exceeds the expected economic gains. We can apply this logic to explain why firms prefer to do certain tasks in-house even if it is costlier to do so. For example, why did Apple design in-house the dual core processor for its tablets? The expected benefits of outsourcing this task would have been lower than the expected loss from losing the IP. Likewise, several food manufacturing companies use strategies to protect their IP as “secret sauce”, Cisco Systems retains in-house manufacturing for its cutting edge routers (Arruñada and Vázquez, 2006) and so on.

Azoulay (2004) finds that pharmaceutical firms are more likely to outsource the coordination of data-intensive clinical trials, while they are more likely to assign knowledge-intensive trials to internal teams. However, recently pharmaceutical companies outsource biostatistics in clinical trials to CRO. This exemplifies the need to access special expertise that is not available in-house. However, as Mehta and Peters (2007) explain, an accumulation of critical resources and tacit knowledge could allow the CRO to emerge as an independent competitive player in the drug development business. Thus, pharmaceutical companies should carefully assess whether they need to outsource critical tasks to CRO.

1.8 Existing Literature on Protection of IP in Outsourcing

Since almost any task can be done in-house or outsourced, a natural question arises: When does a firm outsource certain task? A brief review of the transaction cost and property rights theory is warranted to understand the “make or buy/outsourced”

decision of a firm. These theories help us understand whether a firm should do a task within its own organization or outsource it from the market/independent supplier.

There are transaction costs in both kinds of arrangements, as pointed out by Coase (1937). The market mechanism entails certain costs: discovering the relevant prices, negotiating and enforcing contracts, and so on. Within the firm, the entrepreneur may be able to reduce these “transaction costs” by coordinating these activities himself. However, internal organization brings other kinds of transaction costs, namely problems of weak incentives, monitoring, and performance evaluation (Klein, 2005). As Grossman and Helpman (2002) point out, if tasks are done in-house, then firms face relatively high fixed and variable production costs due to their lack of complete specialization and the extra governance costs. Therefore, the decision between “make or buy” would depend on the relative costs of organizing the task using the two alternative approaches. A task will be outsourced if the relative cost of outsourcing is less than that of in-house organization. But the benefits of outsourcing come with the drawbacks of incomplete contracts. If there are concerns with IP protection then transaction cost will increase in outsourcing and therefore a firm will tend to choose in-house approach to do the task.

The theory of property rights suggests that transaction costs depend on allocation of property rights. If property rights can reduce transaction costs of outsourcing relative to the cost of performing the task in-house then the task will be outsourced. Aghion and Tirole (1994) analyzed optimal allocation of property rights on innovation between a firm and an innovator. If the innovator’s effort is “important enough” then they suggest that control should be allocated to the innovator. If there is potential for opportunism by

the agent, the Property Rights approach suggests that residual rights may be given to the agent (Ramello, 2005).

It is important to specify all IP related issues in outsourcing contracts. However, contracts are inherently incomplete (Williamson, 1975, Grossman and Hart, 1986, Hart and Moore 1990). It is impossible to specify all future contingencies in a contract.

Existing literature talks about three classic types of risk associated with outsourcing and inter-firm activities: shirking, poaching and opportunistic renegotiation. Given the objective of this dissertation, we focus on IP risk or poaching. After a contract has been signed, and relationship specific investments have been sunk, the agent may behave opportunistically (Ramello, 2005). The Transaction Cost Economics says that this type of ex-post opportunistic behavior leads to contractual hazards and hold-up problem which increase the transaction costs of outsourcing (Coase, 1937, Klein et al., 1978, Williamson, 1975). There are two kinds of solutions to this contractual hazard/ hold-up problem. The property rights theory of firm developed by Grossman-Hart-Moore says that hold up problem can be solved by properly allocating the property rights between the parties. Thus one way to solve the hold up problem is to organize the task in-house i.e. vertically integrating with the supplier. As Hart and Moore (1990) remark, integration is a way to reduce the opportunistic behavior and holdup problems. Another solution is to use contractual safeguards like restrictive covenants, penalty for breach of contract and using incentive payments. Indeed, firms extensively use contractual methods to mitigate IP risk in outsourcing contracts (Chen and Bharadwaj, 2009b). However, as Majewski and Williamson (2004) argue, in a weak IP regime, the solution

of allocating property rights may not work and there is a possibility of IP misappropriation. In addition, the property rights approach says that the rights should be given to the party whose investment matters most for the project. In practical terms, this assessment can be difficult, if not impossible. Finally, the usage of contractual safeguards as a way to solve the hold-up problem depends on the enforceability of contracts. As we have seen in many the real life cases, legal enforcement of contracts can be daunting task in outsourcing. This calls for alternative mechanisms to protect IP while engaging in outsourcing. A review of the existing literature provides the following suggestions on how to protect IP while outsourcing.

Ulset (1996) acknowledges the problem of supplier opportunism in R&D outsourcing through leakage of technology. He suggests that internal organization should be used to manage core R&D projects; outsourcing may be used for small, complementary projects and to tap external resources. He argues while IP laws provide weak protection against technology leakage, contractual laws might be more effective in deterring leakage. When R&D is outsourced, transaction costs will arise due to project uncertainties, bounded rationality, opportunism and non-redeployable efforts (Williamson, 1991). Contractual safeguards are needed to reduce these transaction costs in outsourcing. In order to avoid technology leakage problem, the client must use stronger rights to control the R&D process of the supplier. Contractual safeguards need to be used to prevent the supplier from leaking R&D results to competitors. Therefore, when designing the contracts, firms should use controls as well as high powered incentives to manage outsourced projects.

Future business prospects may also deter IP leakage problem (Ulset, 1996). As Arruñada and Vázquez (2006) point out, a long term contract can hinder a CM from abandoning the OEM. Long term contracts are commonly used in clinical delivery alliances, where CRO receives incentive payments in terms of milestone based payments and royalties. These are also extensively used by Japanese car manufacturers (Holmström and Roberts, 1998; Taylor and Wiggins, 1997).

Lai et al. (2009) assumes that leakage of information will reduce R&D firm's market share. They find that the mode of compensation plays an important role in deterring IP theft. In particular, a revenue sharing scheme is more effective than a fixed fee scheme in protecting IP.

Ho (2009) examined R&D outsourcing contract between a firm and a contractor, who can leak information to a rival firm. Due to the possibility of information leakage in the interim stage, there will be increased competition between the original firm and the rival firm. This will push up the compensation to the supplier. Thus the principal may not be able to write a profitable contract. However, if the firm hires two contractors, then allowing for competition between them along with a non disclosure punishment can alleviate the problem of information leakage. Ho's solution essentially relies on non-disclosure agreement and competition between the suppliers.

Chen and Bharadwaj (2009a) examine IT outsourcing contracts and find that companies use incentive mechanisms and modular design of outsourced tasks to mitigate IP risk. Companies typically use two contractual approaches to safeguard against opportunistic behavior of suppliers: IPR-sharing and restrictive covenants. Companies

use non-compete clauses in order to prohibit a partner from contracting with a third party or developing the same technology outside of the current contract.

It is noteworthy that some researchers argue that if a firm is concerned about protection of IP, then the task should be done in-house. This argument is based on the assumption that in-house employees will not misappropriate IP. This is possible when in-house employees have prospect of promotion (Baccara, 2007) or when they receive a loyalty premium over the market wage (Lai et al., 2009). However, this assumption may be questionable since in-house employees could also behave opportunistically. This possibility was addressed by Ziegler (1985), Rajan and Zingales (2001) among others. Finally, there are some authors who acknowledge the problem of IP leakage in outsourcing. These papers provide insight on effects of IP leakage on the market for information (e.g. Baccarra, 2007), innovation and relative wages in a North-South trade model (e.g. Glass, 2004) but do not provide suggestion on how to protect IP while outsourcing.

It can be said that the existing literature confines attention to the supply side of the problem, i.e. how to manage the agent using various kinds of mechanisms. The supplier management solutions may be broadly classified into the following categories.

- a) Compensation: The agent must be paid incentive payments.
- b) Rules: Contracts should be written with safeguards like non-compete/ exclusivity clauses and restrictive covenants (e.g. Non Disclosure Agreement).
- c) Modularization: Break the outsourcing tasks into smaller modules and outsource them to different suppliers.
- d) Length of contracts: Long term contracts are also useful to deter short term opportunistic behavior. The extant literature is summarized in Table 3.

Table 3. Contributions of Existing Literature on IP Protection in Outsourcing

Author(s)	Research question	Principal (P) and Agent (A)	Type of IP and motivation to outsource	Mechanism of IP leakage	Problems Acknowledged	Solutions offered	Limitation
Ulset 1996	1. What affects the choice between outsourcing and in-house R&D (Boundary) 2. If R&D outsourcing is chosen then how to govern it? (Governance)	P: Private manufacturing firms in R&D intensive industry (IT) A: Universities and R&D companies	Foreground IP Tap advanced knowledge and technology	After end of project, the A can sell modified copies of R&D output to competitors	1. Loss of control 2. Technology leakage 3. Creation of bilateral monopoly over time	1. Internal organization to conduct core projects, Outsource complementary small project and tapping external knowhow. 2. Hybrid contracts: Control over supplier's production and give supplier some property rights on R&D output. 3. Exclusivity clauses in R&D contracts	No knowledge sharing between P and A. Control over supplier's production requires high coordination costs. Enforceability of contracts is often absent.
Mehta and Peters 2007	problem faced by pharmaceutical companies when they are outsourcing core activities like R&D	P: Pharmaceutical companies A: Contract Research Organization Type of work: Biostatistics, clinical trials	Background IP Motivation: Reduce cost and time of bringing products to the market	Extensive knowledge sharing by P	Knowledge sharing can lead to emergence of independent competing firms	Bring tasks in-house if IP is a concern	Does not provide solution on how to protect IP within outsourcing relationship.

Table 3 Continued

Author(s)	Research question	Principal (P) and Agent (A)	Type of IP and motivation to outsource	Mechanism of IP leakage	Problems Acknowledged	Solutions offered	Limitation
Baccara 2007	What is the effect of R&D outsourcing on the market for information	P: Firms in Management consulting industry (Monopolistic competitive market) A: Contractor	Background IP	Contractor learns the R&D developed by the firm as a byproduct of main task. Unintentional spillover of knowledge by A or A sells information to competitors	Contractors learn the clients' technology and then diffuse it to competitors	No suggestion on IP protection	A perfectly learns the cost-cutting technology developed by the P, No uncertainty.
Lai et al. 2009	Choice of payment mechanism- lumpsum contract vs. revenue sharing contract	P: owner of production firm A: research firm	Foreground IP	Information sharing between partners facilitate leakage		<ol style="list-style-type: none"> 1. A fixed pay cannot deter IP theft, Revenue sharing mechanism can do so. 2. While outsourcing might be efficient, it might not be chosen because of the potential information leakage problem 3. A strengthening of IP system may not induce more R&D outsourcing as it might favor more in-house R&D due to increased length product cycle. 	No uncertainty. The paper does not address how the information gets leaked. The principal continues outsourcing from the agent even after IP theft occurs.

Table 3 Continued

Author(s)	Research question	Principal (P) and Agent (A)	Type of IP and motivation to outsource	Mechanism of IP leakage	Problems Acknowledged	Solutions offered	Limitation
Ho 2009	Protection of IP in R&D outsourcing with possibility of leakage of information.	P: Firm A: Contractor	Foreground IP R&D is Process innovation	A sells the R&D to a rival firm	There is asymmetric information between P and A with respect to R&D outcome	1. A profitable leakage free contract does not exist because of the competition among the original client and its rival firm and increased bargaining power of the contractor. 2. When there are two contractors, a relative performance scheme along with a disclosure punishment could mitigate the problem of information leakage.	1. IP leakage cannot be prevented with one Agent. 2. With two agents, the solution depends on disclosure punishment, i.e. legal tool and enforceability 3. Competing firms produce homogeneous products
Chen and Bhardwaj 2009a	Empirical analysis on determinants of contract structure. How contracts are used to protect IP.	P: IT firms A: outsourcing firms Task: Outsourcing of software development				Two IP protection mechanisms employed by firms are a) IPR sharing arrangements and b) restrictive covenants	Solutions depend on enforceability of contracts

1.9 Limitations of the Existing Literature

The limitations of the existing literature are noteworthy in the light of the various real life examples enumerated earlier in section 1.4.3.

- i) The extant literature does not consider explicitly the role of knowledge sharing by the principal. This is contrary to the real life examples described earlier.
- ii) Most papers address the problem of protecting IP that is created within an outsourcing relationship (for instance, Lai et al., 2009, Ho, 2009). However, in many of the real life cases, we found that the principal typically shared their pre-existing IP with the agent, which eventually was misappropriated. The two papers that address the pre-existing IP are Baccara (2007) and Mehta and Peters (2007). While Baccara explains the effect of IP leakage on the market for information, no suggestion is offered on how to protect IP. Mehta and Peters (2007) on the other hand suggests that core competency tasks should be performed in-house to protect the IP. Thus the literature does not offer any suggestion on how to protect pre-existing IP of the principal.
- iii) The literature does not provide any solution on how to mitigate the two agency problems related to IP misappropriation and shirking behavior by the agent.
- iv) The solutions offered by the existing literature deals only with the supply side of the problem, i.e. how to manage the agent.

1.10 Contributions of Dissertation

This dissertation contributes to the literature by tackling the three omissions mentioned above in section 1.9. First, it is argued that information or knowledge sharing is a key source of the IP misappropriation problem occurring in outsourcing. As will be demonstrated later, the principal can strategically use this knowledge sharing to deter opportunistic behavior by the agent. In particular, by sharing less knowledge, the principal can reduce the agent's willingness to walk away from the project. This, along with sufficient incentive payments can deter the two agency problems due to IP theft and shirking behavior by the agent.

Second, the case where the principal shares its pre-existing IP with the agent is considered. Post knowledge sharing, the agent might walk away with information and set up an independent competing firm. This approach is close to most of the real cases.

Third, it is argued that companies contemplating to outsource should develop complementary strategies to deter the IP misappropriation problem. Traditionally, researchers have looked into the supplier management strategies like higher efficiency wages and contractual clauses. However, from the real life cases of IP disputes in outsourcing, it is possible to argue that only supply side management strategies would provide incomplete protection. Companies should use strategic safeguards like less knowledge sharing, product differentiation and modularization, as well as contractual safeguards like incentive payments and penalties in order to prevent IP misappropriation while outsourcing.

CHAPTER II

PROTECTION OF INTELLECTUAL PROPERTY IN RESEARCH AND DEVELOPMENT OUTSOURCING

2.1 Introduction

Maintaining ownership in all aspects of a vertically integrated business can be very costly. As a result, entrepreneurs are increasingly finding it profitable to outsource some non-core activities outside their own boundaries. Until recently, core activities like R&D were looked upon as sacrosanct areas which management preferred to keep in-house. However, perceptions are changing these days and companies are looking to outsource even R&D. For instance, the drug development industry is an emerging area of entrepreneurship where tasks are extensively outsourced to specialized contract research organizations. Likewise, start-up software entrepreneurs routinely outsource development and debugging tasks to contract agents. Evidently, outsourcing R&D is becoming a strategic tool for companies. This contention is supported by the National Science Foundation (2010) finding that in 2007, companies in the United States (U.S.) contracted-out \$19 billion worth of R&D to other organizations in the U.S. Over the time period 1993-2007, while the growth rate of in-house R&D was 1.6%, the same for contracted out R&D was 4.5%.

However, lately entrepreneurs are realizing that management of IP in outsourcing relationships can be a daunting task. A survey conducted by R&D Magazine (2007) cites IP protection as the main reason firms did not outsource R&D. For an entrepreneur, IP is

often the most important asset. As Rajan and Zingales (2001) note, entrepreneurs with unique, critical ideas and superior management techniques form the basis of surplus generating enterprises. If IP can be easily misappropriated, the ability of entrepreneurs to generate rents from proprietary knowledge becomes limited. This paper aims to provide strategies for entrepreneurs to protect their IP while outsourcing R&D when contract enforcement may be costly or impossible.

With outsourcing's allure and risks, contractual relationships are gaining increasing importance. As entrepreneurs are outsourcing R&D work to contract agents, two questions arise: why do they outsource, and if they outsource, what strategies might be used to protect IP from misappropriation? The 'why' part of the question is attributed largely to cost savings offered by outsourcing and access to external specialized expertise. For example, it was estimated that the U.S. information technology (IT) industry would save \$390 billion in 2010 through offshore outsourcing of software development (McKinsey Global Institute, 2003). The second question requires a more careful examination and is the subject of this chapter. As rightly pointed out by Ho (2009), although some governments are implementing new laws in an effort to become credible offshore outsourcing destinations, the problem of enforcement still prevails. Therefore, outsourcing of R&D in the presence of inadequate IP protection is a paradox and remains an interesting research area.

Several examples involving IP misappropriation in outsourcing engagements have been described in Chapter I. These cases share some common features. An entrepreneur (principal) shares proprietary knowledge and trade secrets with an

outsourcing partner (agent) to benefit through collaboration. Critical information is shared by the principal in order to facilitate the tasks of the agent. Finally, the shared information is misappropriated either directly by the outsourcing partner through creation of competing products or indirectly through employee theft that may be the result of inadequate contract employee screening and oversight. The question arises: if there is a possibility of eventual misappropriation of IP shared in an outsourcing relationship, how might entrepreneurs share their knowledge in a way to achieve the benefits from outsourcing while at the same time reducing the risk of misappropriation of knowledge? Further, what economic factors determine how much knowledge should be shared? Admittedly, legal tools like patents and copyrights do exist, but the problem of weak enforceability can make them ineffective. Our objective is to design an outsourcing contract mechanism and complementary strategies that might enable entrepreneurs to protect their existing IP. This can be achieved through well aligned incentives so that the benefits of outsourcing might be obtained while reducing the likelihood of needing to enforce ownership through legal proceedings.

2.2 Related Literature

Relatively few researchers have dealt with the problem of IP protection in outsourcing. Although the problem has been acknowledged in the literature (Arruñada and Vázquez, 2006; Baccara, 2007), effective solutions have been scarcely offered. Legal tools like patents and trade secrets exist, but enforcement problems remain. Especially when tasks are outsourced to offshore locations, IP litigation gets further

complicated due to differential laws across countries (Chen and Bharadwaj, 2009a). The extant literature provides the following suggestions on how to protect IP in outsourcing engagements.

Opportunistic behavior by an R&D supplier (agent) may be reduced by aligning the compensation structure with the objectives of the entrepreneur (principal). Ulset (1996) suggests that contractual safeguards be used to reduce transaction costs of outsourcing. To prevent technology leakage, a client should contractually secure stronger rights to control the supplier's R&D production process and exclude others from using the resultant R&D output. Ulset (1996) argues that contractual controls along with high powered incentives would lead to efficient provision of R&D. Lai et al. (2009) find that a revenue or gain sharing contract might be more useful in protecting IP compared to a lump-sum payment often used in real-world contracts for outsourced R&D. Ho (2009) finds that when a firm outsources R&D to a single contractor, the latter can leak R&D results to a competitor. In Ho's model, both the client and competitor compete to obtain the R&D results, and hence push up payments to the contractor. As a result, payments to the contractor might be so high that a profitable contract may not be possible for the client. However, she finds that when there are two contractors, a relative performance scheme along with a disclosure penalty can mitigate information leakage. However, the relative performance contract relies on the ability of the principal to enforce a disclosure penalty, which may be difficult in many situations. Chen and Bharadwaj (2009a) find that IT firms often use incentive mechanisms, including rights sharing and restrictive covenants, to mitigate IP theft risks in software outsourcing

contracts.

