Essays on Small and Medium Sized Enterprises as Drivers of Competition in the Software Market: An Intellectual Property Rights Perspective

DISSERTATION

zur Erlangung des akademischen Grades
doctor rerum politicarum
(Doktor der Wirtschaftswissenschaft)

eingereicht an der

Wirtschaftswissenschaftlichen Fakultät
der HumboldtUniversität zu Berlin

von

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Datum der Promotion: 20.10.2009

Dedication:

To my family

Contents

Chapter 1

1. Introduction

Traditionally, classical and neo-classical economists considered technology not as an economic phenomenon but rather a scientific one that exogenously affected firm decisions. The focus of these economic theories was to achieve a stable equilibrium through the efficient allocation of a given set of resources[1] and the determination of price.[2] The cornerstone of analysis here is the diminishing returns concept[3] where such accounting enables static efficiency.

Static efficiency aims at continuous improvements within a fixed set of initial conditions, e.g. by cutting costs, streamlining processes, efficient resource allocation and so on where the only adjustments occur from changes in prices and quantities. Consumers thus, greatly benefit from reduced prices and increased variety. In other words, the economy is constantly pushed towards smooth and continuous adjustments to reach the equilibrium state in the short run interrupted intermittently along its path by transient technological advances.

Schumpeter (1911, 1942), however postulated that technology was endogenous to the economic system. He suggested that the economy was not continuously striving for a stable and static equilibrium i.e., static efficiency, but instead constantly changing through innovation i.e., dynamic efficiency. Through *dynamic efficiency*, initial conditions are constantly being changed leading to a very different set of gains, which in turn affect future investment and innovation structures. He referred to this phenomenon as *creative destruction*.[4]

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[1] Efficiency in allocation is referred to as Pareto-optimality where no situation exists in which one person can be made better off without making someone else worse off.

[2] By assuming free market entry, it implies that firms are price takers with no influence on the market level of prices. Competition is purely price based. Hence the market forces enable easy and automatic adjustments to reach the static equilibrium.

[3] Diminishing returns suggest that past a certain point, further increases of inputs lead to less output than the last unit of input did. In other words, the cost of producing an additional unit is higher than that of the previous unit i.e., increased marginal costs.

[4] Schumpeter (1942) defined creative destruction as a "process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one." In other words, he postulated that economic growth is driven by actual or potential competition which led to new production methods, new markets, and new forms of industrial organization (Scherer, 1992).

Schumpeter placed great relevance on the ability of entrepreneurs, who he believed were driven by monopoly profits, to search out new ways of doing things. Thus, he conjectured that innovation was the result of competition, unlike the neo-classical economists who focussed only on price competition. Dynamic competition thus eroded the old norm and created new forms of industrial organization enabling economic growth and increased overall output.

As an extension to Schumpeter's approach, in the late 1980s, Romer (1986) and Lucas (1988) showed that technology was central to economic growth and could be studied using mainstream economics. New growth theory or endogenous growth theory suggests that technological progress is a product of economic activity i.e., technology is endogenous to the economic system. The changes occurring in the economy as a result are not smooth and continuous but instead tend to be abrupt and create un-even developments – through new market leaders, products and new forms of industrial organization. The main departure here from neo-classical economic analyses is the emphasis on knowledge and the fact that knowledge generates increasing returns to scale and economic growth (Cortright, 2001). Another central aspect of endogenous theory is the focus on knowledge spillovers. The theory recognizes that knowledge is not completely excludable and non-rival, hence third parties can benefit from a firm's ideas. This aspect will be explored further in the subsequent sections.

Present day economic growth is attributed in a large part to technological progress and innovation in the industrial organization literature (Boldrin and Levine, 2004). High-tech knowledge based industries such as software, semiconductors and biotechnology have shown immense innovative activity and increasing returns to scale. Such industries normally exhibit monopolistic competition where competition is based on innovative developments visible through changes in the quality or features of a product and *not* on price (Bresnahan and Greenstein, 1999). These industries experience continuous innovation and make large costly investments in research and development (R&D) creating technological improvements that often render parts of existing knowledge obsolete. Such competition can be likened to Schumpeter's *creative destruction* concept. This concept seems highly relevant to broaden our understanding of these markets (Howitt, 2007).

In technology based markets, situations of static efficiency are periodically replaced by new technology winners with improved technology. For example, in the software industry, the market for word processors was first dominated by Wordstar and then taken over by Corel's

WordPerfect, only to be supplanted by Microsoft several years later.[5] Dynamic efficiency, characterized by increasing returns to scale and growth, thus seems to be in conflict with situations of perfect competition and static efficiency. Seen from the Schumpeterian perspective, technology based markets exhibit a trade off between static efficiency today and achieving long run efficiency tomorrow through optimal investment in R&D and innovation (Carlton and Gertner, 2002). To further understand the implication of Schumpeter's postulations on present day knowledge industries, we examine his two broad contributions in the following section.

1.1   Schumpeter

Schumpeter's work can be broadly divided in to Schumpeter 1911 and Schumpeter 1942. In 1911, Schumpeter published the Theory of Economic Development: In this work he put forth the idea that small and medium sized enterprises (SME), outside the "circular flow" of existing production, are the primary source of innovative activity (Scherer, 1992). However, thirty years later, in Capitalism, Socialism and Democracy (1942), he advanced the well known hypothesis that large firms with substantial market power are better suited for and able to accelerate innovative activity.

Schumpeter (1942), it is said, developed the idea that large firms with substantial market power are highly relevant for technological progress based on the merger wave at the turn of the century (Nicholas, 2003). He believed that dynamic efficiency with all its benefits i.e., increased rewards to society in terms of new technological improvements and increased standards of living would, outweigh the welfare losses created by temporary monopolies. Hence, he believed this provided a rationale for no government intervention. The intuition for his logic lies in dynamic efficiency where monopoly power is constantly challenged by competition from entrants who change the existing equilibrium state through new technology, giving way to new market leaders. Thus Schumpeter advocated that temporary static inefficiencies should be tolerated for the greater good of dynamic efficiency.

The biggest departure from his earlier work in 1911 comes from the change in perspective regarding market structures most suited to technological progress. However, the two

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[5] This pattern of innovation can also be seen in the market for spreadsheets and the markets for operating systems themselves.

viewpoints are not entirely in disaccord with one another when considering the idea of creative destruction, where new firms may take over or dominate the market, is present in both works (Nicholas, 2003).

Much of research thus far has focussed on Schumpeter's 1942 assertion that large firms with substantial market power are required for rapid technological progress. Theoretically it has been shown that market power stimulates innovative activity based on firms' expectations of monopoly profits (Aghion and Hewitt, 1992, Caballero and Jaffe, 1993, Aghion et al., 2001). Aghion et al., (2001) using a panel of UK firms find that firms that are engaged in intensive competition tend to increase overall innovation. Hence confirming the existence of Schumpeterian type innovation based competition. However, they also caution that in industries that exhibit unequal development, excessive competition would reduce the incentive to innovate particularly as new entrants would perceive a reduction in post-entry profits.

While Scherer (1992) notes that much of the existing empirical evidence goes against Schumpeter's theory that larger firms with market power are generators of innovative growth,[6] several empirical studies suggest that large firms obtain more patents and invest more in R&D than their smaller counterparts indirectly implying that they innovate more (Scherer, 1992, 1983). This result could be attributed in part to the fact that formal statistics have not been able to capture informal or part time innovative activity – largely prevalent in SME (Kleinknecht, 1987).

Alternate literature suggests that smaller firms innovate disproportionately to their size (Blundell et al., 1999). Zoltan and Acs (1990) found that SME produce more innovations per thousand employees and on average produce more innovations per million dollars worth of R&D spending. Himmelberg and Peterson (1990) tested 179 US small high tech companies to see whether limited assets reduce R&D expenditure. They found that R&D expenditure rose significantly with higher ratios of internal cash flow to initial asset values.

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[6] Reasons cited for this range from organizational inertia to insulation from competition which discourages innovation (Porter, 1990). Positive aspects related to large firm size include economies of scale in staffing and research facilities and risks can be spread more widely.

Thus, the empirical literature does not provide a clear answer on what type of market structure is most suited to innovative activity (Nicholas, 2003). These results may also be inconclusive because current data is being used to substantiate hypotheses created for a different time period. Despite conclusive evidence pointing either to Schumpeter 1911 or 1942, it seems safe to suggest that keeping market entry open for new entrants positively impacts innovation (Scherer, 1992).

Schumpeter's two contributions and the subsequent literature has brought forth the question as to what type of market structure is most suited to technological progress enabled growth (Scherer, 1992). As previously noted, while the there has been extensive examination of Schumpeter's 1942 contribution, research on his 1911 contribution remains comparatively less. Though we will draw on aspects from Schumpeter 1942, this work is largely confined to enhancing the findings of Schumpeter 1911 in the context of SME in the software market.

1.2   Focus of study

The goal of this study is to obtain a better understanding of the role that SME play in innovation based competition in the software market. We postulate that software is a unique good and one that is different to other products in the high tech industry. In the following, we briefly examine the main issues related to software as a product and consider certain basic conditions in order to better understand innovation based competition, namely, the public good aspect of knowledge, the free rider problem, appropriability and intellectual property rights. This provides a basis for the chapters that follow where these aspects and the associated literature will be examined in greater depth.

1.3   Software

The software industry is an example of a knowledge based human capital intensive industry (Graham and Mowery, 2003) that has shown tremendous innovative activity primarily resulting from performance increases in hardware and the Internet. As a product that is sold, software is the R&D itself (Hall, 1999). In other words it is both the information and the technology simultaneously. It possesses all the features of a durable good yet it does not depreciate over time. Hence, existing software can only be replaced by new innovative developments. The industry is subject to rapid and continuous technological change where innovative developments occur in a sequential and cumulative manner implying the need for

an incessant supply of innovative ideas (Scotchmer, 1991). Innovative development (i.e. R&D) costs are very high whereas duplication and distribution costs are low. Software also enables modular improvements where modules can be improved upon without affecting the structure of the whole program (Narduzzo and Rossi, 2005).[7] This feature allows sequential and cumulative innovation. Further software exhibits both direct and indirect network effects. While some of these characteristics can also be observed in other high tech products, the collective whole seems to be unique to software.

1.4 Public good aspect

Software or source code can be likened to knowledge. Knowledge in itself is a public good and hence software has all the characteristics of public goods - namely non-excludability and non-rival consumption. These two features suggest that all consumers are able to avail of a public good and the consumption by one does not diminish the consumption of others nor does it exclude others from the good. Such goods give rise to two main problems: the free rider problem and the appropriability problem. The former refers to the situation where some consumers benefit from the good without paying for it. Under such circumstances, private provision of a public good will be below the optimum level, assuming there is any provision at all. This is because firms foresee the inability to appropriate profits from the provision of public goods i.e. the appropriability problem. Both these problems imply that there is a market failure in terms of desired public good provision.

Software R&D is considered a risky investment that is only profitable when the expected profits exceed the initial development costs. Further, static efficiency requires that price be equal to marginal (opportunity) cost of production, which implies that in the case of intangible goods like software, the price would be equal to zero (Regibeau and Rockett, 2004). In other words, once an idea is made public it can be reused infinitely. As a result the private benefits may quickly dwindle to marginal cost.[8] Thus, private agents are unwilling to invest in software development in the presence of free riders and the absence of means to appropriate profits (Nelson and Romer, 1996). Another related area refers to knowledge spillovers where third parties benefit from private party developments further reducing the

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[7] For further information on the differences between modular and integrated architectures, see Ulrich (1995).

[8] However, Scherer (1980) suggests that natural market imperfections may result in first mover advantages which in turn could reduce the need for intellectual property protection.

incentives to provide the public good. For example, Xerox invented the mouse and the graphical user interface however it was Apple and Microsoft that capitalized on these technological advances (Jarboe and Atkinson, 1998). Therefore, in order to induce private parties to provide the good, incentives must be administered, bringing us to the sticky issue of property rights for such goods.

1.5   Intellectual Property Rights (IPR)

Traditional intellectual property (IP) theory provides economic justification for tangible property (Lemley, 2007). In the case of knowledge, the non-rivalrous and non-excludable aspects ensure that everyone can use the knowledge without its value diminishing. This is in direct contrast to tangible goods implying that traditional IP theory does not provide a perfect fit for knowledge (Lemley, 2007). However knowledge creation requires incentives otherwise private agents will not invest in its creation. Once disclosed, knowledge is very difficult to control due to its public good characteristics (Arrow, 1962). Thus, leading Lemley (2007) to suggest that the economic justification for the use of IPR is to make certain that there are enough incentives to ensure that private actors will innovate. Hence the actors are not being rewarded for their labour instead they are being given incentives to provide a public good.

IPR both encourages and inhibits the provision of public goods where institutions like copyright and patents have an impact on how knowledge is created and distributed (Cortright, 2001). IPR grant short term monopoly profits so as to provide incentives to innovate. From a theoretical point of view, intellectual property rights are designed to create incentives for the innovator (ex ante incentive) and to ensure that information is disclosed within the public domain (ex post efficiency) to stimulate future innovation and competition. In a sense they seek to solve both the appropriability and free rider problem and reward innovators for the provision of a public good. However, monopoly profits result in welfare losses creating dynamic market failure. This trade-off between ex-ante incentive and ex-post efficiency forms the crux of the IPR debate.

The main argument for intellectual property protection within the software market comes from the fact that imitation costs are very low and thus appropriation would be difficult from pure information innovations if not for IPR. However intellectual property rights for basic innovations could limit or stifle further innovation (Nelson and Romer, 1996, Cortright,

2001). Further, when considering the cost structure for knowledge production, firms who use "protection" have the ability to garner large profits. The following section and the coming chapters will highlight that the use of IPR in the software market, with particular reference to SME, has varying implications due to the uniqueness of software as a product. In this work, we focus only on the use of copyrights and patents in the software industry. Specifically, we examine how the use of IPR affects SME (firm) strategies, competition, innovation, and knowledge sharing enabled through spillover activity.

1.6 In case of software: IPR results in OSS and proprietary software

The software market is unique in that the use of IPR has led to the development of two forms of software provision: open source and proprietary software. The primary difference between the two lies in the accessibility of the underlying source code.[9] Proprietary software developers rely on IPR to ensure that their knowledge is protected whereby any uncompensated spillover loss would result in a reduction of profits. Thus proprietary software provision leads to excludability enabling firms to appropriate their investment through license and duplication fees.

Open source software (OSS) can be considered as an endogenous open solution which voluntarily supplies the public good. This phenomenon has been referred to as the private provision of a public good (von Hippel and von Krogh, 2003, Johnson, 2001) where numerous experienced private agents using their own resources contribute to the public good (Lakhani and Wolf, 2001). In this case knowledge is shared freely and the actual software is available for free thereby fulfilling the non-excludability requirement and promoting knowledge spillovers and future innovation. Users are able to run, study and modify existing programs without having to pay the initial creators royalties (Renner et al., 2005, Wheeler, 2005). In fact a large majority of the users are free riders. Hence OSS enables a novel alternative to traditional innovation patterns (von Hippel and von Krogh, 2003) and traditional use of IPR while also facilitating sequential and cumulative innovation.

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[9] The former refers to software where the source code is accessible while the latter refers to when it is not. Access to open source software source code depends on the license under which the product operates. Broadly the licenses can be divided in to the Berkeley Software Distribution (BSD) license where there are no restrictions on redistribution except that credit be given to the original authors and the General Public License (GPL) where there are restrictions upon redistribution.

The software market thus exhibits a co-existence of two types of technology sharing strategies (Jansen, 2006) for the same public good where one shares the information of the good freely and the other does not (Lessig, 2002). Market agents are able to decide whether they prefer to be open or closed. However the trade-off from pursuing a particular strategy is still unclear as the incentives for each system vary. In the case of proprietary software the pecuniary benefits are greater and seem to be the main motivator, whereas in the case of OSS, signalling and fame seem to be greater motivators in ensuring the provision of the public good (Lerner & Tirole, 2002). As a result, OSS has been considered as a no-cost competitor to proprietary suppliers of software (Bitzer, 2004, Casadesus-Masanell and Ghemawhat, 2003) thereby altering the nature of competition.

Both forms of technology sharing strategies suffer from certain drawbacks. OSS through its lack of direction and focus on user/developer needs indicates distortions in provision and investment structures (Bitzer and Schroeder, 2006). In the case of proprietary software, Carlton and Gertner (2002) suggest that the use of IPR can push technology based markets towards market concentration and significant market power, through extensive network effects and economies of scale in R&D. This market power often results in the market being dominated by a single technology often belonging to a single firm. These actions could curtail or impede subsequent efforts by competitors, particularly SME, in dynamic markets.

1.7 IPR versus competition policy

IPR limit the distribution of knowledge based goods by temporarily preventing competition. This allows private agents to sell knowledge above the marginal cost of reproducing it. Hence less people would buy it than if the good was available under more competitive conditions and would pay more for it. The production of public goods' argument can only be used as long as IP laws on balance offset the costs of producing such goods (Gallini and Anderson, 1998, Landes and Posner, 1987). This balance is sought to be achieved through the scope and duration of IPR mechanisms (Lemley, 2007) after which inventions are to be freely available in the public domain.

Landes and Posner (1987) examined whether the excludability that IPR enable, creates value. Hence they implied that IPR are only justifiable to the extent that they create value. By temporarily limiting competition, IPR create static inefficiencies i.e., deadweight losses to

society, and firms are able to charge a price higher than marginal cost. This restriction on new knowledge limits the dynamic innovation process (Webbink, 2005). New innovations develop on existing ideas and technology. Excessive control of positive externalities associated with new innovation also determines the further development and uses of subsequent innovations (Webbink, 2005). Since IPR afford market power, rent seeking through the same has resulted in overinvestment in R&D and duplication efforts.

Schumpeter type innovation often imposes a deadweight loss on society through the reduction of output and increased prices. The balance between what society gains from Schumpeterian type innovation and high costs in terms of prices, switching costs and limited supply is a highly contended issue particularly in the anti-trust literature (Gilbert and Katz, 2001). It has also been suggested that monopolists tend to invest less in innovation than their competitive counterparts (Lemley, 2007, Arrow, 1962).[10] Thus the main aim of modern antitrust law is to use competition such that it facilitates economic efficiency (Lemley, 2007).

Economic efficiency according to Lemley (2007) is to achieve a balance between the social benefit of providing incentives to innovate and the costs of limiting knowledge diffusion. Anti-trust laws aim to ensure competition and hence provide a set of checks for activities that threaten competition i.e., anti competitive behaviour (Samuelson, 1987). IP law tends to create framework conditions that could lead to monopolies. Very strong IP laws tend to negatively impact competition and reduce welfare. In such cases antitrust law constrains what companies can do with their IPR. Too strong competition laws also have negative consequences as they promote static efficiency at the cost of long term efficiency. While there appears to be a conflict between intellectual property law and competition policy/antitrust

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[10] Joseph Schumpeter suggested that monopolies favour innovation while Arrow suggested that it was competition that favours innovation. Schumpeter based his arguments on the idea that large firms tend to have more capital for R&D in-house overcoming agency problems and information asymmetries that other firms in the market might face (Baker, 2007). By virtue of being the market leader with an installed base and reputation allows monopolists a head start. The first firm to develop and market an innovation captures the largest rent. Arrow suggested that monopolists have less incentives to innovate as the value of marginal benefit of subsequent innovation is not as high as it would be for a newcomer who would – if he succeeds – gain much market share and therefore has very high incentives to innovate. The process of a competitive firm taking over an existing market is referred to as the Arrow effect of replacement effect. The replacement effect is the strongest when the new product or process completely replaces the old innovation.

laws in the context of knowledge, the main goal of both is to achieve a balance between competition and monopoly in the context of dynamic efficiency.[11]

Scherer (1992) suggests that industries like software that exhibit high levels of technological innovation tend to have fewer sellers resulting from barriers to entry facilitated by IPR. Thus there appears to be a trade-off between facilitating static efficiency through competition and dynamic efficiency through optimal investments in R&D in high tech markets. As it is evident that such goods are beneficial to society, enabling temporary market power in high tech markets seems justified.

However, Carlton and Gertner (2002) explain that there is a fundamental tension between anti-trust law and IP law in such markets where IP law creates market power and antitrust law restricts its use. They suggest that the former provides a static framework to analyze a dynamic setting which leads to errors. High tech markets exhibit creative destruction where one company is the market leader today only to be displaced by another firm tomorrow. Antitrust law was not designed based on this type of competition (Carlton & Gertner 2002). However the authors suggest that antitrust law should focus on preserving innovation based competition since firms with static market power tend to distort the dynamic innovation process.

It should be noted that not all firms with IPR abuse their power and hence decisions taken in the interest of a firm itself are not always bad and not the target of antitrust law. Instead Carlton and Gertner (2002) suggest that IP laws should be used to promote more open standards and systems to create a competitive environment.

1.8   Main question

In summary: The above discussion briefly examined framework conditions that impact competition in the software market. These along with the unique features of software, further examined in the next chapter, lead us to postulate that competition within this market is

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[11] Lemley (2007) in fact suggests that seen from the dynamic context, IP law and competition policy share the common goal of achieving maximum wealth by producing what consumers want at minimum cost. Hence IP laws provide incentives to innovate and new innovations imply increased competition through creative destruction (Samuelson, 1987).

unique. The work that follows consists of three essays which examine the following question: *In the context of IPR, what impact do SME have on competition in the software industry?*

1.9   Outline & Contributions

In the following essays, we begin from the starting point that SME are a given in the software market and further contend that they are beneficial to dynamic efficiency. These essays focus on three reoccurring themes, namely: proprietary and open source software, intellectual property rights and knowledge sharing (spillovers). The choice of open source or closed source software depends largely on the extent to which firms are willing to engage in knowledge sharing and the importance of learning and spillovers. IPR thus could be viewed as a strategic tool to either increase or decrease knowledge sharing and competition.

The thesis is structured as follows: Chapter 2 of this work seeks to expand upon the issues raised in the introduction and considers the associated literature in greater depth. Specifically this chapter examines the unique features of software as a product to better understand the unique pattern of innovation based competition in the software market. It further examines how the instruments of IPR are used in the software market and how IPR impacts upon the strategies of existing and potential agents i.e., SME. The chapter also highlights how the use of IPR affects the closed versus open systems within the market. Chapter 2 closes with three broad summary aspects related to the software industry and the building blocks needed for the subsequent chapters.

Chapter 3 examines the issue of co-existence i.e. open source and closed source software within the software industry and how this promotes competition. While it is evident that co-existence is relevant to the software market, few attempts have been made to understand the reason behind this co-existence. In this theoretical chapter we focus specifically on explaining what we believe is one of the primary reasons for co-existence. The chapter builds on three concepts, namely: bundling by the incumbent, the sequential and cumulative nature of software innovation and spillover activity.

Bundling is often considered anti-competitive and the negative effects of the same have been considered in numerous articles (Whinston, 1990, Carlton and Waldmann, 2001, Choi and Stefanadis, 2001 and Nalebuff, 2000). However we show that in the context of the other two

factors, bundling could have varying implications for the software industry. Thus providing an instance where the direct applicability of traditional anti-trust doctrines may not work. The sequential and cumulative nature of software refers to the systematic development of new software based on existing developments in contrast to isolated innovations. The last aspect comes from the observation that there exists spillover activity between the proprietary and open source segments. This chapter attempts to incorporate the unique features of software in explaining one facet of competition within the software market.

In light of the creative destruction concept, an inherent part of competition within the software market, it is evident that current technology leaders constantly need new innovations so as to effectively compete and maintain their market power. We postulate that these innovative inputs are provided to the incumbent through spillover activity from the open source segment. In other words, proprietary incumbents are willing to tolerate increased competition from the open source community, in order to be able to obtain and benefit from knowledge spillovers. Thus we suggest that the co-existence enabled by spillover activity ensures dynamic competition.

We explain our postulation with the help of a Hotelling model (Hotelling, 1929). Our model has 3 firms, a proprietary firm and two competing open source firms taken to represent a simplified form of proprietary and open source firms in the software market. The proprietary firm provides two products while the competing firms provide one product each such that each product has a direct competitor. The proprietary firm is faced with the possibility of spillovers from the open source firms where spillovers are captured in the cost function. We consider three varying asymmetric spillover frameworks under bundling and no bundling. Only asymmetric spillovers are considered as we assume that due to IPR the open source firms obtain no spillovers from the proprietary firm. By bundling, the proprietary firm encourages the competing firms to increase R&D spending. This increased spending is carried over to the integrated firm in the form of reduced R&D costs. *As a result, past a specific threshold of spillovers, it makes more sense for the proprietary firm to bundle as profits from bundling are higher than from not bundling. When considering spillovers and welfare, we find welfare to be higher when Firm 1 bundles. We further find that the proprietary firm will only bundle when there is more than one competing open source firm highlighting the importance of many innovative ideas and firms to sustain innovation based competition.* Our findings reinforce the cumulative and sequential aspects of software innovation and the

importance of spillover activity for the same. Thus, it might be said that co-existence further reduces overall R&D expenditure and duplication but at the same time ensures diversity.

In summary: Chapter 3 makes a normative contribution to the dynamic policy literature. The main aspect studied in this chapter refers to spillovers and the extent to which they can be appropriated. In particular we examine spillover exchange between SME and large software firms in the context of bundling. Bundling and the resulting competition policy measures are well understood under static conditions. Based on the findings of our static model, we extrapolate that bundling and spillovers in a dynamic setting could render the standard argument against bundling not entirely true. Thus we suggest that competition policy in the software market should consider bundling under dynamic competition because it could lead to a different conclusion resulting from the factors unique to the software market e.g., OSS programmers.

In chapter 4 we examine whether increased IPR adoption by small and medium sized enterprises (SME) enables greater competition within the information and communications (ICT) sector which includes the software industry. The discussion thus far briefly highlighted the possible negative distortions that IPR can have on competition, investment and innovation structures. These distortions have resulted in impeding market entry for small and medium sized firms in to the software market. Schumpeter (1942) believed that large firms had a critical advantage with respect to innovation and that small firms lack the assets to be able to innovate. However, Williamson suggests that the adoption of IPR can enable SME to sell their knowledge and enter markets dominated by larger players and thereby increase competition. While there is an extensive breadth of literature focusing on the use of IPR by large firms, the question with regard to small firms still remains unclear and inadequately researched.

Our aim in chapter 4 is to provide further insights on small and medium sized firms and their adoption of IPR. The analysis is based on a dataset of SME in the information and communications sector which also includes the software industry. We make use of the analysis of variance (ANOVA) in order to study the impact of varying one factor and its subsequent effect on the other variables in the model. Four factors were studied to observe their impact on SME adoption of IPR: globalization, legal frameworks, cooperative research and OSS use and development.

Our analysis brought forth four interesting findings. The *first* finding indicates there is a significant relationship between globalization and the level of patenting. Globalization refers to market reach i.e. regional, country and international markets. In other words, the more an SME competes in varying markets the higher is the tendency to adopt IPR. There appears to be little (if any) literature that suggests that this correlation has been examined before. Most studies have used firm innovation or R&D as the major determinant of IPR adoption. *Second* we find that co-operative research plays an important role in globalization and IPR adoption. Thus the more SME collaborate and compete, the greater is the emphasis on IPR adoption. *Third*, we find that there is a significant and positive relationship between legal frameworks that aid in innovation and the adoption of IPR. Thus, SME will adopt IPR when it enables them to sell and develop their intellectual property. This in turn allows market entry thereby increasing competition. *Fourth,* we find that the use of OSS reduces the tendency to adopt IPR which in turn creates competition between the open and closed systems operating in the market.