When there is a possibility that the agent can misappropriate IP, some authors suggest that a long-term (infinitely repeated play) contract may be a viable remedy for the problem (Ulset, 1996). This line of research stems from the successful long term contracts prevalent in the Japanese auto industry (Holmström and Roberts, 1998; Taylor and Wiggins, 1997). In contrast, we focus on limited duration (one-shot stage-game) contracts that might be used when outsourcing R&D for developing a new product.

Our study contributes to the literature along several important dimensions. In the light of the IP theft cases enumerated in Chapter I, we identify important missing elements in the existing literature which are addressed in this chapter. First, the literature (e.g. Baccara, 2007; Lai et al., 2009, and Ho, 2009) bypasses the knowledge sharing and learning mechanism that allows an agent to understand the principal's IP sufficiently well to use the technology towards its own benefit. We consider the complexity and costliness of this learning process as a vital element of the IP misappropriation problem and explicitly incorporate a learning effect by the agent in our model. Further, in our model, information leakage is not due to an unintended spillover occurring from the principal to the agent. Rather, the agent makes a strategic decision on whether to abandon the contract by misappropriating the knowledge or continue with the current contractual relationship.

Second, previous works typically address the problem as an agent misappropriating IP and eventually selling it to a competitor of the client firm (e.g. Lai et al., 2009; Ho, 2009). In contrast, we consider the possibility of an agent emerging as a

direct competitor of the entrepreneur firm. This prospect could arise when the agent gets access to critical production knowledge (Prahalad, 1990). Our approach is corroborated by the pharmaceutical, biotech, automotive, footwear and semiconductor industries where contract manufacturers have often emerged as direct rivals of their clients.

Accumulation of critical know-how and tacit knowledge might enable contract agents to emerge as competitors of software start-ups; or a contract manufacturer could emerge as direct competitor of an original equipment manufacturer (Arruñada and Vázquez, 2006).

Third, the literature does not distinguish between protection of pre-existing IP of an entrepreneur and protection of IP produced in an outsourcing relationship. This dissertation is specifically intended for protection of pre-existing IP of a firm as appears was the case in several of the examples enumerated in Chapter I.

In what follows, we develop an optimal contract under the possibility of IP theft. We also discuss several complementary strategies that might be used in conjunction with an appropriately designed contract to reduce the agent's incentive for misappropriating IP in an outsourcing relationship. We consider an outsourcing contract between an entrepreneur (principal) and a R&D contractor (agent), most often thought of as a contract research organization, contractor, supplier, or vendor. A stage game is developed where the principal delegates R&D to the agent through a contract. If the agent accepts the contract, the principal disseminates its pre-existing IP for the purpose of the project. The pre-existing IP is the know-how that the entrepreneur has already developed by incurring substantial cost. After knowledge is shared by the principal, the agent exerts effort which affects the quality of R&D produced. Knowledge sharing could

potentially reduce the agent's cost of exerting effort through a learning effect, so much so that it becomes profitable to walk away from the contract and establish a rival product. The objective of the principal is to design an incentive compatible contract such that it is optimal for the agent not to misuse the knowledge as well as exert effort on the project. We contrast this case with the situation where the entrepreneur does not have the possibility of IP theft when a technological solution is available.

We obtain several interesting results from this model. The principal must share a level of knowledge that is just sufficient for the agent to perform the task. This may be accomplished through modularization of tasks. The level of knowledge shared under the possibility of IP theft is shown to be less than what would have been shared when IP theft is not feasible. While less than optimal knowledge sharing comprises the stick approach, the principal has to provide enough carrots too, such that the agent stays with the contract and exerts high effort on the R&D project. The principal achieves this by designing an incentive compatible contract that ensures a profit of the agent equal to his "outside option" which we define as profits from selling a differentiated rival product. This will keep the agent from misappropriating the principal's IP and also induce optimal effort exertion.

At this point we enumerate some of the managerial implications of our findings. Contractual performance incentives could work favorably given the two agency problems. For instance, contractors often receive bonuses when they exceed service level agreement (SLA) performance targets. The contractual payments must be as large as the outside option that the agent could have earned by selling a competing product. In

addition to the carrot and stick mechanism, we find that firms might use complementary strategies like product differentiation and/or task modularization to protect their IP.

2.3 A Model

The basic issue is how best to delegate a task which is either too complex or too costly for a firm to do on its own. The theory of incentives is used to address the two problems due to shirking and IP misappropriation by the contractor. We develop a model where an entrepreneur signs a contract with an agent to organize and produce R&D. In the first stage, the principal offers a R&D contract to the agent. If the agent accepts the contract, the principal decides how much knowledge to share with the agent. Firms typically possess a portfolio of IP comprised of technological know-how, software, database, process or manufacturing knowledge, and trade secrets. The agent gets access to some or all of these in order to complete the outsourcing task. For instance, automobile manufacturers share design information with their component suppliers to reduce production cost. Likewise, in software development tasks, the principal must share critical information in the form of source codes with the agent. Let K_P denote the amount of knowledge shared by the principal. Since R&D tasks are inherently risky and the agent can only be imperfectly monitored, the principal is most likely to face post-contractual opportunism problems emanating from choice of effort and IP theft by the agent.

In the intermediate stage, the agent decides whether to abrogate the contract and set up an independent rival firm.

In the second stage the agent decides on the level of effort, $e \in [0,1]$ to expend in developing the R&D. Higher effort is assumed to increase the probability that R&D has more desirable characteristics and higher value for the entrepreneur. The probability of realizing high quality, high value R&D \bar{v} is $p(e)$; that of realizing low quality, low value R&D \underline{v} is $1 - p(e)$. We specify $p(e) = e$, so that the probability of getting high quality R&D is equal to the level of effort exerted by the agent. One could interpret these high (low) quality levels as outcomes of the project when it is a blockbuster (flop).

In the final stage, if the agent does not steal the principal's IP and continues work within the contract, either high or low quality R&D is realized and payments are made according to contract terms. However, if the agent copies the technology and establishes a competing product, the contract fails and the two firms play a duopoly game. The sequence of actions by the two players is as follows.

Time 0: Principal decides to outsource R&D from the agent and offers contract $\{(\bar{v}, \bar{T}), (\underline{v}, \underline{T})\}$. Payment to the agent is high (\bar{T}) or low (\underline{T}) if quality of R&D is high (\bar{v}) or low (\underline{v}), respectively. We assume $\bar{v} > \underline{v}$ and $\bar{T} > \underline{T}$. The agent accepts or rejects the contract.

Time 1: If the agent accepts the contract, the principal chooses how much of existing IP to share (K_p). The agent decides on whether to continue with the project or abrogate and establish an independent rival product.

Time 2: The agent decides on level of effort, $e \in [0,1]$.

R&D quality is realized: $v = \begin{cases} \bar{v} & \text{with probability } p(e) \\ \underline{v} & \text{with probability } 1 - p(e) \end{cases}$

Time 3: If the agent fulfils the contract, payments are made according to realized R&D level and contract terms. If agent abrogates the contract and produces a rival product, then the two competing firms play a duopoly game.

We assume both the principal and the agent are risk neutral. This assumption is consistent with the notion that both the principal and the agent are firms managed by executives seeking to maximize expected profits. The profit of the principal from the contract when the agent does not misappropriate IP is given by:

$$\pi_p = p(e) \cdot (\bar{v} - \bar{T}) + (1 - p(e)) \cdot (\underline{v} - \underline{T}) - \frac{\gamma}{2} K_p^2 \quad (2.1)$$

where $\gamma > 0$. The profit of the agent from the contract is

$$\pi_A = p(e) \cdot \bar{T} + (1 - p(e)) \cdot \underline{T} - C_A^{contract} \quad (2.2)$$

where $C_A^{contract}$ denotes the cost of the agent if he stays with the contract. The components of the cost function are described shortly.

The goal of the principal is to design an incentive compatible contract such that the agent would not misappropriate the IP as well as exert high effort on the project. In order to do so, the principal must give the agent, in expected terms, a transfer that is at least equal to the outside option, Ψ . This outside option is computed as the duopoly profit the agent might earn, if he walks away from the contractual relationship and produces a competing product with stolen IP. In order to derive this outside option, we first specify how knowledge transfer occurs from the principal to the agent.

Knowledge sharing is modeled following an adapted version of D'Aspremont and Jacquemin (1988). The agent's cost of production depends on the intensity with which he can assimilate the knowledge shared by the principal. The intensity of imitation is captured by parameter $\alpha \in [0,1]$. Formally, we specify the agent's cost function under piracy as

$$C_A^{piracy} = c - \alpha \cdot K_p \quad (2.3)$$

where c denotes the marginal cost of production and α is the knowledge assimilation parameter that denotes the unit cost savings associated with knowledge transferred from the principal to the agent. In this chapter, sharing of proprietary knowledge by the principal leads to reduced cost of production for the agent. Thus when knowledge is misappropriated, both the principal and the agent have the same know-how to produce competing products as illustrated in the GM-Chery example, where both cars appear to share similar mathematical formulae and design (Liu and Fernandez, 2007). However, doing R&D for the principal entails an additional effort through increased communication and coordination (of supply chain related) activities and hence, higher cost for the agent. In particular, let the disutility of effort be given by a convex cost function $g(e) = e^2$. Thus, working for the principal renders the agent's cost function as

$$C_A^{contract} = c - \alpha \cdot K_p + g(e). \quad (2.4)$$

We use backward induction to obtain the Bayes-perfect equilibrium of this game.

Stage three

If there is no IP theft, the agent fulfills the contract and R&D is realized according to exerted level of effort. Contingent on the realized quality of R&D the principal makes

payment to the agent. The profits of the principal and the agent are specified in (2.1) and (2.2) respectively. Instead, if the agent abrogates, the firms compete non-cooperatively in the product market. In this case, assuming that the agent cannot successfully replicate the principal's brand, each company produces a differentiated product. We assume consumer demand for each product is given by

$$w_i = 1 - q_i - \theta q_j \quad (2.5)$$

where i, j = principal, agent and $i \neq j$. w 's and q 's denote prices charged and quantities produced. The parameter $\theta \in [0,1]$ captures the degree of substitutability between the competing products produced by the two firms when the agent misappropriates the principal's IP and establishes a rival product. If θ is close to unity then the products are near perfect substitutes, whereas if it is zero, there is no substitutability between the products. Thus, when IP is misappropriated by the agent, the profit functions of the two firms are given by

$$\pi_P^{piracy} = (1 - q_P - \theta q_A - C_P)q_P - \frac{\gamma}{2} K_P^2 \quad (2.6a)$$

and

$$\pi_A^{piracy} = (1 - q_A - \theta q_P - C_A^{piracy})q_A \quad (2.6b)$$

where $C_P = c \geq C_A^{piracy} = c - \alpha \cdot K_P$. Since IP is shared by the principal, the agent gets costless access to the knowledge. The principal, on the other hand, had to invest substantial time and money in developing IP. Thus it is reasonable to assume that the two competing firms would have different costs of production. This may have been the case in the GM-Chery example. The R&D required by GM to produce Spark took 40

months, while Chery was able to develop similar technology to produce the QQ in only 24 months (Liu and Fernandez, 2007). This suggests the cost of development for the QQ was less than that of Spark. Also, for simplicity, we assume that the entrepreneur cannot obtain any indemnity from the agent. This simplifying assumption may be attributed to the fact that legal protection is imperfect (Rønde, 2001). It is straightforward to include an expected damage parameter in the profit functions above. However, the equilibrium conditions would not change.

When the agent decides to establish an independent rival product, the Cournot-

Nash equilibrium quantities are obtained by solving $\frac{\partial \pi_A^{piracy}}{\partial q_A} = 0$ and $\frac{\partial \pi_P^{piracy}}{\partial q_P} = 0$:

$$q_P = \frac{2 \cdot (1-c) - \theta \cdot (1-c + \alpha \cdot K_P)}{4 - \theta^2}, \quad (2.7)$$

$$q_A = \frac{2 \cdot (1-c + \alpha \cdot K_P) - \theta \cdot (1-c)}{4 - \theta^2}. \quad (2.8)$$

Lemma 2.1

The agent can successfully establish a rival product and produce profitable positive

output when $\frac{2 - 2c - \theta + \theta c}{\theta \alpha} > K_P$. This may be interpreted as an upper bound on the

level of knowledge shared by the principal to prevent the agent from producing a rival product.

Proof: From equation (2.7), $q_P > 0$ when $2 - 2c - \theta + \theta c > \theta \alpha K_P$ and from (2.8), $q_A > 0$

when $2 - 2c - \theta + \theta c > -2\alpha K_P$. We combine these two inequalities as

$2 - 2c - \theta + \theta c > \text{Max}\{\theta \alpha K_P, -2\alpha K_P\} = \theta \alpha K_P$. This proves Lemma 2.1.

Substituting the quantities from (2.7) and (2.8) into the profit functions (2.6a) and (2.6b) yields the equilibrium profit levels in terms of the principal's first stage choice variable,

K_P :

$$\pi_P^{piracy} = \left[\frac{2 - \theta - 2c + \theta \cdot (c - \alpha \cdot K_P)}{4 - \theta^2} \right]^2 - \frac{\gamma}{2} K_P^2 \text{ and} \quad (2.9)$$

$$\pi_A^{piracy} = \left[\frac{2 - \theta + \theta \cdot c - 2 \cdot (c - \alpha \cdot K_P)}{4 - \theta^2} \right]^2 \equiv \psi(K_P) \quad (2.10)$$

Thus, the outside option $\psi(K_P)$ of the agent is given by (2.10) above. This is the profit that the agent could earn had he decided to misappropriate the IP and develop a rival product. We observe that the outside option of the agent is not exogenous, as in canonical principal-agent models (Laffont and Martimort, 2002). Specifically, the value of the agent's outside option depends on demand and cost parameters, the knowledge assimilation parameter, and most importantly, the level of knowledge shared by the entrepreneur. As we will see later, by appropriately choosing the level of K_P , the principal can vary the attractiveness of the agent's outside option. The principal can thus induce the agent not to misappropriate IP and stay with the contract. In particular, by reducing the level of IP shared, the principal can successfully diminish the value of outside option of the agent and hence deter the IP theft problem.

Stage two

At this stage the principal has already shared her IP with the agent. After the agent has learnt the technology, he exerts effort to produce R&D for the principal.

Stage one

At this stage the contract terms are already chosen and the agent has accepted the contract. The principal chooses the level of IP to share with the agent that would maximize her profit given by (2.1).

Stage zero

The principal designs a contract to maximize her profit in (2.1) subject to the participation constraint/individual rationality constraint (IRC) of the agent:

$$\pi_A = p(e) \cdot \bar{T} + (1 - p(e)) \cdot \underline{T} - C_A^{contract} \geq \psi(K_p) \quad (2.11)$$

where $\psi(K_p)$ is given by (2.10) above. The IRC ensures that the agent accepts the contract.

2.4 First Best Solution (FB)

In this section, we develop the full information first best solution, where the principal can perfectly observe effort exerted by the agent. Thus the principal need not worry about the agent's opportunistic behavior with respect to effort, but only the agent's willingness to work for the principal. The principal's optimization problem is given by maximization of profit (2.1) subject to the agent's IRC (2.11), which yields the first best solution as follows:

Proposition 2.1

(i) The first best full information payment to the agent is a fixed transfer

$$\bar{T} = \underline{T} = T^{FB} = \psi(K_p^{FB}) + c - \alpha \cdot K_p^{FB} + \left(\frac{\bar{v} - \underline{v}}{2} \right)^2. \quad (2.12)$$

(ii) The first best knowledge shared by the principal is

$$K_p^{FB} = \frac{\alpha - \frac{4\alpha}{(4-\theta^2)^2} \cdot (2-2c-\theta+\theta c)}{\gamma + \frac{8\alpha^2}{(4-\theta^2)^2}}. \quad (2.13)$$

(iii) The first best effort exerted by the agent is $e^{FB} = \left(\frac{\bar{v} - \underline{v}}{2} \right)$. (2.14)

where $\psi(K_p^{FB})$ is computed by substituting (2.13) into (2.10).

Proof: The Lagrangean of the optimization problem is

$$L = e \cdot [\bar{v} - \bar{T}] + (1-e) \cdot [\underline{v} - \underline{T}] - \frac{\gamma}{2} \cdot K_p^2 + \lambda \cdot [e \cdot \bar{T} + (1-e) \cdot \underline{T} - c + \alpha \cdot K_p - e^2 - \psi(K_p)]$$

where λ denotes the Lagrange multiplier. The first order conditions with respect to the variables $\bar{T}, \underline{T}, K_p, \lambda$ and e yield the solution enumerated in Proposition 2.1. The solution of the Lagrange multiplier is $\lambda = 1$, implying that the agent's IRC is binding in equilibrium. The economic interpretation of Proposition 2.1 is as follows. First we note from part (i) that the principal pays the agent a fixed wage, T^{FB} . In the first best case, the principal can observe and verify effort exerted by the agent. Therefore the principal offers a lump-sum payment in order not to distort the agent's incentive to work. At the optimum, the payment to the agent must equal the duopoly profit associated with his outside option as a competing firm plus the cost of his extra effort expended in producing the R&D. Part (ii) implies that the level of knowledge shared by the principal in the first best case is determined by equating the marginal benefit associated with reducing the cost of R&D production to the marginal cost of IP sharing. We note that the

marginal cost of knowledge sharing not only has a direct component γ , but also an indirect component $\frac{\partial \psi(K_P)}{\partial K_P} > 0$ through the anticipated effect knowledge sharing will have on duopoly profit if the agent misappropriates knowledge. Thus a forward looking principal must always take into account how IP sharing might affect the value of the outside option of the agent. Part (iii) gives the optimal level of effort chosen by the agent. The marginal benefit of an extra unit of effort exertion must be equal to the marginal cost of the same.

Lemma 2.2

The optimal level of knowledge shared by the principal with the agent is always positive. The difference in contract values of R&D (depending on whether it is a blockbuster or flop) is bounded between 0 and 2.

Proof: Equation (2.13) implies that $K_P^{FB} > 0$ whenever $c > \frac{\theta^3 + 2\theta^2 - 4\theta - 4}{4} = f(\theta)$.

It is easy to see that $f(0) = -1$, $f(1) = -1.25$, and $f(\theta) < 0$ over the permissible values of $\theta \in [0,1]$. On the other hand, c , being cost of production, is non-negative. Thus the condition $c > f(\theta)$ is always satisfied. Moreover, since $e \in [0,1]$, equation (2.14) implies that $0 \leq (\bar{v} - \underline{v}) \leq 2$.

2.5 Second Best Solution (SB)

In the second best asymmetric information case, the principal cannot be sure of the agent's effort since the possibility of costless monitoring is precluded. In this case, the entrepreneur must be concerned with both agency problems due to IP misappropriation and suboptimal effort on the part of the R&D contractor. Since the entrepreneur cannot perfectly monitor the agent, the latter might shirk as exertion of effort to develop R&D is costly. In this case, the optimal contract must be designed so that the agent desires to produce R&D with high effort since otherwise it would not pay for the principal to offer any incentive. To achieve incentive compatibility, the principal must anticipate the agent's optimal effort given the contractual payments. Thus in the second best case, the relevant constraints faced by the principal are the IRC of the agent specified in (2.11) and the incentive compatibility constraint (ICC) given below.

$$e = \underset{\tilde{e} \in [0,1]}{\arg \max} \left\{ p(\tilde{e}) \cdot \bar{T} + (1 - p(\tilde{e})) \cdot \underline{T} - c + \alpha \cdot K_p - g(\tilde{e}) \right\} \quad (2.15)$$

When effort is not observed by the principal, she cannot write the contract contingent on effort. However, the principal anticipates that the agent will exert effort that will maximize his profit which depends on observed and verifiable outcomes. This explains the agent's ICC.

Proposition 2.2

(i) The optimal second best asymmetric information payment to the agent includes a fixed component and a variable component that is contingent on realized R&D quality.

$$\begin{aligned}\bar{T}^{SB} &= \psi(K_P^{SB}) - \alpha \cdot K_P^{SB} + c - \left(\frac{\bar{v} - \underline{v}}{2}\right)^2 + (\bar{v} - \underline{v}) \text{ if high quality R\&D is realized, and} \\ \underline{T}^{SB} &= \psi(K_P^{SB}) - \alpha \cdot K_P^{SB} + c - \left(\frac{\bar{v} - \underline{v}}{2}\right)^2 \text{ if low quality R\&D is realized.}\end{aligned}\quad (2.16)$$

(ii) The optimal second best knowledge shared by the principal is

$$K_P^{SB} = \frac{\alpha - \frac{4\alpha}{(4 - \theta^2)^2} \cdot (2 - 2c - \theta + \theta c)}{\gamma + \frac{8\alpha^2}{(4 - \theta^2)^2}}. \quad (2.17)$$

(iii) The optimal second best effort exerted by the agent is $e^{SB} = \left(\frac{\bar{v} - \underline{v}}{2}\right)$. (2.18)

Proof: See Appendix 1.

When effort is unobservable, a part of the payment depends on the quality of R&D actually realized which, in turn, depends on agent effort. This result is in contrast to the first best solution, where we found that the agent would be paid a fixed fee. We also find that $\bar{T}^{SB} > \underline{T}^{SB}$, implying that the optimal incentive payments depend on the level of R&D produced by the agent. When effort cannot be observed, the principal must incentivize effort by rewarding good outcomes. Further, the agent's expected profit is exactly equal to the outside option that he could have earned by selling a rival product. This is because at the optimum, the agent's IRC must bind.

The difference between first best and second best cases emanates from the verifiability of effort exerted by the agent. The marginal conditions that define optimal knowledge sharing by the principal remain identical whether or not effort is verifiable.

Thus we find that same level of knowledge will be shared by the principal in both first and second best situations. The expected marginal benefit of increasing effort by one extra unit is $(\bar{T} - \underline{T})$, whereas the marginal cost of doing the same is $2e$. The principal designs the optimal incentive payments $\{\bar{T}^{SB}, \underline{T}^{SB}\}$ such that agent's expected marginal benefit of exerting effort is equal to $(\bar{v} - \underline{v})$. Second best effort exerted by the agent is obtained at the effort level that equates expected marginal benefit with marginal cost. This leads to the result that the optimal second best contract implements the first best effort when the agent is risk neutral (Laffont and Martimort (2002), pp.154). The agent exerts an efficient level of effort and gets expected profit equal to his outside option from producing a rival product.

2.6 Fully Protected Solution (FP)

Finally, we consider the situation where the principal does not face the possibility of IP theft. This scenario might be interpreted as if the principal had access to a technology that would prevent IP theft or where IP can be fully protected through a perfectly enforceable legal system. For instance, companies that outsource database operations often use encryption technology. Also, when a semiconductor "fab" produces chips from client's masks, copies can be made quite cheaply; consequently semiconductor firms are implementing novel technological solutions to protect IP from outsourced fabrication contractor piracy (Roy et al., 2008). We assume that the principal can implement the technological solution by incurring a monetary cost $\beta \geq 0$. This

parameter might also be interpreted as the cost of perfect legal enforcement. In this case, the principal's profit under the fully protected IP regime would be

$$\pi_p^{FP} = p(e) \cdot (\bar{v} - \bar{T}) + (1 - p(e)) \cdot (\underline{v} - \underline{T}) - \frac{\gamma}{2} K_p^2 - \beta \quad (2.21)$$

When IP is fully protected, either through technological solution or under the law with no enforcement problem, there is no IP misappropriation related outside option for the agent. However, the principal must still be concerned about the agent's opportunistic behavior with respect to shirking on effort. Thus the problem faced by the principal is to maximize profit (2.21) subject to the ICC specified in (2.15) and a modified IRC of the agent:

$$\pi_A^{FP} = p(e) \cdot \bar{T} + (1 - p(e)) \cdot \underline{T} - C_A^{contract} \geq 0 \quad (2.22)$$

The solution to this problem is presented in the following proposition.

Proposition 2.3

(i) When a fully protected technological solution is available to the principal, the optimal payment to the agent includes a fixed component and a variable component that is contingent on realized R&D quality.

$$\begin{aligned} \bar{T}^{FP} &= c - \frac{\alpha^2}{\gamma} - \left(\frac{\bar{v} - \underline{v}}{2} \right)^2 + (\bar{v} - \underline{v}) \text{ if high quality R\&D is realized, and} \\ \underline{T}^{FP} &= c - \frac{\alpha^2}{\gamma} - \left(\frac{\bar{v} - \underline{v}}{2} \right)^2 \text{ if low quality R\&D is realized.} \end{aligned} \quad (2.23)$$

(ii) The optimal level of knowledge shared by the principal is

$$K_p^{FP} = \frac{\alpha}{\gamma}. \quad (2.24)$$

$$(iii) \text{ The optimal effort exerted by the agent is } e^{FP} = \left(\frac{\bar{v} - \underline{v}}{2} \right). \quad (2.25)$$

Proof: See Appendix 2.

Since the principal cannot observe effort exerted by the agent, she would design the optimal incentive payments $\{\underline{T}^{FP}, \bar{T}^{FP}\}$ contingent on the level of R&D realized. These incentive payments ensure that the agent will not behave opportunistically by providing too little effort in R&D development. We note that payments made by the principal do not include a “carrot” to offset duopoly profits as in first or second best cases because of the impossibility of IP theft due to the technological solution.

The level of IP shared by the principal is determined by equating the marginal benefit of knowledge sharing with marginal cost. Due to the technological solution, the principal need not worry about the possibility of knowledge misappropriation. Thus the principal’s marginal cost of knowledge sharing is less when a technological solution is available compared to when it is not. Consequently, more knowledge will be shared by the principal. Finally, optimal effort exerted by the agent is obtained using equi-marginal principle described earlier.

Proposition 2.4

Optimal knowledge sharing by the entrepreneur is lower when IP cannot be fully protected.

$$K_p^{FP} > K_p^{FB} = K_p^{SB} \quad (2.26)$$

Proof: Straightforward difference from (2.13) and (2.24) establishes this result.

This comprises the “stick approach” to manage the IP misappropriation problem. The entrepreneur should disseminate less knowledge when IP theft is possible compared to a regime where full protection is available, either through technological protection or perfect legal enforcement. Without full IP protection, the entrepreneur must take a judicious approach while sharing her intellectual property with the outsourcing partner. While a high level of knowledge sharing can greatly enhance the performance of the agent, it can also pave the path towards misappropriation of IP. Therefore, the principal must not share all of her pre-existing IP with the agent. In practical terms, this may be accomplished by breaking the task of R&D into modules and sharing only selective knowledge with the agent on a “need to know” basis to develop subcomponents of a larger system known only to the entrepreneur. We note from equation (2.10) and Lemma 2.1 that $\psi(K_p)$, the outside option of the agent, is increasing in K_p . By sharing less knowledge the principal can increase the agent’s cost of production and consequently dampen the agent’s incentive to walk away from the contractual relationship and become a rival.

Proposition 2.5

The principal would have to pay more to the agent when effort is not observable and full protection is unavailable compared to the situation where a technological solution is available.

$$(i) \bar{T}^{SB} \geq T^{FB} \geq \underline{T}^{SB} \geq \bar{T}^{FP} \geq \underline{T}^{FP} \text{ when } (\bar{v} - \underline{v}) < \min\{2, D^*\}$$

$$(ii) \bar{T}^{SB} \geq T^{FB} \geq \bar{T}^{FP} \geq \underline{T}^{SB} \geq \underline{T}^{FP} \text{ when } D^* \leq (\bar{v} - \underline{v}) \leq \min\{2, D^{**}\}$$

$$(iii) \bar{T}^{SB} \geq \bar{T}^{FP} \geq T^{FB} \geq \underline{T}^{SB} \geq \underline{T}^{FP} \text{ when } (\bar{v} - \underline{v}) > D^{**}$$

where $D^* = \psi(K^{SB}) + \alpha(K^{FP} - K^{SB})$ and

$$D^{**} = \psi(K^{FB}) + \alpha(K^{FP} - K^{FB}) + \frac{(\bar{v} - \underline{v})^2}{2} \quad (2.27)$$

Proof: See Appendix 3.

This is the “carrot approach” that the principal can use to protect her IP. In the first best situation, the principal can observe and verify effort exerted by the agent. Therefore, as stated in Proposition 2.1, the principal would offer a lump-sum payment to the agent.

This lump-sum payment equals the duopoly profit from selling a competing product plus the cost of his effort expended in producing the R&D.

In the second best situation, the principal cannot observe effort exerted by the agent. This leads to the hidden action problem, whereby the agent might under-invest in effort to develop high quality R&D since exertion of effort is costly. Therefore the principal must design the contract such that the agent has incentive to exert high effort to produce R&D. As stated in Proposition 2.2, the optimal incentive payments depend on the level of R&D produced by the agent. Further, the agent’s expected profit is exactly equal to the outside option that he could have earned by producing a rival product.

Finally, in the fully protected regime, while IP theft is impossible, the principal still cannot observe effort exerted by the agent. This calls for incentive payments

contingent on the level of R&D realized. These incentive payments ensure that the agent would exert optimal effort. However, unlike in the first and second best case(s), we note that the payments do not have to include the duopoly profits because of impossibility of IP theft due to the technological solution. Consequently, the profit of the agent is zero when a full protective solution is available.

From the above discussion we can say that the principal would have to pay less to the agent when full protection is available compared to a situation where it is not. This is the essence of the “carrot approach” of managing IP. The payments must be higher in a regime where IP theft is possible compared to the situation where IP theft is not feasible. In the first or second best cases, the payments must internalize the duopoly profits that the agent may be able to earn if he were to develop a rival product.

Proposition 2.6

As marginal production cost increases, the entrepreneur will share more knowledge with the agent. In contrast, as the marginal cost of knowledge sharing increases, she will share less knowledge. Also, if the ability of the agent to assimilate knowledge exceeds a threshold value, the principal will reduce knowledge sharing. Equivalently, if the degree of substitution between the entrepreneur’s product and the potential rival product resulting from misappropriated IP exceeds a threshold value, then the principal must share less knowledge with the agent.

$$(i) \frac{\partial K_P^{FB}}{\partial c} > 0$$

$$(ii) \frac{\partial K_P^{FB}}{\partial \gamma} < 0 \text{ under Lemma 2.1.}$$

$$(iii) \frac{\partial K_P^{FB}}{\partial \alpha} < 0 \text{ if } \alpha > \sqrt{\frac{\gamma(4-\theta^2)^2}{8}} \equiv \alpha^* \Leftrightarrow \theta > \sqrt{4 - \left(\frac{8\alpha^2}{\gamma}\right)^{1/2}} \equiv \theta^* \quad (2.28)$$

Proofs of parts (i) and (ii) are straightforward and hence omitted for brevity.

$$\text{Proof of part (iii): } \frac{\partial K_P^{FB}}{\partial \alpha} = \frac{\left(\frac{8\alpha^2}{(4-\theta^2)^2} - \gamma\right) \cdot \left(-1 + \frac{4}{(4-\theta^2)^2} \cdot (2 - 2c - \theta + \theta c)\right)}{\left(\gamma + \frac{8\alpha^2}{(4-\theta^2)^2}\right)^2}$$

The expression in the second parentheses of the numerator is negative by Lemma 2.1.

The denominator is positive, being a square term. Thus the whole expression is negative when the expression in the first parentheses of the numerator is positive. Formally, the

required condition is $\alpha > \sqrt{\frac{\gamma(4-\theta^2)^2}{8}} \equiv \alpha^*$. An equivalent condition would

$$\text{be } \theta > \sqrt{4 - \left(\frac{8\alpha^2}{\gamma}\right)^{1/2}} \equiv \theta^*.$$

Intuitively, part (i) implies that if the principal's cost of production increases, the entrepreneur will outsource more vigorously. In that case, she would be willing to share more knowledge in order to make the outsourcing contract successful. Part (ii) implies that with an increase in the marginal cost of knowledge sharing, the entrepreneur would reduce the optimal level of knowledge shared.

In part (iii), the parameter α is the degree to which the agent can effectively assimilate IP shared by principal. It could encompass the absorptive capacity, complementary

assets, and co-specialized knowledge that would determine how effectively the agent can learn the shared technology. Indeed, as Teece (1986) explains, the possibility of knowledge leakage depends on the degree to which the supplier can effectively use the shared know-how. When it is easier for the agent to assimilate knowledge, the principal would share less IP if the intensity of imitation exceeds a threshold level α^* . This result provides an idea on the plausibility of the technology being copied. If the technology is difficult to copy, the entrepreneur may share more knowledge with the agent.

An alternative interpretation of part (iii) is also possible. If the degree of substitutability in customer demand parameter, θ , exceeds a certain threshold level, θ^* , then the entrepreneur should be concerned with potential IP theft by the R&D contractor. If the principal expects that the agent might walk away from the contract and produce a highly substitutable product, she should share less IP in the first place. Both of these interpretations provide insight on issues like, “when is it safe for an entrepreneur to share pre-existing IP with the agent?” When the agent has a brand name and portfolio of related products already established in the marketplace, it has higher chance of walking away from the relationship and introduce a rival product. This might have played a role in the Lexar and Toshiba example discussed in Chapter I.

Proposition 2.7

As the entrepreneur shares more of her intellectual property with the agent, the latter is able to charge a lower price for his competing product. It also affects the profit of the agent favorably:

$$\frac{\partial w_A}{\partial K_p} < 0, \frac{\partial \pi_A^{piracy}}{\partial K_p} > 0$$

Proof: $\frac{\partial w_A}{\partial K_p} = \frac{\alpha(\theta^2 - 2)}{4 - \theta^2} < 0$ since $\theta \in [0,1]$.

$$\frac{\partial \pi_A^{piracy}}{\partial K_p} = \frac{\partial \psi(K_p)}{\partial K_p}. \text{ We note that } \psi(K_p) = (q_A)^2. \text{ Thus } \frac{\partial \psi(K_p)}{\partial K_p} = \frac{4\alpha q_A}{4 - \theta^2} > 0 \text{ since}$$

$q_A > 0$ is ensured by Lemma 2.1 and $\alpha \in [0,1], \theta \in [0,1]$.

This proposition captures the effect of the principal's IP sharing on the agent if the latter decides to walk away from the contract and develop a rival product. We find that increased IP sharing by the principal reduces the price charged by the pirate firm. It also has a positive effect on the pirate's profit. This result is consistent with the Chery example, where Chery charged a lower price for its QQ than Spark produced by GM-Daewoo (Liu and Fernandez, 2007). Thus we see how the agent might use IP shared by the principal towards its own commercial benefit.

Proposition 2.8

The entrepreneur makes a higher profit when a technological solution is available at a low cost. However, if the cost of technological solution is higher than a threshold, then the entrepreneur is better off using the carrot and stick approach.

$$\pi_p^{FP} > \pi_p^{SB} = \pi_p^{FB} \text{ when } \beta < \psi(K_p^{SB}) + \alpha(K_p^{FP} - K_p^{SB}) - \frac{\gamma}{2} \left[(K_p^{FP})^2 - (K_p^{SB})^2 \right]$$

$$\pi_p^{FP} \leq \pi_p^{SB} = \pi_p^{FB} \text{ otherwise.}$$

Proof: See Appendix 4.

This result captures the relative attractiveness of the carrot and stick mechanism when IP theft is feasible vs. the technological/legal solution when IP theft is not feasible. The equality of profits under the first and second best case is due to our assumptions of risk neutrality of the agent; even if effort exerted by the agent is not observable by the principal, the second best contract leads to the first best effort and profit for each party.

The interesting tradeoff involves the second best case where IP theft is feasible vs. the full protection solution where IP theft is not feasible. If β , the cost of implementing the technological solution or perfect legal enforcement is lower than a threshold, the entrepreneur would be better off investing in these technologies. However, if cost of legal enforcement/technological solution is prohibitively high, the appropriate mechanism would be the use the carrot and stick approach. In that case, we suggest that the principal share less of her pre-existing IP and give high incentive payments to the agent so that IP theft is deterred and high effort is ensured simultaneously.

2.7 Discussion

What can entrepreneurs do to mitigate risks of IP loss while outsourcing R&D to an agent? According to our paper, entrepreneurs can use two types of strategies. The first strategy is to implement a carrot and stick approach while designing an outsourcing contract. The second strategy is to ensure that the shared IP cannot be duplicated easily by the agent. There are three alternative approaches to implement the second strategy. One approach would be to produce a differentiated product and invest in branding and advertising to enable consumers to better understand the unique characteristics of the

product. The second approach might be to break the task into modules and outsource them to different contractors. The third approach is to invest in technological solutions that would render IP theft infeasible. We discuss these different strategies in the light of real life examples and relate them to the suggestions offered by existing literature.

i) Carrot and Stick (CS): The suggested approach of using higher payments to the agent and less knowledge sharing by the principal concurs with the high powered incentive based solutions in the literature (e.g. Ulset, 1996; Lai et al., 2009). We suggest that firms should use incentive payments along with appropriate disincentives through less knowledge sharing. Following Proposition 2.4, a forward looking entrepreneur who suspects eventual theft of IP ought to share an amount of knowledge that is just sufficient for the completion of the outsourcing project.