In summary: This empirical essay makes a positive contribution to the IPR policy literature. The main aspect studied here is how SME are able to appropriate their innovations. Through the use of IPR, firms are partially able to solve the problem of appropriability arising from public goods/knowledge. Consequently this paper examines the reality of SME and IPR use.

Next we turn to the essays themselves.

Chapter 2

2. Software as a product and IPR

2.1 Software

In the introductory chapter we focused on two main aspects namely dynamic efficiency and Schumpeter's 1911 supposition that SME drive innovation. Small firms tend to be technology leaders in markets that are highly innovative and have a high proportion of large firms (Acs and Audretsch 1987). Further SME seem to have a greater competitive advantage in markets that more closely resemble the competitive market model (Acs and Audretsch 1987).[12] They can be quick to market, flexible and hence are able to exploit certain market niches. However, it has been suggested that due to the limited use of IPR by SME, their innovative capacity is not fully exploited (Iversen, 2004). Research shows that SME tend to make more use of informal methods of protection e.g. lead-time advantages instead of formal ones as they prefer to invest their resources in developing new innovations (Kitching and Blackburn, 1998).

In the context of IPR, we postulate that SME have an important role to play in facilitating dynamic efficiency in the software market. In order to further explain our postulation this chapter seeks to provide an understanding for software as a product and the implications for its development. In addition the chapter examines how the use of IPR affects firm strategies within this industry i.e., proprietary and OSS models. We build upon the introductory chapter and while not exhaustive, the issues explored in this chapter provide a prelude to the chapters that follow. We begin with basic definitions and desirable properties of software.

2.1.1 Definitions and desirable properties of software

Software consists of programs that run on a computer, e.g. Microsoft Excel.[13] These programs are written as text documents called the source-code i.e., the underlying knowledge of a software program. The source-code contains readable instructions that control the program's operation. Note that software must be compiled before it can be used by a computer. This

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[12] Their empirical study uses a slightly modified Schumpeterian hypothesis where they assume that the innovative advantage of a firm, large or small, is determined by the extent of imperfect competition prevalent in the market under study.

[13] Brief historical reviews of the software industry are documented in Bruegge et al. (2004) and Steinmueller (1995).

compiled material is called the binary code which consists of zeros and ones. The computer application can be used once its binary code has been created, and is difficult to modify or improve unless programmers have access to the source code.[14] Since many consumers are interested only in using the program, it is possible to sell software without access to the underlying knowledge.

In the following we briefly enumerate the desired qualities of software (Fielding, 2000). It is important to understand this set of desirable features since different ownership structures might encourage a different subset of these attributes.

- *Reliability*: is measured as the length of time a system can stay in operation before it requires intervention (Nielson, 2000). Reliability also refers to *high quality* which is typically measured by the number of errors in a fixed number of lines of code.
- *Secure*: Software is secure when it is not vulnerable to intervention by unauthorized users (Howard, 1997, Pfleeger, 1997).
- *Flexibility*: is measured by how easily software can be customized to meet specific needs of the user and run on different types of devices (Messerschmitt and Szyperski, 2001).
- *Interoperability and open standards*: The definition of interfaces between individual components and the definitions or settings of standards are of great importance for interoperability. With compatible interfaces and open standards, various applications with different functionalities can be bundled and offered (Varian et al., 2004).
- The attractiveness of software is greatly enhanced by *low switching costs*, i.e., the cost of moving from one system to another should be low.
- Finally the *total cost of ownership*[15] should be low. In other words the costs i.e., development, use and maintenance, incurred over the lifetime of the software product should be low.

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[14] The source code is written in one of several "high level" languages like C, C++, Java and Visual Basic. Computer games are typically written in C, C++ while server related software is usually written in Java. Windows is written in C and C++ while Linux is written mostly in C. These high level languages have compliers that translate the instructions into binary code that can be understood by the computer hardware. Thus the value of the program resides in its source code written in these high level languages.

[15] The total cost of ownership (TCO) has been defined by the Gartner Corporation (1987) as "all costs, direct and indirect, incurred throughout the life cycle of an IT asset including acquisition and procurement, operations and maintenance and end of life management. Often the procurement cost is a very small part of the TCO for example in OSS – however this can be misleading as the other costs related to OSS are not immediately visible (Gartner, 2004). Currently there is much debate as to whether OSS or proprietary software have higher TCO.

2.1.2 Unique features of software

Our next task is to define the characteristics that make software different from other goods.

- Software and hardware are complementary goods that only have value and utility when consumed together.

- Software has the features of a durable good, but unlike a durable good it does not depreciate over time and hence the consumer's utility from using it does not decrease over time. Thus existing software can only be replaced by innovation.

- Software is subject to rapid technological change which is often facilitated through cumulative and sequential innovative development. This development is subject to economies of scale.

- The use of software is subject to direct network effects (application software) and indirect effects (operating systems and platforms) which play an important role in the adoption of software products.[16]

- Another distinguishing feature of software is the nature of production costs. Typically there is a very high fixed cost which is the development cost or the R&D cost. Distributing the software itself is virtually costless since it is inexpensive to duplicate the software and make it available to end-users. This creates a situation where the marginal cost of production declines rapidly and hence lies below the average cost of production. Firms that use marginal cost pricing therefore will make losses. Average cost pricing is necessary to recoup development costs. Thus software shares features of a natural monopoly. The nature of production costs also has implications for the demand side of the market making the choice of a pricing strategy difficult for the monopolist. After selling to consumers who value the product highly, the monopolist would like to reduce prices to sell to consumers with low valuation. Anticipating this behaviour, consumers will wait till prices drop. From the Coase conjecture it then follows that the monopolist

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[16] A good or service is said to have a network effect if its value to a potential buyer depends on the number of existing users of the good or service (demand side externality). Typically network effects become significant after a critical mass of users are present, which is often referred to as the "tipping point." Further the large user base allows better communication and sharing which facilitates the production of complementary products (supply side externality) i.e., software and hardware.

will be forced to lower her prices and sell at marginal cost almost immediately (Coase, 1972, Gul, Sonnenschein and Wilson, 1986).[17]

- Finally software can be developed in modules which allow improvements in certain modules/parts of a program or operating system without affecting other parts of the whole structure.

While some of these characteristics are also exhibited by other high tech products, the interplay of the features discussed above have a unique impact on the innovation and competition process in the software industry. We next explain two features, specific to software innovation, which further impact the innovation and competition process.

2.1.3   Two features specific to software innovation

Reverse engineering: is the process of extracting know-how or knowledge from a man-made artifact in order to develop a competing stand alone product (Vives, 2002). While reverse engineering is allowed legally for interoperability reasons, Samuelson and Scotchmer (2002) advocate reverse engineering in general. They suggest that reverse engineering contributes to an increase in overall innovation when comparing it to the harmful effects it creates. Within the software industry reverse engineering occurs at the applications level and usually not on the platform level. It converts closed interfaces in to open ones and as a result increases rival firms R&D and decreases that of incumbent firms. Consequently, Vives (2002) suggests that prices of incumbents will be higher in the short run and lower in the long run due to increased competition. While in theory this may be the case it is important to note that reverse engineering in software without access to the source code is quite difficult (Weber, 2004).[18]

Cumulative and sequential nature: Another feature that influences innovation in software is the cumulative nature of knowledge acquisition and the complementarities provided by the same (Friedewald et al., 2002). Often innovation in the software industry is characterized as

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[17] It can be argued that this problem is mitigated by the entry of new consumers into the market who place a high value on the product. Another way out is to create new versions of the product, though here again the monopolist has to compete with older vintages of her own product.

[18] When considering this, the probability of stealing ideas or imitating seems to be quite low. In fact, such a scenario could suggest that the process of imitation actually leads to either complementary innovation or new ideas.

new expressions of existing knowledge.[19] Bessen and Maskin (2000) propose, in a dynamic setting, that innovation in software markets is both sequential and complementary and that imitation actually spurs innovation. Their idea can be explained as follows: Sequentiality refers to the idea that each successive innovation builds upon the previous innovation. Complementarity refers to the fact that each innovator will pursue different research paths and thereby increasing the overall chances of reaching an innovation goal sooner.[20] This implies that a greater number of competing firms will create a greater number of innovations.

Theoretically the impact of sequential innovation has been studied, among others, by Scotchmer (1996), Green and Scotchmer (1995) and Chang (1995). Scotchmer (1991) suggests that often the most important function an innovation has, is to provide impetus to innovations that follow it. Thus, incentive mechanisms need to exist for both early and subsequent innovators especially in cases where first mover profits can be greatly reduced through reverse engineering and imitation. However, these authors acknowledge that those who contribute to the cumulative innovation process are many in number, often geographically dispersed and hard to identify making rewarding them a difficult task. Further they highlight the difficulties of rewarding a pure information innovator.

Often commercial value only occurs in later versions of a product where innovators have learned from their predecessors. Pure information is important to society and while costs might be higher for the first innovator, society will benefit more from the second innovator's commercial application. As a result it could present a problem for initial innovators to gain commercial benefits from their innovations. Anton and Yao (1998) show that it is difficult for initial innovators to provide only parts of their innovation if they wish to reap some benefit from their innovation. The authors suggest that in the absence of complete disclosure of the source code, initial innovators will find it hard to make their product acceptable. Consequently, strong property rights for the first innovator reduce the incentives for subsequent innovators (Hall 1999).

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[19] In fact the Oracle Corporation states that "Whether a software program is a good one does not generally depend on the newness of a specific technique, but instead depends on the unique combination of known algorithms and methods."

[20] This is also referred to as the 'scarce idea' concept developed by Scotchmer (1991).

In summary In the case of software, what is being sold is the R&D itself which distinguishes it from other physical products (Hall, 1999)[21]. Hence firms that are innovative will be imitated by others or maybe unable to commercialize their products and thus would not innovate further due to the inability to appropriate gains. This aspect is more pronounced when considering the high initial development costs and minimal if not zero duplication and distribution costs of software. This implies that if left to the free market forces, the incentives to innovate would decrease entirely. The discussion thus far provides justification for the use of IPR for software which the next section seeks to address.

2.2 IPR and software

As seen in the introduction, Schumpeter advocated monopolies and monopolistic practices as necessary means to ensure appropriate innovation and incentive structures needed for future research. He claimed that increased rewards to society in terms of new technological improvements would level the welfare loss created by IPR. His intuition for this laid in dynamic efficiency where monopoly power is constantly challenged by competition from entrants who change the existing equilibrium state through new technology, giving way to new market leaders.

However, unlike property rights for physical goods, IPR for software and other information goods are not fully transferred but only licensed (Gehring, 2006). Thus the costs for subsequent innovations depend on how easily innovators are able to use, license and build upon existing knowledge i.e., spillover activity (Besen and Raskind, 1991). The more extensive IPR protection, the greater are the costs for subsequent innovators i.e. SME, limiting market competition. We now turn to explaining the main forms of IPR used in the software industry and how they affect competition.[22]

2.2.1 Copyright

Traditionally, software was primarily protected by copyright. This form of intellectual property law protects the expression of an idea but *not* the idea itself. Copyrights are long

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[21] We consider pure information to be synonymous with the source code where both have no stand alone value.

[22] While we acknowledge the importance of trade secrets in the software industry, particularly when considering that is the only viable option when it comes to architecture protection issues, we focus only on copyrights and patents in this work.

lived and normally extend for 70 years after the life of the creator. According to the copyright statute for software, only the actual creator of the code is allowed to run, copy, modify or distribute the program unless stated otherwise by the copyright owner.[23] Copyright protection for software is automatically obtained and rights of use are normally transferred through license agreements.

In Europe, copyrights are not formally applied for nor are they registered. Under European software copyright law, the source code and the binary code are covered by the definition of a "computer program". The law states that the owner of the source code, i.e., the programmer, will be the automatic owner of object or binary code unless there is more than one programmer where there is a possibility of co-ownership. This ownership criteria changes when the software was developed as part of work requirements. In such cases, the software code belongs to the employer unless contractually stipulated otherwise.

Copyright protection does not protect against independent original creation which enables knowledge spillovers and hence allows horizontal market entry for those innovators who manufacture similar or complementary products. Despite being traditionally protected by copyright, some authors (Cohen and Lemley, 2001 Samuelson et al. 1994 and Menell 1987) suggest that copyright is not suitable for software as it does not protect the useful behaviour of software i.e., its source of value.

2.2.2 Patents

Next we turn to the second most common form of software protection; patents. Similar to copyrights, patents do *not* protect the underlying idea of an innovation but protect the technical application of a particular idea. Patents are exclusive rights awarded to innovations for originality, novelty and non-obviousness in exchange for disclosure of the innovation to society through publication of the patent application (Jaffe et al., 1998). The patent is the most powerful intellectual property rights mechanism and also the most expensive form of

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[23] Direct copying is not allowed according to the law and this applies to the use of parts of the source code. Copying refers to both compilation i.e., converting source code to object code or decompilation i.e., converting object code in to source code. The latter is quite difficult but both require special licenses from the copyright holder, normally done only to ensure interoperability.

protection. It enables the inventor to enjoy the commercial benefits arising from her innovation (Hall et al., 1999, Jaffe et al., 1998, Deakins, 1999).

When granted, the patent is a public document which contains information about the innovation, the person who invented it, the assigned patent holder and the technological antecedents of the innovation (Masurel, 2005). Patent information can be an important source of information for subsequent competitors. This form of intellectual property law provides protection for a period of 20 years. The length of the patent has been questioned by Deakins (1999) who argues that the extremely short life cycles of technological products may not warrant such lengthy protection.

As a result of the Diamond vs. Diehr case in 1981, patent protection was extended to software in the United States. It was decreed that algorithms qualified for patent protection as the distinction between abstract and physical was not clear (Merges, 1990a). Despite resistance from the United States Patent Office, in 1998, a decision by the US Federal Circuit stated that a mathematical algorithm i.e. source code, can not be excluded from patenting until and unless it does not provide a useful, concrete and tangible result.

In Europe, the parliament vetoed patent protection for software in 2005 in order to protect Europe's small and medium sized firms both using and creating software. Despite this veto, alternative practices have developed including computer implemented inventions (CII). There is no official definition of CII however evidence from court cases suggests that patents can be granted to software in the event that a process or piece of software requires hardware (International think tank for innovation and competition, 2005). Patents are thus granted for the hardware which enables a technical innovation.

In the following we examine the third alternative mechanism available to software producers, OSS, as a means to govern software development. OSS presents an example where software development depends on the continuous disclosure of knowledge and the possibility to use and re-use this knowledge freely

2.2.3 OSS[24]

In recent years there has been an unprecedented growth in the development of open source software[25], including investment by major corporations, making it important to understand what makes this possible.[26] In other words why do so many programmers contribute to the provision of this public good despite extensive evidence of free-riders?

A programmer receives an immediate, and a delayed payoff based on her actions. The current payoff consists of the benefit, monetary or otherwise, obtained from the task and the current costs stem from the disutility of effort. The delayed payoff can be in the form of reputation which consists of recognition among peers, sometimes called the ego gratification incentive. The delayed pecuniary payoff occurs in the form of future job offers, shares in commercial open source based companies, or future access to venture capital funds. Both types of delayed incentives are often jointly labeled as the signaling incentive (Lerner and Tirole, 2002). The signaling incentive is strong in the open source environment since it is possible to identify the creator of a particular program. As a result independent private programmers are willing to participate in the development of OSS.

Additionally independent programmers are also motivated by the OSS ideology (Von Hippel, 2005). The ideology of OSS rests upon the idea that own innovation should and can also be

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[24] The history of software development is replete with cooperative efforts and can be divided in to three phases according to Lerner and Tirole (2002). The first period lasted from the early sixties to the early eighties where much of the activity took place in academic settings. Much of the effort was directed towards developing an operating system that could run on multiple platforms and there was virtually no attempt to restrict use or establish proprietary rights. However, in the early eighties, AT&T began enforcing its property rights over Unix related operations which marked the beginning of the second phase till the late nineties. The most important development in this period was the establishment of a licensing procedure for cooperatively developed software i.e., GPL. The third era began in the early nineties and is tied to the rapid growth of the Internet. A new contractual agreement called the "Debian Social Contract" became popular which provided greater flexibility in using the program. It allowed proprietary software to be bundled with cooperatively developed software. In this period we see the emergence of such bundled products or multiple variants of the same basic software. The objective of this approach was to foster R&D in areas the open source community was not keen to venture in to. The fact that open source software would be used as an intermediate input in this process has had a positive impact on the open source community and its future growth. For an extensive review of open source software, its development and business models see Weber (2004).

[25] Refer Kuan, 2001, Franke and von Hippel, 2003, Weber, 2004, Narduzzo and Rossi, 2005

[26] Companies like Google and IBM contributed software engineers and programmers to the open source software movement and to developing open source software.

used by third parties as a building block for further innovation (Benkler, 2002, von Hippel (2005b). In other words the source code is made available for all who wish to use it. Notable examples of OSS include Linux, the operating system, Apache, a website server, and MySQL, a database environment. It is different from shareware and freeware where software can be downloaded free of charge but access to the source code is prohibited.

The following describes the main features of open source software.

- OSS can be easily customized and localized to suit individual needs as the source code is readily available and users are allowed to modify the software to their specific needs.

- Within the open source software movement, users are encouraged to participate in the innovation process (von Hippel, 2005) which has the added positive side effect of speedy bug elimination (Raymond 2000).[27] This implies that OSS provides more flexibility and security than proprietary software where users are dependent on vendors for improvements and updates due to the binary nature of the product.

- OSS with its open interfaces implies lower switching costs compared to proprietary software where interfaces are usually protected by copyright and thus are closed. Thus it could be said that there is competition in both the product and input markets for OSS.

- Open source software enables these features by using existing intellectual property rights i.e., copyright laws to ensure the freedoms of use, modification, and redistribution associated with open source software known as "copyleft".[28] Upon redistribution users are subject to some restrictions depending on the license under which the software operates.

OSS licenses can be divided into the the BSD (Berkeley Software Distribution) and GPL (General Public License) which characterize the two main types of licensing agreements: weak

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[27] It is important to note that only projects of interest to the community benefit from early and timely bug corrections. Thus the development of OSS is very much dependent on the needs of those who create and use it. Eliminating errors in proprietary software usually takes much longer and could be attributed to the integrated architectural structure where solving a single aspect could require revamping of the entire system. However, von Hippel (2005) suggests that though this argument is often provided by proprietary software vendors, if carefully examined, it is possible to separate the individual elements of the integrated architectures.

[28] The copyleft concept was originally created by MIT hacker Richard Stallman in the early 1980s (Weber, 2004). Stallman's copyleft principle forms the basis for the GNU General Public License. Recently the principles of copyleft were sustained in court (Ebinger, 2005).

and strong.[29] The former permits the user to use, modify, copy and withhold their own modifications to the source code and sell it as a proprietary product with the only stipulation that credit be given to the original authors.

The latter refers to licenses like the GNU Public License (GNU GPL, EUGPL[30] or GPL) – These licences allow the user to use, modify, copy and redistribute any variation of the source code under the same GPL license. Users may charge a fee for this service or provide it freely, but under no circumstance can they make the product proprietary. These licenses could represent an in-built mechanism that enables continued contributions to the common information pool.

In summary Both the proprietary and OSS ideologies favour selling software for a positive price. Despite being a durable good, the price of software cannot be above the cost of copying due to its public good nature. Particularly in the case of OSS, by allowing third parties full access to source code, prices tend to zero. Firms can however sell complementary products and services around the software for a positive price e.g. RedHat, and IBM employ this business model. OSS licenses thus, depict a market endogenous commitment mechanism which requires complete disclosure and low license fees. These licenses, from a transaction cost perspective cheaply promote sequential innovation, particularly in the case of GPL through the re-use of third party ideas (Gehring, 2006). In the following section, we examine how the above discussed ideologies affect firm strategies within the software industry.

2.3 Open versus closed systems: IPR and competition

Software, similar to other industries with network effects, exhibits the presence of open and closed systems i.e., open source software and proprietary software. This section[31] examines the literature on three possible firm strategies of protection namely: Copyright, patents and open source software and their effects on competition. We discuss the pros and cons of adopting

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[29] The multitude of other open source licenses existing in the market fall in between these two extremes. A description of OSS licenses can be found in Bruegge et al. (2004) and www.opensource.org

[30] EUPL –European Union Public License, is a European drafted software license and similar to the GPL. However, it differs to the GPL in that the freedoms associated with the license can be revoked through a unilateral decision of the EU Commission.

[31] Parts of the following discussion draw from Baake and Swaminathan (2007)

each strategy in order to be able to shed some light on the impact of such strategies on SME in the software industry.

2.3.1   Copyright as a strategy

As noted previously, copyright protection as a strategy represents the most easily attainable form of IPR for software (Menell, 1987). This form of intellectual property law does not require disclosure which implies that new solutions need not be made public nor does there need to be access to the source code. While this may seem to limit cumulative and sequential innovation through limited spillover activity, in reality the scope of copyright protection is low implying that barriers to entry are also low. As a result, the costs of circumventing copyright protection, through imitation and continued innovation, are low which in turn enables horizontal differentiation. In the context of sequential innovation, it could be said that copyright seems to be the more efficient option (Bessen and Maskin, 2000).[32] Thus one could deduce that the incentives to innovate are high for subsequent innovators under copyright protection.

Despite the above stated benefits of copyright protection, there are also some negative side effects. When considering that copyrights allow imitation this must also necessarily imply that the costs of reverse engineering are almost zero. Thus, while copyright protection enables subsequent innovators to also avail of profits, it lessens the overall incentive to innovate. In other words, profits for subsequent innovators take profits away from the existing technology leader.

In recent times, copyrights have taken on much more significance in the software market (Varian et al., 2004). This effect is particularly visible in the case of software interfaces where due to the presence of strong network effects and asymmetric markets, the protection of interfaces has resulted in skewing competition and innovation processes.[33] As a result, barriers to entry and incompatibilities increase for new innovators or existing firms including SME.

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[32] However, Rossi (2004) suggests that the fact that software is both the information and technology at the same time limits the adequacy of copyright protection.

[33] Copyright protection has given Microsoft a great deal of control and market power over interfaces like desktop software and other software i.e., middleware and other software running on Windows (Varian et al., 2004). In the anti-trust case of Microsoft vs. the US government, Microsoft fought vigorously to keep its interfaces closed and

In analyzing the impact of copyright in the current context of interfaces, Varian et al., (2004) suggest that by conferring excessive protection to one firm, society gives the entire responsibility to innovate to this one firm. They explain their supposition using a concave function indicating that the chances that this one firm would continuously come up with all new innovations is relatively low if not zero. However, they acknowledge that the goal is to ensure this firm continues to innovate. Hence, they suggest this dilemma can be analyzed from two perspectives: The first approach suggests that copyrights are important in order to ensure innovation and prevent piracy which is inefficient. Whereas the second approach suggests that due to the resultant concavity, more firms are needed in order to have constant innovation. In other words, current innovations depend on past innovations and thus, copyright protection should be less extensive thereby enabling dynamic efficiency.[34]

In summary: Copyright affords the longest time period of protection for software. Despite some of its negative effects resulting from the presence of industry specific features, it allows for increased competition in the software market through horizontal market entry since the costs of working around copyright are low thereby enabling spillover activity.

2.3.2   Patents as a strategy

The benefits of software patents as a strategy are still highly debated and there is no clear consensus on the effects of patents on technology creation or competition. The theoretical literature focus is on determining the optimal *length* of patent protection (Nordhaus, 1969) i.e., the time awarded to the innovator where she has exclusive rights over her innovation and the *breadth*[35] (Gilbert and Shapiro, 1990, O'Donoghue, Scotchmer and Thisse, 1998) i.e., the extent of protection such that it increases the costs of imitation and improvements of subsequent and existing competitors (Regibeau and Rockett, 2004). The development of software implies that increased breadth would distort the innovation process while excessive length would correspond to increased welfare losses. However, the negative effects of greater lengths of protection i.e., welfare loss, can be compensated through continuous innovation

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limit any fines to be paid as a result of this action. It should be noted however that when trying to achieve compatibility, it is legally possible to copy and reverse engineer software in both the US and the EU.

[34] The flexibility of copyright protection can be seen in the differing ideologies of Microsoft and Linux.

[35] The breadth of patent protection has been further divided in to lagging breadth and leading breadth. The former refers to protection against imitation while the latter refers to protection against improvements (Regibeau and Rockett, 2004).

which is made possible when patent breadth is limited (Arundel, 2000). Reducing patent breadth would in turn reduce the ability of patent holders to block subsequent competitors from using and continuing to develop technologies.

When considering patents using a static model, the results show that in fact, patents do not provide sufficient incentives for innovators (Varian et al., 2004). The intuition is explained as follows: When compared to the consumer surplus resulting during the lifetime of the patent plus the increase in consumer surplus due to a price reduction upon expiry of the patent, what the innovator can appropriate is much less. The static model assumes that the innovation would not have been developed had it not been for this one innovator which implies less than suitable R&D investments. If this same problem is considered in a dynamic setting, due to increased R&D efforts from other firms, the social cost of the patent and the deadweight loss associated to it suggest that the rewards to the patent holder may be higher.[36]

Empirically it has been shown that there has been a considerable increase in the number of business and software patents issued however often without proper adherence to patentability requirements (Scotchmer and Gallini, 2001). Bessen and Maskin (2000) studied a sample of software patents in the US where they found that firms that patent did not increase their R&D spending in comparison to those who had a lower propensity to patent. Further they found, subsequently confirmed by Lerner and Zhu (2005), that when patenting becomes easier and less costly, firms tend to patent more. Varian et al., (2004) and Mann (2005) contend that in the software industry, compared to other industries, the barriers to entry are lower and therefore, the use of IPR is more intense thereby distorting competition. The studies above, point to the fact that often companies patent for strategic reasons which includes the preservation of market positions and hinders competition often through litigation.[37]

An example of how companies restrict competition refers to *patent thickets* where one product is tied to several patents (Bessen, 2002, Gallini, 2002). For example, software patents may not

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[36] For more on this, refer to Varian et al., (2004) The Economics of Information Technology, Cambridge University Press.

[37] For an understanding of the importance of intellectual property litigation see Lanjouw and Shankerman (2001) and Meurer (2003). The former provides an empirical analysis while the latter a legal perspective of the same.

cover an entire computer program but only certain parts of it (Cohen and Lemley, 2001).[38] Such protection may be limited to one step in an innovation making the patent trivial but its impact broad for subsequent innovators (Pilch, 2004). Further, patent protection of individual software modules also affects the sequential nature of software development particularly when considering each of these modules as complementary products. Cross licensing and patent pools, examined below, are regarded in the literature by some researchers (Shapiro, 2001, Lerner and Tirole, 2002) as solutions to the patent thicket problem.

Patent law allows agreements known as *cross licensing* agreements which give two parties access to each others patent portfolios. The agreements between companies can be without license fees if the patent portfolios are about the same size. In addition, colluding firms are able to enter new markets at relatively low costs and collusively set prices. Firms do not deviate from these set prices as the threat of punishment increases in repeated games (Whinston, 1990). In addition such behavior results in short term equilibria (Shapiro, 2003) and often results in increasing barriers to market entry for SME (Regibeau and Rockett, 2004).[39] A related concept refers to *patent pools*. Patent pools refer to cross licensing agreements relating to a particular technology. As such they can also lead to tacit collusion thereby increasing barriers to entry for non members.

In general larger companies seem more knowledgeable about formal rights and tend to be more successful in their applications and grants of patents (Iversen, 2004). According to a study on Norwegian SME, the costs of patents are much higher for a smaller company making them either not patent as it is not part of company strategy or withdraw their applications (Iversen, 2004). Farrell and Shapiro (2004) find overall that monopoly structures resulting from strategic patenting impose high prices on consumers creating inefficiencies or

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[38] Cohen and Lemley (2001) thus suggest that it is not possible to compare "copyrighted software" in the same context as "patented software".

[39] Companies like IBM, Intel, Hewlett-Packard and Motorola and other European counterparts have large patent portfolios allowing them to defensively and offensively keep competitors out of specific market niches and to negotiate cross licenses (Smets-Solanes, 2000, 2001, Giuri, Mariani et al 2006). Cohen et al. (2000) empirically found that many firms obtain patents in order to block out competition. Licensing is often considered a lucrative business of its own (Farrell, Shapiro, Varian, 2004) where firms are able to benefit from competitors through royalties.

deadweight losses[40] and extend the breadth of protection where alternative directions of innovation are restricted. Thus, based on the above discussion, it can be said that patent protection can increase the costs of using existing information (Rossi, 2004) and can reduce R&D incentives of competitors (Bessen, 2002).[41]

Alternatively it could be argued that descriptions provided in patent applications could lead to positive spillovers and make inventing around the patent easier. In the following we briefly discuss the implications of patent application disclosures. The question whether disclosure is a fair stipulation depends on whether disclosure results in a loss of profits to be earned from an innovation. If there are no losses from disclosure, then neither static nor dynamic efficiency is reduced.

On the positive side third parties are able to reduce their information costs and understand new solutions and applications enabling dynamic efficiency. As Blind et al. (2005) point out, in a setting with interdependent spillovers, wasteful expenditure on R&D could be reduced. On the negative side Crampes and Langinier (1998) found under certain conditions, that firms chose not to renew their patents so as to prevent information leakages. This aspect has been examined both in the theoretical (Horstman et. al. 1985, Scotchmer, 1991 and Harter, 1993) and empirical literature (Arundel, 1998 and Cohen et al., 1998). Such firms normally opt for secrecy and forgo patent protection.

However, Levin (1988) and Cohen et al. (1998a) have argued that descriptions given in exchange for patent protection are often not clear or precise enough for it to be beneficial to others. As a case in point, Arundel and Steinmueller (1998) and Hall et al., (1999) found that SME were unable to benefit from information in patent disclosures. However, Arundel and Steinmueller (1998) acknowledge that firm size, the use of patents as appropriation methods and the sector in which the firm operates significantly impact upon the importance of patent disclosures.

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[40] Thus when the social value of a patent is high, prices should be high but lower than the maximum willingness to pay of users. Price discrimination allows producers to appropriate a larger share of their innovation i.e., license fees for software that vary with the number of users.

[41] Refer Samuelson, 1990, Bessen and Maskin, 2000, Scotchmer and Maurer, 1998, Gallini, 2002, Lessig, 2004.

The discussion on patents and disclosure poses an interesting question in the context of reverse engineering. In the software industry, competition is innovation based implying that disclosure is central to sequential and cumulative innovation. As seen before, Weber (2004) suggests that reverse engineering is difficult in software which could imply that firms would achieve maximum protection from distributing their software in binary code. Thus, the question that comes to mind is why does patent protection not require complete disclosure in light of the sequential nature of software?

This can be explained as follows; A firm has two options, either it is awarded a patent and thereby should disclose all knowledge, as assumed in some theoretical studies including Scotchmer (1991), or they choose secrecy. In the former case, there is ample spillover opportunity to promote further innovation and reduce R&D expenditure wastage but at the same time, innovators are able to enjoy profits from patent protection. This perspective provides economic justification for patents rewarded to innovators. In the latter case, there is no protection and hence no disclosure which negatively impacts the sequential nature of software development. In the current context, patent protection seems to enable both monopoly profits and limited disclosure. This is particularly poignant when considering that firms may also leverage other options like lead time advantages, technical complexity and complementary services to appropriate their investments (Arundel, 2000). However, if these profits were to be used in increasing innovation, in the long run, this may increase welfare (Arundel, 2000).

In Summary The problem of whether patents are good or bad is difficult to answer both theoretically and empirically as the multitude of literature shows. On the positive side, Arundel (2001) and Mazzoleni and Nelson (1998) suggest that changes in patent law, global competition and the increasingly knowledge driven economy has resulted in increased use of patents by SME who signal their expertise through this medium. Brouwer and Kleinknecht (1999) suggest that some firms compensate for market share, networks and advertising by more actively seeking patent protection. Further they suggest that SME that engage in R&D collaboration tend to make more use of patents particularly in high tech industries. On the negative side, patent protection, considering the strategic motivations results in market failure negatively affecting dynamic efficiency and spillover activity (Bessen, 2002).

Considering the effects of strategic patenting and the sequential nature of software innovation, an efficient patent might perhaps be one that enables spillovers so as spur subsequent innovative activity. However this strategy is also not perfect as it could induce the collection of many similar patents either by the innovating firm or through cross licensing. As a result there is ample opportunity to increase protection for an innovation which consequently restricts market entry. It could thus be said that software innovation requires low license costs to enable market entry and subsequent investments in R&D by competitors. However, only credible circumvention of patents at minimum cost could induce patent holders to provide low license fees. Given the absence of a very clear pronouncement on the impact of patents it provides ample scope for further research in this area. This provides one of the motivations for some of the research and analysis described in chapters that follow.

Overall when comparing the impact of copyrights and patents on competition in the software market we find: Though not a panacea, copyrights enables horizontal market entry and increases efficient competition and price structures, and therefore maybe the more the viable option to ensure innovation. However, it is to be noted that recent legal provisions have resulted in copyright law and patent law overlapping a great deal in the context of software (Cohen and Lemley, 2001) making this distinction rather weak.

Next we turn to examining OSS as a strategy.

2.3.3 OSS as a strategy

It is difficult to say which of the two licenses i.e., GPL or BSD is more conducive to dynamic efficiency. In general the BSD license seems to provide greater incentives to innovate as it allows the combination of open and closed source software to be sold commercially (Schmidt and Schnitzer 2002), However, this increased incentive for BSD type software could negatively impact the investment structures leading to inefficient levels of software differentiation and incompatibilities. This in turn could negatively affect the sequential pattern of innovation. The GPL license is an efficient commitment mechanism when innovation is dependent on disclosure of information. This license prevents agency cost problems related to interfaces and the ownership of modular software parts while, at the same time, allowing best

fit solutions (Weber, 2004). Thus, due to the compatible and interoperable nature of GPL software, switching costs are minimal if not zero (Gehring, 2006).[42]

In order to ensure that technology develops in certain ways, particularly with reference to basic or fundamental innovations it maybe more efficient to have GPL based interfaces and open standards (Aigrain, 2002). This in turn would enable downstream applications and consequently dynamic competition. It is evident based on the principles laid out in the GPL license that it is more attuned to the cumulative and sequential aspects of software innovation (Samuelson and Scotchmer, 2002).

At present, most of the OSS applications can run on Windows and other proprietary operating systems and thus do not require an open source operating system to function.[43] However, as commercial exploitation of GPL software is still relatively low, there tends to be inefficiently low investments in catering to the mass consumer since open source software primarily caters to computer programmers and advanced users. Yet with the growth of OSS, it has been observed that there are more applications available for the mass consumer market e.g. Gnome, a graphical desktop interface and StarOffice, a package with programmes including a word processor, spreadsheet, and several games (Schiff, 2002).

The GPL license, like all other public goods is subject to the free-rider problem where the majority of users are passive users.[44] Carver (2005) suggests that the perception that open source software is 'free' makes companies hesitant to develop open source applications which could further distort investment structures. The non-proprietary nature of GPL software can also negatively impact the innovation and investment incentives of programmers where investment structures are dependent only on the OSS programmer/user needs. As such, they

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[42] Proprietary software is characterized by strong network effects which make costs of switching to another network extremely high.

[43] Alternatively proprietary systems can always be made compatible to the open source systems due to source code access. This is the case for both Oracle and IBM databases which are able to run on the Linux operating system. However, only certain proprietary formats have chosen to make their applications compatible with open source operating systems.

[44] Jensen and Scacchi (2007) refer to the 'onion layer' model of organization where passive users are located on the outer level. The second layers and closer to core finds those who write bug reports, test new and pre releases etc. while the core consists of those who contribute the most to the code and in turn have the most responsibilities and privileges. It is in fact these core developers who maintain and control each individual OS project.

may not invest in solving problems or creating software to address fundamental problems of general interest (Shapiro, 2003) reducing investment and efficiency levels.[45]

Thus, firms who want or need certain developments in GPL software must invest in R&D themselves which could alleviate the free-rider problem to an extent. This logic suggests that the efficiency of GPL licenses should be assessed on the extent of the free-rider problem and the difference between the utility of the programmer versus that of societal utility in creating software.

In Summary One could argue that all else being equal, there is a strong case for OSS as it provides an endogenous solution to many problems resulting from proprietary software[46] (Bessen, 2002, Comino and Manenti, 2003) including increased competition and cumulative and sequential innovation as highlighted below:

–   In terms of innovation it considers the sequential nature of software development and seems to promote greater competition. By having access to the source code, OSS provides transparency[47] and reduces the lock-in effect that arises from vertically integrated market structures and strong network effects. Hence OSS enables market entry.

–   The start-up costs of OSS are low since the software can be downloaded from the Internet for free, though it is not clear whether it always has a lower total cost of ownership i.e., learning costs and maintenance costs.

–   OSS does not impose any restrictions on users thereby reducing problems of incompatibility and interoperability. All restrictions are relevant only for software re-distribution after modification.

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[45] The lack of a structured goal limits future expectations and demand. "Forking" is a common occurrence in the open source movement where programmes with differing ideologies break off at a certain tangent because they feel a project is not heading in the appropriate direction. Varian and Shapiro (2003) believe that this is the biggest threat to OSS. In this respect, proprietary software seems to have the upper hand.

[46] Bessen (2002) suggests OSS as a remedy to increase consumer options. Further, Comino and Manenti (2003) suggest that this market failure is related in part to users uninformed about OSS alternatives and can be corrected through the use of OSS. Their model suggests that increasing OSS awareness increases welfare.

[47] In response, in 2001, Microsoft started the Shared Source Initiative (SSI) where much of the Windows source code was revealed to certain pre-approved government and business clients but it was not open for modification. Shortly after, in 2003, Microsoft launched the Government Security Program where government clients were given access to source code for several of Microsoft's products.

The state can encourage the use and development of OSS through direct subsidies (Comino and Maneti, 2003, Schmidt and Schnitzer, 2002) or through mandatory use in government offices. However, the literature in this area (Evans and Reddy, 2003, Lessig, 2002, Schmidt and Schnitzer, 2002, Bessen, 2002) does not favour outright government support of OSS. It instead suggests that government should act like any other commercial consumer and market forces should decide between the two technology sharing strategies.[48] In the case of basic innovations that are publicly funded, however, software should be subjected to complete disclosure i.e., GPL licensed software (Aigrain, 2002).

Despite all its benefits, the overall discussion above tends to suggest that OSS alone does not provide the solution for dynamic efficiency. The inability of one system to cater to market needs could imply the need for both systems as briefly examined in the conclusion of the entire section below.

In the following we briefly revert to the opening question of this section whether open or closed systems are most attuned to dynamic efficiency: Lerner and Tirole, (2002) examine a software development model where OSS code is combined with proprietary code. Several large technology firms have made selected portion of their software code available and even encourage their employees to participate in the open source community. Presumably this allows them to channel the open source movement in directions that they would find useful (Varian et al., 2004).

Baake and Wichmann (2004) demonstrate the economic forces at work in a hybrid model using a stylised model. The model relies on spillovers with two firms having the right to choose how much of their software code will be publicly available, i.e., they choose an optimal level of OSS software keeping the rest proprietary. Revealing the source code leads to lower costs for both firms as they benefit from each other's openness. However, lower software costs can also lead to more intense competition among firms, which could in the end raise coding expenses. Moreover, given that entry costs can be low in the presence of OSS code, it might also facilitate entry in the market. They show that the final outcome depends on the relative strengths of these effects.

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[48] Bessen (2002) and Lessig (2002) however do propagate the elimination of patent protection for software as the most appropriate form of government intervention. Evans (2002) suggests a more moderate approach through limiting patent lives and stronger standard enforcement.

Further, empirical studies by Bonaccorsi and Rossi (2003) and Dalle and Jullien (2003) provide evidence showing that the long run will also be characterized by the co-existence of OSS and proprietary software. A subsequent study by Bonaccorsi, Rossi and Giannangelli (2004) uses a sample of Italian firms to examine the incentives of individual firms in this context. They find costs and network externalities to be the most significant determinants of firm decisions in producing open and/or closed software.

In accepting the co-existence of both systems in the software market, a natural consequence refers to competition between OSS and proprietary software as highlighted by some central findings in the literature below. Casadesus-Masanell and Ghemawat (2003) develop a dynamic mixed duopoly model to examine competition between Linux and Windows. They consider Linux to be a no-cost competitor compared to other commercial market players and examine whether commercial companies can successfully compete in such an environment or will they be displaced eventually. They find a solution where either the operating systems co-exist or Windows will push Linux out of the market. If they co-exist, what is clear from simple economic theory is that more firms imply greater competition and less profit for the incumbents. This could suggest that fewer resources are being devoted to R&D activity by commercial firms thereby reducing overall innovation in the software industry. Their analysis in favour of Windows is based on the speed of demand side learning and the assumption that Microsoft will not be short sighted in its pricing decisions so as to be able to influence consumer valuations in subsequent periods. However, despite their findings, the authors do acknowledge that cost asymmetries could work in Linux's favour.

From a demand side perspective, Kuan (2001) theoretically examines whether consumers prefer to make their own software i.e., user innovation or buy their software from a proprietary vendor. The former is subject to the free rider problem and the latter to information asymmetries. She finds that OSS is the more stable option by analyzing data that measures the rate of bug fixing. Bitzer and Schroeder (2006) theoretically and empirically show that the entry of OSS in to OSS and commercial market segments results in increased competition and innovative activity. With the help of a theoretical model they examine the impact of competition on innovation by studying the impact of moving from a monopoly to a duopoly in the software market. The model shows that having an OSS producer as a competitor increases innovative activity.

In summary: As evident, the question whether a closed or an open system is better for the software market still requires further analysis. What we can however deduce from the literature is that both systems exist in the market and to an extent compete against each other. Further the literature thus far has not extensively examined co-existence from the point of view of SME, prompting the current research to study the same in greater depth.

2.4 Conclusion

The discussions in the introduction and this chapter have provided some key insights in understanding competition within the software market. These key insights enumerated below provide the basis for the essays to follow.

– *Sequential and cumulative innovation*: This form of innovation forms the crux of software development. When considering the two forms of technology sharing strategies, OSS and proprietary software, we find: The biggest advantage of closed source software is the one conferred by property rights. Ownership of software and the ability to extract rents from ownership arguably provides incentives for creative work. However, these same positive externalities of proprietary software lead to distortions in investment and competition by limiting the sequential and cumulative innovation process. While OSS provides endogenous solutions to many of these problems, its most important contribution by far is that it promotes sequential and cumulative innovation.

– *Close versus open systems/Co-existence*: It is evident that neither proprietary nor open source software alone provides a solution for dynamic efficiency in the software market. It is however worth noting that these two forms need not necessarily be in competition with each other – they can co-exist. Evidence shows that many large corporations that have the ability to develop their own proprietary software, e.g. IBM, Sun Microsystems and Google, and also invest in open source software (Varian et al., 2004). Currently they occupy different market segments with OSS predominant in the web server and database markets and proprietary software vendors predominant in mass consumer markets.

– *Spillovers*: As seen in the introduction and in this chapter, a central aim of copyrights and patents seems to focus on reducing the amount of knowledge spillovers that new innovations create. Firms depend on knowledge spillovers from rivals which contribute to own R&D investment and spurs subsequent innovation (Jaffe, 1986, Henderson and Cockburn, 1996). Thus, restricting spillovers negatively impacts innovation structures and the cumulative and sequential nature of software development. As a result, the costs

of market entry increase and potential competitors, particularly small and medium size enterprises, are locked out. This aspect is further examined in the next chapter.

In summation: The issues discussed here broadly examine specific aspects of software and how they affect competition in the software industry. While it is clear that copyrights and patents result in static losses and distort competition ex-post, they also provide incentives to innovate and ensure competition and therefore a complete lack of protection would also not have the desired result. Thus, one needs to weigh the importance of competition ex-post and the necessary incentives required to enable innovation ex-ante.

As seen IPR can increase barriers to entry for SME enabling large firms to better exploit the benefits of innovation. Research has largely focussed on large firms and their use of IPR despite evidence pointing to the fact that SME are highly innovative (Hayward and Greenhalgh, 1994). The remaining chapters seek to contribute to the literature on SME in the software industry. Specifically the chapters examine the impact of SME on competition in the software industry based on the issues discussed thus far.

Chapter 3

3. Bundling, spillovers and quality investments

3.1 Introduction

In many high technology markets today, market structure is characterized by the presence of a few large firms selling multiple products along with several smaller firms that offer a significantly smaller number of products. This phenomenon can be observed in the software industry where the large firm vs. niche producers construct is seen in the co-existence of proprietary and open source software firms. We begin this essay by listing some stylized facts about the software industry which will be used subsequently to develop a model.

It is observed that large producers like Microsoft offer a variety of office applications i.e., Word, Excel, Power Point and Exchange to consumers in the form of individual applications or in a bundle. However, since individual applications are more expensive than the bundle, most consumers tend to buy the bundle i.e., Microsoft Office. This is the case regardless of whether they use other products in the bundle or not.[49] Thus, it might be said that consumers end up with additional applications they do not necessarily want.[50]

Much of Microsoft's innovations are the result of systematic imitation and gradual innovation. For example, Microsoft Word is a refined version of previously existing word processors. Excel owes much of its success to Lotus 123 while Power Point benefited a great deal from Harvard Graphics and other similar programs. Thus, by improving upon existing innovations, Microsoft was able to displace other market players. The underlying pattern that emerges from these examples is that ideas are not original (Scotchmer, 1991), and the ultimate product is a refinement and reformulation of ideas and products that already existed in the market. More formally, innovation in software is sequential and cumulative i.e., firm innovations depend, benefit and build upon external R&D spillovers. Thus, based on the

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[49] According to Google Trends (2008), while consumers buy Microsoft Office, the most commonly used program is Microsoft Excel. This result varies from time to time as seen in 2006 when Microsoft Word was the most commonly preferred tool.

[50] According to Bakos and Brynjolfsson (2000) and Katz and Shapiro (1998), sellers of information goods are better able to extract rent and cover a large customer base when large numbers of information goods are sold in a bundle than when they are not, assuming that consumers have independent valuations for the products being bundled. This is exemplified by the fact that information goods normally have high fixed costs and low marginal costs, implying that additional or slightly varied production can be achieved at minimum cost.

anecdotal evidence above, we observe spillover activity exists within the software market, a phenomenon that could perhaps be used to explain the co-existence of OSS and proprietary firms as well.

For example, much of the software used to develop operating systems and power the Internet is the result of open source code. Notable examples include Apache and Linux upon which firms like Google, Yahoo and Amazon power their servers. Microsoft has also made use of open source software in several of its software offerings (Varian and Shapiro, 2003). Further, several proprietary companies including IBM and Oracle have opened up their source code in order to benefit from product improvement facilitated by the open source community. More recently[51], Microsoft has also agreed to open up some of its software in order to facilitate greater compatibility and a more level playing field. However, Microsoft does also acknowledge that access to their source code for external parties enables additional products which in turn develop further consumer interest in Windows. Thus the aforementioned examples highlight the visible spillover activity taking place between the proprietary and open source software producers. This spillover exchange seems highly relevant when considering that innovation is sequential and cumulative in the software industry and competition revolves around innovation.

In general, when a large firm benefits from a smaller firm's spillovers, microeconomic theory suggests that the suitable strategy for the large firm is to merge with the smaller firm. While in theory, a merger may be the best solution, in practice, there may not be enough incentives to perform all the functions of a firm in-house. In the software industry, the inability to merge is further exemplified when considering the OSS ideology.[52]

The majority of programmers contributing to the OSS movement are unpaid volunteers who contribute time and effort developing software code that can be used by third parties for free, or for a minimal fee, as building blocks for subsequent innovation (Benkler, 2002).[53] Users and programmers alike are encouraged to participate in software development i.e., user innovation (von Hippel and von Krogh, 2003, Lerner and Tirole, 2002, Harhoff et al., 2000). As the source code is open, individual OSS programmers have the ability to *signal* their

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[51] Refer article: Microsoft to share more technical secrets, www.nytimes.com/2008/02/22/technology/22soft.html
[52] Refer to Chapter 2 for a more lengthy discussion on the ideology of OSS.
[53] The source code is open to all with the only restrictions occurring upon re-distribution of the software.

quality and performance and consequently build a reputation. In addition to the signaling incentive, community participation and identification have also been cited as strong motivators to participate in the OSS movement (Hertel et al., 2003, Diamond and Torvalds, 2001, Akerlof and Kranton, 2000) where there is no central authority (Lakhani and Wolf, 2003) but reciprocity (Raymond, 1999).[54] These programmers are responsible for their projects and have less firm-specific capital resulting in greater fluidity of labor markets (Rossi, 2004, Lee, Moisa and Weiss, 2003, Lerner and Tirole, 2002).

This is in contrast to proprietary software development which normally occurs within a traditional firm environment where employees are not individually responsible for products or performance and where only the functionality and usage of a program is disclosed to third parties (Schiff, 2002). As such the differing ideologies make outright mergers between open and closed software firms rather difficult.[55] Thus in light of this external given, we make use of bundling as a possible solution for the large firm to avail of spillovers from small OSS firms in the market.

Specifically, we examine the following question: *In the context of spillover activity between the large producer and the niche producers, how does bundling by the large producer affect the R&D decisions of all the firms in the market?* Thus, we focus on two observations, namely, the fact that large firms often tend to bundle products and secondly, the fact that there exists spillovers between these firms. The goal of this paper is to investigate if there is a relationship between these two aspects. To the best of our knowledge, these two aspects have not been studied together in the context of high technology markets. In order to better understand this relationship, we abstract from all the negative effects of bundling in terms of predation, entry and exit and focus *only* on the effect of bundling on spillovers and R&D investment decisions of both the large and niche firms.

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[54] Community participation is considered by some authors (Rossi, 2004, Lakhani and Wolf, 2001, Weber, 2000 and Raymond, 1999b) to be primary as it is evident that not all OSS programmers will be leaders or highly reputed. Thus, it seems that participation in the OSS community takes greater precedence over forking or intentional breakaways from the OSS community.

[55] It should be noted that some proprietary firms encourage their programmers to work on OSS projects e.g. Google and IBM. Such participation allows proprietary firms to better assess their competition and benefit from the current developments of OSS (Schiff, 2002).

Therefore, we examine the bundling decision of a large firm faced with the possibility of spillovers from two smaller firms already existing in the market. This simplified market structure represents the current co-existence of proprietary and open source software firms we observe in the market. Our analysis rests primarily on the assumption that spillovers from the smaller firms are beneficial to the large firm and as such create this co-existence. We further assume that due to various intellectual property rights mechanisms i.e., patents and copyrights, spillovers from the large firm to the niche firms are zero.

We consider three varying spillover scenarios: Case 1 where there are no spillovers is our benchmark case. Case 2 refers to where there are asymmetric spillovers i.e., spillovers accrue only to the large firm. In both these two cases we assume that the level of spillovers is equal from each of the smaller firms. Cases 3 and 4 examine the impact of varying spillover activity from the individual niche firms. In addition to spillovers, we also consider economies of scope to examine whether other aspects contribute to the bundling decision.

Based on these varying spillover frameworks, we examine the effects of bundling by the large producer and then compare it to the case when he does not bundle. Similar to Choi (2004) we also assume that bundling is a credible commitment and one that can not be easily changed. We base this assumption on the visible success of the Microsoft Office package (Nalebuff, 2004) despite each application being offered individually.

We derive the following results from the formal model: In the absence of spillovers, under bundling, Firm 1 will offer a lower price quality pair and has smaller market share than Firms 2 and 3 who will offer greater qualities. In the presence of bundling and spillovers, we find that Firm 1 offers a higher quality but at a lower price and its market share is lower than that of Firms 2 and 3. Thus, in equilibrium, Firm 1 will choose not to bundle unless spillovers exceed a certain threshold. Once this spillover threshold has been exceeded, bundling is always the optimal decision for Firm 1. Further we find when Firm 1 obtains spillovers only from one firm, it will not bundle. This finding implies that spillovers need to accrue from more than one competitor in order to be beneficial to Firm 1's R&D and innovation. When considering spillovers and welfare, we find welfare to be higher when Firm1 bundles.

Welfare is higher under bundling due to quality increases accruing to Firm 1 through spillover activity. Usually bundling is considered an aggressive strategy which brings profits to a

powerful firm at the cost of total welfare. In our model bundling is more of a defensive commitment strategy which brings welfare to the consumer and if spillovers are large enough we find that it also results in profits for the powerful firm.

Thus, in effect, Firm 1 employs a "puppy dog" strategy[56] where it signals soft behavior by bundling. In order to induce investment and benefit from spillovers, Firm 1 bundles i.e., here bundling is used as a strategic tool. Competitors in the market respond to this soft behavior by increasing their quality or R&D investments. We explain this phenomenon of increased quality investment by the competitors based on the idea that bundling sends a clear commitment signal that Firm 1 will no longer compete in prices. Consequently we find that bundling results in the large firm reducing its R&D costs. Contrary to other findings (Choi and Stefanadis, 2001, Choi, 2004), we suggest that this reduction in R&D investment by the large firm is compensated by an increase in spillovers resulting from increased quality investments by Firms 2 and 3. These findings, we believe, suggest a possible reason for the co-existence of proprietary and open source software vendors we observe in the market and why bundling in this case may actually be beneficial.

In the following, Section 3.2 provides a literature review of selected references followed by Section 3.3, the general model setup. Sections 3.4 to 3.7 consider the unbundled and bundled case respectively in the context of varying spillover activity and discuss the results and implications. Section 3.8 examines the impact of economies of scope. The welfare analysis is found in Section 3.9 and the paper concludes with Section 3.10.

3.2 Literature review

There has been much debate as to whether bundling is an anti-competitive practice. The Chicago school (Director and Levi, 1956, Schmalensee, 1982) states that there is only "one monopoly profit" and as such, bundling has no additional effect. Others, after modifying the Chicago model to reflect risky market conditions, contend that bundling by a monopolist allows price discrimination (Stigler, 1968, Adams and Yellen, 1976) which in turn increases barriers to entry (Whinston, 1990) thereby increasing profits. A third reason to bundle refers

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[56] Through this strategic ploy, the firm essentially encourages competition and gives the impression of being weak but is not. This is a particularly profitable strategy if it makes the incumbent tougher in the second round and the second period reaction curves slope up (Fudenberg and Tirole, 1984)

to cost savings (Salinger, 1995) resulting from the integrated product; a reason Microsoft always highlights when responding to criticisms regarding its tying behavior.[57] Regardless of the possible synergies, in terms of efficiencies that can occur from a bundle, Nalebuff (2004) shows that an incumbent selling complementary products in a bundle, has a substantial advantage over rivals who sell applications individually.[58]

However, despite its negative implications, bundling is also a long-term decision that signals that a firm will not compete further in prices. Thus, on the positive side for competitors, the decision to bundle indicates commitment on the part of an incumbent (large producer) i.e., bundling can be used as a commitment device. Whereas on the negative side, it allows the integrated firm to enter complementary markets reducing competition (Carlton & Waldman, 2002) and/or driving other firms out of the market.