We find support for our proposition of cautious IP sharing among medical device manufacturers who outsource everything (prototyping, materials, and electronics) except their core IP. For instance, Medtronic never outsources the development of the algorithm that its pacemaker uses to monitor heart rhythm, but does outsource tasks involving specialized expertise (Boehner, 2008). Additional support for guarded IP sharing is provided by Incat, the Australian manufacturer and designer of large, high speed catamaran ferries. This company successfully manages risk associated with potential dissipation of its IP and know-how by not transferring mainstream design to its Hong Kong based partner (McCaughey et al., 2000).

ii) Product Differentiation (PD): By producing differentiated products and using

branding and advertising as a strategy, firms can mitigate IP concerns. Using this strategy, the entrepreneur can diminish the profit of the R&D contractor from establishing a rival product. Consequently, it also lowers the incentive payments necessary to outsource R&D from the contractor. In our model, when θ , the degree of product differentiation is low, the entrepreneur may share more IP with the outsourcing agent, by Proposition 2.6 part (iii). More importantly, the strategy of product differentiation can also work favorably for companies who have actually experienced IP misappropriation. Indeed, no matter how much precaution a firm takes, leakage may not be prevented to the fullest extent (Liebeskind, 1997). Therefore firms ought to think of strategies that would work in an ex-post sense, after IP leakage/misappropriation has actually occurred. According to our model, in case of IP misappropriation, there will be two competing products in the market with same basic IP embedded in them. Other things remaining the same, if the competing products are too similar then consumers will prefer the one that is cheaper. There are various reasons why the pirate firm might be able to undercut the entrepreneur. Proposition 2.7 enumerates the effect of the principal's knowledge sharing on the price charged by the pirate firm and there is evidence of this undercutting effect in both the GM-Chery and Lexar-Toshiba examples (Liu and Fernandez, 2007; Fair Disclosure Wire, 2005).

Given the plausibility of price undercutting by the (newly formed) rival firm, the entrepreneur might find it useful to employ business strategies that would make her product more dissimilar at least as perceived by customers. The entrepreneur may achieve this by providing complementary inimitable services with the products,

introducing new versions of products, or establishing brand reputation. To the extent that the products are favorably received by consumers, the entrepreneur might be able to survive an otherwise dangerous IP theft. For example, Lexar invested in product differentiation strategy by introducing flash memory cards with higher writing speed and larger capacities to remain competitive (Lexar Media, 2006).

iii) Modularization (M): Another practical way to deter IP theft would be to invest in technologies that would make copying too costly for the agent. This might be accomplished by modularization of outsourcing tasks along the lines of what is called structural isolation (Liebeskind, 1997). If the agent gets access to only parts of the production process or trade secrets, it might be too costly for him to misuse the information. Chen and Bharadwaj (2009a) find that firms in the IT sector often use modularity of outsourced tasks to protect IP. In our paper, the “stick” approach of less knowledge sharing might be regarded as a modularization strategy. The solution essentially relies on exposing small parcels of knowledge so that the agent cannot fully understand the overall technology and so cannot misappropriate the entrepreneur’s IP.

iv) Fully Protected solution (FP): The final approach would be to invest in technologies to ensure IP is secured completely. Examples include advanced encryption, watermarking, and digital rights management (DRM).

The relative effectiveness of these four strategies in protecting pre-existing IP of the entrepreneur depends on several factors. CS requires the entrepreneur to provide high powered incentives to the R&D contractor which can be costly to negotiate and enforce. Further, while less knowledge sharing is recommended, in realistic terms, it can be very

difficult to determine the extent of knowledge that should be shared. Less knowledge sharing by the principal might render the agent less productive and hence affect the outsourced R&D project adversely. The M strategy could be too costly for the principal. It would require coordination of the tasks in different locations and involve high transaction costs in a Coasean sense. The PD strategy relies on consumer acceptance and willingness to pay a premium for the differentiated product. Finally, the FP strategy would require additional ex-ante investment by the entrepreneur. Notwithstanding the fact that legal tools like Non Disclosure Agreements, restrictive covenants exist, one cannot guarantee that any of the methods are infallible. Indeed, companies ought to assess the relative costs and benefits of adopting these alternative strategies to protect IP under outsourcing engagements.

Finally, the nature of the industry is also an important factor. For entrepreneurial ventures in certain industries (like biotechnology, pharmaceutical, semiconductor and electronics) the cost of developing new products is enormous. While the development of IP involves huge R&D investments, the cost of copying the technology is relatively low (Branscomb et al. (1999), pp. 308). Therefore these products are characterized by high intensity of imitation (α in our model). Consequently, firms in these industries must carefully evaluate the outsourcing proposition and take proactive strategies before sharing their pre-existing IP with their agents. Investing in product differentiation, modularization and technological solutions might be particularly effective.

2.8 Conclusion

Firms need to share their IP with supply chain partners ever more frequently under outsourcing contracts. However, assets such as know-how and trade secrets are intrinsically difficult to protect, particularly when enforcement is weak. Under certain circumstances, this can lead to supplier opportunism and emergence of rival products. Protection of IP in outsourcing relationships calls for strategic management tools. In particular, a carrot and stick approach may be useful to combat the problem. An entrepreneur should share less IP with the agent if there is potential misappropriation problem. This “stick” approach renders the prospect of misappropriation less attractive when compared to continuing with the contract relationship. In conjunction with the stick approach, the agent must also be given “carrots” in the form of incentive payments such that he exerts optimal effort towards the R&D task. In addition, we suggest that complementary strategies like product differentiation and modularization of tasks could make misappropriation of IP too costly for the agent. Product differentiation might be a useful strategy not only to prevent IP theft, but also when IP theft has actually occurred.

CHAPTER III

OUTSOURCING BY FOOD PROCESSING FIRMS: PROBLEMS AND PROSPECTS

3.1 Introduction

“Although we have more than 4500 people in Nestlé Food and Beverages R&D, we cannot achieve our ambitions simply by working internally. We increasingly operate in an Open Innovation mode to enhance our own internal R&D capability by tapping into external resources.”- From www.nestle.com

Strategic alliances are becoming increasingly important in the food and agribusiness industry. As firms outsource their non-core activities to suppliers-contractors, they are able to concentrate on their core functions like product development, marketing and so on. The economic benefit of organizing tasks through outsourcing is attributed to efficiency gains from specialization. According to Prahalad and Hamel (1990), firms should keep core activities in-house and outsource non-core tasks if there are significant cost advantages. Examples of core competencies include chocolate technology (Hershey), baking (Nabisco), and refrigerated dough (Pillsbury) which are kept in-house. H-E-B maintains a new product development staff and develops private label products in-house. In contrast, companies like Domino Foods, Kraft routinely outsource non-core tasks like Information Technology (IT) to Capgemini, which allow them to concentrate on their core competencies.

Evidently, food processing companies are assessing their core competencies and revisiting “make or buy” decision (Lord, 2000). For instance, according to a survey by

Grant Thornton and Food Processing magazine, almost 68% of food and beverage manufacturers indicated that some part of their production is outsourced (Grant Thornton, 2008). In contrast, 68% of food and beverage manufacturers choose to keep their R&D/product development activities in-house. The survey suggests that while it is common among food processing companies to outsource manufacturing, they generally organize R&D tasks internally.

For the purpose of this chapter, we focus on R&D /innovation activities that can be very costly if done entirely in-house. Food processing companies willing to develop new, innovative products face several technical challenges. For example, R&D tasks like flavor formulation are becoming increasingly complex as companies are trying to produce differentiated products with low calorie, low fat content without sacrificing the taste. Therefore firms are taking advantage of supplier expertise in ingredients to enhance quality, taste, texture, or health benefits (Lord, 2000). Food and beverage companies outsource R&D to gain access to technology/equipment, access new ideas, increase capacity and lower costs (Grant Thornton, 2008). Thus modern food product development requires technologies that are available beyond a firm's own boundaries. For example, we present the following cases of innovation outsourcing by some of the successful brands:

- a) Procter and Gamble (P&G) launched a new line of Pringles potato chips with pictures and words printed on each crisp (Huston and Sakkab, 2006). If the R&D were done with in-house resources it would have taken at least two years to launch the product. But with a successful open innovation approach, Pringles was

able to bring the new product in less than a year and at a fraction of the cost of in-house development.

- b) General Mills launched its Worldwide Innovation Network in 2007 and since then it has outsourced innovation for several of its products. General Mills worked with longtime supplier, Kerry Ingredients and Flavors to develop the breakthrough innovation like Yoplait Smoothie (www.generalmills.com).
- c) In 2010, Coca-Cola outsourced flavor technology from Chromocell Corp. to develop sweetness enhancers and natural sweeteners for its reduced calorie beverages. Likewise, PepsiCo collaborated with Senomyx to develop sweetness enhancers and natural high-intensity sweeteners for its innovative products.

These examples corroborate with Berne (1995)'s observation that companies need no longer conduct product development inside company walls under a shroud of secrecy with no outside assistance. Since firms rarely possess all of the necessary expertise to develop new products, they are facing the need to outsource product development activities to outside suppliers (Lord, 2000).

3.2 Problems Related to Outsourcing

While outsourcing has opened up new avenues for companies in terms of organizing tasks, the benefits come with two critical problems. The first problem arises when a company outsources a task, it has to disclose its valuable intellectual property (henceforth, IP) like trade secrets including product formulations, processes, knowhow, business plans with the contractor/service provider. While the company shares its pre-

existing IP with the contractor for the purpose of the project, under certain circumstances the latter can misappropriate the IP towards its own benefit. Depending on available opportunities, the agent might sell the company's IP to its rivals or even start producing a competing product. For example, according to a 1996 joint venture agreement between Danone and Wahaha, the latter could not manufacture goods that compete directly with products produced by the joint venture. In 2007, Danone accused Wahaha of setting up operations that competed with its own dairy operations (Wall Street Journal, 2009). This was in defiance of contractual obligations and resulted in an estimated loss of \$100 million in revenue. Given that modern enterprises derive significant value from their IP, a loss of IP may lead to adverse effects on profitability, brand image and competitive advantage of a company. As knowledge is becoming recognized as a strategic asset and a basis for rivalry among firm (Teece, 2000a; Sporleder and Moss, 2002), companies are concerned with protecting their IP when they outsource business functions to contractors.

The second problem associated with outsourcing emanates from the fact that it is impossible for a company to monitor the activities of the contractor. In particular, the company cannot control whether the contractor is exerting desired effort on the project or shirking. Depending on the nature of the outsourced task, shirking may lead to severe consequences for a company. Thus if a contract manufacturer exerts less effort it can lead to higher costs; if a R&D contractor shirks then it can lead to low quality product.

Food processing companies are indeed concerned about these two problems associated with outsourcing. The survey conducted by Grant Thornton and Food

Processing magazine indicates that higher costs (25%), poor product (25%) and loss of IP (16%) are significant problems encountered when outsourcing production. Moreover, about 36% of the firms that outsource R&D indicate that loss of IP is the most significant problem. In order to avoid these pitfalls, companies often resort to internalization of tasks. By doing R&D in-house these companies seek to control their products and protect their intellectual property more effectively. However, doing tasks in-house may involve higher cost due to loss of efficiency.

3.3 Research Questions

Food processing companies face an important trade-off when deciding to do a task in-house or via outsourcing. Organizing tasks in-house involve higher cost whereas outsourcing comes with the problem of IP misappropriation risk. Given this trade off, we inquire, what determines a firm's choice of organization between in-house and outsourcing? Secondly, how does a company mitigate the two agency problems associated with outsourcing. In particular, how does a company safeguard its IP and ensure that the contractor exerts optimal effort on the outsourced tasks? We find that the organizational choice depends on three factors: the degree of in-house inefficiency, the strength of contractual enforcement and value of the IP under consideration. We also find that it is possible to mitigate the agency problems by designing contracts appropriately. In particular, a carrot and stick strategy of sharing less knowledge and rewarding the agent with incentive payments is an effective way to manage the IP misappropriation and shirking problems.

3.4 Literature Review

Economic theory suggests that firms would organize a task in-house if the transaction costs of using the market are high (Coase, 1937). Thus the organizational criterion is minimization of transaction and production costs (Williamson, 1979). Several studies underline the role of vertical integration as a solution to increased transaction costs. According to Hennessy (1996), information asymmetry about input quality is one of the major reasons behind vertical integration in the food industry in the U.S. Barkema and Cook (1993) point out that integration can lead to reduced transaction costs due to search cost and risk cost of procuring inferior raw material. According to Ulset (1996), transaction costs in R&D depend on uncertainty, non-deployable effort and potential technology leakage problem.

In the food and fiber chain there are opportunities to outsource business functions that can lead to competitive advantages (Hansen and Morrow, 2003). They find that cotton producers' decision to outsource marketing is positively related with trust that producers place on the cooperatives. They also find that managers may not outsource if the expected costs from loss of control exceed the expected benefit of putting a business function into the hands of an outside agent. Spaulding and Woods (2006) found that outsourcing significantly reduces product development time in the North American confectionary manufacturing industry. Thus outsourcing makes the product development more efficient when a firm lacks in-house expertise. However, two important concerns with outsourcing are loss of control and risk of exposing the new product idea to outsiders (Spaulding and Woods, 2006). The existing literature offers the following

solutions to the problem of IP protection in outsourcing.

According to Ulset (1996), firms should use contractual safeguards (like exclusivity clauses) as well as high powered incentives to manage outsourced R&D projects. If the supplier develops R&D, then it must be given property rights on the R&D output. Lai et al. (2009) consider innovation outsourcing in the presence of information leakage. They find that when an agent develops a new process innovation, a revenue sharing contract can deter IP leakage by the agent. Finally, Ho (2009) finds that when a contractor might sell the R&D to a rival, the reward needed to prevent leakage will be pushed up to the extent that a profitable leakage-free contract does not exist.

Our paper differs from the existing literature in following ways. First, we consider the problem of protecting pre-existing IP of the principal. This is in contrast to Ulset (1996), Lai et al. (2009) and Ho (2009) who consider protection of IP that is developed by the agent. We argue that sharing of pre-existing IP is an important source of IP misappropriation. Food processing companies need to share their trade secrets, knowhow, business plans with their outsourcing supplier. While knowledge sharing is imperative for the supplier to accomplish the tasks, it can lead to unintended consequences of misappropriation. Secondly, when a company outsources productive activities to a contractor-supplier, it loses control over the task. It is impossible for the principal to monitor the actions of the agent and consequently faces a moral hazard problem. The contractor may shirk on the R&D task, which would lead to considerable project uncertainty. We contribute to the literature by designing a contractual solution to mitigate two problems in outsourcing due to a) IP misappropriation and b) shirking

by the agent.

3.5 A Model

In order to facilitate the discussion, we consider a food processing company (principal) developing a breakthrough product with reduced calorie content. During the R&D phase of the product development the principal wants to test certain attributes of the product. The R&D task could be testing human allergic reaction or a flavor preference study to discern appropriate flavor formulation and so on. The principal has two options to conduct the product testing and flavor preference study. It may establish a R&D unit in-house or outsource the task to an independent supplier/R&D contractor (agent). Thus in the first mode of organization, the agent is an employee of the principal, whereas under outsourcing the agent is independent unit. In order for the agent to accomplish the R&D task, the principal discloses its pre-existing intellectual property with the agent using a Non Disclosure Agreement. We consider the principal's IP to be a trade secret involving the product formulation/ know-how related to manufacturing process that has economic value from not being known to the public. However, once the agent gets access to the principal's IP, it may misappropriate the IP and sell it to a rival of the principal. Instead, if the agent decides to work for the principal, it exerts effort to do the testing and evaluation of the product. The nature of information asymmetry faced by the principal is that of moral hazard. The agent exerts effort that is unobserved and not verifiable by the principal. We develop a principal- agent model by closely following Laffont and Martimort (2002). The problem of the principal is to design a contract to

ensure that the agent does not misappropriate its IP and also exerts optimal level of effort on the R&D project.

3.5.1 Timing of Actions

We consider a game comprising of the following stages.

Stage1. The principal offers a R&D contract $C \in \{(v, h), (u, l)\}$ contingent on project outcome $X \in \{success, failure\}$. If the project outcome is a “success” then a high quality product is realized. The principal gets gross revenue v from selling the high quality product and pays h to the agent. On the other hand, if the project outcome is a “failure” then a low quality product is realized. In this case the principal gets gross revenue u from selling the low quality product and pays l to the agent. We assume $v > u$ and $h > l$. Thus the project return spread is $(v - u)$ and the payment spread is $(h - l)$.

If the agent accepts the contract then the principal shares its pre-existing intellectual property (k) with the agent. The agent signs a NDA that it would not disclose the principal’s trade secret to third parties. If the agent breaches the contract it will have to pay a penalty β .

Stage2. The agent decides $Y \in \{stay\ with\ contract, leave\ contract\}$.

Stage3. If the agent leaves the contract, it sells the IP of the principal to a rival. If the agent stays with the contract, then he exerts non contractible effort, e on the R&D project.

Stage4. The payoffs are realized according to the observed project

outcome $X \in \{success, failure\}$.

3.5.2 Solution

We solve the game using backward induction to obtain Bayesian Nash Equilibrium, Stage 4: In the last stage of the game, the payoffs are realized according to the R&D contract. Given the project outcome $X \in \{success, failure\}$, the payments are made according to the contract $C \in \{(v, h), (u, l)\}$. We assume that the probability distribution of return depends on e , the level of effort exerted by the agent as well as k , the level of knowledge shared by the principal. Thus knowledge sharing is intended to facilitate the task assigned to the agent. Specifically, let the probability of success be $(e + k)$ and the probability of failure be $1 - (e + k)$. The project uncertainty is formalized as follows:

$$Gross\ return = \begin{cases} v & \text{with probability } (e + k) \\ u & \text{with probability } 1 - e - k \end{cases}$$

We assume that the principal incurs a cost of sharing its IP with the agent. Specifically, we consider the cost of knowledge sharing to be a convex function $f(k) = k^2$. Thus the expected profit of the principal from outsourcing is

$$E\pi_p^o = (e + k) \cdot (v - h) + (1 - e - k) \cdot (u - l) - k^2. \quad (3.1)$$

After the principal shares its IP with the agent, the agent decides whether to stay with the contract or to misappropriate the IP towards its own benefit. The possibility of IP misappropriation comprises an agency problem associated with outsourcing. After getting access to the principal's valuable IP, the agent might sell it to a rival firm. We

assume that the agent is able to sell the IP to a rival at a price sk , where $1 \geq s \geq 0$.

However, since the agent signs a NDA with the principal, it also has to pay a penalty β for misappropriating the IP. Thus the outside option of the agent is equal to the net benefit from misappropriating the principal's IP. Formally, the outside option is denoted by

$$\psi(k) = s \cdot k - \beta. \quad (3.2)$$

If the agent decides to stay with the contract, then it has to exert effort on the R&D project. We consider the cost of exerting effort to be a convex function $g(e) = e^2$. Thus the expected profit of the agent from the contract is

$$E\pi_A^O = (e+k) \cdot h + (1-e-k) \cdot l - e^2. \quad (3.3)$$

We note that the effort of the agent is not contractible. This leads to the second agency problem associated with outsourcing. Since the effort is not contractible, the agent may choose to shirk. From the principal's perspective shirking is not desirable since her expected profit is increasing in the level of effort exerted by the agent. The objective of the principal is to design a contract that would mitigate the two agency problems associated with outsourcing, viz. IP misappropriation and shirking by the agent.