Carlton and Waldman (2002) show that if a competitor were to enter the secondary market with a superior product complementary to the incumbent's product, then entry would be welcomed. This is due to the fact that some of the profits would accrue to the incumbent. However, if the entrant subsequently enters the primary market, the incumbent would lose profits. As a result, the incumbent tends to bundle so as to keep the entrant out. Other literature (Choi, 2004, Carbajo et al 1990, Chen, 1997) has however indicated that bundling need not necessarily remove competitors from the market and yet remain profitable for the incumbent.

In other words, bundling refers to a product range being strategically used to deter entry and increase profits. This allows the incumbent to remain dominant despite the rapid technological change occurring in an industry. On observing the software market, we note that all the Microsoft Office products are available individually and that there are open source offerings in both the primary and secondary markets. It is obvious, despite this fact that the Microsoft package still dominates. Critics of monopolization claim that limiting entry in to complementary markets is not beneficial to industries such as software where innovation and new products are the result of existing technology i.e., source code is combined and

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[57] Microsoft tied its operating system with its Internet browser program, Internet Explorer. Important to note is that we consider only the bundling of applications.

[58] In particular he considers the success of Microsoft Office and how it successfully displaced existing individual applications in the market.

reformulated in new and unique ways (Bessen & Maskin, 2000). This often results in a distortion of R&D investment and incentive structures.

R&D decisions within a firm have a major role to play and are normally those undertaken in order to improve market positioning. As early as 1962, Arrow explained the phenomenon of positive externalities arising from private investment in R&D. Spence and Ghemawat (1985) further postulated that firms that benefit from spillovers experience cost reductions from both its own learning and that which it learns by way of spillovers from competing firms. Jaffe (1986) empirically confirmed this and further found that R&D spillovers tend to benefit third party innovation. However, it was Rosen (1991) who suggested that spillover activity among firms is often asymmetric. Eeckhout and Jovanovic (2002) suggest that asymmetric knowledge spillovers promote inequality among firms due to free riding.[59]

Industries like software are primarily based on technology and know-how where the benefits of spillovers depend on the absorptive capacity of firms (Cohen and Levinthal, 1989, Cassiman and Veugelers, 2002). As software depreciates only with newer versions and innovations, competition in this market is considered innovation based. Further, as innovation in software is cumulative (Scotchmer, 1991), it could be said that entry and the presence of competing firms maybe something that the incumbent firm requires in order to ensure in-novation.[60] This maybe a way for the monopolist to continue making profits and keep ahead of the rest (Dasgupta & Stiglitz, 1980) even when there is a large number of competitive entrants all of whom have a similar pool of knowledge (Lyons et al. 1988).

In general, literature on the effect of bundling on R&D investment considers the impact on the entry and exit of competing firms. These papers contend that bundling by the incumbent tends to reduce R&D investment incentives on the part of the competitor or entrant. Choi and Stefanadis (2001) consider a "risky upfront investment" and assume that two products; A and B, only have value when they are consumed together. Their findings suggests that bundling

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[59] However, contrary to this paper, they assume that the more a firm knows, the less it benefits from spillover activities.

[60] A point to note is that R&D costs are often compensated for with patents and other forms of intellectual property protection. This might have counter balancing effects for innovation: As Arrow (1962) pointed out, low fear of entry results in under investment in R&D, similar to effects arising from patent protection.

results in reducing the entrants' (in our case the existing competitor's) incentive to invest and innovate because the entrant with only one product is unable to compete.

In a later paper by Choi (2004), he states that in the presence of R&D competition, bundling tilts the market in favor of the incumbent as it can spread its costs over a larger number of units making it cost ineffective for other firms. Thus, the exit of competing firms is not relevant. He further contends that due to this cost reduction achieved through bundling, entrants are less willing to invest in R&D. Gilbert and Riordan (2006) also consider the effect of bundling and how it affects incentives to innovate. They find that though bundling leads to foreclosure there could be an increase in social welfare.

Similar to our study, Nalebuff (2004) examines the bundling of applications by the incumbent i.e., Microsoft Office, but considers how bundling results in the exit of competing firms. He considers two goods A and B and two strategic players in the market where one is an incumbent and the other is a challenger. Nalebuff (2004) goes on to show that if the incumbent has market power in both products A and B, by bundling he puts the challenger, with market power only in one product, at a disadvantage. This, he suggests, could induce the challenger to exit the market.

In our paper we examine the decision to bundle on the part of the large producer and examine how this decision affects its competitors. We contend that bundling is a strategy tool i.e., puppy dog strategy, used by the large producer in order to induce quality investments by the competitors. These quality investments in turn benefit the large producer's own R&D through spillover activity and as a result decrease the large producer's costs. Thus, we consider spillover externalities between competitors. We find that bundling with spillovers always results in additional welfare for the consumer and when quality increases are large enough it leads to increased profits for the large firm. The following section presents our model in detail and solves the one stage Hotelling game.

3.3   Model

We consider a market comprising of three firms that sell four differentiated products. Firm 1 is the integrated firm that sells two products − product A and B, while firm 2 provides product

C and firm 3 provides product D.[61] We assume that applications A and D are substitutes as are B and C. We also assume that the products sold by Firm 1 are located on one end of the product spectrum while D and C are at the other end. Without loss of generality, we further assume that A and B are located at the left end of the unit interval while D and C are at the other end.

Consumer behavior. We assume that there are consumers who only wish to buy one of the two applications − those who wish to purchase either A or D and another set that chooses between applications B and C. These two groups are completely separate and no consumer wishes to own both products i.e., consumers derive value from only *one* product and the products can be consumed independently. Consumers for each of the two applications are distributed uniformly along the unit interval.

The utility of consumer i who buys a product from Firm 1 or Firm 2 (Firm 3) respectively, is given by:

$$u_i = V + q_1 - x_i - p_1 \text{ and } u_i = V + q_k - (1 - x_i) - p_k \text{ where } k = 2, 3.$$

Here q_1 and p_1 denote the quality and price respectively of the product sold by Firm 1 (regardless of whether it is A or B), while q_k and p_k denote the same variables for the other two firms. Note that V can be interpreted as the base utility from having the application while q is the utility derived from the quality of the application. It is a scale parameter which ensures that consumers always have positive utility and hence every consumer buys the product. Also in order to prevent the consumers from favoring one application over the other, it is assumed that the value of V is the same for both applications.[62] This allows us to write the utility functions for all four applications as follows:

$$u_i = V + q_A - x_i - p_A \text{ and } \quad u_i = V + q_D - (1 - x_i) - p_D$$
$$u_i = V + q_B - x_i - p_B \text{ and } \quad u_i = V + q_C - (1 - x_i) - p_C$$

---

[61] Entry and exit are not issues considered the model. Following Choi (2004) it is assumed that the firms are already in the market and have incurred sunk entry costs.

[62] In principle, consumer *i* can have a scale parameter V_i. However, this will yield qualitatively similar results.

Equating the utilities from A and D we can obtain the location of the indifferent consumer denoted by λ_{AD} as follows:

$$\lambda_{AD} = \frac{p_D - p_A + q_A - q_D + 1}{2}$$

Similarly, for the second group of consumers who prefer either B or C we obtain the indifferent consumer λ_{BC}

$$\lambda_{BC} = \frac{p_C - p_B + q_B - q_C + 1}{2}$$

Profits. Based on the afore-derived equations, we can write the profit functions of the firms. In the first stage of the game, Firm 1 decides whether or not to bundle. If the large firm does not bundle then it sells to consumers separately in the two different markets and it sets individual prices for products A and B. If it chooses to bundle then $p_A = p_B = p$. However in this case, consumers in both markets buy both products, without deriving any utility from the second product. We assume that the decision to bundle creates no cost advantage or disadvantage to the integrated firm.

We first consider profits from the unbundled case. The third and fourth terms denote production costs of applications A and B which is a function of the quality of the product as well as spillovers from the other firm. Thus, in the third term α denotes the spillovers that Firm 1 obtains from Firm 3 and in the fourth term it captures the spillovers obtained from Firm 2. It is clear that such spillovers lead to lower costs for firm 1. Note for simplicity we assume that the value of spillovers from both firms 2 and 3 are the same. Later in the paper we consider the implications of relaxing this assumption.

$$\pi_1^u = p_A \lambda_{AD} + p_B \lambda_{BC} - \frac{q_A^2}{2(1 + \alpha q_D)} - \frac{q_B^2}{2(1 + \alpha q_C)}$$

where π denotes profits and the superscript refers to the fact that this is the unbundled case.

The profits of firm k = 2, 3 can be written respectively as

$$\pi_2^u = p_C(1 - \lambda_{BC}) - \frac{q_C^2}{2(1 + \tilde{\alpha} q_B)}$$

$$\pi_3^u = p_D(1 - \lambda_{AD}) - \frac{q_D^2}{2(1 + \tilde{\alpha} q_A)}$$

where $\tilde{\alpha}$ refers to the spillovers accruing to the competing firms (Firms 2 and 3) from Firm 1.

We now consider profits in the bundled case. In this scenario Firm 1 sells both products A and B together and charges a common price, i.e., $p_A = p_B = p$. The location of the indifferent consumer remains unchanged and is given by:

$$\lambda_{AD} = \frac{p_D - p + q_A - q_D + 1}{2} \text{ and } \lambda_{BC} = \frac{p_C - p + q_B - q_C + 1}{2}$$

Similar to the profits derived in the unbundled case, the profits for the bundled case are defined as follows:

$$\pi_1^b = p(\lambda_{AD} + \lambda_{BC}) - \frac{q_A^2}{2(1 + \alpha q_D)} - \frac{q_B^2}{2(1 + \alpha q_C)}$$

Profits of Firms 2 and 3 are the same as before except for the fact that the profit function now has a superscript b denoting bundling by Firm 1.

Further, we will assume throughout that $\alpha > \tilde{\alpha} \geq 0$ i.e., that spillovers from the competing firms to Firm 1 are higher. Our reasoning for this assumption is based on the idea that intellectual property protection like patents and copyrights used by proprietary software makers prevent spillover exchanges to the open source firms i.e., $\tilde{\alpha} = 0$. Additionally, differing license agreements within the open source community allow for differing amounts of spillover appropriation. The open source licenses can be broadly divided in to the General Public License (GPL) and the Berkeley Software Distribution (BSD). The former license creates limitation on use due to its viral nature, while the latter license allows for appropriation of open source without having to give anything back. Thus, due to the existence of the BSD license, our assumption that $\alpha > \tilde{\alpha}$ is further strengthened.[63]

Thus the cost functions above capture the idea that spillovers from competing firms contribute to own innovation resulting in improved products implying that the higher are the spillovers to Firm 1, the lower are Firm's 1 costs. Observe that in our case, spillovers increase with competitor activity. Additionally, the quadratic cost function implies that large increases of quality come at large costs. Therefore in addition to R&D spillovers accruing from the niche

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[63] Currently however, large software companies like IBM and Sun Microsystems are voluntarily publishing source code enabling access to the GPL community which in turn allows their source code to be improved upon. This is then combined with their other services and sold thereby increasing the quality of their products. Thus, even under the GPL license, spillovers still seem to work in favor of the incumbent.

producers, the opportunity to spread costs also provides incentive for the large producer to play soft, i.e., bundle.

Timing of moves. In our three stage game the timing of moves is as follows[64]:

Stage 1: The large firm (Firm 1) decides whether or not to bundle products A and B.

Stage 2: Based on this decision, all three firms chose their quality levels.

Stage 3: In this stage all firms set prices for their products based on decisions taken by all firms in the first two stages.

The timing of the game indicates that bundling and quality investments are long-term decisions and ones that are not easily changed, unlike price decisions. Thus, the decision to bundle, we assume, is a credible commitment signal to competitors in the market.

3.4   Results

In this section we will compare the results of the bundled and unbundled cases obtained by using backward induction in our three stage game.

3.4.1   The unbundled case

We begin by solving for the unbundled case. Recall in this situation Firm 1 sells applications A and B separately and can set a different price in each market.

3.4.1.1 Price game

Each firm chooses price p_j, $j = A, B, C, D$ in each market to maximize its own profit given the other firm's price. Substituting the λ in to the profit functions and assuming interior solutions, we obtain equilibrium prices in terms of own quality and the competitor's quality in each of the two markets.

$$p_A^u(q_A, q_D) = \frac{q_A - q_D + 3}{3} \text{ and } p_D^u(q_A, q_D) = \frac{q_D - q_A + 3}{3};$$
$$p_B^u(q_B, q_C) = \frac{q_B - q_C + 3}{3} \text{ and } p_C^u(q_B, q_C) = \frac{q_C - q_B + 3}{3}.$$

Two facts stand out here. First, observe that the price reaction functions are symmetric. Second, as expected we find that there are no interdependencies across the two markets.[65]

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[64] In our model the large firm's bundling decision is followed by all firms' decisions regarding qualities and prices, similar to Choi and Stefanadis (2001) and Riordian (2006).

Quality decisions

In order to obtain the quality decisions, we substitute the prices obtained in the previous stage in to the profit function. Differentiating the profit functions we obtain the optimal quality decisions first for the integrated firm i.e., the reaction functions of Firm 1 given the effect of spillovers from Firms 2 and 3:

$$q_A^u(q_D, \alpha) = \frac{(q_D - 3)(\alpha q_D + 1)}{\alpha q_D - 8}$$

$$q_B^u(q_C, \alpha) = \frac{(q_C - 3)(\alpha q_C + 1)}{\alpha q_C - 8}$$

We assume that quality investment is an effort made by the seller in order to induce greater consumer buying and therefore is always positive. Again as before, we see that the quality q_A of product A is dependent only on the quality q_D of product D and the spillover parameter α. Similarly, q_B depends only on q_C and the parameter α. Note if we assume α = 0 i.e., no spillovers, we find that q_A (q_D) and q_B (q_C) have a negative relationship. However, when α > 0, i.e., spillovers exist, the higher the α, the greater is the impact of q_D and q_C on q_A and q_B. Thus, we find a positive relationship between qualities A and D and qualities B and C.

Given the new q_A and q_B, the optimal quality decisions for the other two firms are provided next.

$$q_C^u(q_B, \tilde{\alpha}) = \frac{(q_B - 3)(\tilde{\alpha} q_B + 1)}{\tilde{\alpha} q_B - 8} \quad \text{and} \quad q_D^u(q_A, \tilde{\alpha}) = \frac{(q_A - 3)(\tilde{\alpha} q_A + 1)}{\tilde{\alpha} q_A - 8}$$

Again observe that if α̃ = 0, we find that qualities q_C (q_B) and q_D (q_A) have a negative relationship.[66] Additionally by comparing the reactions functions, we observe that the interdependencies between the qualities are symmetric. To sum up, if there are positive spillovers, α > α̃ ≥ 0, then the more Firms 2 and 3 invest in quality, the higher are the benefits to Firm 1.

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[65] The range of q_A, q_B, q_C, and q_D is such that interior solutions exist.

[66] For the sake of argumentation, if α̃ ≥ 0, the higher the spillover, the greater is the impact of q_A and q_B on q_D and q_C However, due to the line of reasoning taken in the paper, we assume that spillovers from proprietary software producers to the open source segment are minimal if not zero.

3.4.2 The bundled case

In the bundled scenario, Firm 1 bundles products A and B and charges a common price p for both products. All the other steps in the game remain the same.

3.4.2.1 Price game

In the price sub-game, from the first order conditions we obtain the following equilibrium price for Firm 1.

$$p^b(q_A, q_B, q_C, q_D) = \frac{q_A + q_B - q_C - q_D + 6}{6}$$

Similarly, for products C and D equilibrium prices are given by:

$$
\begin{aligned}
p_C^b(q_A, q_B, q_C, q_D) &= \frac{q_A - 5q_B + 5q_C - q_D + 12}{12} \quad \text{and} \\
p_D^b(q_A, q_B, q_C, q_D) &= \frac{q_B - 5q_A - q_C + 5q_D + 12}{12}
\end{aligned}
$$

Observe that p is not the sum of p_A and p_B. Further, while $p^b{}_C$ and $p^b{}_D$ are symmetric as in the unbundled case, they are quite different from their values in that scenario.

3.4.2.2 Quality decisions

Using the optimal prices from above we obtain the stage two profit functions. Maximizing Firm 1's profit functions, we obtain the reaction functions shown below. Note that q_A and q_B are symmetric and both depend on the qualities of application C and D, but not on each other.

$$
\begin{aligned}
q_A^b(q_B, q_C, q_D, \alpha) &= \frac{(q_C + q_D - 6)(\alpha q_D + 1)}{\alpha(q_C + q_D) - 16} \\
q_B^b(q_A, q_C, q_D, \alpha) &= \frac{(q_C + q_D - 6)(\alpha q_C + 1)}{\alpha(q_C + q_D) - 16}
\end{aligned}
$$

The new reaction quality functions of products C and D are shown below. Again observe that these reaction functions are symmetric and quite different from their unbundled counterparts. Moreover, unlike the reaction function for A and B, these reaction functions depend on the quality of all the other three products.

$$
\begin{aligned}
q_C^b(q_A, q_B, q_D, \tilde{\alpha}) &= \frac{5(q_A - 5q_B - q_D + 12)(\tilde{\alpha} q_B + 1)}{25\tilde{\alpha} q_B - 119}, \quad \text{and} \\
q_D^b(q_A, q_B, q_C, \tilde{\alpha}) &= \frac{5(5q_A - q_B + q_C - 12)(\tilde{\alpha} q_A + 1)}{25\tilde{\alpha} q_A - 119}
\end{aligned}
$$

Unfortunately, these reaction functions do not lead to simple closed form solutions, making it impossible to solve the general model. However, we are able to obtain the necessary insights about the relationship between bundling and spillovers by considering some special cases for which the model can be solved. This follows next.

3.5   Results under no spillovers

Our first set of results concerns the situation with no spillovers, i.e., $\tilde{\alpha} = \alpha = 0$. This will serve as the benchmark case since it will explain the role of bundling without any additional factors.

Table 1: No Spillovers

	Unbundled	Bundled
Qualities	$q_A = q_B = 1/3$	$q_A^b = q_B^b = 0.320988$
	$q_C = q_D = 1/3$	$q_C^b = q_D^b = 0.432099$
Prices	$p_A = p_B = 1$	$p^b = 0.962962$
	$p_C = p_D = 1$	$p_C^b = p_D^b = 1.037037$
$\lambda_{AD} = \lambda_{BC}$	0.5	0.481481
Profits of Firm 1 (A+B)	0.888889	0.824265
Profits of Firms 2 and 3	0.444444	0.444368

For the unbundled case, as one would predict we find that the equilibrium outcome is symmetric. In equilibrium all three firms have the same prices, qualities and profits. As a result of bundling however, we observe changes in firm qualities, prices and profits. We find that Firm 1 offers lower quality than Firms 2 and 3 and also charges a lower price. From the location of the indifferent consumer we also see that Firms 2 and 3 have a larger market share than Firm 1. Thus bundling leads to an equilibrium situation that is no longer symmetric and Firm 1's profits are lower than the sum of the profits of the other two firms. We now summarize our results in the proposition below.

Proposition 1: *In the absence of spillovers, bundling leads to an asymmetric outcome. In this outcome Firm 1 offers a lower price quality pair and has a smaller market share than the two remaining firms. In equilibrium Firm 1 will not bundle the products and Firm 2 and 3 also prefer this outcome. When observing the qualities, we find a marked increase in the qualities of Firm 2 and Firm 3 under bundling.*

The intuition for this result is fairly clear. Given that Firm 1 has to produce A and B separately, even though it sells them for the same price, it faces strong pressure to reduce costs. So in equilibrium firm 1 will lower its quality and offer the two products at a lower price. Given the reduction in quality it also loses some market share to the other firms. Anticipating this, as a best response Firms 2 and 3 raise their quality and price. This also allows them to garner a greater market share. The increase in quality by the fringe firms softens the intensity of price competition and allows product differentiation i.e., open source offerings. This implies, in this case, that if there is no competition, there is no increase in quality.

3.6   Results with asymmetric spillovers

In the previous section we see that in the absence of spillovers, under bundling, the large producer's quality investment decreases. The decision to bundle also seems to induce greater quality investments by the other two firms.

In this section we introduce spillovers to see how it affects the bundling decision. Recall that the general model lacks a closed form solution and to obtain a solution it is necessary to simplify. Here we assume that there are no spillovers from the large firms to the small firms or $\tilde{\alpha} = 0$. However, the large firm obtains spillovers from the small firms. One way to interpret this assumption is to claim that a large firm (like Microsoft) protects its "own knowledge" through patents and copyrights and hence no spillovers accrue to smaller firms. To start with we assume that $\alpha = 1$. We explore the implications of changing α later in this section.

Table 2: Asymmetric Spillovers ($\alpha = 1$)

	Unbundled	Bundled
Qualities	$q_A = q_B = 0.46003$	$q_A^b = q_B^b = 0.48036$
	$q_C = q_D = 0.3175$	$q_C^b = q_D^b = 0.40639$
Prices	$p_A = p_B = 1.0475$	$p^b = 1.0247$
	$p_C = p_D = 0.95249$	$p_C^b = p_D^b = 0.97535$
$\lambda_{AD} = \lambda_{BC}$	0.52376	0.51233
Profits of Firm 1 (A+B)	0.93665	0.88585
Profits of Firms 2 and 3	0.40322	0.39307

Examination of Table 2 reveals that it is different from Table 1. We see that under bundling Firm 1 offers a higher quality product at a lower price and loses some market share. As in the previous case, profits are still higher in the unbundled case.

Comparison with the benchmark case however provides some interesting insights. We find that spillovers always lead to quality increases in products A and B regardless of the bundling decision. The combination of bundling and spillovers leads to the highest quality levels for Firm 1. Compared to the benchmark case with no spillovers, Firm 1's market share always exceeds 1/2. Despite spillovers, costs of production are still high relative to spillovers such that Firm 1 prefers not to bundle. For Firms 2 and 3 we find that bundling always leads to a higher quality choice, presumably because they assume lower price competition from Firm 1. However, we also find that qualities are higher under the no spillover case regardless of the bundling decision of Firm 1. Therefore the highest quality level is obtained in the presence of bundling and no spillovers. We summarize our findings about Table 2 in the proposition below.

Proposition 2: *In the presence of spillovers we find asymmetric outcomes for both the bundled and unbundled cases. In the presence of spillovers and bundling Firm 1 offers a higher quality but a lower price, and has a lower market share than the other two firms. In equilibrium Firm 1 will not bundle the products and Firm 2 and 3 also prefer this outcome. Further in presence of bundling, we find a marked increase in the qualities of Firm 2 and Firm 3 as compared to the unbundled levels.*

The intuition for this result is also clear. The difference in the current proposition arises from the fact that the bundling decision on the part of Firm 1 allows it to benefit from asymmetric spillovers from Firms 2 and 3. Thus Firm 1 is able to increase its quality and charges a lower price to sell to both sets of consumers. Through increased quality levels, Firms 2 and 3 are also able to increase their market share. However, relative to costs the spillovers are still not high enough to make it worthwhile for Firm 1 to bundle.

The next proposition shows that there exists a threshold value of α beyond which it is profitable for Firm 1 to bundle products A and B. To investigate the importance of spillovers for bundling we consider the implications of raising the value of α. This is shown in the table below.

Table 3: Asymmetric Spillovers (α = 4.9)

	Unbundled	Bundled
Qualities	$q_A = q_B = 0.924931$	$q_A^b = q_B^b = 1.0547023$
	$q_C = q_D = 0.259838$	$q_C^b = q_D^b = 0.3137577$
Prices	$p_A = p_B = 1.221849$	$p^b = 1.2469815$
	$p_C = p_D = 0.77815$	$p_C^b = p_D^b = 0.753018$
$\lambda_{AD} = \lambda_{BC}$	0.610925	0.6234907
Profits of Firm 1 (A+B)	1.116207	1.11656484
Profits of Firms 2 and 3	0.269119	0.234296

From the table above, it is evident that *bundling is suitable strategy for Firm 1 after a certain threshold value of spillovers has been reached*. The point at which Firm 1 is indifferent between bundling and unbundling occurs at α = 4.867. As evident from the above table, profits from bundling exceed unbundled profits for $\alpha \geq 4.9$.[67]

Proposition 3: *In the presence of spillovers α > 4.9 and bundling, we find that Firm 1 offers a higher quality and price pair and has a higher market share than the other two firms. In equilibrium Firm 1 will always bundle. Once again we observe that the qualities of Firms 2 and 3 increase when Firm 1 bundles.*

The intuition for this is as follows. Bundling always induces the non-integrated firms to raise their quality levels.[68] However if the benefits to the large firm in the form of spillovers from these higher quality levels are not sufficiently large, then Firm 1 will not bundle. Once the level of spillovers crosses the threshold value, it lowers cost of production sufficiently through substantial increases to Firm 1's own qualities, leading to larger profits and making it worthwhile for the large firm to bundle.[69]

Thus, bundling is beneficial to the incumbent firm when it's own innovations benefit from external R&D spillovers. Hence, it makes sense for the incumbent to pursue a puppy dog

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[67] The actual point at which bundling profits exceed unbundled profits is α = 4.868. However, for the sake of illustration, we employ α = 4.9. It is to be noted that rounding up the alpha value does not change the results obtained under the case α = 4.868. It just makes the results more pronounced.

[68] Note: Due to increased spillover activity, Firms 2 and 3 have lower qualities than before.

[69] To see how further increases in spillover values impacts Firm 1's profits, refer to the appendix.

strategy or play soft initially and encourage competition in order to benefit from increased quality investments from the niche firms. We contend that the compensatory increase in R&D by the competing firms avoids duplication of research efforts but at the same time allows diversity of research since both the incumbent and competing firms continue R&D efforts.

Till now we have assumed that Firm 1 gets the same amount of spillovers from both Firms 2 and 3. Now we explore what happens when Firm 1 gets different spillovers from the two different firms. So let α_D denote the spillovers that accrue from Firm 3 and α_C denote the spillovers from Firm 2. We still retain the assumption that neither Firm 2 nor Firm 3 gets any spillovers from Firm 1. For the sake of illustration consider the situation where $\alpha_D = \alpha_C = 1/2$. Observe that the pattern here is similar to the one shown in Table 2. Results for this case are shown in Table 4 below.

Table 4: Asymmetric Spillovers ($\alpha = 1/2$)

	Unbundled	Bundled
Qualities	$q_A = q_B = 0.39679$	$q_A^b = q_B^b = 0.40072$
	$q_C = q_D = 0.3254$	$q_C^b = q_D^b = 0.41924$
Prices	$p_A = p_B = 1.0238$	$p^b = 0.99383$
	$p_C = p_D = 0.9762$	$p_C^b = p_D^b = 1.0062$
$\lambda_{AD} = \lambda_{BC}$	0.5119	0.49691
Profits of Firm 1 (A+B)	0.91275	0.85494
Profits of Firms 2 and 3	0.42354	0.41831

Next we consider the case where $\alpha_D = 1$ and $\alpha_C = 0$. The results for this are given in Table 5 below. For both these cases notice that the total spillovers for Firm 1 add to the same value ($\alpha_D + \alpha_C = 1$).[70] As before we observe that for Firm 1 the unbundled case yields higher profits than the bundled case. However there are some interesting differences. Under bundling Firm 1 prefers to have spillovers from both firms, while it prefers spillovers only from one firm when it does not bundle the products. Profits are also the highest in this case. Moreover, under bundling Firm 2 gains at the expense of Firm 3, which alone provides all the spillover benefits to Firm 1.

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[70] Unfortunately it is not possible to solve for a case where α_D does not equal α_C and α_C does not equal zero simultaneously.