Stage 3: At this stage, the agent exerts effort on the project. The principal needs to design a contract that is incentive compatible for the agent to exert optimal effort on the project. Formally, the contractual payments must satisfy the following incentive compatibility constraint (ICC) of the agent:

$$e = \arg \max_e E\pi_A^O. \quad (3.4)$$

The first order condition of the agent's optimization problem yields the optimal effort under outsourcing:

$$e = \frac{1}{2}(h-l). \quad (3.5)$$

Stage 2: At this stage of the game the agent has access to the IP of the principal and decides on $Y \in \{\textit{stay with contract}, \textit{leave contract}\}$. The decision is made by comparing the profits from the alternative choices. Since the principal wants that the agent should not misappropriate its IP, it would have to ensure that the expected profit of the agent from the contract is higher than the outside option of the agent. In other words, the incentive payments must satisfy the following individual rationality constraint (IRC) of the agent:

$$E\pi_A^O = (e+k) \cdot h + (1-e-k) \cdot l - e^2 \geq \psi(k). \quad (3.6)$$

Stage 1: At this stage, the principal offers contract C to the agent. If the agent accepts the contract, the principal shares its pre-existing IP with the agent. Formally, the principal solves the following optimization problem:

$$\underset{h,l,k}{\text{Max}} E\pi_p^O \text{ subject to (3.5) and (3.6)}. \quad (3.7)$$

Proposition 3.1

(i) When the project is outsourced, the optimal payment to the agent is

$$h^O = (1+s) \cdot (v-u) - \frac{1}{2} \cdot s^2 - \frac{3}{4} \cdot (v-u)^2 - \beta \text{ if project outcome is success,} \quad (3.8a)$$

$$l^O = s \cdot (v-u) - \frac{1}{2} \cdot s^2 - \frac{3}{4} \cdot (v-u)^2 - \beta \text{ if project outcome is failure,} \quad (3.8b)$$

(ii) Optimal level of knowledge shared by the principal is

$$k^o = \frac{1}{2} \cdot (v - u - s), \text{ and} \quad (3.8c)$$

(iii) Optimal level of effort exerted by the agent is

$$e^o = \frac{1}{2} \cdot (v - u). \quad (3.8d)$$

(iv) Consequently the expected profit of the principal from outsourcing is

$$E\pi_p^o = \frac{1}{2} \cdot (v - u)^2 - \frac{s}{2} \cdot (v - u) + \frac{s^2}{4} + u + \beta \quad (3.8e)$$

and the expected profit of the agent is

$$E\pi_A^o = \frac{1}{2} \cdot s \cdot (v - u - s) - \beta \text{ respectively.} \quad (3.8f)$$

Proof: See Appendix 5.

From part (i) of the proposition, we note that the optimal incentive payments vary across the realizations of R&D output. In other words, the optimal contract offered to the agent is not “fixed payment” type. Instead, a variable payment contract is required to ensure that the agent has appropriate incentive to exert effort in the presence of moral hazard.

The parameter β may be considered as an indicator of enforcement of IP laws in the economy. The magnitude of this parameter reflects how easy it would be for the agent to misappropriate the principal’s IP. If contractual enforcement is weak (i.e. β is low) then the principal would have to pay higher incentive payments to the agent. This is due to the fact that when enforcement is weak, the agent would have more incentive to misappropriate the principal’s IP. Therefore the principal needs to increase the incentive payments so that the agent stays with the contract. The practical implication of this result

is noteworthy. If a company is willing to outsource tasks to a location with weak legal enforcement, it needs to optimally increase the payments to the agent. In contrast, if the task is outsourced to a location with strong enforcement of IP laws, then the principal needs to pay lower incentive payments.

From part (ii) of proposition 3.1 we observe that the optimal level of IP shared by the principal is increasing in project return spread. Also, as expected, it is decreasing in the parameter s , the price that the rival is willing to pay for the IP. The higher the market value of the IP, the lesser will it be shared.

In part (iii) we observe that the optimally chosen effort is an increasing function of the spread of project return. The incentive payments are designed such that the ICC of the agent is satisfied and it exerts optimal effort on the project.

Lastly, in part (iv) we note that the agent gets from the contract an expected profit exactly equal to the outside option from selling the IP. This is due to the fact that that the IRC of the agent is binding. Thus the incentive payments are designed to deter both the IP misappropriation and the shirking problems.

Lemma 3.1

The principal will share a non-negative knowledge with the agent. This is ensured by

$$k^o = \frac{1}{2} \cdot (v - u - s) \geq 0 \Leftrightarrow (v - u) \geq s.$$

Also, the probability of success is bounded within $[0,1]$. Therefore we need

$$1 \geq e^o + k^o \geq 0 \Leftrightarrow 1 \geq v - u - \frac{s}{2} \geq 0.$$

Combining the two inequalities we have

$$1 + \frac{s}{2} \geq (v - u) \geq s. \quad (3.9)$$

The above inequality suggests that the project return spread is bounded.

3.6 In-house R&D

We now consider a regime where the principal organizes the R&D task in-house. In order to capture the interesting trade-offs between outsourcing and in-house organization, we introduce two differences. First, we assume that if the task is accomplished in-house then more time and resources will be required. Let the cost of exerting effort in-house be $d \cdot e^2$ where $d > 1$. In other words, the principal faces operational inefficiency if the task is done in-house. This captures the situation in Pringles Prints example described earlier. Secondly, we assume that the principal can avoid the problem of IP misappropriation if the task is done in-house. This assumption is along the lines of Lai et al. (2009) who consider that in-house employees have no incentive to leak information due to loyalty to the company. However, even if the R&D is done in-house, the principal cannot monitor the effort of the agent and therefore continues to face the moral hazard problem due to shirking. Given this setup, the expected profit of the agent is

$$E\pi_A^I = (e + k) \cdot h + (1 - e - k) \cdot l - d \cdot e^2. \quad (3.10)$$

When R&D is conducted in-house, the effort is determined from the ICC:

$$e^I = \arg \max_e E\pi_A^I. \quad (3.11)$$

The first order condition of this optimization problem yields

$$e^I = \frac{1}{2d} \cdot (h - l). \quad (3.12)$$

When R&D is done in-house, IP misappropriation is not possible. Thus in contrast to outsourcing, the outside option of the agent is equal to the market wage, which we normalize to zero. Consequently the participation constraint of the agent is

$$E\pi_A^I = (e + k) \cdot h + (1 - e - k) \cdot l - d \cdot e^2 \geq 0. \quad (3.13)$$

The principal would maximize its expected profit given by (3.1) subject to (3.12) and IRC (3.13) of the agent. The solution to this problem leads to the following proposition.

Proposition 3.2

(i) If the project is done in-house, the optimal payment to the agent will be

$$h^I = (v - u) - \left(\frac{2d + 1}{4d} \right) \cdot (v - u)^2 \text{ if project outcome is success and} \quad (3.14a)$$

$$l^I = \frac{1}{4d} \cdot (2uv + 4uvd - 2v^2d - 2u^2d - v^2 - u^2) \text{ if project outcome is failure,} \quad (3.14b)$$

(ii) Optimal level of knowledge shared by the principal is

$$k^I = \frac{1}{2} \cdot (v - u) \quad (3.14c)$$

(iii) Optimal effort exerted is

$$e^I = \frac{1}{2d} \cdot (v - u). \quad (3.14d)$$

(iv) Consequently, the expected profit of the principal is

$$E\pi_p^I = \left(\frac{1+d}{4d}\right) \cdot (v-u)^2 + u \quad (3.14e)$$

and expected profit of the agent is

$$E\pi_A^I = 0. \quad (3.14f)$$

Proof: See Appendix 6.

We observe that the payments are contingent on the realized R&D outcome. Thus incentive payments are designed to solve the moral hazard problem due to shirking. Since there is no possibility of IP misappropriation, optimal knowledge sharing depends only on project return spread. The optimal effort is increasing in return spread and is decreasing in d , the inefficiency associated with in-house R&D. Finally, we note that the expected profit of the agent is equal to zero, the normalized market wage. This is due to the fact that the participation constraint of the agent is binding. In contrast to proposition 3.1 part (iv), we find that the agent makes more than the market wage under outsourcing. This is because the principal would have to increase the incentive payments under outsourcing to dissuade IP misappropriation.

Lemma 3.2

Since the principal will share a non-negative knowledge with the agent, we need

$$k^I = \frac{1}{2} \cdot (v-u) \geq 0 \Leftrightarrow (v-u) \geq 0.$$

Also, the probability of success is bounded within $[0,1]$. Therefore we need

$$1 \geq e^I + k^I \geq 0 \Leftrightarrow \frac{2d}{1+d} \geq v-u \geq 0. \quad (3.15)$$

This suggests that the project return spread is bounded.

Proposition 3.3

Optimal level of effort exerted under outsourcing is greater than effort exerted in-house:

$$e^o > e^l. \quad (3.16)$$

Proof: $e^o - e^l = \frac{1}{2}(v-u) \cdot \left(1 - \frac{1}{d}\right) > 0$ since by assumption $d > 1$.

This result is due to the fact that the marginal cost of exerting effort is more if the task is done in-house. Hence lower effort will be exerted in-house compared to outsourcing regime. This result explains the Pringle Prints example- had the R&D been done in-house it would have taken at least two years to accomplish the objective. Since the task was outsourced, the product development was possible within less than a year. The increased effort leads to efficiency gain in outsourcing.

Proposition 3.4

The optimal incentive payments are higher under outsourcing when legal enforcement is weak. In contrast, under strong legal enforcement the in-house incentive payments are higher than under outsourcing. Formally,

$$h^o \geq h^l \text{ and } l^o \geq l^l \text{ if } \beta \leq \beta^* \text{ and}$$

$$h^o \leq h^l \text{ and } l^o \leq l^l \text{ if } \beta \geq \beta^* \text{ where}$$

$$\beta^* = s \cdot (v-u) - \frac{1}{2} \cdot s^2 - (v-u)^2 \cdot \left(\frac{d-1}{d}\right). \quad (3.17)$$

Proof: From part (i) of Proposition 3.1 and Proposition 3.2 we obtain

$h^o - h^l = l^o - l^l = s \cdot (v - u) - \frac{1}{2} \cdot s^2 - (v - u)^2 \cdot \left(\frac{d-1}{d}\right) - \beta$. This expression is positive

if $\beta \leq \beta^* = s \cdot (v - u) - \frac{1}{2} \cdot s^2 - (v - u)^2 \cdot \left(\frac{d-1}{d}\right)$ and negative if $\beta \geq \beta^*$.

The economic intuition for this result is as follows. If legal enforcement is weak, the penalty parameter β is low. Therefore the agent will have more incentive to sell the IP to a rival. In order to avoid this situation, the principal would have to increase the incentive payments to the agent. We observe that the incentive payments $\{h^o, l^o\}$ offered under outsourcing are both higher than the in-house payments $\{h^l, l^l\}$. Thus when legal enforcement is weak, a food processing firm would have to pay higher incentive payments to the agent in order to deter IP misappropriation. This explains why companies tend to organize R&D in-house instead of outsourcing even though the latter is efficient.

On the other hand, if legal enforcement is strong (β is high), then the outside option of the agent becomes too low. Hence the agent will have less incentive to walk away from the contract. The principal would need to pay less incentive payments for the agent to stay within the contractual relationship.

Since the problem of IP protection becomes severe under weak legal enforcement, we consider a scenario where β is low. Then from Proposition 3.4 we can derive the following result.

Corollary 3.1

(i) Carrot and Stick strategy: When legal enforcement is weak, the principal will have to pay higher incentive payments to the agent under outsourcing:

$$h^o \geq h^l \text{ and } l^o \geq l^l \text{ if } \beta \leq \beta^* = s \cdot (v - u) - \frac{1}{2} \cdot s^2 - (v - u)^2 \cdot \left(\frac{d - 1}{d} \right).$$

(ii) However, the principal will share less information with the agent under outsourcing:

$$k^o \leq k^l. \quad (3.18)$$

Proof: Part (i) follows directly from (3.16) and $k^l - k^o = \frac{s}{2} \geq 0$.

If there is possibility of misappropriation, the principal must optimally share less knowledge with the agent. It is important to note the consequences of reduced knowledge sharing on $\psi(k)$, the outside option of the agent. Less knowledge sharing will diminish the attractiveness of outside option of the agent and weaken its incentive to misappropriate the principal's IP. As the agent stays within the contract, he must exert high effort to increase the probability of success, since reduced knowledge sharing by principal decreases the probability of success. Therefore there is a built in mechanism in the contract so that the agent must increase effort to increase the probability of success. Increased effort, however, entails higher cost and consequently the principal must pay higher incentive payments to the agent. Thus a carrot and stick strategy of lower knowledge sharing and higher incentive payments may mitigate the two agency problems associated with outsourcing.

Proposition 3.5

Even under the possibility of IP misappropriation, the choice of organizational form is not trivial. The principal may outsource the R&D project to an independent contractor if it is inefficient to do the task in-house. Formally,

$$E\pi_p^o \geq E\pi_p^i \text{ if } d \geq d^* \text{ and}$$

$$E\pi_p^o \leq E\pi_p^i \text{ if } d \leq d^* \text{ where}$$

$$d^* = \frac{(v-u)^2}{(v-u-s)^2 + 4\beta}. \quad (3.19)$$

Proof: Difference of profit of the principal from (3.8e) and (3.14e) establishes the result.

The principal will choose to outsource the project if it is more costly to do the task in-house. Thus the make-or-buy decision depends on transaction costs of doing the task in-house vs. outsourcing. In this case, the transaction cost of outsourcing is due to the IP misappropriation risk. If the inefficiency associated with in-house R&D exceeds a threshold d^* then the task will be outsourced. Another explanation of the organizational choice is also possible. We note that

$$E\pi_p^o - E\pi_p^i = \frac{1}{2} \cdot (v-u)^2 - \frac{s}{2} \cdot (v-u) + \frac{s^2}{4} + \beta - \left(\frac{1+d}{4d} \right) \cdot (v-u)^2 \geq 0 \text{ if}$$

$$\beta \geq \tilde{\beta} = \frac{1}{4d} \cdot (v-u)^2 - \frac{1}{4} \cdot (v-u-s)^2. \quad (3.20)$$

Consequently, if the level of penalty is higher than a threshold $\tilde{\beta}$, then the expected profit of the principal is higher under outsourcing.

3.7 Discussion

First, an interesting finding of this paper is that food processing companies can still gain from outsourcing even if there is possibility of IP misappropriation and shirking. In order to achieve the gains, however, it is important to design the incentive contracts in such a way that it is optimal for the supplier-contractor not to misappropriate and also exert effort on the outsourced task. Therefore we suggest that firms need not remain confined to inefficient internalization provided they can design the contracts appropriately. By forgoing outsourcing they might miss the efficiency from specialization and lower costs.

Second, our model suggests that the optimal incentive payments are higher in outsourcing vis-à-vis in-house, which might explain why food processing companies generally conduct R&D in-house (Grant Thornton, 2008). This is an outcome of the IP misappropriation problem and may be considered as a form of increased transaction cost of outsourcing. We note, however, that the expected profit of a company is higher under outsourcing due to the inefficiency associated with in-house organization. Thus a company faces a trade-off between increased transaction costs of outsourcing vs. inefficiency cost of doing tasks in-house.

Third, according to our paper, the principal is able to control the project by using a carrot and stick strategy. This result is along the lines of Ulset's (1996) suggestion that firms should use contractual safeguards and high powered incentives to manage outsourced projects. In particular, the company must share less of its existing IP with the agent and ensure that the contractual payments are incentive compatible. Thus if tasks

are organized via outsourcing, information sharing with the supplier should be done strategically on a need-to-know basis. This reduced IP sharing strategy concurs with the findings of Kinsey and Ashman (2000) who suggest that retailers may share less information with their suppliers due to potential supplier opportunism. Once the suppliers learn about their inventory, sales, and ordering practices, they may share this information with rivals or otherwise use it in ways that would diminish retailers' profitability. This eventually leads to reduced information sharing.

Fourth, we propose that the carrot and stick strategy may be used as a substitute for legal enforcement. Note that the outside option of the agent is decreasing in the penalty β . Although legal tools exist, lack of enforcement may render them ineffective in deterring misappropriation. Since litigation involves expenses and diverts managerial attention, it is advisable that companies pursue a defensive strategy by sharing less knowledge with their contract agents. In other words, manipulating the extent of IP sharing may be an effective strategy when contractual enforcement is uncertain.

Fifth, some authors have suggested the importance of trust in outsourcing relationships (Hansen and Morrow, 2003; Spaulding and Woods, 2006). Since product development tasks require confidentiality, they suggest that trust needs to be established between the company and the supplier. We recommend that contractual safeguards are also needed along with development of trust. Recall that the contractual solution developed in this paper comprises of lower IP sharing as well as higher incentive payments. While lower IP sharing by the principal is an outcome of lack of trust, the higher incentive payments might augment trust between the two parties.

Sixth, according to our paper, in order to reduce the IP misappropriation risk, companies need to assess the value of their IP that they are sharing with their contractor. This quantitative valuation of IP is a necessary component of any risk assessment model that a company might have. Depending on the nature of IP, however, the valuation of intangible assets may be a difficult task. Therefore food processing companies ought to develop methodologies to assess the value of their IP before engaging in outsourcing.

3.8 Conclusion

This paper addresses the practical problems faced by food processing companies that want to develop breakthrough innovation. They might lack some of the required expertise in-house and hence outsource R&D to outside contractors. However, the operational benefits of outsourcing come with two transaction risks due to a) IP misappropriation and b) shirking by the supplier-contractor. Therefore companies face an important tradeoff: organizing productive activities in-house involves higher cost due to loss of efficiency, whereas outsourcing leads to increased transaction cost due to IP loss. If companies are willing to outsource, then they must design contracts to implement a carrot and stick strategy developed in this chapter. We recommend that food processing companies need not relinquish the benefits of outsourcing if they can use contractual governance and appropriate IP management strategies. Indeed, companies that outsource and yet protect their brands successfully can do so because of proper management of their contractual relationships with their suppliers.

CHAPTER IV
TRADE SECRET THEFT OF LEXAR MEDIA: A SINGLE FIRM
EVENT STUDY

4.1 Introduction

“Many factors could cause the market price of our common stock to fluctuate, including: announcements related to our outstanding litigation, and...market conditions in our industry and the economy as a whole.” -Excerpt from 10-Q Report filed by Lexar Media (2006).

These two factors form the basis of event study methodology followed in this chapter. Outsourcing arrangements between companies often require extensive information/knowledge sharing among the transacting parties. This knowledge sharing can potentially lead to information leakage. In a knowledge based economy, loss of critical intellectual property (IP) can lead to adverse effects on the value of a company. This was the case when Lexar and Toshiba agreed to co-develop flash memory based technology. Lexar shared its key IP (to be discussed in details below) with Toshiba towards the joint development project. Eventually, Toshiba misappropriated the trade secrets and shared Lexar’s proprietary information with its rival SanDisk. What was the effect of this trade secret theft on Lexar’s value? How did it eventually manage to survive the trade secret theft? In order to reduce its manufacturing costs, Lexar is still pursuing outsourcing strategy to obtain flash memory, which is one of the primary inputs in flash memory card products. What does this case suggest for companies willing to

outsource while sharing IP with their supply chain partners? These are the key issues that we seek to address in this chapter.