Table 5: Asymmetric Spillovers ($\alpha_D = 1$, $\alpha_C = 0$)

	Unbundled	Bundled
Qualities	$q_A = 0.46003$	$q_A^b = 0.46393$
	$q_B = 0.3333$	$q_B^b = 0.33085$
	$q_C = 0.3333$	$q_C^b = 0.43729$
	$q_D = 0.3175$	$q_D^b = 0.40226$
Prices	$p_A = 1.0475$	$p^b = 0.99254$
	$p_B = 1.0000$	
	$p_C = 1.0000$	$p_C^b = 1.0495$
	$p_D = 0.95249$	$p_D^b = 0.96543$
$\lambda_{AD}, \lambda_{BC}$	0.52376, 0.5	0.51728, 0.47526
Profits of Firm 1 (A+B)	0.91277	0.85366
Profits of Firms 2 and 3	0.4444, 0.40322	0.4551, 0.38512

This case is also interesting for another reason. Table 1 considers the case of no spillovers while Table 2 covers the situation when Firm 1 benefits from spillovers from both firms. Table 5 considers the situation when Firm 1 has spillovers from only one firm and therefore allows us to isolate the differences caused by spillovers and bundling. We find that for Firms 2 and 3 quality increases always lead to an increase in the market share.[71] This is not always the case for Firm 1. We observe that spillovers always lead to quality increases for Firm 1. Keeping spillovers constant however, we find that Firm 1 offers a higher quality when it bundles but has a lower market share. As expected, profits of Firm 1 are always higher when it benefits from spillovers. Hence when it obtains spillovers only from one firm, Firm 1 always prefers not to bundle the products. Additionally as previously noted, the firm that does not provide spillovers gains at the expense of the firm that does.

We also calculated values for $\alpha_D = 9.8$ and $\alpha_C = 0$ and further to see the impact of increased spillovers on Firm 1's decision.[72] We find that the results obtained in the case where $\alpha_D = 1$ and $\alpha_C = 0$ hold for increased spillovers too. Thus, it is clear that Firm 1 needs spillovers from both firms to bundle i.e., spillovers from only one product will not induce bundling. The following proposition summarizes the findings for all the cases considered here.

---

[71] Note: This does not apply when $\alpha \geq 4.9$.

[72] The values of the same can be found in the appendix.

Proposition 4: *The large firm always benefits from spillovers but, in equilibrium will always choose not to bundle the two products. The qualities of Firm 2 and Firm 3 increase in the bundled case even in the presence of varying spillovers from Firm 2 and Firm 3.*

3.7   Results with symmetric spillovers

Though we contend that the spillover activity from the large firm to the smaller firms may be negligible due to IPR protection, for the sake of argument we consider the symmetric spillovers case as well, i.e., we set $\tilde{\alpha} = \alpha$. Figure1 represents spillovers which vary from 0 to 1 on the x-axis and the profits of Firm 1 on the y-axis. We find that symmetric spillovers lead to lower profits regardless of whether the firm bundles or not. This makes perfect sense since the large firm is not only benefitting from but also providing spillovers to the niche firms, which reduces its revenue.[73] However, profits from bundling are still lower than when the firm does not bundle. As before this is because we are in the range where costs are high relative to the value of spillovers.
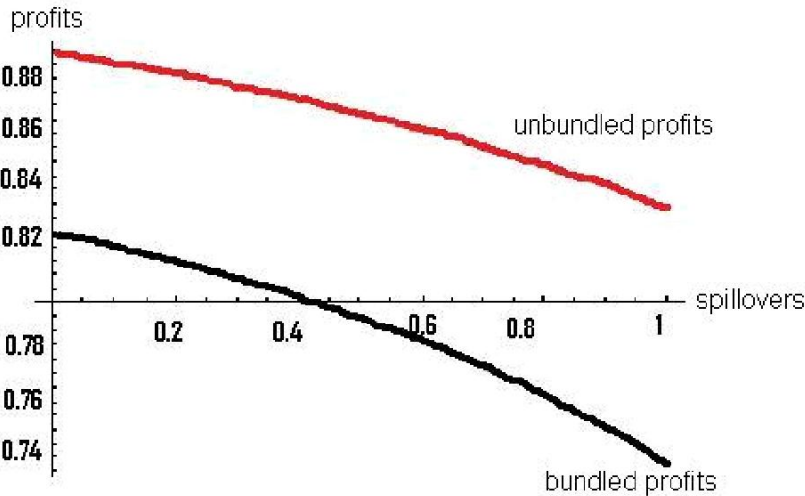
Figure 1: Firm1 Profits and Symmetric Spillovers

Figure 2 shows the quality levels (y-axis) of the large firm in the context of symmetric spillovers (x-axis). We see that as α increases from 0 to 1, quality levels increase for both scenarios. However, after 0.4 we find that Firm 1's quality in the bundled case is higher than

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[73] This is an interesting finding in the light of recent happenings where Microsoft, due to anti-trust legislation has been asked to make available documents in order to make the market more competitive. Microsoft predicts that this sharing will have a relatively minimal impact on its revenues. In this scenario, it makes little sense for the large producer to play soft as he has little incentive to do so.

in the unbundled case since bundling motivates the other two firms 2 to raise their quality. Hence when the spillover value is greater than 0.4 the benefits to Firm 1 in the form of spillovers make it feasible for the firm to bundle.
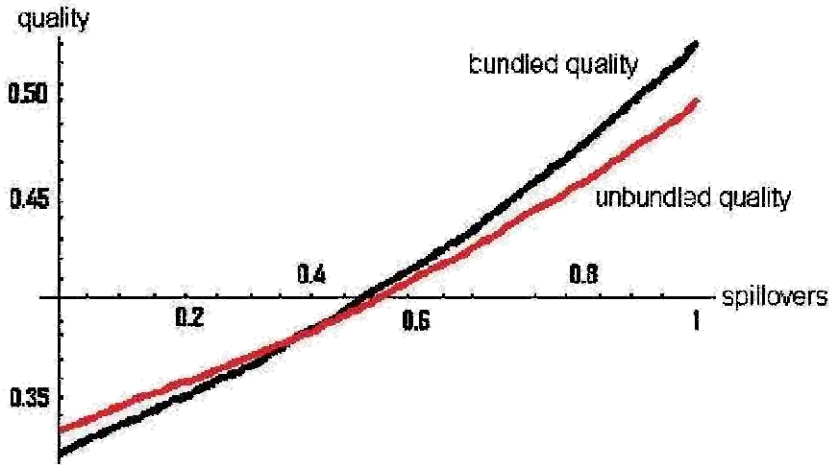
Figure 2: Firm 1: Qualities and Symmetric Spillovers

For Firms 2 and 3 there are no surprises. As α increases both firms invest more in quality and as before quality investments are higher under bundling. Based on this one could speculate that in the absence of IPR, the quality of products might be higher, though the revenues are lower for the large producer.

3.8 Economies of scope

From the section above, three main results emerge: First, in equilibrium, the large firm will always choose not to bundle as long as $\alpha < 4.9$ whereupon bundling becomes more profitable than unbundling. Second, the increases in Firm 2 and Firm 3 qualities occur only when Firm 1 bundles. Third, Firm 1 will only bundle when it receives spillovers from more than one competing firm.

In order to examine whether there are factors other than spillovers which determine the bundling decision, we introduce economies of scope which are often characteristic of high technology markets. We speculate that in providing a bundled product instead of two individual products, Firm 1 makes a cost saving through economies of scope. Accordingly, we adapt this idea in to the bundled profit function as shown below where the entire cost function captures economies of scope.

$$\pi_1^b = p(\lambda_{AD} + \lambda_{BC}) + \frac{1}{8}(q_A + q_B)^2 - \frac{q_A^2}{2(1 + \alpha q_D)} - \frac{q_B^2}{2(1 + \alpha q_C)}$$

In order to assess the impact of economies of scope, we set α = 1/2 and calculate the remaining values. These are given in the table below. The values of the unbundled case remain the same as calculated in the asymmetric case with spillovers α = 1/2 (Table 4). We find the profits of the large firm to be higher in the bundled case with economies of scope. We find in the presence of low spillovers, bundling and economies of scope, the large firm offers significantly larger qualities at higher prices and gains greater market share through the same.

Table 6: Asymmetric Spillovers (α = 1/2)

	Unbundled	Bundled with economies of scope
Qualities	$q_A = q_B = 0.39679$	$q_A^b = q_B^b = 1.157232$
	$q_C = q_D = 0.3254$	$q_C^b = q_D^b = 0.297221$
Prices	$p_A = p_B = 1.0238$	$p^b = 1.2866704$
	$p_C = p_D = 0.9762$	$p_C^b = p_D^b = 0.713329$
$\lambda_{AD} = \lambda_{BC}$	0.5119	0.643335
Profits of Firm 1 (A+B)	0.91275	1.1591954
Profits of Firms 2 and 3	0.42354	0..2102495

We summarize our findings with the following proposition.

Proposition 5: *In the presence of economies of scope and bundling, very low spillovers are required to make bundling a profitable strategy. Thus, in equilibrium, Firm 1 will always choose to bundle. It is evident from the above result that spillovers contribute greatly towards making bundling profitable.*

3.9 Welfare analysis

This section examines total welfare for society in our price quality game. The following equations denote consumer surplus for products A and B and products C and D respectively. The equations thereafter denote total welfare which is calculated as the sum of consumer surplus plus producer profits.

$$CS_a = CS_b = \int_0^{\lambda_1} q_a - \lambda_1 - p_a = \lambda_1 q_a - \frac{\lambda_1}{2} - \lambda_1 p_a$$

$$CS_c = CS_d = \int_{\lambda_1}^1 q_d - (1 - \lambda_1) - p_d = \frac{2\lambda_1 q_d - 1 + 2\lambda_1 + \lambda_1^2 - 2\lambda_1 p_d}{2}$$

$$W_1 = CS_a + CS_b + \pi_1$$
$$W_2 = CS_c + \pi_2$$
$$W_3 = CS_d + \pi_3$$

Based on the above equations, we can calculate welfare at equilibrium levels for all four cases i.e., unbundling and bundling with no spillovers and unbundling and bundling with spillovers. Note that in this section profits for Firm 1 include profits from both products A and B. Moreover, V has not been added to the consumer surplus results as they would only increase the scale of the existing results. Similarly, consumer surplus is the sum of surplus from both applications.

We begin with Table 8 which considers the $\tilde{\alpha} = \alpha = 0$ case, or the no spillovers case. As is evident, total welfare is higher under bundling. Profits of all the firms decrease under bundling. However, the consumer surplus of those buying products from Firms 2 and 3 increases due to the higher quality offered by these firms. Though quality increases raise costs, the decrease in profits is small when comparing the increase in consumer surplus. Consequently, welfare is higher under bundling.

Table 7: Welfare under No Spillovers

Case 1: $\alpha = \bar{\alpha} = 0$	Firm 1	Firm 2	Firm 3
Unbundled			
Profits	0.888889	0.444444	0.444444
Consumer Surplus	-0.916667	-0.208333	-0.208333
Sum	-0.027766	0.236111	0.236111
Total Welfare		0.444456	
Bundled			
Profits	0.824265	0.444368	0.444368
Consumer Surplus	-0.85002	-0.193871	-0.193871
Sum	-0.025755	0.250497	0.250497
Total Welfare		0.475239	

In Table 9 we consider the case of asymmetric spillovers or $\tilde{\alpha} = 0$ and $\alpha = 1$. As in Table 8 we find consumer surplus to be higher for Firms 2 and 3 and lower profits for all the firms in the bundled case. This is due to the higher quality choice made by Firms 2 and 3 under bundling. Interestingly however, spillovers seem to increase total welfare under bundling.

The intuition for this result is as follows. When there are spillovers the large firm is able to make use of these and lower its costs, which allows it to offer a higher quality. Since the spillovers are asymmetric they provide no benefits to the two smaller firms. Consequently the profits of Firm 2 and 3 do not vary much, though there is some improvement in consumer surplus under bundling. The major effect on total welfare is through Firm 1's consumer surplus obtained through increased qualities, from Firms 2 and 3, which are higher when Firm 1 bundles.

Another interesting finding is that the profits of Firms 2 and 3 only differ marginally in all the four cases. We also find that the presence of spillovers leads to higher welfare regardless of the bundling decision.

Table 8: Welfare under Spillovers

Case 2: $\alpha = 1, \bar{\alpha} = 0$	Firm 1	Firm 2	Firm 3
Unbundled			
Profits	0.93665	0.40322	0.40322
Consumer Surplus	-0.889684	-0.1716597	-0.1716597
Sum	0.046966	0.23156	0.23156
Total Welfare		0.5100866	
Bundled			
Profits	0.88585	0.39307	0.39307
Consumer Surplus	-0.820245	-0.147924	-0.147924
Sum	0.065605	0.245146	0.245146
Total Welfare		0.555897	

We also calculated the total welfare values for α = 4.9 to gauge the impact that increased spillovers and Firm 1 profits may have on welfare. As evident from the table below, the main result obtained for the case α = 1 still holds i.e., increased spillovers and bundling seem to increase total welfare. In fact the higher the level of spillovers, the more significant are the increases to total welfare. We find that with increased spillovers and bundling, Firm 1's consumer surplus drastically increases. Firm 1's increased quality results from spillovers from Firms 2 and 3 bringing about a positive shift in market share under bundling. This is in contrast to the no spillover case where Firm 1's market share decreases on account of bundling. Further we find Firm 1's profits are higher in the bundled case inducing it to bundle. The consumer surplus of Firms 2 and 3 under bundling also increases in comparison to the α = 1 case. This could be explained by the increased quality choice made by Firms 2 and 3 in the bundled case. As in the previous case, we find that the profits of Firms 2 and 3 decrease in the bundled case with spillovers.

Table 9: Welfare under Spillovers

Case 3: $\alpha = 4.9, \bar{\alpha} = 0$	Firm 1	Firm 2	Firm 3
Unbundled			
Profits	1.116207	0.269119	0.269119
Consumer Surplus	-0.89280	-0.01911	-0.01911
Sum	0.22340	0.250001	0.250001
Total Welfare		0.723402	
Bundled			
Profits	1.11656484	0.234296	0.234296
Consumer Surplus	-0.62851	0.0439858	0.0439858
Sum	0.488055	0.278282	0.278282
Total Welfare		1.04462	

The proposition below summarizes our finding about welfare.

Proposition 6: *Welfare is higher under bundling when there are no spillovers. In the presence of spillovers welfare is higher when Firm 1 does bundle products A and B.*

We find as a result of the welfare analysis that in this context, bundling is not an aggressive strategy but instead a defensive commitment strategy i.e., puppy dog strategy on the part of Firm 1 which brings additional welfare to the consumer. This increase in welfare is brought about by quality increases in Firms 2 and 3 which are carried over to Firm 1 by way of spillovers. If the spillovers are large enough, not only does total welfare increase, the profits of Firm 1 also increase.

3.10 Conclusions

This paper examines the relationship between the bundling decision of a large firm and the impact of spillovers on innovation within the software industry. Using a linear city model, we assume that there exists a complementarity in the form of spillovers between the large firm and the two open source firms. This set-up captures the co-existence observed in the software market between proprietary and OSS firms. We suggest that OSS firms provide innovative potential for proprietary software firms. As such it makes sense for the large player to use bundling as a strategy tool where he appears soft and encourages competition so that he may benefit from cost reductions and increased quality investments through spillovers accruing from the competitive fringe. We consider decisions to bundle and investments in quality as long-term decisions which send commitment signals.

We find that bundling does increase price competition but it encourages the competing firms to invest in R&D by sending a clear commitment signal. In fact, it is only on account of the bundling decision that firms 2 and 3 increase their quality levels and is not motivated by an increase in profits for Firms 2 and 3. A part of this increased quality is carried over to the integrated firm in the form of spillovers reducing the production costs of the integrated firm. The effect of bundling was examined in varying spillover scenarios based on the assumption that there are only asymmetric spillovers.

In short, we find that in the absence of spillovers, under bundling Firm 1 will offer a lower price quality pair and has a smaller market share than Firms 2 and 3 who will offer greater qualities. In the presence of bundling and spillovers, we find that Firm 1 offers a higher quality but at a lower price and its market share is lower than that of Firms 2 and 3. Thus, in equilibrium, Firm 1 will choose not to bundle unless spillovers reach a certain threshold i.e., α > 4.9. After which point, bundling becomes the suitable strategy for Firm 1 as profits from bundling and spillovers are higher than no bundling with spillovers. In fact, after this threshold the profits of Firm 1 are always higher than the no spillover case. We further find that Firm 1 will not bundle when it receives spillovers only from one firm i.e., one product. This suggests that the incumbent needs several competitors who provide spillovers in order for spillovers to benefit own innovation. This corroborates earlier findings which suggest that many firms are needed for continuous innovation and ideas (Varian et al., 2004). When considering spillovers and welfare, we find welfare to be higher when Firm 1 bundles.

Based on our paper, it could be said that by bundling, a large firm like Microsoft is able to benefit from the R&D investments made in the open source community. This finding provides a possible explanation for co-existence i.e., the underlying interaction which allows both open source firms and proprietary firms to function in the market reducing overall R&D expenditure and duplication and yet ensuring diversity. Further, small firms may innovate at a faster rate making spillovers from such firms more valuable to large firms. This can be seen in the example of Microsoft's recent source code disclosures aimed at not only leveling the playing field but also to ensure R&D takes place and continued consumer interest in its products. This finding also reinforces the cumulative and sequential aspects of innovation prevalent in the software industry and the importance of spillover activity. However, important to note is that protection of "own" knowledge reduces spillover activity from the

integrated firm to the competitive fringe which might be inefficient for innovation in the long run.

The paper is limited to the extent that it largely considers the bundling decision in the context of spillovers save a brief examination of economies of scope. More extensive analysis of economies of scope and network effects, excluded here due to limitation in the current cost function, are highly relevant for analyzing innovation strategies in the software market. Future research should therefore, consider the bundling decision and its impact on spillovers, network effects and economies of scope simultaneously.

Another limitation is that we only make a horizontal analysis of the situation at hand. Therefore future research should examine the impact that a vertical structure within the software market i.e., large firm catering to the mass consumer versus small competitive firms who cater to sophisticated users, would have on this question. Finally, in this paper we assume that α is exogenous. The next step would therefore be to endogenize α so that firms can chose how much information they want to reveal.

3.11 Appendix I

The following tables examine the impact of increasing α values on Firm 1's profits and subsequently its bundling decision. We calculated α values equal to 4, 4.5, 5, 6, and 7. It is evident that the increase in spillovers is accompanied by significant quality increases in products A and B. Further Firm 1's profits and market shares steadily increase with increased spillovers. While the qualities of Firms 2 and 3 increase, their profits, prices and market shares decrease. This could perhaps be attributed to the fact that increased asymmetric spillovers to the integrated firm bring no benefit. As evident from the tables below, from α ≥ 5, Firm 1 will always bundle before which it will not as the profits from unbundling are higher.

$\alpha = 4$	Unbundled	Bundled
Qualities	$q_A = q_B = 0.824068$	$q_A^b = q_B^b = 0.93333$
	$q_C = q_D = 0.27199$	$q_C^b = q_D^b = 0.33333$
Prices	$p_A = p_B = 1.184025$	$p^b = 1.2$
	$p_C = p_D = 0.815974$	$p_C^b = p_D^b = 0.8.$
$\lambda_{AD} = \lambda_{BC}$	0.592012	0.6
Profits of Firm 1 (A+B)	1.076677	1.06667
Profits of Firms 2 and 3	0.295917	0.26444

Asymmetric Spillovers (α = 4)

	Unbundled	Bundled
Qualities	$q_A = q_B = 0.880687$	$q_A^b = q_B^b = 1.0017689$
	$q_C = q_D = 0.264914$	$q_C^b = q_D^b = 0.322295$
Prices	$p_A = p_B = 1.205257$	$p^b = 1.226491$
	$p_C = p_D = 0.794742$	$p_C^b = p_D^b = 0.773508$
$\lambda_{AD} = \lambda_{BC}$	0.602628	0.6132456
Profits of Firm 1 (A+B)	1.098827	1.0947271
Profits of Firms 2 and 3	0.280717	0.247221

Asymmetric Spillovers (α = 4.5)

$\alpha = 5$	Unbundled	Bundled
Qualities	$q_A = q_B = 0.93584$	$q_A^b = q_B^b = 1.067678$
	$q_C = q_D = 0.25802$	$q_C^b = q_D^b = 0.311665$
Prices	$p_A = p_B = 1.22594$	$p^b = 1.252004$
	$p_C = p_D = 0.77741$	$p_C^b = p_D^b = 0.747995.$
$\lambda_{AD} = \lambda_{BC}$	0.61297	0.62600
Profits of Firm 1 (A+B)	1.120502	1.1219357
Profits of Firms 2 and 3	0.26629	0.23118

Asymmetric Spillovers (α = 5)

$\alpha = 6$	Unbundled	Bundled
Qualities	$q_A = q_B = 1.0415052$	$q_A^b = q_B^b = 1.191667$
	$q_C = q_D = 0.244812$	$q_C^b = q_D^b = 0.291667$
Prices	$p_A = p_B = 1.265564$	$p^b = 1.3$
	$p_C = p_D = 0.734435$	$p_C^b = p_D^b = 0.7.$
$\lambda_{AD} = \lambda_{BC}$	0.63278	0.65
Profits of Firm 1 (A+B)	1.162289	1.173611
Profits of Firms 2 and 3	0.239731	0.20246

Asymmetric Spillovers (α = 6)

$\alpha = 7$	Unbundled	Bundled
Qualities	$q_A = q_B = 1.140735$	$q_A^b = q_B^b = 1.305192$
	$q_C = q_D = 0.23241$	$q_C^b = q_D^b = 0.27336$
Prices	$p_A = p_B = 1.302776$	$p^b = 1.343945$
	$p_C = p_D = 0.697224$	$p_C^b = p_D^b = .0.656055$
$\lambda_{AD} = \lambda_{BC}$	0.651387	0.671973
Profits of Firm 1 (A+B)	1.20185	1.221487
Profits of Firms 2 and 3	0.216054	0.177842

Asymmetric Spillovers (α = 7)

3.12 Appendix II

The tables below examine the impact of increasing α_D. As evident spillovers from one firm and unbundling leads to greater profits for Firm 1. Therefore in equilibrium Firm 1 will not bundle. Further, we find that increasing this value does not overturn the decision of Firm 1 not to bundle as long as it receives spillovers only from one product or firm. Once again the competing firm that does not give spillovers gains at the expense of the firm that does.

	Unbundled	Bundled
Qualities	$q_A = 1.319798$	$q_A^b = 1.2237572$
	$q_B = 0.3333$	$q_B^b = 0.383247$
	$q_C = 0.3333$	$q_C^b = 0.464867$
	$q_D = 0.210025$	$q_D^b = 0.2436804$
Prices	$p_A = 1.369924$	$p^b = 1.1497243$
	$p_B = 1$	$p_C^b = 1.1156812$
	$p_C = 1$	$p_D^b = 0.584833$
	$p_D = 0.630076$	
$\lambda_{AD}, \lambda_{BC}$	0.684962, 0.5	0.7075835, 0.4421593
Profits of Firm 1 (A+B)	1.081453	1.0139682
Profits of Firms 2 and 3	0.4444, 0.176442	0.5143215, 0.1413247

Asymmetric Spillovers ($\alpha_D = 9$, $\alpha_C = 0$)

	Unbundled	Bundled
Qualities	$q_A = 1.384435$	$q_A^b = 1.271742$
	$q_B = 0.3333$	$q_B^b = 0.386557$
	$q_C = 0.3333$	$q_C^b = 0.46661$
	$q_D = 0.201946$	$q_D^b = 0.23366$
Prices	$p_A = 1.394163$	$p^b = 1.159671$
	$p_B = 1$	$p_C^b = 1.119861$
	$p_C = 1$	$p_D^b = 0.560797$
	$p_D = 0.605837$	
$\lambda_{AD}, \lambda_{BC}$	0.697082, 0.5	0.7196014, 0.4400693
Profits of Firm 1 (A+B)	1.094602	1.0243227
Profits of Firms 2 and 3	0.4444, 0.1631281	0.5181828, 0.1299469

Asymmetric Spillovers ($\alpha_D = 9.8$, $\alpha_C = 0$)

	Unbundled	Bundled
Qualities	$q_A = 1.4$	$q_A^b = 1.2831876$
	$q_B = 0.3333$	$q_B^b = 0.387346$
	$q_C = 0.3333$	$q_C^b = 0.4670243$
	$q_D = 0.2$	$q_D^b = 0.231276$
Prices	$p_A = 1.4$	$p^b = 1.1620388$
	$p_B = 1$	
	$p_C = 1$	$p_C^b = 1.1208584$
	$p_D = 0.6$	$p_D^b = 0.555064$
$\lambda_{AD}, \lambda_{BC}$	0.7, 0.5	0.7224680, 0.439571
Profits of Firm 1 (A+B)	1.09777	1.0267966
Profits of Firms 2 and 3	0.4444, 0.16	0.519106, 0.1273035

Asymmetric Spillovers ($\alpha_D = 10$, $\alpha_C = 0$)

Chapter 4

4. Small and medium sized firms and IPR adoption

4.1 Introduction

Recent literature argues that the knowledge a firm possesses in terms of intangible assets contributes greatly to the competitiveness of firms (Albert and Bradley, 1997). In fact, small and medium sized enterprises have been identified as significant contributors to the knowledge pool and innovative activity. As early as 1962, Muller showed that much of Du Pont's innovations came from small firms external to the company. Thus in order to protect their intellectual property (IP) in negotiations with large firms, be it collaboration or competition, some form of intellectual property rights protection mechanisms must be undertaken by SMEs, particularly when the firm deals in knowledge based activities. However, it is not clear to what extent IPR plays a role in the SME innovation process. While much attention has been paid to large firms and their use of IPR as incentive mechanisms to innovate, not enough attention has been paid to small and medium sized firms in the same context. This paper contributes to the literature by providing new and additional insights to the literature on SME and IPR adoption.

IPR can be broadly divided into formal and informal mechanisms. The former refers to patents, copyrights, trademarks and registered designs.[74] The latter includes lead time advantages, secrecy and market dominance. Research suggests that SME largely rely on informal IPR mechanisms as the existing legal framework does not consider the unique requirements of SME which includes the inability to commercialize innovations, a lack of financial means and the inability to litigate. As a result, the environment provided by formal IPR is rather weak.

Weak IPR could have two implications. Firstly, if IPR are weak, SME don't have enough incentive to create the technology (Gambardella, 2007). Second, even if they do innovate, they are often integrated by larger companies either upstream or downstream (Gans and Stern, 2003). As an alternative to IPR, it has also been noted that SME tend to make use of open source software (OSS) or open systems. The ideology of the OSS movement eliminates many

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[74] In this chapter we briefly cover trademarks and registered designs as they feature in the dataset. However the focus of this work rests primarily on copyrights and patents.

of the obstacles currently facing SME in terms of cost, litigation and distribution.[75] Firms that employ or create OSS tend not to patent.

Despite studies that point to the low usage of formal IPR mechanisms by SME, there are some industries for which IPR is quite relevant even for small firms. These industries that offer primarily knowledge based products and services include pharmaceuticals, biotechnology and ICT (information and communication technology). In fact research suggests (Moulin et al., 2005) that SME in the ICT sector are more aware and avid users of the formal IPR system.

Our aim in this paper is to examine SME adoption patterns in the ICT sector. ICT industries have short product cycles but high R&D costs where the use of IPR could help in appropriating profits. ICT manufacturing industries tend to appropriate most of their profits through licensing agreements (Elevald, 2007). These industries are also characterized by open innovation and research collaborations. The onset of the Internet, has made copying large scale and firms are coming up with other strategies and business models to protect their IP which includes double licensing with open source software.

Thus, we begin with the premise that these sectors are using IPR as a base condition. We employ a dataset from the e-Business watch project[76] which is confined to SME in the ICT manufacturing sector, software sector and ICT services sector. In doing so, we are able to examine whether ICT SME do indeed use IPR and whether it plays an important role in SME innovation.

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[75] The OSS ideology uses a formal IPR mechanism i.e., copyright in order to grant freedom of use, modification and redistribution of knowledge protected under its licences. The specific conditions of each license vary and are only relevant upon distribution.

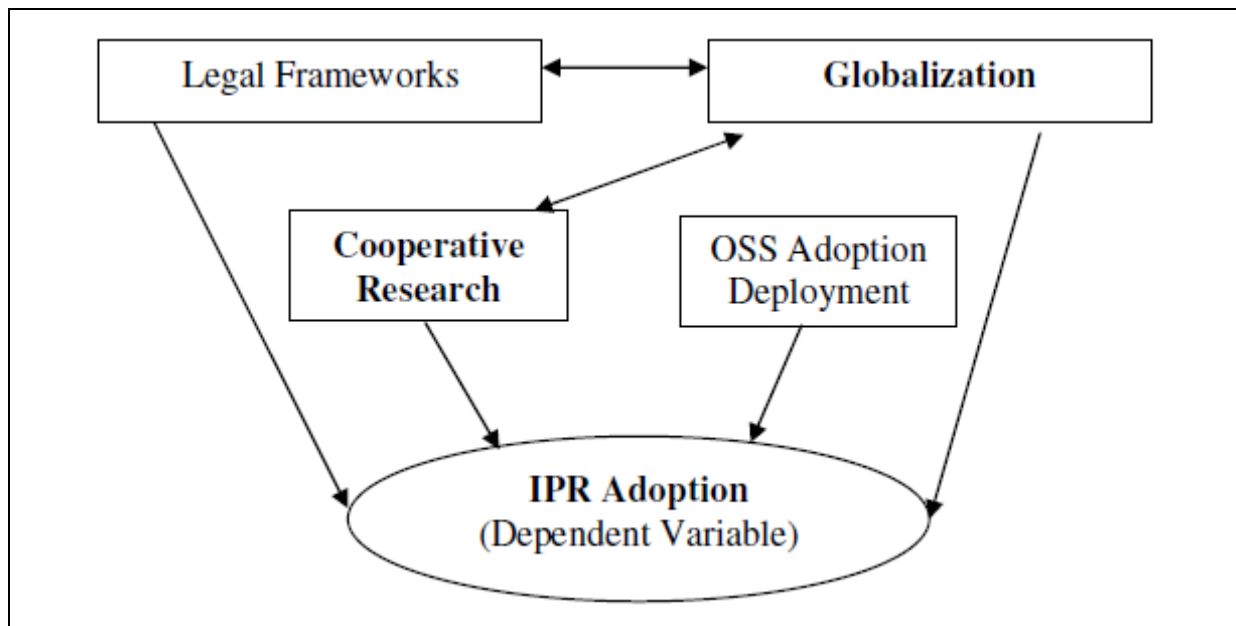[76] See www.ebusiness-watch.org for further information.

Figure 4.1: Diagrammatic representation of various factors affecting SME adoption of IPR

The diagram above provides a visual description of the research model used in this paper. We make use of the analysis of variance in order to study the impact of varying one factor and its subsequent effect on the other variables in the model. The former refers to, as indicated in the diagram, globalization, legal frameworks, cooperative research and OSS use and adoption. We examine how these four factors affect IPR adoption by ICT SME. We further postulate that these four factors have differing impacts on the adoption of IPR by ICT SME. These factors are studied in greater detail in the following sections. The diagram also depicts possible relationships that might be further clarified through our analysis including the effect of globalization on legal frameworks and vice versa, how legal frameworks influence collaborative research and whether OSS use is also a form of cooperative research.

Our analysis brings out the following four important results. First, while it has been suggested that globalization has affected the use of IPR, most studies till date have focused on firm innovation or R&D as the major determinant of IPR adoption. Our study attempts to find whether a correlation exists between the exact tendency of SME to patent and globalization. There appears to be little (if any) literature that suggests that this correlation has been examined before. Second, we examine whether there is a correlation between cooperative research and IPR adoption. Third, we examine whether the relationship between legal frameworks and the propensity to patent that has been explored in previous studies holds in the

78

SME context as well. Finally, we customize the study in the context of OSS to examine whether there is an association between the development and deployment of OSS and the propensity of SME to patent.

The rest of the paper is structured as follows. Section 4.2 provides a brief general overview of IPR mechanisms. Section 4.3 provides a literature review of the four entities mentioned in the introduction, namely, innovation, the generation of IP, SME and IPR. This overview indicates gaps in the literature and focuses on the contributions of this paper towards these gaps. Section 4.4 examines the research questions in detail and formulates testable hypotheses. Descriptive statistics, data analysis and a discussion of the same are provided in Section 4.5 and the paper concludes in Section 4.6.

4.2   IPR Mechanisms in brief

IPR are unique in that they make a public good excludable and allow inefficiency during the granted period (Acs and Audretsch, 2005). The innovator is able to charge a monopoly price and recoup what he incurred in terms of R&D cost in developing the innovation. Thus, from a theoretical perspective, IPR are designed to create incentives to innovators and to ensure that these innovations are brought in to the public domain as soon as possible.[77] As previously stated, IPR can be broadly divided in to formal and informal IP mechanisms where the former refers to patents, copyrights, trademarks and registered designs among others. The latter includes lead time advantages, secrecy, market dominance and advertising. We now briefly revisit the formal IPR mechanisms.

4.2.1   Patents

A patent, perhaps the most debated IPR instrument, is granted to an innovator for originality, novelty, and non-obviousness in exchange for early disclosure in to the public domain. They protect the new technical application of a particular idea but not the idea itself (Lemley and Cohen, 2001). Patents expire 20 years after the filing date and are not subject to renewal. When comparing with other solutions, patents, it has been suggested in the theoretical literature, provide some relief to the market failure arising from innovators being unable to appropriate their investments (Gallini & Scotchmer, 2001, Scotchmer, 2004). The decision to patent or not is theoretically modelled as a profit maximisation choice of firms (Choi, 1990,

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[77] This trade-off was formalized analyzed by Nordhaus (1969).

79

Anton and Yao, 2004, Langinier, 2005) where only some of the inventions are patented. These models abstract from the differences that exist across industries, firms, and innovations, all of which affect the propensity to patent (Griliches, 1990, Kleinknecht et al., 2002).

The effect of patent strength on innovation was empirically studied by Lerner (2001) where he examined 60 countries over a period of 150 years with respect to policy shifts. In his results, Lerner (2001) finds an inverted 'U' shape relationship between patents and innovation where low levels of protection result in greater innovation and vice versa. In 2000, Cohen et al. studied R&D labs in 1478 firms from the US manufacturing industry for the year 1994, to examine what mechanisms firms use to extract most profit from their innovations. They found that informal IPR mechanisms to be more important to firms in the US manufacturing industry.[78] Hall and Ziedonis (2001) studied patenting behaviour using data collected from 110 semiconductor firms during the period 1975-1996 where patents were found to be quite high even after controlling for R&D expenditures and size of firms. They suggest that pro patent policy shifts within the semiconductor industry created a situation where innovators used litigation as a means to obtain rents from possible infringers. Thus, leading Hall and Ziedonis (2001) to suggest that resources that are invested in expanding patent portfolios are removed from research.

Much of the existing empirical literature on the impact of patents is based on surveys across various industries which focus on large firms' appropriation of innovation. However, it has been suggested that examining such issues, on a firm by firm basis, within a particular industry still remains scant (Mann, 2006). Mann (2006) focuses on patenting behavior within the software industry and finds that patenting behavior can vary within an industry too.[79] His dataset includes both large and small firms in the software industry from the late 1990s which allows analysis of the software industry after the rise of the Internet and the legal measures which made patenting easier. Mann (2006) finds that the sectors with the highest propensity to patent include among others operating systems, database, security, wireless/mobile and application service providers.

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[78] For similar findings, refer to Arundel (2001) and Anton and Yao (2004).

[79] Graham and Mowery (2003) published the most extensive study on IPR in the US software industry. Refer: Stewart J.H. Graham and David C. Mowery, Intellectual Property Protection in the US Software Industry, in Patents in the Knowledge-Based Economy 219 (Wesley M. Cohen & Stephen A. Merrill eds., 2003)

4.2.2 Copyrights

The second form of formal IP protection refers to copyrights. Copyrights protects the expression of an idea but the not idea itself. Therefore, while direct copying is not allowed, copying the underlying idea is. The duration of copyright protection within the EU is usually the life of the creator plus either 50 or 70 years after. In Europe, copyrights are obtained automatically for creative works once they are made public in some form and there is neither a formal application process nor an official register. Software was traditionally protected by copyright and though patents are being granted[80], software has generally flourished under the copyright regime as it does not prohibit subsequent or cumulative innovation.

The presence of IPR within the software market has made way for an alternative endogenous solution namely, open source software which allows access to the source code i.e., disclosure of core information. The principles of which are also governed by copyright but referred to as "copyleft" and serve as a contract to all to read, modify, and use the software where possible constraints are only relevant upon distribution.

It has been often said that patents contribute more to innovation because they encourage more information disclosure as compared to copyrights. A study by Lerner and Zhu (2005) empirically consider patents and copyrights to be substitutes in the protection of software in the US. They evaluated the impact of the Lotus vs. Borland case which resulted in a decrease in the use of copyright protection for software. Based on this result, they postulated that a reduction of one must lead to an increase in the other. They consider two subsets of firms: those more directly affected by the Lotus vs. Borland decision and the other subset of firms not directly affected by the decision. They examine the shift in behaviour of the first group in comparison to the second subset of firms. Their results show that the decision to reduce copyright protection for software in the Lotus vs. Borland case resulted in dramatic patenting increases. Further they found that increased reliance on patenting was correlated to the growth of R&D expenditures, number of employees, sales volume, market capitalization and number

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[80] Patents are more effective in preventing imitation than copyrights in the software market. However, it should be noted that software patents are only granted in the US. However, alternative practices such as computer implemented inventions (CII) are developing in Europe. There is no official definition of CII, however, based on various court decisions, it seems evident that when a process or piece of software requires hardware, then the EPO can grant a patent on the basis that hardware can enable technical innovation.

of business lines. Thus, their results show that patenting did not have any negative effects on innovation.

4.2.3 Trademarks and registered designs

Trade marks refer to badges of origin for goods or services, and can be words, names, logos, colors, sounds or shapes (Gowers, 2006: 15). Trade marks must be registered and once registered, others are not allowed to use them. However, they lose their protective value when what it represents becomes the general term for items of a particular class. An example refers to Sony's 'walkman' which no longer has trade mark value in Austria (Gowers, 2006:15).

Registered designs refers to protection firms can obtain related to the appearance of a product which includes colours, shapes, contours, texture, materials and/or the product itself. The granting of a registered design prevents against third party copying. In Europe, registered designs are granted for a minimum of 5 years and a maximum of 25 years through renewals. Firms must register them either with national authorities or get a community registered design. Often industrial design is used in conjunction with registered designs.

In general, based on the above literature, one can say that there is an overall increase in the use of formal IPR which research suggests can be attributed to three main reasons (Arundel, 2000): First, the change in legislation which has made patenting easier particularly in the US. This also includes international agreements from the WIPO (World Intellectual Property Organisation) or EPO (European Patent Office) through which firms are able to extend their IPR from their home territory. Second, we observe the changing attitudes of firms regarding IPR and the final reason refers to the focus of innovation moving from mechanical engineering to that of knowledge based activities where competitive strategies are based on knowledge and innovation. These three reasons have led to what some experts refer to as the 'pro-patent' era.

However, the situation in Europe is somewhat different when considering IPR. European firms are generally considered to be behind their American and Japanese counterparts. In fact, an empirical study carried out by Arundel (2000) shows that European firms patent less in comparison to American firms. Based on a study by Arundel and Kabla (1998), it should be noted however, that industrial distributions greatly affect the average propensity to patent across industries.

In the case of SME, patents are used to signal expertise, enable research collaborations or investment (Mazzoleni and Nelson, 1998). As noted, SME are often the drivers of innovation especially in the areas of information technology and biotechnology. It is in this area that we seek to provide additional insights on whether SME particularly in the area of knowledge based products and services (software, telecommunications, pharmaceuticals and biotechnology) are indeed making greater use of formal IPR mechanisms.

4.3   Literature review

Schumpeter (1942), Galbraith (1952) and Chandler (1977) all believed that larger firms had a critical advantage with respect to innovation and that small firms lack the knowledge assets required for innovation. Their logic was based on the fact that R&D is a risky and costly undertaking and hence industrial organizations of large monopolistic firms offers decisive welfare advantages and as such are able to achieve scale economies, diversification, and market reputation (Scherer et al. 1959, Cohen 1995). It was Acs and Audretsch (1988) however, who suggested that both small entrepreneurial firms as well as large established firms facilitate innovation and technological change.

Smaller firms have a greater role to play depending on the type of industry involved and spatial contexts (Acs and Audretsch, 2005). In high tech markets (software, pharmaceuticals, telecommunication), innovation is highly competitive and small firms are in a better position to fully exploit it and take over from the incumbent (Malerba, Orsenigo, and Peretto 1997). The use of capital and labour resources has been shown to be more efficient by smaller firms (Acs & Audretsch 1991b) combined with their focus on new innovative technologies (Hicks et al 2001).

Intellectual property protection in these industries is justified on the basis of high initial costs which are difficult to appropriate when considering minimal reproduction and distribution costs. However, IPR was ideally designed for isolated innovations resulting from R&D. Though this is a useful framework, it does not accurately describe the case where research is cumulative whereby earlier researchers provide the basis of innovation for subsequent innovators. The WIPO (World Intellectual Property Organization) in their 2003a report highlight several reasons for formal IPR usage namely; as a bargaining tool, a method to

formalize innovations, to signal competence and attract funding and reduce wasteful expenditure through cooperative R&D.

Hall and Ziedonis (2001) suggest that small firms patent in order to be able to use their IP as a bargaining tool with larger firms. The concept of using IP as a credible bargaining tool was further examined by Arora and Merges (2004) and Arora, Fosfuri and Gambardella (2001) who found that it is particularly relevant as most buyers are large firms. By using empirical case studies they suggest that small firms have greater chances of assuring their independence and returns from IP the more customized the innovative input.

Alternatively, Gambardella (2007) suggests that the innovation elasticity of using IPR is greater for small firms than for large ones who can rely on alternative measures to protect their innovations. The use of informal IP mechanisms varies from firm to firm (Kuusisto, 2007, Cohen et al., 2000). A study by Kitching and Blackburn (1998) showed that firms in computer services, design, electronics and mechanical engineering found that informal IP mechanisms were cheaper, more effective than formal IPR and they believed result in lesser misuse and loss of IP. Arundel (2001) using the Community Innovation Survey in Europe shows that in general firms find secrecy to be a more relevant IP mechanism than patents especially for SME. He explains this by suggesting that firms are wary of information disclosures which might affect their competitive advantage. This aspect has been considered previously by Horstmann et al. (1985), Scotchmer (1990)[81] and Harter (1993) and empirically by Arundel et al., (1995) and Cohen et al. (1998).

However, Arundel (2001) also suggests that as firms increase in size, patents become a more important IP mechanism than secrecy for product innovations while finding no such relationship for process innovations. In a related study, Kitching and Blackburn (1998) further found that those SME possessing IPR preferred not to litigate upon infringement and preferred to use their resources for future innovation. Interestingly their results show that the adoption of formal IPR varies with the owners' perception of the innovation's market value and with increased size of the firm.

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[81] Theoretical models in general assume that all innovations are patented unless there is some reason why not disclosing would lead to greater benefits. Thus, informal IP mechanisms such as secrecy are not accounted for.

To summarize, the aforementioned literature review highlights that the use of IPR is normally related to firm innovation where the decisive input in the production function is new knowledge generated by R&D (Cohen and Klepper, 1991, 1992). This new knowledge is then protected using either formal or informal IPR mechanisms. As seen in the previous sections, there is an extensive amount of literature covering the use of both formal and informal IPR mechanisms though the bulk of this literature is partial to large firms and their use of IPR.

However, it is evident from later studies that SME contribute significantly to the innovation and knowledge pool. This could in part be attributed to the changing nature of production activities where in recent times, greater emphasis is being laid upon knowledge and innovation based products and services. In particular this refers to the areas of biotechnology and information technology where SME tend to be more IPR savvy than their counterparts. Though these ideas have been explored in the past, studies on specific industry sector and use of IPR still remain limited (Mann, 2006). Our paper contributes to this area of the literature where our dataset, which focuses exclusively on SME across eight countries in the ICT industry, enables us to examine whether the ICT industry promotes greater use of IPR and what the main motivators of formal IPR adoption within this sector are. It further highlights possible insights to whether knowledge based industries do result in higher levels of patenting by SME.

Research suggests that SME tend to make extensive use of informal IPR mechanisms which often tend to be cheaper and more effective. However, it has also been suggested that size impacts upon the use of formal IPR though some SME still prefer to use informal IPR mechanisms to avoid loss of competitive advantage. Due to the evident ambiguity, we examine this issue in the context of SME in the ICT industry and combine both the size difference within this segment and the impact of this industry being exclusively dependent on knowledge based innovation.

We further contribute to the literature by studying the use of IPR by SME within the ICT industry in a co-existence framework. This framework provides insights on how OSS affects the adoption of IPR within the ICT industry as measured by our dataset. Our final and most important contribution to the literature lies in the use of globalization as a determinant of IPR usage and *not* innovation as previously used by almost all the studies in the literature.

4.4 Research gaps and hypotheses

When considering early patenting behavior, one finds that innovative activity was concentrated in areas of close geographic proximity (Sokoloff, 1988, Jaffe et al, 1993, Moser, 2005): Mostly in cities and areas close to transportation facilities. Thus, knowledge spillovers were found to be highly localized. Moser (2005) analyzed geographical data on locations of innovations at a palace fair and data on the location of workers between 1841 and 1901. She finds that certain industries that originally focused on secrecy to protect their innovations, once patenting was introduced, these same innovations became more diffused. In other words she finds that the need for geographical proximity decreased with the onset of patents, particularly for the manufacturing industry. Patents enabled innovators to sell their inventions to adopters in different locations and promote subsequent economic activity and spillovers. Thus, patents enabled geographic diffusion.

In present day context, the onset of globalization has resulted in geographic dispersion and necessitated that firms become more competitive. A global industry is referred to as one where there is intense competition, standardized products, presence in key international markets and significant levels of international trade (Morrison, 1990). In general, high technology sectors tend to be more globally oriented and need patents to protect their innovations in the international market. Arundel (2000) suggests that those firms involved in R&D tend to patent more and firms that want to enter or export to foreign markets also find patenting important.

Johansson and Yip (1994) find in the context of globally integrated competitive strategy that firms who chose to go 'global' need also to consider strategy changes to suit the global environment. Drezner (2001) suggested that as firms become more international there is a natural convergence that takes place in terms of traditional national policies. Johansson and Yip (1994) contend that this integrated strategy to be pursued by global companies should facilitate greater benefits of globalization. However there is limited evidence regarding the presence of such global strategies.[82]

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[82] It should be noted that the benefits of globalization including cost reductions (Kogut, 1985), improved qualities (Yip, 1989), increased competitive leverage (Hout et al., 1982; Hamel and Prahalad, 1985) are dependent on the individual industry structure (Johansson and Yip, 1994).

We suggest that IPR adoption can be considered as one such global strategy that could be applicable to firms and perhaps also relevant in the SME context. The ICT industry can be classified as a global industry which depends solely on technological and knowledge based sustainability (Thoenig and Verdier, 2003). Put more simply, knowledge based firms are constantly looking for ways to maintain their market position and protect their IP.

Existing studies examine the question of IPR adoption from a more restrictive perspective by centering on innovation as the main determinant of IPR adoption. A survey of the relevant literature shows that the correlation between the tendency to patent in the ICT industry and globalization has not been studied before. Thus, based on the above discussion, the logical intuition that follows is that there is a positive correlation between globalization and the adoption of IPR. We further postulate that this is particularly relevant for the ICT industry which is highly global with production, distribution and knowledge being created all over the world. Thus, we formulate our first hypothesis.

H1: Companies with a higher number of patents exhibit higher levels of geographic dispersion.

Next we turn to the reasoning behind our second hypothesis. Research (Blackburn, 2003, Thumm, 2006) indicates that the main reasons for lack of use of IPR by SME are the costs of IP protection, enforcement of IP rights, the time it takes to process an application and limited awareness. A survey (Arundel and Steinmueller, 1997) carried out on Dutch SME in five high technology sectors showed high application costs, defence costs and information disclosure as the main reasons for not using patents. Application costs primarily refer to patent costs, particularly the Euro-patent which is more expensive than American or Japanese patents. Important to note is that patents can only be applied for at the national level which implies that firms wanting to extend the IPR to another country must apply and incur costs once again. This also includes costs of translating the patent in to the local language. Further when considering how innovation works in these sectors i.e., through sequentiality, the patent system seems to be too cumbersome and time consuming to keep pace with the short time-to-market and the rapid need for new products. Litigation costs i.e., defence costs, with large firms also create additional cost for SME who do not have the financial means to defend themselves.

According to the empirical study by Arundel (2000), it seems as though American firms favor IPR more as a means to facilitate independent innovation while their European counterparts favor IPR more as a means to share information through licensing or negotiations. Large firms are better informed about IPR systems and tend to obtain patents more frequently than SME. In fact the study by Cohen et al., (2002) found that the main reasons to patent were defensive i.e., to prevent copying, block competitors and limit or prevent lawsuits. A study carried out on Norwegian SME (Iverson, 2004) showed that large firms have a higher success rate of actually obtaining a patent. The author suggests that formal IPR has a larger role to play in the large firm's business strategy which is not necessarily the case for SME.

However, non-use of the formal IPR system also has negative effects which include wasted resources, duplication and litigation costs arising from infringements (Hall & Ham, 1999 and 2000). Pitkethly (2007) showed that limited knowledge about foreign patent laws combined with high costs resulted in restricting SME from patenting abroad. SME contribute much to innovation and as such may benefit a great deal from protection of innovative ideas.

While it is evident that there are many studies capturing the ineffectiveness of the current patent system for SME in terms of various costs, it is not clear whether SME would actually increase their use of formal IPR were the system revamped. Several studies indicate that SME believe that formal IPR mechanisms are more subject to misuse of IP and loss while informal methods are cheaper, more effective and tend to protect SME better (Kitching and Blackburn, 1998). SME still have less patents in absolute numbers than large firms (Iversen, 2002, Hanel, 2004, Gambardella, 2005) though it is still higher for those firms that are in the ICT industry who tend to be more informed about formal IPR methods, though they too rely largely on copyright (Moulin et al., 2005). Therefore we postulate the following:

H2: If legal frameworks were to be strengthened and made more SME friendly, SME would patent more.

Our third hypothesis is related to the lack of resources that SME tend to face and how they counter the same. Arrow (1962) in his theoretical model suggests that when IPR exist, competitive firms are more likely to innovate than monopolists. However, this model does not consider the financial situation of SME who are often more competitive than the incumbents but do not have the financial assets required to market their innovations. Levinthal and March

(1993) show that firms that are best suited to 'exploration' are not always the ones best suited to 'exploitation'. Mann (2005) suggests on the basis of an empirical study that small firms often have very valuable technology patents but are not able to enforce them. He further contends that this situation improves as firms grow. Thus, often SME need to license their IP in order to be able to commercialize their innovations. SME depend a lot more on licensing revenues for their future ventures than large firms do. Licensing reduces wasteful research imitation thereby allowing an inefficient patent in terms of length and breadth to be more optimal.

A very recent study carried out by Byma and Leiponen (2007) in Norway on innovative small firms in the Finnish manufacturing and service sectors shows that regardless of the industry, level of R&D intensity, innovations or R&D cooperation, the smallest firms rarely benefit from patenting. An explanation for this could be the lack of resources to commercialize various innovations. Thus, it seems that the benefits of IPRs for SMEs are mixed, on the one hand it gives them greater bargaining powers but at the same time they face greater litigation, reducing the net value of their patents. A solution to this scenario is in the form of cooperative research. Gambardella and Arora (1995) find in their study of the biotechnology industry found that small firms account for a significant amount of innovative activity but are unable to commercialize them. They observe that the result has been a new division of labor where the research is conducted by SME and the commercialization by large firms.

Research collaboration has been found to increase the propensity of firms to patent i.e., the percentage of innovations that are patented (Brower and Kleinknecht. 1999, Baumol, 2002). Arundel (2001) also finds weak evidence to state that firms collaborating in R&D ventures tend to patent more. Though there is scant evidence on the impact of research collaboration and the adoption of IPR, the existing studies seem to indicate that research collaboration does indeed play a role for SME adoption of IPR. The propensity to patent is different across sectors and firm size where high tech sectors have a higher propensity to patent than low tech sectors. Firms can use patents as a signaling mechanism to other firms in the market (Long, 2002). This enables them to attract funds, investment capital and research partners. We consider this particularly relevant for SME start-up firms in the ICT sector who generally tend to have only knowledge as their core asset which we believe should induce greater use of formal IPR technology transfer. Therefore, we hypothesize:

H3: The more SME participate in cooperative research, the higher are the chances that they will use formal IPR methods.

Our final hypothesis is related to the use of open source software and SME. Moulin et al., (2005), based on a study of Nordic firms and their use of IPR, found that firms involved in the production or use of open source software (OSS) tend to have more clarity regarding formal IP mechanisms i.e., copyright has a strong role to play in open source management. It should also be noted that companies that focus on OSS tend not be in favor of the patent system. This applies particularly to the ICT manufacturing sector which applies patents the most. Further firms that engage in OSS development place great importance on interoperability whereas formal IPR tends to inhibit the innovation and interoperability process (Farrell, 1995). Blind et al., (2003) studied German software enterprises and found that those firms developing OSS software were greatly inhibited by IPR. OSS provides several solutions to the problems of formal IPR mechanisms.

As evident, the economic literature provides a rich variety on the adoption of IPR and on the advantages and disadvantages of the same and the use of open and closed (proprietary) source software. However, there are very few papers (Bitzer, 2004, Casadessus-Masanell & Ghemawhat, 2003, Kuan, 2001) which examine the co-existence of open and closed source software and its impact on the adoption of IPR and there appears to be little work done which has examined this question in relation to SME. We believe that this co-existence is highly relevant to IPR adoption and provides SME an alternative opportunity to protect their IP. Therefore we formulate the following hypothesis.

H4: If an SME deploys and/or develops open source software, then the propensity to patent decreases.

4.5   Data collection, analysis and discussion

The dataset used in this paper is derived from the e-Business watch[83] project launched by the European Commission and its main purpose is to monitor the adoption, development, and the impact of electronic business on different sectors across Europe. As of 2007, the project also collects data on specific topical reports one of which was a survey on SME use of IPR in the ICT industry. Our data is confined to the European Union where SME form the bulk of firms

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[83] For further information regarding this project please consult, www.ebusiness-watch.org

representing 99% of all enterprises (European Commission 2005) across Europe. Prior to the accession of Bulgaria and Romania, the EU 25 had around 23 million SME in 2005 (Schmiemann, 2006). Thus, focusing our study on SME has particular relevance to the European context.