Event study technique is used to examine the effect of the IP litigation on Lexar value. Event studies are well suited to measure the impact of firm specific events on its value. Event analysis is also appropriate given the nature of events related to litigation. Stock market valuation of a firm is based on expectations of the stream of net income that the firm can generate from its tangible and intangible assets (Cockburn and Griliches, 1988). A company's intangible assets like IP, R&D, goodwill, advertising, and marketing skills, dictate the survival and profitability of the company in the long run (Raghu et al., 2008). Market prices of securities reflect all publicly available information relevant to determining the expected cash flows and profits to the firm. New information, if any, contained in the commencement (or termination) of a litigation would cause the market to revise its expectations about the risks related to future cash flows and profits, and adjust the value of the firms accordingly. If the market is efficient, then these adjustments are immediately witnessed by changes in the stock prices of the firms (Raghu et al., 2008). While conducting the event study we address an important methodological issue related to the appropriateness of parametric tests in single firm event studies. A novel non-parametric test developed by Gelbach et al. (2009) is used to examine the stock market reaction to the event of trade secret theft as experienced by Lexar.

4.2 Company Background

Lexar Media designs, develops, manufactures memory cards and connectivity products for digital photography, consumer electronics, and communication markets.² Its digital media products include a variety of flash memory cards with a range of speeds, and capacities. The company's products, including memory cards and flash drives, are used to store digital photos in cameras and music in MP3 players and phones.

The company uses its patented NAND flash technology³ to manufacture Memory Stick, JumpDrive, and CompactFlash products. Lexar outsources key inputs like flash memory from Samsung, controllers from United Microelectronics Corporation and contracts with independent foundry and assembly units to manufacture the flash card products. This outsourcing strategy allows Lexar to focus on design of new products, which is its core competency. Outsourcing minimizes fixed cost and facilitates access to advanced manufacturing capabilities (Lexar Media, 2005).

4.3 Description of Problem: Trade Secret Misappropriation

Lexar had claimed that Toshiba, Japan's second biggest chipmaker, broke a 1997 joint development agreement to co-develop flash memory technology, by secretly sharing its technology with SanDisk, Lexar's largest competitor. As part of the agreement, Toshiba invested \$3million in Lexar and received a seat in the company's board. For two and a half years, Toshiba retained its seat, and consequently gained

² Micron acquired Lexar for approximately \$850 million in 2006.

³ NAND flash is a type of memory that retains data even when its power supply is cut off.

access to Lexar's technology. Toshiba persuaded Lexar to divulge its confidential technical and business information with promises of a long-term, strategic partnership. Toshiba was thus given access to details of Lexar's key IP, flash memory controller technology⁴ (Multipage Write Technology), its business strategies, and other methods of achieving high performance flash devices. Each of these constitutes Lexar trade secrets, which the company shared with its outsourcing partner Toshiba. Eventually Toshiba divulged these trade secrets to SanDisk, and incorporated them into its own flash chips and flash systems (Lexar Media, 2005). It is important to note that Lexar's IP is in the NAND die. Since the NAND die itself incorporates the trade secrets, Lexar sought an injunction on Toshiba products that incorporated them (Fair Disclosure Wire, 2005).

Toshiba argued that it had independently developed the disputed technology, while the jury disagreed, saying Toshiba's actions were "oppressive, fraudulent or malicious." How important was the stolen IP for Toshiba? During the six-week trial, Lexar claimed that during the period of 1999-2004, Toshiba earned profits of \$3.7 billion using flash memory covered by its trade secrets. Also, a Toshiba document revealed as much as 50% of U.S sales might be attributed to Lexar's IP.

Following an epic litigation in 2005, Lexar was awarded \$465.4 million in total. This was reportedly the largest IP verdict in California history and the third largest IP verdict in the U.S. Immediately after the conclusion of the litigation in its favor, Lexar shares traded at \$5, more than 60 percent higher than the pre-verdict price. Later, in 2006 Toshiba and Micron (the parent company of Lexar) settled the NAND flash

⁴ Flash memory controller technology acts like a "stoplight" to regulate the flow of data in a memory card.

memory related litigation. As part of the deal, valued at \$288 million, Toshiba purchased certain Micron semiconductor technology and licensed patents formerly owned by Lexar Media.

4.4 Chronology of Events

To keep track of the series of events that took place over a span of nine years, we present them chronologically below.

1. In 1996, Toshiba invested \$3 million in Lexar, gaining a 10 percent stake in the startup. At that time, Lexar was outsourcing flash memory component from Toshiba.
2. In 1997 Lexar and Toshiba agreed to co-develop and use flash memory technology. Lexar shared its IP related to flash memory controller technology, and business strategies with Toshiba.
3. On May 10, 2000 a joint venture deal between Toshiba and SanDisk (a prime competitor of Lexar) was formally announced.
4. In 2001, Toshiba published the technology that clarified use of Lexar's intellectual property.
5. On November 4, 2002, Lexar filed a lawsuit claiming that Toshiba had misappropriated its core IP.
7. Trial began on February 7, 2005.
8. On March 23, 2005 the jury concluded that Toshiba Corporation and Toshiba America Electronic Components Inc. misappropriated Lexar's trade secret. Lexar was awarded \$381.4 million.

9. On March 24, 2005, the jury awarded an additional \$84 million in punitive damages.

4.5 Literature Review

Event studies have often been used as evidence for damages and liabilities in litigation. In addition to direct monetary costs, litigations can lead to indirect costs such as management distraction and difficulty in obtaining credit (Raghu et al., 2008). Such high indirect costs cause market participants to reevaluate the litigating firms' market valuation. Event studies are thus naturally suitable for examining capital market reactions to litigation announcements. Carr and Gorman (2001) used event study analysis to examine the stock market effect of trade secret theft. Raghu et al. (2008) investigate the factors that could affect the market's reactions to patent infringement litigations in the IT industry. They found that R&D intensity, average age of patents (i.e. how new is the invention), and patent importance (measured by citations) are some of the factors that affect market reaction to IT patent litigations.

Another application of event studies relates to understanding the effect of announcement of an outsourcing decision on company valuation. For instance, Agrawal et al. (2006) found that companies that outsourced E-business projects achieved abnormal positive returns. Likewise, pharmaceutical companies that outsource R&D through acquisitions tend to realize significant positive returns (Higgins and Rodriguez, 2006). Oh et al. (2006) examined stock market data to assess investors' responses to various transactional risks associated with IT outsourcing. They find that several factors significantly influence investors' perceptions of the risks involved in IT outsourcing.

These factors include the size of outsourcing contracts, difficulties in performance monitoring, asset specificity of IT resources, vendor capability, and the lack of cultural similarity between client and vendor firms. Results indicate that investors will 'bid up' the stock prices of firms that are able to pursue low-risk outsourcing engagements, while punishing firms that become entangled in outsourcing contracts posing a high level of risk.

4.6 Research Questions

Our research question is how did the event of trade secret theft by Toshiba affect the value of Lexar? In particular, we want to measure the effect on the stock returns of Lexar around the beginning of litigation as well as around the day the litigation was settled. While doing so, we also address a critical question related to the methodological aspect of event studies with single firm. It is well known that standard t-tests might not be valid in single firm event studies. Gelbach et al. (2009) propose a novel test that does not require the assumption of normality of abnormal returns. We use this test along with the usual parametric tests to make statistical inferences.

4.7 Event Study Methodology

We utilize event study methodology to assess the effect of trade secret misappropriation by Toshiba on the value of Lexar. Use of the event study method is appropriate given the firm specific nature of the event, as quite often done in legal liability cases to assess damages (Campbell et al., 1997). Event studies are based on

econometric techniques to estimate and draw inferences about the impact of an event in a particular period or over several periods. It is generally believed that stock prices of publicly traded companies accurately reflect its true value. When any new information is publicly disclosed, investors revise their beliefs and consequently stock prices change to reflect the consensus view regarding the fair value of a firm (Carr and Gorman, 2001).

The implicit assumption in this methodology is that financial markets respond to event/news that affect a security's value, so a change in stock price is a good proxy for the impact of a given event. It relies on the theory of efficient markets, according to which security prices incorporate at each instant all currently available information and adjusts to new information whenever investors get the (new) information. Thus, a loss of trade secret might lead to financial losses (through loss of reputation, brand value) which would be reflected in its stock price. The economic impact of this event can be examined by looking at the stock prices in the event window.

Event studies have been widely used by researchers to investigate the market effects of litigation (Raghu et al., 2008). One can potentially isolate causal effects of isolated events (e.g. corporate governance adoption, announcement of outsourcing, IP litigation) through event studies. A study by Mitchell (1989) on Tylenol poisoning in 1982 is relevant in the context of this research. Not only it was a single firm event study, just like ours, two event periods were considered in order to examine: a) investors' initial reaction to the poisonings, and b) the subsequent recovery of Johnson and Johnson. As Mitchell explains, information about product poisonings would affect investors' belief

about how consumers would react to Johnson and Johnson products. After forming an initial prediction, investors realized that they had been wrong about their initial forecast regarding response of consumers to Johnson and Johnson products.

The methodology involves three steps: (1) compute the parameters in the estimation period; (2) compute the forecast errors for an event window; and (3) aggregate across time and infer about the average effect of the event. Broadly speaking, events reflecting negative (positive) news would lead to decrease (increase) in firm's stock price (Carr and Gorman, 2001).

4.7.1 Identification of Event(s)

For this study there are two events that are potentially relevant. These are: a) commencement of litigation and b) litigation termination with announcement of judgment by the court. The start of the litigation on February 7, 2005 conveyed information to the public about the loss of trade secret of Lexar. In order to accommodate a time lag for the news to propagate, we consider the following calendar date (02/08/2005) as the event date. Although the litigation ended on March 23, 2005, the jury awarded additional \$84 million as punitive damages the next day. To accommodate this additional reward, we consider 03/24/2005 as the second event date for the purpose of this study.

4.7.2 Abnormal Returns (AR)

The crux of an event study depends on analyzing the behavior of the abnormal

returns (AR). Normal return of a security is defined as the return that would be expected in the absence of the event under consideration. Abnormal returns are subsequently defined as the actual ex-post return of the security over the event window less the normal return of the firm over the event window (Campbell et al., 1997). Abnormal returns are prediction errors of the market model (described in details in the following section) over the event window. It is assumed that the abnormal returns are the result of the event announcements and not some other random event occurring on the same day (Subramani and Walden, 2000).

4.7.3 Cumulative Abnormal Returns (CAR)

CAR gives us an idea about investors' beliefs about a firm's value following an event under consideration. Positive CAR signify that investors on an average perceive that the event will result in future cash flows. Negative CAR, on the other hand would occur when investors are pessimistic about the impact of the event on future cash flows.

4.7.4 Market Model

Following the extant literature, we use the market model to examine the effect of the IP litigation event on Lexar stock price. The model assumes a stable linear relationship between the market return ($R_{m\tau}$) and the return of the security (R_τ). It is assumed that the coefficients are constant during the estimation and event periods.

Formally, the market model is

$$R_\tau = \alpha + \beta \cdot R_{m\tau} + \varepsilon_\tau, \text{ with } E[\varepsilon] = 0, \text{ var}[\varepsilon] = \sigma^2 \quad (4.1)$$

where τ indicates time in estimation window and ε is a white noise random component that is uncorrelated with R_m . For R_m , the market index, there are several alternative indices to choose from. The Center for Research on Securities Prices (CRSP) provides returns for equal-weighted and value-weighted portfolios of all available stocks each trading period. The equal-weighted market return is a simple average of the returns of all traded stocks (<http://www.library.hbs.edu/helpsheets/wrdscrspstock.html>). The value-weighted market return is a weighted average of all stock returns, with the weights given by the market value of the stock issue (price times shares outstanding) at the end of the previous trading period. Finally, the most commonly used index is the S&P 500, a capitalization-weighted index based on a broad cross-section of the market. We use all of these three alternative indices to check for robustness of our findings. Under general conditions OLS estimates of the parameters are consistent and efficient (Campbell et al., 1997). We estimate (4.1) to obtain the abnormal returns as differences of realized and predicted returns at date τ in the event window. Formally,

$$AR_{\tau} = \hat{\varepsilon}_{\tau} = R_{\tau} - E[R_{\tau} | R_{m\tau}] \quad (4.2)$$

where τ indicates time in event window.

Abnormal return is the part of the actual return that cannot be explained by market movements. Thus AR_{τ} is the excess return of a security after extracting the market factor.

4.7.5 Selection of Estimation Window

The estimation period provides the parameter estimates used to obtain CAR in the event window. In order to ensure that returns realized during the estimation period

are typical and representative of performance prior to the event, we took the estimation window to be of length 242 trading days and ending 11 days before the first event, i.e. the start of litigation. This estimation window is consistent with the works of Carr and Gorman (2001), Oh et al. (2006), and Agrawal et al. (2006), among others. Figure 2 shows the time line of the event study. The estimation window is $[T_0, T_1]$ with a length of M days. The event window is $(T_1, T_2]$ with a length of L days.

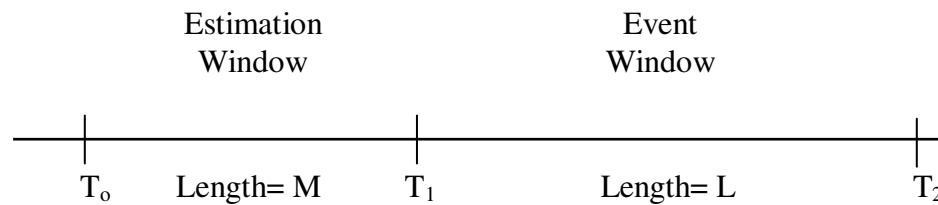


Figure 2. Estimation Window and Event Window

4.7.6 Selection of Event Window

We want to examine whether mean abnormal returns for periods around the event are equal to zero. To do so, we need to select an appropriate event window. If the event is partially anticipated, some of the abnormal return behavior related to the event might show up in the pre-event period. Also, in testing market efficiency, the speed of adjustment to the information revealed at the time of the event is an empirical question (Binder, 1998). Researchers prefer shorter event periods for a better estimation of the effects of information on stock prices since it reduces the possibility of confounding effects of other announcements not related to the event of interest. In addition to this

benefit, it also increases the power of the tests. Longer event windows may severely reduce the power of the test statistic, thereby leading to false inferences about the significance of an event. Finally, the market might have acquired information prior to the actual announcement of the litigation or its results. To accommodate the possibility of any information leakage, researchers take $[-t, +t]$ as the event window, assuming that the event occurred at $t = 0$. For instance, Carr and Gorman (2001) calculates the AR for $[-10, +10]$ centered around the event date. Raghu et al. (2008) used similar approach but considered shorter event windows. Mitchell (1989), on the other hand, calculated the AR for $[0, 21]$ days after the event.

We consider three symmetric event windows $[-3, +3]$, $[-2, +2]$ and $[-1, +1]$ around each of the two event dates. Following the extant literature, we searched the LexisNexis Academic Database near the dates of the announcements to see if there were any confounding announcements related to the companies involved in litigation. This was done to eliminate any confounding factors that might have affected abnormal returns in the event window.

4.7.7 Parametric Test for Significance of Cumulative Abnormal Returns

In order to draw inferences, we test the statistical significance of estimated AR for different sampling intervals within the event window. To that end, cumulative abnormal returns (CAR) are calculated for event window $[T_1, T_2]$ as follows:

$$C\hat{A}R(T_1, T_2) = \sum_{\tau=T_1}^{T_2} A\hat{R}_\tau \quad (4.3)$$

It is conjectured that when an event occurs, market participants may revise their beliefs causing a shift in the firm's return generating process. The null hypothesis is that the event has no impact on the cumulative abnormal returns of Lexar. To put it formally,

$$H_0 : C\hat{A}R(T_1, T_2) = 0 \quad (4.4)$$

Event studies typically use parametric Patell test. The test statistic is

$$t_{Patell} = \sqrt{\frac{M-p-3}{M-p-1}} \cdot SCAR_\tau \quad (4.5)$$

where M is the length of the estimation window, p is the number of explanatory variables in the abnormal return regression (4.1) and SCAR is Standardized Cumulative Abnormal Return. SCAR is computed as follows

$$SC\hat{A}R(T_1, T_2) = \frac{C\hat{A}R(T_1, T_2)}{\sqrt{S^2(T_1, T_2)}} \quad (4.6)$$

where $S^2(T_1, T_2) = \text{var}[C\hat{A}R(T_1, T_2)]$ denotes the variance of estimated CAR.

If we assume independence among estimated AR over the event window, then

$$S^2(T_1, T_2) = (T_2 - T_1 + 1) \cdot \text{var}(A\hat{R}_\tau | R_{m\tau}) = L \cdot \text{var}(A\hat{R}_\tau | R_{m\tau}) \quad \text{where} \quad (4.7)$$

$$\text{var}(A\hat{R}_\tau | R_{m\tau}) = \text{var}(\hat{\epsilon}_\tau | R_{m\tau}) = \sigma^2 \cdot \left(1 + \frac{1}{M} + \frac{(R_{m\tau} - \bar{R}_m)^2}{\sum_{\tau=T_0}^{T_1} (R_{m\tau} - \bar{R}_m)^2} \right), \quad (4.8)$$

and $\sigma^2 = \frac{\hat{\boldsymbol{\varepsilon}}'\hat{\boldsymbol{\varepsilon}}}{M-2}$ is the residual variance estimated from the OLS regression (4.1).

Evidently this standard error depends on M , the length of the estimation window. Thus longer estimation windows lead to low standard errors.

From (4.7) as the length of the event window increases, i.e. $L \rightarrow \infty$, one may use

$$S^2(T_1, T_2) = L \cdot \sigma^2 \quad (4.9)$$

Under the null hypothesis of no event effect, the test statistic SCAR follows t distribution with $M-2$ degrees of freedom. If we assume that estimated AR are intertemporally uncorrelated, the variance of CAR is estimated as the sum of the variances of the individual AR. Such an assumption relies on the weak form of the efficient markets hypothesis, according to which the true AR are intertemporally uncorrelated. However, since estimated AR are based on market model parameters, it is a nothing but a forecast error, not a true error. The same market model parameter estimates enter into the calculation of all AR for a firm. Consequently, the estimated AR would be correlated with each other. It is well known in the econometrics literature (Theil, 1971, pp. 122–123) that prediction errors have greater variance than the regression disturbances, since prediction errors are a function of estimation error in the parameters as well as disturbance variance (Binder, 1998). Salinger (1992), Mikkelsen and Partch (1988) provide a corrected formula of variance of estimated CAR that

considers the intertemporal correlation between the estimated abnormal returns.

$$S^2(T_1, T_2) = L \cdot \sigma^2 \left[1 + \frac{L}{M} + \frac{L \sum_{\tau=T_1}^{T_2} (R_{m\tau} - \bar{R}_m)^2}{\sum_{\tau=T_0}^{T_1} (R_{m\tau} - \bar{R}_m)^2} \right] \quad (4.10)$$

As pointed out by Binder (1998), the parametric tests reject too often when testing for positive abnormal performance and too seldom when testing for negative abnormal performance. This is an important fact to keep in mind while making inferences using parametric tests. There is another problem in using parametric test for a single firm event study. As Brown and Warner (1985) note, daily stock return for an individual security exhibits substantial departures from normality. Distributions of daily returns tend to be fat-tailed and right skewed relative to a normal distribution (Fama, 1976). The Central Limit Theorem (CLT) ensures that if the excess returns in a cross-section of securities are independent and identically distributed drawings from finite variance distributions, then the distribution of the sample mean excess return would converge to normality as the number of securities increases. However, in a single firm event study we cannot use this result and hence non parametric tests are necessary.

4.7.8 Non-Parametric Test for Significance of Abnormal Returns

When the assumption of normality of abnormal returns is violated, parametric tests are not well specified. Non-parametric tests are well-specified and more powerful at detecting a false null hypothesis of no abnormal returns.

4.7.9 Dummy Variable/Event Parameter Approach

In the traditional approach the market model parameters are estimated over a period that excludes the event dates. Then in the second stage, the abnormal returns are estimated as prediction errors from the market model. An alternative to this method is the so called event parameter/dummy variable approach. In this method, the market model includes the event dates. The model is augmented with event specific dummy variables which allow joint estimation of the market model parameters and the abnormal returns. Since our case study involves two event dates, we augment the market model with two dummy variables as follows.

$$R_{\tau} = \alpha + \beta \cdot R_{m\tau} + \gamma^1 \cdot D_{\tau}^1 + \gamma^2 \cdot D_{\tau}^2 + e_{\tau} \quad (4.11)$$

In this equation, τ includes the two event dates. The dummy variable D^1 is equal to 1 at the start of litigation and 0 otherwise; and D^2 is 1 at the end of litigation and 0 otherwise. The coefficients γ^1 and γ^2 estimates the impacts of the two events on returns of Lexar. These two coefficient(s) are also the abnormal return(s) on the two event dates. However, the validity of using t statistic for a single firm study remains questionable, as la Gelbach et al. (2009). If γ^1 and γ^2 were Normally distributed then under null we could use usual t -test to examine the effects of the events. However, as Gelbach et al. (2009) explains, CLT holds when γ^i can be written as a sample mean of large number of observations since sample mean is asymptotically normal. But when there is a single firm, gamma cannot be written as a sample mean of many observations. Therefore a non parametric test is used to examine the event effect of trade secret loss experienced by Lexar. Formally, the null hypothesis is

$$H_0: \gamma^1 = \gamma^2 = 0 \quad (4.12)$$

The alternate hypothesis is that the start of litigation will lead to negative abnormal returns and the end of litigation with a favorable ruling for Lexar will lead to positive abnormal returns.

$$H_A: \gamma^2 > 0 > \gamma^1 \quad (4.13)$$

The test developed by Gelbach et al. (2009) is as follows.

- i) Obtain OLS estimates of the parameters for equation (4.11).
- ii) Obtain the fitted abnormal returns \hat{e} and rank them in increasing order.
- iii) For a level α test define $\hat{e}_{\sqrt{\alpha}}$ and $\hat{e}_{1-\sqrt{\alpha}}$ as the sample $\sqrt{\alpha}$ and $(1-\sqrt{\alpha})$ quantiles of the distribution of fitted abnormal returns.
- iv) Rejection rule for the test: reject H_0 against H_A if and only if both

$$\hat{\gamma}^1 \leq \hat{e}_{\sqrt{\alpha}} \text{ and } \hat{\gamma}^2 \geq \hat{e}_{1-\sqrt{\alpha}} \quad (4.14)$$

4.8 Hypotheses Development

Generally speaking, there could be several factors leading to fluctuation in market price of Lexar's common stock. The annual 10-K report filed by the company outlines these broad factors (Lexar Media, 2005):

- announcements of technological innovations by Lexar or its competitors;
- introduction of new products or new pricing policies by Lexar or its competitors;
- announcements related to outstanding litigation; and
- market conditions in the industry and the economy as a whole.

We discuss the factors that investors might take into consideration while forming their beliefs about the stock price of Lexar. If they anticipate that Lexar might not be profitable in the future, stock prices would be negatively affected. There are risks of several kinds that could lead to negative sentiment among investors. Lexar's profitability depends on the cost of its components for producing flash memory products and the rate of price decrease for its products in order to sustain the "irrational" price cutting strategy followed by its key competitors like Toshiba and SanDisk (Lexar Media, 2005). It also depends on the growth of the markets for digital cameras or other devices that need digital storage media produced by Lexar. Hence stock prices are determined by expectations related to market acceptance of Lexar products and its ability to charge a premium price for its high performance products. In part these expectations also depended on the license revenue that Lexar can earn from its IP. Therefore news pertaining to IP misappropriation would cause negative expectations among investors since IP theft can lead to loss of sales and market share. It can also lead to reduced average selling prices, resulting in further loss of revenues. Consequently a loss of IP would lead to lower shareholder and market value. In the spate of adverse expectations on Lexar's profitability, the market price of its common stock would decline significantly. Indeed, as pointed out in Lexar media (2005):

"If we are unable to generate increased revenue from licensing our intellectual property, our gross margins and results of operations would be negatively impacted. Therefore if the loss of IP is serious, it could have great ramifications on the competitive advantage of Lexar."

Consequently, an initial announcement of trade secret loss would adversely affect investors' belief about the value of Lexar. If the competitors of Lexar can produce similar products with the misappropriated IP then customers might choose non Lexar products if they are cheaper. Thus IP loss would lead to reduced future income for Lexar and consequently, a depreciation of abnormal returns. If the loss of trade secret hampers the ability of Lexar to design and manufacture products that are technologically superior from its competitors, then it would lose its brand value. Thus the start of litigation would impact investor's confidence adversely. Investors might believe that the loss of trade secret would lead to a fall in future cash flows of Lexar. We would expect in the presence of negative factors enumerated above, that a news regarding start of litigation would affect stock prices of Lexar adversely. Thus our first hypothesis is:

Hypothesis 1

The market price of Lexar's stock may decline if investors believe that loss of IP would be critical for the company's profitability in the future. Loss of IP would adversely affect Lexar's ability to secure licensing revenue from potential licensees and consequently have a negative impact on its stock. Initial announcement of trade secret theft litigation would lead to negative abnormal returns for Lexar.

Though the market may be monitoring the progress of the litigation and update forecasts of the firm's prospects, the termination may still contain new information which is unanticipated by the markets (Raghu et al., 2008). How the market will react to a decision also depends on the importance of Lexar's IP. In 2004, Lexar had an agreement with Kodak to sell flash cards under the Kodak brand. With worldwide brand

recognition, Kodak complemented Lexar's core IP. This validates the importance of Lexar's IP to a large extent. If customers have faith in Lexar brand, they would not shy away from the Lexar products. Given this brand recognition among its customers, an end in litigation in favor of Lexar would lead to positive abnormal returns. Thus we have our second hypothesis of this event study.

Hypothesis2

A termination of litigation in favor of Lexar would assure investors as well as customers about the company's core IP. To the extent the investors' confidence is restored, they will update their belief about the value of Lexar. This might increase the demand for its product and hence we would expect positive abnormal returns for Lexar. An unfavorable outcome, on the other hand, could lead to a decline in Lexar stock price and negative abnormal returns.

4.9 Data

The data were obtained from CRSP database provided by Wharton Research Data Services. We use daily data on volume, outstanding number of shares and stock market return of Lexar Media (NASDAQ:LEXR). For market return index, three variables were considered: the value weighted portfolio market return, equally weighted portfolio return and S&P 500. News related to the event dates and 10-K, 10-Q reports were accessed using LexisNexis Academic database.

4.10 Results

4.10.1 Parametric Tests

We consider event 1 as the start of litigation on February 8, 2005. This corresponds to $t = 0$. Table 4 presents the OLS estimates of regression (4.1). The estimation window is $[-252, -11]$.

Table 4. Coefficient Estimates^(a) and Cumulative Abnormal Returns around Event 1:
Start of Litigation

Independent variable (R_m)	Intercept ($\hat{\alpha}$)	Slope ($\hat{\beta}$)	Event Window	Cumulative Abnormal Return (CAR)	Patell Z ^(b)	P value ^(c)
CRSP ^(d)	-0.00299	2.5**	[-3,+3]	-11.66%	-1.048	0.1474
Equally			[-2,+2]	-3.18%	-0.339	0.3673
Weighted/ S&P 500 ^(e)			[-1,+1]	-1.08%	-0.15	0.4404
CRSP Value	-0.00328	2.57**	[-3,+3]	-11.84%	-1.074	0.1415
Weighted			[-2,+2]	-3.11%	-0.336	0.3686
			[-1,+1]	-0.96%	-0.133	0.447

**Statistically significant at 5% level

(a) Estimates of equation 4.1 where the dependent variable is Lexar stock return

(b) Cumulative window Z statistics are adjusted for serial dependence for the Patell test

(c) Tests are one sided

(d) CRSP denotes Center for Research on Securities Prices

(e) S&P 500 denotes Standard & Poor's 500 Index

Table 4 provides the cumulative abnormal returns of Lexar for three event windows: [-1, +1], [-2, +2] and [-3, +3]. Cumulative abnormal returns after the start of litigation were negative. The result is robust to the choice of R_m and the event window. However, we note that the CAR are not statistically significant using the parametric test. This result is robust to the choice of R_m and the event window.

We consider event 2 as the end of litigation on March 24, 2005. This corresponds to $t = 32$. As before, the estimation window is [-252,-11].

Table 5. Coefficient Estimates^(a) and Cumulative Abnormal Returns around Event 2: End of Litigation

Independent variable (R_m)	Intercept ($\hat{\alpha}$)	Slope ($\hat{\beta}$)	Event Window	Cumulative Abnormal Return (CAR)	Patell Z ^(b)	P value ^(c)
CRSP ^(d)	-0.00299	2.5**	[+29,+35]	94.43%	8.491	<.0001
Equally			[+30,+34]	83.38%	8.902	<.0001
Weighted/ S&P 500 ^(e)			[+31,+33]	82.83%	11.46	<.0001
CRSP Value	-0.00328	2.57**	[+29,+35]	94.97%	8.615	<.0001
Weighted			[+30,+34]	84.67%	9.123	<.0001
			[+31,+33]	83.15%	11.604	<.0001

**Statistically significant at 5% level

(a) Estimates of equation 4.1 where the dependent variable is Lexar stock return

(b) Cumulative window Z statistics are adjusted for serial dependence for the Patell test

(c) Tests are one sided

(d) CRSP denotes Center for Research on Securities Prices

(e) S&P 500 denotes Standard & Poor's 500 Index

Table 5 shows that around the end of litigation, Lexar stock exhibited statistically significant positive CAR. The result is robust to the choice of R_m and the event window.

4.10.2 Non Parametric Test

Equation (4.11) is estimated using data encompassing both estimation and event window as previously defined. OLS estimates of the coefficients on the event dummy variables give us the estimated event effects directly. The dummy variable D^1 is 1 for the event 1 date February 8, 2005 and 0 otherwise. The variable D^2 is 1 for the event 2 date March 24, 2005. We report the results with S&P 500 as the index for R_m . Regressions using CRSP value and equally weighted indices yield similar results and are therefore not reported here. Table 6 provides the OLS estimates of equation (4.11). The CAR and

standard error of CAR are numerically identical to the conventional approach (Salinger, 1992) and hence not reported.

Table 6. Coefficient Estimates^(a) of Equation (4.11)

	Estimated Coefficient	t statistic	P value
Intercept ($\hat{\alpha}$)	-0.005	-1.608	.109
Slope ($\hat{\beta}$)	2.143	5.028**	.000
Litigation start dummy ($\hat{\gamma}^1$)	-0.031	-0.617	.537
Litigation end dummy ($\hat{\gamma}^2$)	1.000	19.997**	.000

**Statistically significant at 5% level, Adjusted $R^2=0.59$, Durbin Watson =2.09

^(a) The dependent variable is Lexar stock return

Although the signs are as expected, we find no statistical significance of event 1: Start of Trial. On the other hand, event 2: End of Trial had significant positive effect on value of Lexar. However, as has been pointed out by Gelbach et al. (2009), the assumption of normality of abnormal returns is questionable with single firm event study. Therefore we apply the non parametric test described above in (4.14).

We choose a level α (=0.05) test. For $n = 289$ and $\sqrt{\alpha} = 0.2236$, we obtain the $\lceil \sqrt{\alpha} \cdot n \rceil$, or 64th order statistic from the sample of fitted abnormal returns. We obtain $\hat{e}_{\sqrt{\alpha}} = -0.01757$ and $\hat{e}_{1-\sqrt{\alpha}}$, which is the 224th order statistic = 0.023229. We recall the rejection rule for test: reject H_0 against H_A if and only if both $\hat{\gamma}^1 \leq \hat{e}_{\sqrt{\alpha}}$ and $\hat{\gamma}^2 \geq \hat{e}_{1-\sqrt{\alpha}}$. From Table 6 above, we see that both of these required conditions are met. Hence we can reject the null in favor of the alternate hypothesis. Thus we can infer that CAR at the start of event 1 is significantly negative and CAR at event 2 is significantly positive. The

regression results imply that the magnitude of CAR at the start of litigation was -3.1% and CAR at the end of litigation was 100%. Following Lys and Vincent (1995) methodology, these abnormal returns translate to an estimated total wealth loss of Lexar shareholders of \$9.2 million at the start of litigation. This is obtained by multiplying Lexar's Abnormal Return of -3.1% by the pre-event 1 price (on February 7, 2005) of \$3.76 and 79,235,000 shares outstanding. At the termination of litigation, however, the shareholder wealth increased by \$252.7 million, which is obtained by multiplying the pre-event 2 Lexar price of \$3.17 and 79,701,000 shares outstanding.

For event 1: start of litigation, the parametric test yields expected (negative) sign of the CAR but the results are not statistically different from zero. According to the non parametric test, however, there was a statistically significant abnormal decline in the value of Lexar. The non parametric test lends support to Hypothesis 1.

Both parametric and non parametric tests lead to the same inference on the effect of event 2: end of litigation. This validates our second hypothesis. Lexar stock price exhibited positive CAR following the end of litigation which ruled in favor of Lexar. The result is statistically significant, using both non parametric and parametric tests.

We can infer two things from these statistical tests. First, the market received the news of trade secret theft negatively at the beginning. Once the uncertainty was resolved at the end of litigation, investors updated their belief about the IP and value of Lexar. Since the core IP of Lexar was validated by the "epic" litigation, Lexar stock price exhibited statistically positive cumulative abnormal returns after the end of litigation.

4.11 Findings Related to Existing Literature

Previous empirical works in the area reveal that litigations cause markets to reevaluate the firms. Filing of litigations generally led to a 2–3.1% average decrease in the market value of the firms involved (Bhagat et al., 1994; Lerner, 1994). The results are comparable with a CAR of -3.1% for Lexar following the start of litigation.

The termination of litigation with a favorable ruling reveals the validity of the firm's ownership of its intellectual property. Existing literature shows that stock price for prevailing appellate plaintiffs tend to have positive effects on the day of the decision (Lunney 2005). The results found in this event study corroborates with this finding. At the end of litigation, the stock prices of Lexar exhibited a significantly positive CAR of 100%.

4.12 Discussion

The IP misappropriation problem is embedded within the outsourcing strategy pursued by Lexar. The company has been outsourcing an essential input, flash memory, from Toshiba in order to produce its flash memory products. Lexar had to share its critical intellectual property (i.e. flash memory controller technology) with its outsourcing partner, Toshiba. This knowledge sharing was imperative following an agreement in 1997 to co-develop the flash memory technology. The knowledge/trade secret sharing on the part of Lexar ultimately proved to be futile when Toshiba shared the information with SanDisk, a major competitor of Lexar.

What was the effect on Toshiba due to this event? Toshiba being a private company we were unable to examine the effects using event study. However, the end of litigation in favor of Lexar pointed to the fact that Toshiba had indeed misappropriated the IP and used it for its own benefit. When Toshiba and SanDisk announced their partnership to produce what is called Multi Level Cell Technology, Lexar argued that it would not be financially viable without Lexar's IP, i.e. Multipage Write Technology. Not only Toshiba had incorporated Lexar's IP in several of its products, it had also adopted a significant price cutting strategy in due course. It might be argued that Toshiba was able to use this strategy because the trade secrets from Lexar helped it reduce its cost of producing the products. As pointed out in the 2005 Quarter 1 earning conference of Lexar, the irrational price cut by Toshiba and SanDisk might be attributed to the trade secret stolen from Lexar. Indeed, it would have taken several months of time and effort to develop similar technology without infringing on Lexar's core technology (Fair Disclosure Wire, 2005).

Lexar operates in an industry that is subject to rapid technological changes, fast changes in consumer demand and continuous introduction of new, higher performance products with short product life cycles. In the recent years, prices of Lexar products have fallen faster than the cost of its inputs, particularly the cost of flash memory. The industry is characterized by aggressive pricing strategies with an average 30 to 40 percent price decline each year. Lexar had to outsource a critical component, flash memory, from Toshiba. It was precisely the channel that led to eventual

misappropriation of its IP. Lexar ultimately survived the IP misappropriation problem by using the following business strategies.

As a brand, the key thing that Lexar offers is quality and design of its products. It had a 31% market share in the booming flash drive market (Businessweek, 2003). While consumers trust this brand, it ought to remain competitive on the price front. Despite robust demand for digital products from the consumers, Lexar has been unable to cut its costs enough to keep up with retail price cuts. In the first quarter of 2005, Lexar had announced that it would focus on profitability. It reduced the number of promotional programs and maintained a price higher than its competitors. Apparently this strategy did not prove successful as it resulted in a decrease in rate of revenue growth and a loss of market share during 2005 (Lexar Media, 2006). During late 2005, in an effort to return to profitability, Lexar's action plan included launching more of premium-differentiated products including its Platinum Series of cards and the new JumpDrive Lightning, which offered superior data transfer speed (Fair Disclosure Wire, 2005).

Many of the competitors of Lexar (e.g. SanDisk) manufacture their own controllers and/or flash memory in-house. This is in contrast to the outsourcing strategy followed by Lexar since its inception. Since Samsung and Toshiba dominate the market for high density flash memory, the price of this key input is expected to remain high in the future. Unless Lexar was able to introduce new, differentiated products with higher average selling prices, its revenue and gross margins would be negatively impacted. As a response to the price cutting strategy by its competitors, Lexar had to decrease the prices of its products as well. In order to retain its market share, its strategy was to

continuously bring new products and better versions of existing products. A significant part of its revenues come from its JumpDrive flash storage products. For this kind of products, design has become an important selling feature unlike other flash cards which have fixed dimensions and specifications. Therefore Lexar used a strategy to differentiate its JumpDrive products. In order to do so, it continuously developed innovative designs for new flash storage products that would appeal to a broad group of customers.