The dataset that we use for our analysis is based on firms in three sectors that produce information technology defined by the NACE Rev. 2 classification.[84] The segments included in the same are ICT Manufacturing (*manufacture of electronic components, manufacture of computers and peripheral equipment, manufacture of communication equipment, manufacture of computer electronics*), software (*publishing of computer games, other software publishing*) and ICT services (*telecommunications, information service activities*). SME in this context refer to those firms with less than 250 employees which is further subdivided in to micro (1 to 9 employees), small (10 to 50) and medium (50 to 250). A total of 683 SME firms in the 8 countries (Austria, Germany, Spain, France, Italy, Poland, The UK and Ireland) were questioned and the breakup is given below in Table 4.1.

Table 4.1 Break –up of firms by segment and size

ICT Manufacturing	
3-9	76
10-49	93
50-249	92
IT Services	
3-9	51
10-49	55
50-249	34
Software Publishing	
3-9	104
10-49	102
50-249	76

Source: eBusiness Watch

Our dataset, numbering 260 observations, allows us to compare the countries and sector as we

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[84] NACE refers to the General Industrial Classification of Economic Activities within European Communities. It was a classification originally created by Eurostat in 1970. The NACE Rev. 2 refers to a four digit classification of business activities and a revision of the NACE Rev. 1.1 classification. It came in to effect on January 1st, 2008.

have data from firms of a specific size and R&D class allowing us to standardize the survey results. For the purpose of our analysis, we employ the one way analysis of variance (ANOVA) test which is a common and powerful statistical procedure which performs pair-wise correlations. The one way ANOVA tests for differences among sample means across three or more independent variables which represent a single predictor. In our case, the single predictor i.e., the dependent variable is the use of IPR by SME measured by the use of patents.[85]

The ANOVA enables two independent estimates of population variance referred to as a) between groups sum of squares (denoted as Sum of Squares Treatment - SSTR) and b) within groups sum of squares (denoted as Sum of Squares Error - SSE). The former refers to the sum of squared differences of each sample mean from the group means of all the samples under consideration. The latter refers to the sum of squared deviations of each mean from the sample mean. An ANOVA tests whether the mean variances within the sample are greater than the mean variances between the groups of samples. This is established through the construction of an F-statistic, given below:

$$SSTR = \sum n_j \left(\overline{x}_{.j} - \overline{\overline{x}} \right)^2 \qquad MSTR = \frac{SSTR}{k-1}$$

$$SSE = \sum \sum \left(x_{ij} - \overline{x}_{.j} \right)^2 \qquad MSE = \frac{SSE}{n-k}$$

$$SST = SSTR + SSE \qquad F = \frac{MSTR}{MSE}$$

$$SST = \sum \sum \left(x_{ij} - \overline{\overline{x}} \right)^2$$

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[85] It was not possible to individually compare the various formal IPR mechanisms (patents, copyrights, trademarks and registered designs) and whether SMEs prefer one form of formal IPR to another. This was due to a measurement bias resulting from differences across cluster size.

ANOVA Table				
Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Treatments (Between)	SSTR	k-1	MSTR	
Error (Within)	SSE	n-k	MSE	
Total	SST	n-1		

(K -1) and *(N – k)* refer to the degrees of freedom for SSTR and SSE respectively. The new values can be referred to as between mean squares treatments (MSTR) and within mean squares error (MSE). If the former is significantly larger than the latter variance and the p value is less than the value at the .01 level of significance, then the hypothesis is accepted, otherwise rejected. By performing an ANOVA we are able to distinguish where the difference between these groups lies and pinpoint the main area of difference.

In the following we conduct the data analysis and provide short inferences for each result.

4.5.1 Geographic dispersion

Table 4.2: Descriptives

B1a: How many patents does your company currently have or has it applied for?

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Regional market	12	2.61	2.454	.711	1.04	4.18	1	12
(country) market	89	6.76	7.551	.802	5.16	8.35	1	30
International markets	102	15.73	36.656	3.623	8.54	22.92	1	230
Total	203	11.04	26.889	1.888	7.32	14.76	1	230

We first tested the impact of global dispersion on the use of formal IPR. Respondents were asked to identify their most significant market i.e., regional, country or international market. An analysis of the descriptives shows that the means vary across the different sectors i.e., regional, country and international, indicating that the number of patents held across the sectors varies. This result points to a positive relationship between geographic dispersion and the number of patents.

Having established the first significant level of analysis, we move to the next level of analysis, ANOVA.

Table 4.3: ANOVA

B1a: How many patents does your company currently have or has it applied for?

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4724.358	2	2362.179	3.327	.038
Within Groups	141276.69	199	709.933		
Total	146001.07	201			

From Table 4.3, it is evident that there is a significant relationship between increased market reach and the number of patents a company applies for (Table 4.3 shows a 0.038 level of significance). In other words, the further a company's geographic market expands i.e., from regional, country to international, the more number of patents they seem to employ. In order to further substantiate our results we conducted a third level of analysis, namely multiple correlations.

Table 4.4: Multiple Comparisons

Dependent Variable: B1a: How many patents does your company currently have or has it applied for?

	(I) G4: What is your company's most significant market? Is it MAINLY the regional market, the [country] market, or international markets which you consider your main sales area?	(J) G4: What is your company's most significant market? Is it MAINLY the regional market, the [country] market, or international markets which you consider your main sales area?	Mean Difference (I-J)	Std. Error	Sig.	90% Confidence Interval	
						Upper Bound	Lower Bound
Tamhane	Regional market	(country) market	-4.150(*)	1.072	.001	-6.48	-1.82
		International markets	-13.122(*)	3.692	.002	-21.03	-5.22
	(country) market	Regional market	4.150(*)	1.072	.001	1.82	6.48
		International markets	-8.972(*)	3.711	.051	-16.91	-1.03
	International markets	Regional market	13.122(*)	3.692	.002	5.22	21.03
		(country) market	8.972(*)	3.711	.051	1.03	16.91

* The mean difference is significant at the .1 level.

In Table 4.4, we observe that variables (I) and (J) are the same. This denotes that we are using the same variable but grouping it differently to be able to find the sources which lead to significant variances. We find from the results of the Tamhane[86] test that all the market moves are significant i.e., an expansion of market (country to international, regional to country and

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[86] We made use of the Tamhane test in this context because it does not require the homogeneity of variances and thus can be used for the analysis of our dataset.

regional to international) has a positive impact on the number of patents held. Thus, we conducted three levels of analysis to ensure the robustness of one of our main findings.

One possible interpretation of this finding could be that as a firm expands it earns greater revenue and therefore is more able to afford and employ formal IPR. Thus, it could be said that as an ICT SME firm expands geographically, its ability to compete increases which increases its adoption of IPR.

Globalization: As the geographic reach of an SME expands so does the tendency to patent.

4.5.2   Legal Frameworks

In order to consider the impact of legal frameworks on SME use of formal IPR, respondents were asked a series of questions regarding the effectiveness of IPR. The first descriptive table examines firm responses on whether IPR stimulates knowledge creation and innovation. Once again we find there to be a variance in the means which indicates a positive relationship between the number of patents and legal frameworks which aid in the creation of innovation.

Table 4.5: Descriptives

B1a: How many patents does your company currently have or has it applied for?

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
agree	88	16.13	39.248	4.182	7.82	24.44	1	230
disagree	97	7.13	8.024	.814	5.51	8.74	1	35
Total	185	11.41	27.968	2.055	7.35	15.46	1	230

In performing an ANOVA, it is evident that there is a significant relationship between the level of patenting and the ability of legal frameworks in enabling knowledge creation and innovation in a company. This result indicates that ICT SME rely on the patent system to further innovation. It could further imply that the adoption of IPR can enable SME to sell and develop their innovative output. Thus enabling market entry to compete or collaborate with larger firms, thereby increasing competition.

Table 4.6: ANOVA

B1a: How many patents does your company currently have or has it applied for?

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3743.765	1	3743.765	4.882	.028
Within Groups	140325.013	183	766.803		
Total	144068.778	184			

In further determining the impact of legal frameworks, firms were asked whether IPR is well suited to firm needs. Observing the means in the descriptives table, we observe some variance indicating possibly a positive relationship between the level of patenting and the suitability of the legal framework.

Table 4.7: Descriptives

B1a: How many patents does your company currently have or has it applied for?

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
agree	132	12.71	32.708	2.847	7.08	18.35	1	230
disagree	60	7.33	7.557	.976	5.38	9.29	1	30
Total	192	11.03	27.527	1.987	7.11	14.95	1	230

However on moving to the second level of analysis, ANOVA, we find that though there is relationship between the level of patenting and whether the legal framework is suited to a company's needs, the relationship based on the sample size is not significant.

Table 4.8: ANOVA

B1a: How many patents does your company currently have or has it applied for?

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1193.694	1	1193.694	1.572	.211
Within Groups	143507.879	189	759.301		
Total	144701.573	190			

Respondents were further asked whether the legal framework of IPR should be reformed to become more effective for SME. In examining the descriptives of firm responses to this question, we find that the means vary only marginally.

Table 4.9: Descriptives

B1a: How many patents does your company currently have or has it applied for?

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
agree	126	10.98	27.931	2.486	6.06	15.90	1	230
disagree	52	12.79	30.193	4.204	4.35	21.23	1	150
Total	178	11.51	28.531	2.140	7.28	15.73	1	230

We find that the between groups mean square is substantially lower than the within groups means square indicating that there is not so much variance across the groups and only within the groups. The ANOVA table shows us that though there is a relationship between the level of patenting and the reforming of legal frameworks, due to the sample size, the relationship is not significant. This result could provide evidence to the already existing literature that SME prefer informal methods for protecting their IP. This finding could further imply that ICT SME consider informal methods more efficient in enabling market entry and competition.

Table 4.10: ANOVA

B1a: How many patents does your company currently have or has it applied for?

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	119.268	1	119.268	.145	.704
Within Groups	143782.913	175	821.617		
Total	143902.181	176			

The last measure used to describe legal frameworks refers to cost. Firms were asked if the existing legal frameworks for IPR were too costly. Once again, we find that the means vary only marginally. In moving to the second level of analysis, we find that the between groups mean square do not vary and the variance comes from within in groups.

Table 4.11: Descriptives

B1a: How many patents does your company currently have or has it applied for?

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
agree	95	11.60	23.010	2.361	6.91	16.29	1	150
disagree	96	10.85	31.598	3.230	4.44	17.26	1	230
Total	191	11.22	27.585	1.998	7.28	15.16	1	230

Surprisingly, however, we find that the relationship between costs and the level of patenting is not significant (0.853). Much of the literature till now assumes that cost is a significant barrier

in adopting formal IPR by SME. High costs are also considered as impediments to market entry.

Table 4.12: ANOVA

B1a: How many patents does your company currently have or has it applied for?

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26.581	1	26.581	.035	.853
Within Groups	144291.439	188	767.508		
Total	144318.020	189			

We find through our analysis that this linear relationship between cost and the level of patenting not to be relevant for ICT SME. It is worth pointing out that ICT SME may earn more than their other counterparts suggesting that cost may not play a significant role in the adoption of formal IPR. This result provides basis for future research.

Thus, as business processes like legal frameworks aid in the generation of knowledge conducive to innovation, the level of patenting increases.

4.5.3 Cooperative research

The next factor that we examine is cooperative research. Firm were asked whether they participated in co-operative research projects with other firms. From the descriptive tables we observe varying means indicating the possibility of a positive relationship between the level of patenting and co-operative research.

Table 4.13: Descriptives

B1a: How many patents does your company currently have or has it applied for?

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Yes	123	13.02	33.661	3.033	7.01	19.02	1	230
No	76	7.66	8.484	.971	5.73	9.60	1	35
Total	200	10.97	27.043	1.914	7.19	14.74	1	230

In the ANOVA table, we find that the between groups mean square is greater than the within groups means square clearly indicating a relationship between the level of patenting and participating in cooperative research. However, perhaps due to lack of data, the relationship is not significant.

Table 4.14: ANOVA

B1a: How many patents does your company currently have or has it applied for?

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1350.649	1	1350.649	1.849	.175
Within Groups	143880.816	197	730.359		
Total	145231.465	198			

In order to further understand the impact that cooperative research has on patenting and the use of formal IPR, we ran a correlation of certain variables. The multiple correlations table examines pair wise correlations between the dependent variable i.e., how many patents does your company currently have and has it applied for. To add greater visibility for applied patents we also include a question on how many patents were applied for in the past 12 months. These two variables are correlated to three independent variables including a) significant market share i.e., regional, country and international markets, b) co-operative research and c) litigation i.e., firms were asked whether they were involved in a legal dispute over IPR in the last three years. This provided some very interesting insights which are summarized below.

Table 4.15: Multiple Correlations

		How many patents does your company currently have or has it applied for?	And how many patents have you applied for in the past 12 months?	Significant market share	Litigation	Did your company ever participate in a co-operative research project with other companies and organisations?
How many patents does your company currently have or has it applied for?	Pearson Correlation	1	.544(**)	-.174(*)	.(a)	-.079
	Sig. (2-tailed)		.000	.013	.	.263
	N	205	192	205	24	205
And how many patents have you applied for in the past 12 months?	Pearson Correlation	.544(**)	1	-.145(*)	.(a)	.048
	Sig. (2-tailed)	.000		.035	.	.489
	N	192	212	212	26	212
Significant market share	Pearson Correlation	-.174(*)	-.145(*)	1	.(a)	.196(**)
	Sig. (2-tailed)	.013	.035		.	.000
	N	205	212	683	52	683
Litigation	Pearson Correlation	.(a)	.(a)	.(a)	.(a)	.(a)
	Sig. (2-tailed)	.	.	.	.	.
	N	24	26	52	52	52
Did your company ever participate in a co-operative research project with other companies and organisations?	Pearson Correlation	-.079	.048	.196(**)	.(a)	1
	Sig. (2-tailed)	.263	.489	.000	.	
	N	205	212	683	52	683

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
a Cannot be computed because at least one of the variables is constant.

We find that the more patents a firm has, the more it will patent and this result is highly significant (0.544) at the 0.01 level as evident from the correlations table. Further we find that market expansion, from regional to country, country to international or regional to international, markets, is significantly correlated (at the 0.05 level) to patent use.[87] Another extremely interesting finding points to the positive and significant correlation between geographic dispersion and cooperative research (0.196). Geographic dispersion often takes the form of joint ventures or research collaborations which are examples of cooperative research. This is an important result because it also captures the OSS world. While the open source

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[87] As is evident, the value of the significance is negative. We attribute this to a partial correlation analysis which sometimes tends to result in negative values when the influences of other variables are controlled for.

community may not be in favor of increased patenting as a result of geographic expansion, they would be in favor of increased cooperative research through geographic dispersion as this allows technology transfer and increased competition.[88] This suggests that the OSS model is an example of cooperative research as well.

Though the relationship between cooperative research and the level of patenting is not significant, we find that cooperative research is correlated with geographic dispersion indicating that cooperative research has a role to play both for IPR and the co-existence of proprietary and open source software.

4.5.4   Deployment and development of OSS

The last factor that we considered in our analysis refers to open source software. Firms were asked about their development and deployment of open source software. We separated these two issues to examine their individual relationship to the adoption of IPR. The first table examines the development of OSS and how it affects the adoption of IPR among SME. The descriptives table shows us that only a few firms develop OSS.

Table 4.16: Descriptives

B1a: How many patents does your company currently have or has it applied for?

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
yes	50	6.26	7.911	1.119	4.02	8.51	1	30
no	146	12.74	31.152	2.580	7.64	17.84	1	230
Total	196	11.08	27.294	1.951	7.24	14.93	1	230

The ANOVA table shows us that the between groups mean square is greater than the within groups mean square indicating a relationship between the level of patenting and the development of OSS. However, the relationship is not significant.

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[88] Thereby we provide evidence to Bitzer and Schroeder's (2006) boundless cooperation idea of OSS development where due to the OSS ethic of free sharing of information, complementary programming skills can be exploited. Such activity leads to high levels of knowledge diffusion and is pro-innovation.

Table 4.17: ANOVA

B1a: How many patents does your company currently have or has it applied for?

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1560.590	1	1560.590	2.098	.149
Within Groups	143533.889	193	743.699		
Total	145094.479	194			

The descriptives table below indicates that many more of the respondents are using OSS in comparison to those developing OSS. In the second level of analysis we find a significant relationship between the level of patenting and the deployment of open source software. These findings indicate that the use of OSS reduces the level of patenting which confirm findings by other researchers in the field. Decreased levels of patenting could suggest that market entry is easier.

Table 4.18: Descriptives

B1a: How many patents does your company currently have or has it applied for?

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
yes	85	6.61	7.674	.833	4.95	8.26	1	30
no	110	14.37	35.427	3.376	7.68	21.06	1	230
Total	195	10.99	27.321	1.957	7.13	14.85	1	230

Table 4.19: ANOVA

B1a: How many patents does your company currently have or has it applied for?

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2888.408	1	2888.408	3.909	.049
Within Groups	141872.007	192	738.917		
Total	144760.415	193			

Interesting to note here is the fact that there is a relationship between OSS use and development and the level of patenting. This indicates that the use of IPR plays an important role in the presence of both open and closed systems and could imply increased competition

If SME deploy OSS, then the number of patents they have is less. Alternatively, if they don't deploy OSS, then they tend to patent more.In addition, we also examined the effect of firm size, the number of employees and turnover on the adoption of IPR. Respondents were asked

to identify whether their firms were very small, small or medium and whether the number of employees (turnover) had increased, decreased or remained constant over the last year. However, we found that though there was a relationship between these independent factors and the level of patenting, the relationship for all of them was insignificant. In the case of turnover, perhaps a larger sample size might have resulted in a significant relationship.

4.6   Conclusions

Since Schumpeter's original postulation that large firms are more suited to undertake innovative activity, techniques to measure innovative contributions have greatly improved thus enabling the visibility of SME and their role in the innovative process. In addition, social and economic changes focusing exclusively on SME, (Acs and Audretsch, 2005) have also contributed to highlighting the role of SME innovation. It is evident that market structure is changing (Jovanovic, 2001) and with it IPR.

The importance of IPR, both formal and informal mechanisms, varies with the sector and the firm's business strategy regarding innovation. Thus, while some SME do patent, informal methods still seem to be more effective. It has been suggested in the literature that IPR is highly relevant for those industries that revolve around knowledge based activities including telecommunications, software, instruments and pharmaceuticals. While there is extensive literature within this context for large firms, the evidence for small firms within the same context still remains scant.

Our paper focuses on SME within the software, telecommunications and instruments industries across Europe and their adoption of IPR based on e- Business watch data. To better understand the main determinants of IPR adoption by SME, we make use of analysis of variance. Our results provide four insights: First, we find a positive and significant relationship between globalization and the level of patenting. This result, to the best of our knowledge, has not been covered in the literature thus far. The second new finding refers to the importance of cooperative research towards the level of patenting and in geographic dispersion. Thus, higher levels of geographic dispersion lead to increased cooperative research. The third result, which confirms previous conclusions, shows a significant and positive relationship between legal frameworks that aid in the creation of knowledge and innovation and the level of patenting. Finally, we find a significant relationship between the use of OSS and the level of patenting which also corroborates earlier findings. It is evident from this result that IPR contribute to the

presence of open and closed systems within the ICT sector. While we were unable to find a significant relationship between firm size (very small, small and medium firms) and the level of patenting, it is clear that ICT SME are making use of formal IPR.

Our analysis provides a new perspective to the ongoing debate regarding the use of formal and informal IP mechanisms by SME. A possible interpretation to the findings in this paper could be related to the fact that competition in these markets is inextricably connected to innovation. Thus, policy for ICT SME adoption of IPR should focus on enhancing those parts of the legal framework which enhance innovation and in encouraging cooperative research which seems to benefit both the closed and open systems.

4.7 Appendix I: EBusiness Surveys

The e-Business watch project was launched by the European Commission in 2001. Its main purpose is to monitor adoption, development and the impact of electronic business in different sectors across Europe. The data is collected on the basis of representative surveys and questions regarding usage and relevance of ICT are questioned in conjunction with general background information which includes firm size, sector, country of origin, and number of employees. The sample drawn is a random sample of firms from the respective sector population in each country. This data is then used to create industry level indicators of ICT adoption.

Taking the ICT industry defined by the NACE Rev. 2 classification, the EU 25 has about 700,000 firms in the ICT industry of which micro enterprises constitute the large bulk of firms with the only difference being in ICT manufacturing. The survey for the 2007 project was divided in to four parts including sector and topic reports. One of these surveys collected data on ICT SME and their IPR adoption patterns upon which the present study is based. The data in this study covers the following countries: Austria, Germany, Spain, France, Italy, Poland, The UK and Ireland where the questionnaires were translated to the language of each participating country. In some countries, the target sample was not reached both in terms of sectors and size classes. Thus, other countries were used to compensate the sector shortfalls in other sectors. In this sample there was a shortfall of firms from Ireland which was compensated for by additional interviews in the UK. Problems that occurred were related to misinterpretation of various questions which often resulted in firms choosing the 'don't know' option. Additionally, trading companies said that they were not concerned with IPR.

2007 was the first year to have a cut off in terms of company size. Only companies with at least 10 employees were interviewed in order to examine the impact of micro enterprises in the European Union. The universe for this dataset is considered all the companies in the respective sectors and company sizes. For the IPR and SME data survey, the minimum requirements for each size class were fulfilled (0-9 employees, 10-49 employees and 50-250 employees). Samples were drawn locally by fieldwork organisations based on official statistical records and widely recognised business directories such as Dun & Bradstreet (used in several countries) or Heins und Partner Business Pool.[89]

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[89] Taken directly from Annex !: The e-business Survey 2007 – Methodology Report

The surveys were conducted using the computer aided telephone interview (CATI) method. Questions were by and large addressed to those people who were responsible for decisions regarding IPR and ICT products within the company. In smaller firms, this tends to be either the managing director or the owner. Only those firms either protecting IP or planning to protect IP were included in the sample. The only exception was when the company had developed new products, services or processes for the market over the last three years.

Bibliography

Acs, Z., J., D. B. Audretsch and M. P. Feldman, (1994), R&D Spillovers and Recipient Firm Size, in: *The Review of Economics and Statistics*, Vol. 76(2), pp. 336-340

Acs, Z. J. and D. B. Audretsch (1987), Innovation, Market Structure and Firm Size, in: *The Review of Economics and Statistics*, Vol. 69(4), pp. 567-574

Adams, W. J. and J. L. Yellen (1976), Commodity Bundling and the Burden of Monopoly, in: *Quarterly Journal of Economics*, Vol. 90, pp.475-498

Aigrain, P. (2002), A Framework for Understanding the Impact of GPL Copylefting vs Noncopylefting licenses, Working paper available at http://opensource.mit.edu/papers/aigrain2.pdf

Albert S. and K. Bradley (1997), *Managing Knowledge: Experts, Agencies and Organizations*, Cambridge University Press, Cambridge, UK

Anton, J. J. and D.A. Yao (1998), The Sale of Intellectual Property: Strategic Disclosure, Property Rights, and Incomplete Contracts, Duke University and the Wharton School, University of Pennsylvania.

Aoki, R. and Y. Spiegel (2003), Pre-grant Patent Publication, R&D and Welfare University of Auckland Working Paper, Revised version of Foerder Institute Working Paper No. 30-98

Arora, A., A. Fosfuri, and A. Gambardella (2001), Markets for Technology and their Implications for Corporate Strategy, in: *Industrial and Corporate Change,* Vol. 10(2), pp. 419-451

Arora, A. and R. P. Merges (2004), Specialized Supply Firms, Property Rights and Firm Boundaries, in: *Industrial and Corporate Change*, Vol. 13, pp. 451-475.

Arundel, A., (2001), The Relative Effectiveness of Patents and Secrecy for Appropriation, in: *Research Policy*, Elsevier, Vol. 30(4), pp. 611-624,

Arundel, A. (2000), Patents – The Viagra of Innovation Policy? *Prepared as part of the project "Innovation Policy in a Knowledge Based Economy"*, Commissioned by the European Commission

Arundel A. and I. Kabla (1998), What Percentage of Innovations are Patented? Empirical estimates for European firms, in: *Research Policy*, Vol. 27(2), pp.127-141

Arundel, A, and E. Steinmueller, (1998), The Use of Patent Databases by European Small and Medium-sized Enterprises, in: *Technology Analysis and Strategic Management*, Vol. 10(2), pp.157-173.

Arundel, A, I. Demandt, E. Steinmueller, S. Malo, (1997) Should SME's Patent More: Results of a survey and interview study of Dutch small and medium-sized enterprises, Maastricht: MERIT, SPRU paper

Audretsch, D (1995), Innovation, Growth and Survival, in: *International Journal of Industrial Organization*, Vol. 13(4), pp.441-457

Baake, P. and S. Swaminathan (2007), Die Interdependenz zwischen Innovationen in der Softwareindustrie und Patente und Uhrheberschutzrechten sowie der Ausgestaltung von Wettbewerbspolitik, Report for the German Federal Ministry for Economics and Technology

Baake, P. and T. Wichmann (2004), Open Source Software, Competition and Potential Entry, Berlecon Research Papers 0005, Berlecon Research

Bakos Y. and E. Brynjolfsson (2000), Bundling and Competition on the Internet, in: *Marketing Science*, Vol. 19(1), pp. 63-82

Bakos Y. and E. Brynjolfsson (1999), Bundling Information Good: Pricing, Profits and Efficiency, in: *Management Science*, Vol. 45, pp. 1613-1630

Baseman, K.C., F. R. Warren-Boulton and G.A. Woroch (1994), The Economics of Intellectual Property Protection for Software: The proper role for copyright, Economics Working Paper Archive at WUSTL, Washington.

Baumol, W. J. (2002), *The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism*, Princeton University Press

Baumol, W. J. (1977), On the Proper Cost Tests for Natural Monopoly in a Multi-product Industry, in: *American Economic Review,* Vol. 67(5), pp. 809-22.

Benkler, Y. (2002), Coase's Penguin or Linux and the Nature of the Firm, in: *Yale Law Review*, Vol. 112, pp. 369-446.

Berryman, K., J. Jones, and J. Mohiuddin (2007), McKinsey Corporate Performance Analysis Tool: The State of the Software Industry, In Collaboration with the Sand Hill Group M.R. Rangaswami

Besen, S. M. and L. J. Raskind (1991), An Introduction to the Law and Economics of Intellectual Property, in: *The Journal of Economic Perspectives,* Vol. 5(1), pp. 3-27.

Bessen, J. E. (2002), Patent Thickets: Strategic Patenting of Complex Technologies, available at http://www.researchoninnovation.org/thicket.pdf.

Bessen, J. E. (2002), What Good is Free Software? In: Hahn (eds.), *Government Policy Toward F/OSS Software*, AEIBrooking Joint Center for Regulatory Studies, Washington D.C.

Bessen, J. E. (2001), Open Source Software: Free Provision of Complex Public Goods, Research on Innovation Working Paper, available at http://ssrn.com/abstract=278148.

Bessen J. E. and E. S. Maskin (2000), Sequential Innovation, Patents and Imitation, Technical Report 00, MIT, Cambridge

Bessen J. E. and E. S. Maskin (2004), Revisited: Intellectual Property on the Internet: What's Wrong with Conventional Wisdom? Updated Version of Presentation at Internet Publishing and Beyond: The Economics of Digital Information and Intellectual Property, January, 1997

Bessen, J. E. and R. M. Hunt (2004a): An Empirical Look at Software Patents, Federal Reserve Bank of Philadelphia Working Paper 03-17R.

Bessen, J. E. and R. M. Hunt (2004b), The Software Patent Experiment, in: OECD, (ed.), *Patents, Innovation and Economic Performance*, OECD, Paris

Bitzer, J., (2004), Commercial versus Open Source Software: The Role of Product Heterogeneity in Competition, in: Economic Systems, Vol. 28(4), pp.369-381

Bitzer, J. and P.J.H. Schroeder (2006), Impact of Entry and Competition by OSS on Innovation Activity, in: Bitzer and Schroeder (eds.), *The Economics of Open Source Software Development*, Elsevier B.V.

Bitzer, J. and P.J.H. Schroeder (2005), Bug-Fixing and Code-Writing: The Private Provision of Open Source Software, in: *Information Economics and Policy*, Vol. 17(3), pp. 389-406.

Blackburn, R. A. (2003), Small firms, Innovation and Intellectual Property Management The context and a research agenda, in: Blackburn, R.A. (eds.), *Intellectual Property and Innovation Management in Small Firms*, Routledge, London. pp. 4-15

Blind, K. and J. Edler (2003) Idiosyncrasies of the Software Development Process and Their Relation to Software Patents: Theoretical considerations and empirical evidence, in: *Netnomics* Vol. 5, pp. 71–96.

Blind, K, J. Edler, R. Nack, and J. Straus (2003), Hintergrund und Ansatz der Studie [Background and approach of the study] in: *Software-Patente Eine empirische Analyse aus ökonomischer und juristischer Perspektive* [Software patents: An empirical study from an economic and legal perspective], (eds.) Knut Blind, Jakob Edler, Ralph Nack, and Joseph Straus, Heidelberg: Physika-Verlag

Blind, K., J. Edler, and M. Friedwald (2005), *Software Patents – Economic Impacts and Policy Implications,* Elgar, Cheltenham

Boldrine, M. and D. K. Levine (2004), 2003 Lawrence R. Klein Lecture, The Case Against Intellectual Monopoly, in: *International Economic Review*, Vol. 45(2), pp. 327-350

Bonaccorsi, A. and C. Rossi (2003c), Licensing Schemes in the Production and Distribution of F/OSS Software, Working Paper available at http://opensource.mit.edu/papers/bnaccorsirossilicense.pdf

Bonaccorsi, A. and C. Rossi (2003), Why Open Source Software Can Succeed, in: *Research Policy*, Vol. 32(7), pp. 1243-1258.

Bonaccorsi, A., S. Giannangeli, and C. Rossi (2004), Entry Strategies Under Dominant Standards — Hybrid Business Models in the Open Source Software Industry, Social Science Research Network (SSRN) Working Paper*,* at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=519842

Bresnahan, T. F. and S. Greenstein, (1999), Technological Competition and the Structure of the Computer Industry, in: Journal of Industrial Economics*,* Blackwell Publishing, Vol. 47(1), pp. 1-40

Brouwer, E., and A. Kleinknecht, (1999), Innovative Output and a Firm's Propensity to Patent: An exploration of CIS micro data, in: *Research Policy*, Vol. 28(6), pp. 615-624

Bruegge, B., D. Harhoff, A. Picot, O. Creighton, M. Fiedler, and K. Henkel, (2004), *Open Source Software – Eine Oekomische und Technische Analyse*, Springer, Berlin

Brynjolfsson, E. and C. F. Kemerer (1996), Network Externalities in Microcomputer Software: An Econometric Analysis of the Spreadsheet Market, in: *Management Science*, Vol. 42(12), pp. 1627-1647.

Byma J. and A. Leiponen, (2007), Can't Block, Must Run: Small Firms and Appropriability, *Forthcoming Research Policy*

Cabral, L. and B. Polak (2007), Dominant Firms, Imitation and Incentives to Innovate, Working Papers 07-6, New York University, Leonard N. Stern School of Business, Department of Economics

Carbajo, J., D. de Meza, and D. J. Seidmann (1990), A Strategic Motivation for Commodity Bundling, in: *The Journal of Industrial Economics*, Vol. 38(3), pp. 283-298

Carlton, D. W., and R. H. Gertner (2002), Intellectual Property, Antitrust, and Strategic Behaviour, NBER Working Papers 8976, National Bureau of Economic Research, Inc.

Carlton, D. W. and M. Waldman (2002), The Strategic Use of Tying to Preserve and Create Market Power in Evolving Industries, in: *RAND Journal of Economics*, Vol. 33, pp. 194-220

Carver, B.W. (2005), Share and Share Alike: Understanding and Enforcing Open Source and Free Software Licenses, in: *Berkeley Technology Law Journal*, Vol. 20(1), pp. 443-481.

Casadesus-Masanell, R. and P. Ghemawat (2003), Dynamic Mixed Duopoly: A Model Motivated by Linux vs. Windows, Strategy Unit Working Paper No. 04-012 and IESE Working Paper No. D/159

Chang, H.F. (1995), Patent Scope, Antitrust Policy, and Cumulative Innovation, in: *RAND Journal of Economics*, Vol. 26(1), pp.34-57.

Chen, Y. (1997), Equilibrium Product Bundling, in: *Journal of Business*, Vol. 70, pp. 85-103

Choi, J. P. (2004), Tying and Innovation: A Dynamic Analysis of Tying Arrangements, in: *The Economic Journal*, Vol. 114, pp. 83-101

Choi, J.P. (1990), Market structure, incentive to patent, and the pace of innovation, in: *Economic Letters*, pp. 273-283

Choi, J. P. and C. Stefanadis, (2001), Tying, Investment and the Dynamic Leverage Theory, in: *RAND Journal of Economics*, Vol. 32, pp.52-71

Clement, D. (2003), Does Innovation Require Intellectual Property rights? Available at www.reason.com?0303/fe.dc.creation.shtml

Coase, R. (1972), Durable Goods Monopolist, in: *Journal of Law and Economics*, Vol. 15(1), pp. 143-149.

Cohen, J. and M.A. Lemley (2001), Patent Scope and Innovation in the Software Industry, in: *California Law Review Inc*, 89(1), pp. 1-57

Cohen, W.M. (1995) Empirical Studies of Innovative Activity in: *Handbook of the Economics of Innovation and Technological Change*, edited by Paul Stoneman, Blackwell, Oxford

Cohen, W.M. Goto, A., Nagata, A., Nelson, R., Walsh, J. (1998), R&D Spillovers, Patents, and the Incentives to Innovate in Japan and the United States, Mimeo

Cohen W. M. and S. Klepper (1991), Firm Size versus Diversity in the Achievement of Technological Advance, in: *Handbook of Industrial Organization*, Vol. 2 (eds.) R. Schmalensee and R. Willig, pp. 1059-1107, Amsterdam

Cohen W.M. and S. Klepper (1992), The Trade-off between Firm Size and Diversity in the Pursuit of Technological Progress, in: *Small Business Economics*, Vol. 4(1), pp. 1-14

Cohen, W., R. Nelson, and J. Walsh (2000), Protecting their Intellectual Assets: Appropriability Conditions and Why US Manufacturing Firms Patent (or not), NBER Working Paper 7552

Comino S. and F. Manenti (2003), F/OSS vs. Closed Source Software: Public Policies for the Software Market, Working Paper, University of Padova

Crampes, C. and C. Langinier (1998), Information Disclosure in the Renewal of Patents, in: *Annales D'Economie et de Statistique*, Vol. 49/50, pp. 265-288.

Diamond and L. Torvalds, (2001),

Dalle, J. M., and N. Jullien (2003), 'Libre' Software: Turning Fads into Institutions, in: *Research Policy*, Vol. 32, pp. 1-11.

Davies, S and B. Lyons (1988), (eds.), Economics of Industrial Organization, Longman Group UK Limited, Essex, England

Director, A. and E. Levi (1956), Law and the Future: Trade Regulation, in: *Northwestern Law Review*, Vol. 51, pp. 281-296

Drezner, D. W., (2001), Globalization and Policy Convergence, in: *International Studies Review*, Vol. 3(1), pp. 53-78

Ebinger, T. (2005), Tragen die Juristen Open Source Software zu Grabe? in: Lutterbeck et al (eds.) *Die GNU vor Gericht*, Chapter 4, pp. 249-269

Economides, N. and E. Katsamakas (2005) Linux vs. Windows: A Comparison of Application and Platform Innovation Incentives for Open Source and Proprietary Software Platforms, NET Institute Working Paper No. 05-07

Eeckhout, J and B. Jovanovic (2002), Knowledge Spillovers and Inequality, in: *The American Economic Review*, Vol. 92(5), pp. 1290-1307

Elevald, J. (2007), Companies IP Strategy; Presentation at the PATINNOVA 2007 Conference, Munich, April 14, 2007 Presentation available at: http://www.european-inventor.org/pdf/patinova/ The_Marchant_Report_Eleveld.pdf

Enos, J.L. (1962), *Petroleum Progress and Profits: A History of Process Innovation*, Cambridge, Massachusetts, MIT Press.

Evans, D. S. and B.J. Reddy (2003) Government Preferences for Promoting Open Source Software: A Solution in Search of a Problem, in: *Michigan Telecommunications and Technology Law Review*, Vol. 9(2), pp. 313-394.

Farrell, J. (1995), Arguments for Weaker Intellectual Property Protection in Network Industries, in: *ACM Journal*, Vol. 3(2), pp.46-49

Farrell, J. and M.L. Katz (1998), The Effects of Antitrust and Intellectual Property Law on Compatibility and Innovation, in: *The Antitrust Bulletin*, Vol. 43(¾), pp.609-650.

Franke, N. and E. von Hippel (2003a). Finding Commercially Attractive User Innovations, MIT Sloan School of Management Working Paper No. 4402-03

Friedewald, M. K. Blind, and J. Edler (2002), Die Innovationstaetigkeit der Deutschen Softwareindustrie, in: *Wirtschatsinformatik*, Vol. 44(2), pp. 151-161

Fudenberg, D. and J. Tirole (1984), The Fat-Cat Effect, The Puppy-Dog Effect, and the Lean and Hungry Look, in: *The American Economic Review*, Vol. 74(2), pp. 361-366

Galbraith, J. K. (1952a) *American Capitalism: The concept of countervailing power*, Houghton Mifflin, Boston

Gallini, N. (2002), The Economics of Patents: Lessons from Recent U.S. Patent Reform, in: *Journal of Economic Perspectives,* Vol. 16(2), pp. 131-154.

Gallini, N. and S. Scotchmer (2001), Intellectual Property: When is it the Best Incentive System, in: *Innovation Policy and the Economy,* Vol. 2, Cambridge, Massachusetts: MIT Press, chapter 2.

Gambardella, A., 2005, Patents and the Division of Inventive Labor, in: *Industrial and Corporate Change*, Vol.14 (6), pp.1223-1233 (Comment to Arora and Merges, *ICC*, 2004)

Gambardella, A. (2007) Intellectual Property and Markets for Technology, Conference Paper at The Economics of Technology Policy, Monte Verita, Switzerland.

Gambardella, A. and A. Arora (1995), Division of Innovative Labour in Biotechnology, in: Rosenberg, N. and Geijins, A. (eds.) *University-Industry Interface and Medical Innovation*, National Academy of Sciences, Washington DC.

Gandal, N. (1994), Hedonic Price Indexes for Spreadsheets and an Empirical Test of the Network Externalities Hypothesis, in: *RAND Journal of Economics,* Vol. 25(1), pp.160-170.

Garzarelli, G. (2003), Open Source Software and the Economics of Organization, Industrial Organization 0304003, EconWPA

Gehring, R.A. (2006), The Institutionalization of Open Source, in: *Poiesis & Praxis: International Journal of Technology Assessment and Ethics of Science,* Vol. 4(1), pp. 54-73

Ghemawat, P. and M. A. Spence (1985), Learning Curve Spillovers and Market Performance, in: *The Quarterly Journal of Economics*, Vol. 100, pp.839-852

Ghosh, R. (2006), Study on the: Economic Impact of Open Source Software on Innovation and the Competitiveness of the Information and Communication Technologies Sector in the EU, UNU-Merit, Netherlands

Gilbert, R. J. and M. H. Riordan (2006), Product Improvement and Technological Tying in a Winner-Take-All Market, in: *The Journal of Industrial Economics*, Vol. 55(1), pp. 113-139

Gilbert R. and C. Shapiro (1990), Optimal Patent Length and Breadth, in: *RAND Journal of Economics*, Vol. 21, pp.106-112

Giuri, P., Mariani, M., Brusoni, S., Crespi, G., Francoz, D., Gambardella, A., Garcia-Fontes, W., Geuna, A., Gonzales, R., Harhoff, D., Hoisl, K., Lebas, C., Luzzi, A., Magazzini, L., Nesta, L., Nomaler, O., Palomeras, N., Patel, P., Romanelli, M., Verspagen, B., 2007, Inventors and invention processes in Europe. Results from the PatVal-EU Survey, in: *Research Policy*, Vol. 36 (8), pp.1107-1127

Gower's review of intellectual property (2006) available at: http://www.hm-treasury.gov.uk/media/6/e/pbr06_gowers_report_755.pdf

Graham S. and D. C. Mowery (2003), Intellectual Property Protection in the Software Industry, in: W.M. Cohen & S.A. Merrill, (eds.) *Patents in the Knowledge Based Economy*, National Academies Press, Washington D.C.

Griliches, Z. (1990), Patent statistics as economic indicators: A survey, in: *Journal of Economic Literature*, Vol. 28, pp.1661-707.

Gul, F., H. Sonnenschein and R. Wilson (1986), Foundations of Dynamic Monopoly and the Coase Conjecture, in: *Journal of Economic Theory*, Vol. 39(1), pp.155-190.

Hall, B.H. (1999), On Copyright and Patent Protection for Software and Databases: A Tale of Two Worlds, ESF-IISA-NSF Workshop.

Hall, B.H. and R. Ham (1999), The Patent Paradox Revisited: Determinants of Patenting in the US Semiconductor Industry 1980-94, NBER Working Papers 7062

Hall, B.H. and R. Ham (2000), The Patent Paradox Revisited: Determinants of Patenting in the US Semiconductor Industry 1980-94, Development and Comp Systems 9912001, EconWPA

Hall, B.H. and M. MacGarvie (2006), The Private Value of Software Patents, NBER Working Papers 12195.

Hall, B.H. and R. Zeidonis (2001), The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry 1979-1995, in: *RAND Journal of Economics*, Vol. 32(1), pp.101-128.

Heller, M.A. and R.S. Eisenberg (1998), Can Patents Deter Innovation? The Anti-commons in Biomedical Research, in: *Science*, Vol. 280(5364), pp. 698-701.

Henderson, R. and I. Cockburn (1996), Scale, Scope and Spillovers: The Determinants of Research Productivity in Drug Discovery, in: *RAND Journal of Economics*, Vol. 27(1), pp. 32-59.

Hicks, D. T. Breitzman, D. Olivastro, and K. Hamilton (2001), The Changing Composition of Innovative Activity in the U.S.: A Portrait Based on Patent Analysis, in: *Research Policy* Vol. 30, pp. 681-703.

Hotelling, H. (1929), Stability in Competition, in: *The Economic Journal*, Vol. 39(153), pp.41-57

Howitt, P. (2007), Innovation, Competition and Growth: A Schumpeterian Perspective on Canada's Economy, in: *C.D. Howe Institute Commentary*, No. 246 available at: http://www.cdhowe.org/pdf/commentary_246.pdf

Huppertz, M.T. (2004), The Role of IPR for the Software Industry: A Changing Landscape? in: *Patents, Innovation and Economic Performance* – OECD Conference Proceedings, pp. 295-298

IPR Helpdesk: All briefs available at www.ipr-helpdesk.org
- Software Copyright
- Software Copyright Licensing
- Software Copyright and the Computer Programmer
- Exhaustion of Copyright
- Software Development Agreements
- Patentability of Computer Programs in Europe

Iversen, E. J. (2004), Norwegian SMES and the IPR System or a Small Country's Small Companies in an Increasingly BIG and IPR Intensive World, 13th NCSB Conference Proceedings

Jaffe, A. (1986), Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits and Market Value, in: *American Economic Review*, Vol. 76, pp. 984-1001.
Jansen, J. (2006), Share to Scare: Technology Sharing Incentives in the Absence of Intellectual Property Rights, Conference Paper for the 14th WZB Conference on Markets and Politics, Berlin, Germany

Johansson, J. K., and George S. Yip (1994), Exploiting Globalization Potential: U.S. and Japanese Strategies, in: *Strategic Management Journal*, Vol. 15(8), pp. 579-601

Johnson, J. P. (2001), Economics of F/OSS Software, Working Paper available at: http://opensource.mit.edu/paper/johnsonopensource.pdf

Kitching, J., and R. Blackburn, (1998), Intellectual Property Management in the Small and Medium Enterprise (SME), in: *Journal of Small Business and Enterprise Development*, Vol. 5(4), pp. 327-335

Kuan J. (2001), F/OSS Software as Consumer Integration in to Production, Working Paper available at: www.papers.ssrn.com/paper.taf?abstract_id=259648

Lakhani K. and R. Wolf (2001), Does Free Software Mean Free Labor? Characteristics of Participants on Open Source Communities, Boston Consulting Group Survey Report, available at: www.osdn.com/bcg/

Lanjouw J.O. and M. Shankerman (2001), Characteristics of Patent Litigation: A Window on Competition, in: *RAND Journal of Economics*, Vol. 321, pp. 129-151

Lee, J. (2006), New Perspectives on Public Goods Production: Policy Implications of Open Source Software, in: *Vanderbilt Journal of Entertainment and Technology Law,* Vol. 9(1), Stanford Law School.

Lee, S, N. Moisa and M. Weiss, (2003), F/OSS as a Signaling Device: An Economic Analysis, Working paper available at: http://opensource.mit.edu/papers/leemoisaweiss.pdf

Lerner, J. and J. Tirole (2002a), The Simple Economics of Open Source, NBER Working Paper No. 7600

Lerner, J. and J. Tirole (2005), The Economics of Technology Sharing: Open Source and Beyond, in: *Journal of Economic Perspectives*, Vol. 19(2), pp. 99-120.

Lerner, J. and J. Tirole (2002), Some Simple Economics on Open Source, in: *Journal of Industrial Economics,* Vol. 50(2), pp. 197-234.

Lerner, J. and F. Zhu (2005), What is the Impact of Software Patent Shifts? Evidence from Lotus vs. Borland, NBER Working Paper 11168, (forthcoming *International Journal of Industrial Organization)*

Lessig, L (2002), F/OSS Baselines: Compared to What? in: Hahn (eds.) *Government Policy Toward F/OSS Software*, AEIBrooking Joint Center for Regulatory Studies, Washington D.C.

Lessig, L. (2004), *Free Culture*, New York: Penguin Press.
Lucas, R. Jr., (1988) On the Mechanics of Economic Development, in: *Journal of Monetary Economics*, Elsevier, Vol. 22(1), pp. 3-42
Mann, R., J., (2006), Patents and Business Models for Software Firms, in: *American Law and Economics Associations Annual Meetings*, Paper 3 http://law.bepress.com/alea/16th/bazaar/art3

Mann, R.J. (2005), Do Patents Facilitate Financing in the Software Industry, in: *Texas Law Review*, Vol. 83(4), pp. 961-1030.

Masurel, E., (2004), Use of Patent Information: Empirical Evidence from Innovative SMEs, Centre for innovation and corporate sustainability, Free University, Amsterdam, Netherlands

Maurer, S.M., and S. Scotchmer (2006), Open Source Software: The New Intellectual Property Paradigm, NBER Working Papers 12148, available at http://ideas.repec.org/p/nbr/nberwo/12148.html.

Menell, P.S. (1987), Tailoring Protection for Computer Software, in: *Stanford Law Review*, Vol. 39, pp. 1329-1377

Merges, R.P. (1999a), As Many as Six Possible Patents before Breakfast: Property Rights for Business Concepts and Patent System Reform, University of California at Berkeley Working Paper
Merges, R.P. and R. Nelson (1990), On the Complex of Patent Scope, in: *Columbia Law Review,* Vol. 90(4), pp. 839-916

Meurer, M.J. (2003), Controlling Opportunistic and Anticompetitive Intellectual Property Litigation, in: *Boston College Law Review*

Moser, P., (2005), Do Patent Laws Help to Diffuse Innovations: Evidence from the Geographic Localization of Innovation and Production in 19th century England, NBER and MIT Sloan Working Paper

Nalebuff, B. (2004), Bundling as an Entry Barrier, in: *Quarterly Journal of Economics*, Vol. 119(1), pp. 159-187

Nalebuff, B. (2000), Competing Against Bundles, in: P. Hammond and G. Myles (eds.) *Incentives, Organization and Public Economics*, Oxford University Press

Narduzzo A. and A. Rossi, (2005), The Role of Modularity in Free/Open Source Software Development, in: S. Koch (eds.) *Free/Open Software Development*, Idea Group

O'Donoghue, T., S. Scotchmer, and J. Thisse (1998), Patent Breadth, Patent Life and the Pace of Technological Improvement, in: *Journal of Economics and Management Strategy*, Vol. 7, pp. 1-32.

Pilch, H. (2004), Why are Software Patens so Trivial? in: *Patents, Innovations and Economic Performance* – OECD Conference Proceedings, pp. 289-294

Powell, W.W. (1990), Neither Market nor Hierarchy: Network Forms of Organization in: *Research in Organizational Behavior*, Vol.12, pp.295-336

Pruefer, J. (2004) Why do Developers and Firms Contribute to the Production of Open Source Software? University of Frankfurt Working Paper

Raymond, E.S. (2002), The Cathedral and the Bazaar, available at http://www.catb.org/~esr/writings/cathedral-bazaar/cathedral-bazaar/

Regibeau P. and K. Rockett, (2004), The Relationship Between Intellectual Property Law and Competition Law: An Economic Approach, Economics Discussion Papers 581, University of Essex, Department of Economics

Renner T. et al., (2005), Open Source Software – Einsatzpotentiale und Wirtschaftlichkeit, Studie, Fraunhofer-Institut fuer Arbeitwirtschaft un Organization IOA, Competence Center Electronic Business, available at: www.e-business.iao.fraunhofer.de/docs/fhg_oss-studie.pdf

Romer, P. M. (19860 Increasing Returns and Long-run Growth, in: *Journal of Political Economy*, University of Chicago Press, Vol. 94(5), pp. 1002-37

Rossi, M.A. (2004), Decoding the Free/Open Source (F/OSS) Software Puzzle – A Survey of Theoretical and Empirical Observations, Working Paper, University of Siena

Salinger, M. A. (1995), A Graphical Analysis of Bundling, in: *Journal of Business*, Vol. 68, pp.85-98

Samuelson, P. (1990), Benson Revisited: The Case against Patent Protection for Algorithms and Other Computer Program Related Inventions, in: *Emory Law Journal,* Vol. 39, pp.1025-1154.

Samuelson, P., R. Davis, M. Kapor and J.H. Reichman (1994), A Manifesto Concerning the Legal Protection of Computer Programs, in: 94 *Columbia Law Review* 2308

Samuelson, P. and S. Scotchmer (2002), The Law and Economics of Reverse Engineering, in: *Yale Law Journal*, Vol. 111, pp. 1575-1663.

Schmalensee, R. (1982), Commodity Bundling by Single Product Monopolies, in: *Journal of Economic Perspectives,* Vol. 5(1), pp. 29-41

Schmidt, K.M. and M. Schnitzer (2002), Public Subsidies for Open Source Some Economic Policy Issues of the Software Market, Conference Paper: Open Source Software: Economics, Law and Policy, Toulouse June 20-21.

Schiff, A. (2002), The Economics of Open Source Software: A Survey of the Early Literature, in: *Review of Network Economics*, Vol. 1(1)

Schumpeter, J.A. (1942), *Capitalism, Socialism and Democracy*, Harper and Brothers, New York, (Original Publication)

Scotchmer, S. (1991) Standing on the Shoulders of Giants: Cumulative Research and the Patent Law, in: *Journal of Economic Perspectives*, Vol. 5(1), pp.29-41.

Scotchmer, S. (1996), Protecting Early Innovators: Should Second-Generation Products be Patentable, in: *RAND Journal of Economics*, Vol.27, pp. 322-331.

Scotchmer, S. and J. Green (1995), On the Division of Profit in Sequential Innovations, in: *RAND Journal of Economics*, Vol. 26(1), pp.20-33.

Scotchmer, S. and S. Maurer (1998), The Independent Invention Defense in Intellectual Property, John M. Olin Paper 98-11, Boalt School of Law, University of California at Berkeley.

Shapiro, C. (2003) Antitrust Limits to Patent Settlements, in: *RAND Journal of Economics*, Vol. 34(2), pp.391-411.

Shapiro, C. (2001b), Navigating the Patent Thicket, in: Adam Jaffe, Joshua Lerner and Scott Stern eds., *Innovation Policy and the Economy*, National Bureau of Economics, Washington.

Shy, O. and J. Thisse (1999), A Strategic Approach to Software Protection, in: *Journal of Economics & Management Strategy*, Vol. 8(2), pp.163-190.

Smets-Solanes, J.P. (2000), Software Useright: Solving Inconsistencies of Software Patents. Conference Paper for Second Nordic European/USENIX, Sweden

Smets-Solanes, J.P. (2001), Stimulating Competition and Innovation in the Information Society, Working Paper, available at: www.pro-innovation.org.

Steinmueller, E. W. (1995), The Software Industry: An Analysis and Interpretive History, in: David C. Mowery (eds.) *The International Computer Software Industry*, Oxford University Press

Stigler, G. J. (1968), A Note on Block Bundling, in: G. J. Stigler (eds.) *The Organization of Industry*, (Homewood, IL: Richard D. Irwin)

Thoenig M. and T. Verdier (2003), A Theory of Defensive Skill-Biased Innovation and Globalization, in: *The American Economic Review*, Vol. 93(3), pp. 709-728

Torvalds, L. (1998), What motivates free developers?, Interview in First Monday 33, available at: http://firstmonday.org/issues/issue3_3/torvalds/index.html.

Varian, H.R. and C. Shapiro (2003), Linux Adoption in the Public Sector: An Economic Analysis, University of California at Berkeley Working Paper.

Varian, H.R., J. Farrell and C. Shapiro (2004), *The Economics of Information Technology*, Cambridge University Press, Massachusetts.

Vives, R. (2002), Discussion of: The Law and Economics of Reverse Engineering, available at http://faculty.insead.edu/vives

Von Hippel, E. (2005), Open Source Software Projects as user Innovation Networks – No Manufacturer Required, in J. Feller, B. Fitzgerald, S.A. Hissam and K.R. Lakhani (eds.) *Perspectives on Free and Open Source Software,* MIT Press, Cambridge, Massachusetts.
Von Hippel, E. (2005b), *Democratizing Innovation*, MIT Press, Cambridge, Massachusetts

Von Hippel E. and G. von Krogh, (2003), Open Source and the "Private Collective" Innovation Model: Issues for Organization Science, in: *Organization Science*, Vol. 14(2)

Weber, S. (2004), *The Success of Open Source*, Cambridge, Massachusetts: Harvard University Press.

Wheeler, D. A. (2005), Why Open Source Software/Free Software (OSS/FS, FLOSS or FOSS)? Available at www.dwheeler.com/oss_fs_why.html

Whinston, M. D. (1990), Tying, Foreclosure, and Exclusion, in: *American Economic Review*, Vol. 80, pp. 837-859

Selbstständigkeiterklärung

Ich bezeuge durch meine Unterschrift, dass meine Angaben uber die bei der Abfassung meiner Dissertation benutzten Hilfsmittel, über die mir zuteil gewordene Hilfe sowie über fruhere Begutachtungen meiner Dissertation in jeder Hinsicht der Wahrheit entsprechen.