In addition to the product differentiation strategy, in 2004, Lexar entered into an exclusive, multi-year agreement with Kodak whereby it sells digital media to customers under the Kodak brand name. By using brand power and global distribution network of Kodak, Lexar was able to gain a significant share of the market for removable digital memory products. Also, the company continued to develop premium differentiated products to capture the professional photography market.

4.13 Conclusion

The ability of a company to benefit from its IP depends on the vulnerability of the IP, i.e. how difficult it is for the competitors to imitate the technology (Gilbert and Shapiro, 1990). Product differentiation might be a key strategy to survive in the electronic goods industry. Indeed, Lexar survived the trade secret theft largely because it continued investing in innovative new products. In particular, it developed products with enhanced attributes like larger memory capacity, greater writing speed and smaller size to render the new products compatible with the changing needs of its customers,

particularly the professional photographers. In addition, by selling products under the Kodak brand name, the company was able to increase its market share. This case study on Lexar underlines the importance of investing in product differentiation that helped it stay in the business even after losing its IP.

CHAPTER V

SUMMARY AND CONCLUSIONS

As firms outsource supply chain activities, they face agency problems due to ex-post opportunistic actions of their contractors. Two significant risks in supply chain outsourcing involve IP misappropriation and shirking by contractors. A description of these risks and the contributions of this dissertation in terms of mitigating these risks are summarized as follows.

The first type of risk involves the protection of IP while engaging with supply chain contractors. Modern enterprises derive significant value from their IP. The recent occurrences of IP theft under outsourcing have motivated companies, practitioners and researchers to find better ways to manage risk of IP theft.

The existing literature addresses the protection of IP that is created within an outsourcing relationship. When R&D is created by the contractor, contractual safeguards like exclusivity clauses are commonly used and high powered incentives are provided by assigning some of the property rights to the contractor. The allocation of property rights provides appropriate incentive to the contractor to not misappropriate the IP. Lai et al. (2009) find that a revenue sharing contract provides greater incentive than a fixed price contract to avoid the IP misappropriation problem. Ho (2009) considers a similar problem under uncertainty in innovation outcome. She finds that in the presence of uncertainty, if a single contractor is hired, then it is not possible to deter the IP misappropriation problem.

In contrast to the extant literature, the focus of this dissertation is on the protection of the pre-existing IP of a firm. The real life examples described in Chapter I reveal that pre-existing IP plays an important role in the misappropriation problem. Firms possess a portfolio of IP which they share with their contractor/service provider. Knowledge disclosure by the principal firm can affect the outsourcing project in different ways. Two alternative situations are considered in this dissertation. In Chapter II, it is assumed that knowledge sharing by the principal firm enables a contractor to learn the technology and then use the IP towards its own benefit. In Chapter III, the knowledge sharing by the principal firm is assumed to affect the probability distribution of the project returns. In either case, while the principal shares its pre-existing knowledge to facilitate the project, the contractor may misappropriate the shared information towards its own benefit. This ex-post opportunistic action by the contractor comprises the first agency problem in outsourcing relationship.

The existing literature confines attention to only one kind of IP misappropriation problem. For example, Lai et al. (2009), and Ho (2009) addresses the problem where a contractor produces R&D and then sells the innovation output to a competitor of the principal. In this dissertation, two manifestations of the IP misappropriation risk are considered. In Chapter II, a contractor may use the IP of the principal to emerge as a direct competitor of the principal in the final product market. This type of IP misappropriation has occurred in biotech, pharmaceutical, footwear, automotive, semiconductor and electronic goods industries. In Chapter III, the contractor sells the shared IP to a competitor of the principal. This form of IP misappropriation risk is

observed in the software, semiconductor, and food processing industry. Both of these possibilities have occurred in reality, as described at length in Chapter I. Hence the solutions offered in this dissertation are applicable to any form of IP misappropriation problem that might occur in outsourcing.

The second type of risk occurs when a task is outsourced; it becomes difficult for the principal firm to control the actions of the contractor. Thus it is impossible for a firm to detect whether a bad project outcome is due to shirking by the contractor or because of natural shocks. Consequently the principal firm faces a moral hazard problem due to unobservable and unverifiable effort exerted by a contractor on the outsourced project. Depending on the nature of outsourcing project, shirking can lead to adverse consequences for the principal firm. If the task is contract manufacturing, shirking may lead to poor quality product and/or higher than planned costs; if the outsourced task is R&D, shirking can lead to suboptimal research outcomes.

The existing literature does not provide any insight on how to mitigate both of these risks in outsourcing. In Chapters II and III of this dissertation, contractual solutions are developed to mitigate the two agency problems associated with outsourcing. It is demonstrated how firms can protect their IP even if there is a potential threat of IP misappropriation by their supply chain contractors. Incentive contracts are designed to implement a “carrot and stick” strategy. In particular, it is recommended that firms should disclose their pre-existing IP with their contractors only on a “need to know” basis. This may be accomplished by breaking the R&D project into modules and sharing only selective knowledge with the contractor. The limited knowledge sharing reduces

the profit of the contractor that it could have received by walking away from the contract. This weakens its outside option and therefore the contractor stays within the contractual relation. Thus the “stick” strategy enables a firm to deter the first agency problem due to IP misappropriation. As the contractor decides to stay within the contractual relationship, the principal faces the second agency problem due to moral hazard with respect to effort exerted by the contractor. When effort cannot be observed, a forward looking principal designs the contract such that the contractor would exert optimal effort on the outsourced project. This is accomplished by writing an incentive contract contingent on the realized level of R&D output. It is shown that the optimal compensation comprises of a fixed component as well as a variable component that is contingent on realized project outcome. Essentially, the “carrot” strategy provides appropriate incentives to the contractor for exerting optimal effort on the project. Thus by using a carrot and stick strategy a firm may be able to mitigate the two agency problems in outsourcing.

However, it is important to note that the two potential agency problems might lead to increased transaction costs of outsourcing. In Chapter II, a regime is considered where a technological solution is available to the principal firm to protect its IP. It is shown that when IP theft is plausible, the incentive payments must be higher compared to the situation where IP theft is impossible due to the technological solution. Likewise, in Chapter III, it is demonstrated that if a firm is willing to outsource tasks to a location with weak contractual enforcement, it needs to give higher incentive payments to the contractor. The increased incentive payment is an outcome of the agency problems in

outsourcing. Higher incentive payments lead to greater transaction costs and therefore, firms ought to assess these increased transaction costs with the benefits offered by outsourcing.

Finally, this dissertation also contributes to the “make or buy” decision of firms in the presence of the two kinds of agency problems. The existing literature typically favors integration as a solution to the IP theft problem. Moreover, the tradeoff between in-house inefficiency and IP loss in outsourcing has not been addressed in the literature. In Chapter III it is shown that the choice of organization (integration vs. outsourcing) depends on the degree of in-house inefficiency, the strength of contractual enforcement, and the value of the IP under consideration. An important finding is that firms need not confine themselves to inefficient integration even if there is possibility of IP misappropriation in outsourcing. Firms can still reap the benefits of outsourcing if they can design the contracts appropriately.

The recommended strategy is to ensure that the shared IP cannot be duplicated easily by the contractor. As described in Chapter II, this may be accomplished by investing in complementary strategies like product differentiation, task modularization, and technological solutions. Firms might use business strategies to ensure that their products are differentiated at least as perceived by the customers. In Chapter IV, an event study is conducted on the epic case of Lexar trade secret theft by Toshiba. Even though its IP was misappropriated, Lexar continued with the outsourcing strategy and concentrated on product design and development. It sustained the trade secret theft by continuously investing in innovative designs and producing memory cards with greater

writing speed and higher capacities. Companies willing to outsource might revisit product differentiation strategy when it is difficult to protect their IP from supply chain contractors.

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APPENDIX 1

First we derive the second best effort from the ICC of the agent. We use the first order approach to replace the ICC in (2.15) by its first order condition (Laffont and Martimort,

$$2002). \text{ Thus } \bar{T} - \underline{T} - 2e = 0, \text{ or } e = \left(\frac{\bar{T} - \underline{T}}{2} \right). \quad (\text{A1})$$

Substituting e from (A1) in the Lagrangean of the optimization problem yields

$$L = \left(\frac{\bar{T} - \underline{T}}{2} \right) \cdot (\bar{v} - \bar{T}) + \left(1 - \left(\frac{\bar{T} - \underline{T}}{2} \right) \right) \cdot (\underline{v} - \underline{T}) - \frac{\gamma}{2} \cdot K_p^2 + \lambda \cdot \left[\left(\frac{\bar{T} - \underline{T}}{2} \right) \cdot \bar{T} + \left(1 - \left(\frac{\bar{T} - \underline{T}}{2} \right) \right) \cdot \underline{T} - c + \alpha \cdot K_p - \left(\frac{\bar{T} - \underline{T}}{2} \right)^2 - \psi(K_p) \right]$$

$$\frac{\partial L}{\partial \bar{T}} = 0 \text{ and } \frac{\partial L}{\partial \underline{T}} = 0 \text{ yields } \lambda = \frac{2(\bar{T} - \underline{T}) - (\bar{v} - \underline{v})}{(\bar{T} - \underline{T})} = \frac{2 + (\bar{v} - \underline{v}) - 2(\bar{T} - \underline{T})}{2 - (\bar{T} - \underline{T})}. \quad (\text{A2})$$

$$\text{Simplifying equation (A2) yields } (\bar{v} - \underline{v}) = (\bar{T} - \underline{T}) \quad (\text{A3})$$

$$\text{Thus } \lambda = 1, \text{ implying that the IRC binds at the optimum.} \quad (\text{A4})$$

$$\text{Plugging (A3) into (A1) yields optimal effort } e = \left(\frac{\bar{v} - \underline{v}}{2} \right) \quad (\text{A5})$$

$$\frac{\partial L}{\partial K_p} = -\gamma K_p + \lambda \left(\alpha - \frac{\partial \psi(K_p)}{\partial K_p} \right) = 0 \text{ and (A4) solves for optimal knowledge shared}$$

$$K_p^{SB} = \frac{\alpha - \frac{4\alpha}{(4 - \theta^2)^2} \cdot (2 - 2c - \theta + \theta c)}{\gamma + \frac{8\alpha^2}{(4 - \theta^2)^2}} \quad (\text{A6})$$

$$\text{Finally } \frac{\partial L}{\partial \lambda} = 0 \text{ yields}$$

$$\frac{(\bar{T} - \underline{T})\bar{T}}{2} + \left(1 - \frac{(\bar{T} - \underline{T})}{2}\right)\underline{T} - c + \alpha K_p - \frac{(\bar{T} - \underline{T})^2}{4} - \psi(K_p) = 0 \quad (\text{A7})$$

Solving (A7) and (A6) leads to the optimal transfers specified in (2.16) Part (i).

APPENDIX 2

We substitute e from (A5) in the Lagrangean of the optimization problem:

$$L = \left(\frac{\bar{T} - \underline{T}}{2}\right) \cdot (\bar{v} - \bar{T}) + \left(1 - \left(\frac{\bar{T} - \underline{T}}{2}\right)\right) \cdot (\underline{v} - \underline{T}) - \frac{\gamma}{2} \cdot K_p^2 - \beta + \lambda \cdot \left[\left(\frac{\bar{T} - \underline{T}}{2}\right) \cdot \bar{T} + \left(1 - \left(\frac{\bar{T} - \underline{T}}{2}\right)\right) \cdot \underline{T} - c + \alpha \cdot K_p - \left(\frac{\bar{T} - \underline{T}}{2}\right)^2 \right]$$

$$\frac{\partial L}{\partial K_p} = -\gamma K_p + \lambda(\alpha) = 0 \text{ yields}$$

$$K_p^{FP} = \frac{\alpha}{\gamma} \tag{A8}$$

$$\frac{\partial L}{\partial \lambda} = \left(\frac{\bar{T} - \underline{T}}{2}\right) \bar{T} + \left(1 - \left(\frac{\bar{T} - \underline{T}}{2}\right)\right) \underline{T} - c + \alpha K_p - \frac{(\bar{T} - \underline{T})^2}{4} = 0 \tag{A9}$$

Equations (A8) and (A9) yield the optimal transfers specified in (2.23) Part (i).

APPENDIX 3

$$\bar{T}^{SB} \geq T^{FB} \text{ when } (\bar{v} - \underline{v}) \leq 2 \quad (\text{A10})$$

$$T^{FB} \geq \underline{T}^{SB} \text{ since } T^{FB} - \underline{T}^{SB} = \frac{(\bar{v} - \underline{v})^2}{2} \geq 0 \quad (\text{A11})$$

$$\bar{T}^{SB} \geq \bar{T}^{FP} \text{ since } \bar{T}^{SB} - \bar{T}^{FP} = \psi(K_p^{SB}) + \alpha(K_p^{FP} - K_p^{SB}) \geq 0 \text{ since}$$

$$\psi(K_p^{SB}) > 0 \text{ and } (K_p^{FP} - K_p^{SB}) \geq 0 \text{ by Proposition 2.4.} \quad (\text{A12})$$

$$\underline{T}^{SB} \geq \underline{T}^{FP} \text{ since } \underline{T}^{SB} - \underline{T}^{FP} = \psi(K_p^{SB}) + \alpha(K_p^{FP} - K_p^{SB}) \geq 0 \quad (\text{A13})$$

$$\bar{T}^{FP} \geq T^{FB} \text{ when } (\bar{v} - \underline{v}) > \psi(K_p^{FP}) + \alpha(K_p^{FP} - K_p^{FB}) + \frac{(\bar{v} - \underline{v})^2}{2} \quad (\text{A14})$$

$$\bar{T}^{FP} \leq T^{FB} \text{ when } (\bar{v} - \underline{v}) \leq \psi(K_p^{FB}) + \alpha(K_p^{FP} - K_p^{FB}) + \frac{(\bar{v} - \underline{v})^2}{2} \quad (\text{A15})$$

$$\bar{T}^{FP} \geq \underline{T}^{SB} \text{ when } (\bar{v} - \underline{v}) \geq \psi(K_p^{SB}) + \alpha(K_p^{FP} - K_p^{SB}) \quad (\text{A16})$$

$$\bar{T}^{FP} \leq \underline{T}^{SB} \text{ when } (\bar{v} - \underline{v}) \leq \psi(K_p^{SB}) + \alpha(K_p^{FP} - K_p^{SB}) \quad (\text{A17})$$

$$\underline{T}^{FP} \leq \bar{T}^{FP} \text{ follows from (2.23).} \quad (\text{A18})$$

Combining (A10), (A11), (A17) and (A18) we get the ranking in Part (i) of (2.27).

Combining (2.34), (A15), (A16) and (A13) we get the ranking stated in Part (ii) of (2.27).

Finally combining (A12), (A14), (2.35) and (A13) we get the ranking specified in Part (iii) of (2.27).

APPENDIX 4

$$\pi_p^{FP} - \pi_p^{SB} = \psi(K_p^{SB}) + \alpha(K_p^{FP} - K_p^{SB}) - \frac{\gamma}{2} \left[(K_p^{FP})^2 - (K_p^{SB})^2 \right] - \beta.$$

We note that $\psi(K_p^{SB}) + \alpha(K_p^{FP} - K_p^{SB}) - \frac{\gamma}{2} \left[(K_p^{FP})^2 - (K_p^{SB})^2 \right]$ can be written as

$$\psi(K_p^{SB}) + (K_p^{FP} - K_p^{SB}) \left[\alpha - \frac{\gamma}{2} (K_p^{FP} + K_p^{SB}) \right] > 0 \text{ since } \psi(K_p^{SB}) > 0, (K_p^{FP} - K_p^{SB}) \geq 0 \text{ by}$$

Proposition 2.4. We do some algebraic manipulation to show that

$$\begin{aligned} \left[\alpha - \frac{\gamma}{2} (K_p^{FP} + K_p^{SB}) \right] &= \left[\alpha - \frac{\gamma}{2} \left(\frac{\alpha}{\gamma} + K_p^{SB} \right) \right] = \left[\frac{\alpha}{2} - \frac{\gamma}{2} K_p^{SB} \right] = \left[\frac{\alpha}{\gamma} \cdot \frac{\gamma}{2} - \frac{\gamma}{2} K_p^{SB} \right] \\ &= \frac{\gamma}{2} [K_p^{FP} - K_p^{SB}] \geq 0 \end{aligned}$$

Thus $\pi_p^{FP} > \pi_p^{SB}$ when $\psi(K_p^{SB}) + \alpha(K_p^{FP} - K_p^{SB}) - \frac{\gamma}{2} \left[(K_p^{FP})^2 - (K_p^{SB})^2 \right] > \beta$.

APPENDIX 5

The Lagrangean for the optimization problem stated in (3.7) is

$$L = (e + k) \cdot (v - h) + (1 - e - k) \cdot (u - l) - k^2 + \lambda \cdot [(e + k) \cdot h + (1 - e - k) \cdot l - e^2 - sk + \beta]$$

where λ is the Lagrange multiplier. Substituting e from equation (3.5) into the

Lagrangean yields

$$L = \left(\frac{1}{2}(h-l) + k \right) \cdot (v-h) + \left(1 - \frac{1}{2}(h-l) - k \right) \cdot (u-l) - k^2 \\ + \lambda \cdot \left[\left(\frac{1}{2}(h-l) + k \right) \cdot h + \left(1 - \frac{1}{2}(h-l) - k \right) \cdot l - \frac{1}{4}(h-l)^2 - sk + \beta \right]$$

The first order conditions with respect to h, l, k and λ are simultaneously solved to obtain h^o, l^o, k^o as specified in (3.8a), (3.8b), and (3.8c). The solution for Lagrange multiplier is $\lambda=1$ which implies that the IRC of the agent binds. Finally we substitute the values of h^o, l^o in equation (3.5) to obtain the optimal value of e^o as specified in (3.8d). Intuitively, the optimal values of h^o, l^o, k^o, e^o are obtained by equating the marginal benefit of each variable with its respective marginal cost.

APPENDIX 6

When R&D is done in-house, the Lagrangean for the optimization problem is

$$L^I = (e+k) \cdot (v-h) + (1-e-k) \cdot (u-l) - k^2 + \mu \cdot [(e+k) \cdot h + (1-e-k) \cdot l - e^2]$$

where μ is the Lagrange multiplier. Substituting e from equation (3.12) into the

Lagrangean yields

$$L^I = \left(\frac{1}{2d}(h-l) + k \right) \cdot (v-h) + \left(1 - \frac{1}{2d}(h-l) - k \right) \cdot (u-l) - k^2 \\ + \mu \cdot \left[\left(\frac{1}{2d}(h-l) + k \right) \cdot h + \left(1 - \frac{1}{2d}(h-l) - k \right) \cdot l - \frac{1}{4} \left(\frac{h-l}{d} \right)^2 \right]$$

The first order conditions with respect to h, l, k and μ are simultaneously solved to obtain

h^I, l^I, k^I as specified in (3.14a), (3.14b), (3.14c). The solution for Lagrange multiplier is

$\mu=1$ which implies that the IRC of the agent binds. Finally we substitute the values of

h^I, l^I in equation (3.12) to obtain the optimal value of e^I as specified in (3.14e).

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