1. Introduction

1.1 INNOVATION, TRANSACTIONS AND MARKET INTERMEDIARIES

To create and sustain a competitive advantage and subsequently ensure continuous growth, many firms focus on the creation of innovations. These firms often find themselves in an innovation race against competitors, thus being forced to accelerate their processes from ‘simply being ideas’ to their actual launch on the markets (Cooper, 2008). While firms’ tendency to innovate depends primarily on their internal resources in their research and development (R&D) departments, this has become difficult mainly due to the increasing ‘complexity of modern technology’ resulting from the cumulative nature of many technologies[1] and technical products (Hall, 2004: 4). According to Granstrand (2000b: 9), ‘products and services are not only becoming increasingly based on new technologies, but increasingly based on many different technologies. That is, products and services become more multi-technological’.[2]

Nowadays, for instance, automobiles can hardly be regarded as discrete products but must be seen as complex technical systems that include a wide range of electronics and software components that were not built into automobiles in the 1970s (Miyazaki and Kijima, 2000). The global system for mobile communications’ (GSM) standard for mobile telephony is another example. According to Bekkers et al. (2002), GSM includes at least 140 essential patent families with the major share being scattered across large multinational competitors (that is Motorola owns 18 per cent; Nokia 13 per cent; Alcatel 10 per cent; Philips 9 per cent, and Telia 7 per cent).[3] There are various other examples. For instance, the DVD media technology consists of 500 patents from 28 countries owned by nine patent holders, the MPEG four technology is made up of 196 patents from 21 countries owned by 22 patent holders, the Ethernet technology comprises 70 patents from four countries owned by 65 patent holders, and Wifi technology (802.11 wireless) holds 100 patents from seven countries and 91 patent holders (Aggarwal and Walden, 2009).

The growing complexity of technical products is well reflected in empirical statistics. Kash and Rycroft (2002) prove that complex technologies comprised 43 per cent of the 30 most valuable world goods exports in 1970, however by 1996, complex technologies represented 84 per cent of those goods. von Graevenitz et al. (2008) show that there was a strong increase in complex technology patents between 1978 and 2003. This was calculated by determining whether the annual patent applications filed at the EPO and USPTO are complex or discrete according to dichotomic categorization proposed by Cohen et al. (2000).

The growing complexity of technical products and systems has increased firms' uncertainty with regard to freedom-to-operate (that is whether they possess all the necessary intellectual property (IP) assets to be allowed to manufacture a certain product). Consequently, the risk of litigation has increased, especially for large multinational firms. Particularly in the US, but also to some extent in Europe, non-practicing entities (often labeled 'patent trolls') have recently filed enormous infringement cases against large firms pressing for damages and licensing royalties. For instance, in 2001, Research in Motion (RIM), the Blackberry manufacturer, was sued by the 'non-manufacturing entity' NTP for infringing on its patents 'covering the use of radio frequency wireless communications in e-mail systems.' In 2006, the case was settled with RIM paying US$612.5 million to NTP (Tietze and Herstatt, 2010: 8). In another high profile patent case, Intel reached a US$525 million settlement of a suit alleging that Intel's Pentium family of microprocessors infringed Intergraph's patents (Gilbert and Katz, 2007). In Europe, one of the first high-number infringement cases started in 2008 when IP-Com sued Nokia at the German patent court in Mannheim for infringing about a thousand patents of some 150 patent families. IPCom, who bought the patents from Robert Bosch GmbH in 2006, claims €12 billion in damages (Nokia, 2009: 124).

Behnken (2005: 1) concluded this trend, arguing that because 'products and technologies are becoming increasingly complex… supporting activities to conceptualize, develop and promote the product become increasingly detailed and comprehensive… [and] the competencies to develop new technologies or products are functionally and spatially dislocated… [therefore, firms require] various competencies over organizational and geographical boundaries to develop a complex innovation.'[4] In addition, Granstrand (2003a: 233f) summarized this trend arguing that nowadays new technologies are 'interacting with each other and with old technologies in more complex and interdependent ways … [meaning] that patents and businesses become more cross-linked and interdependent with each new business becoming reliant on an increasing number of patents and each new patent having an impact on an increasing range of businesses on average… Thus, in a new technology as well as in a product market, there will be not only more agents on average, but increasingly interdependent agents in a mixture of cooperation and competition ('coopetition' or 'competeration').'

Opening up the innovation process to cope with growing complexity

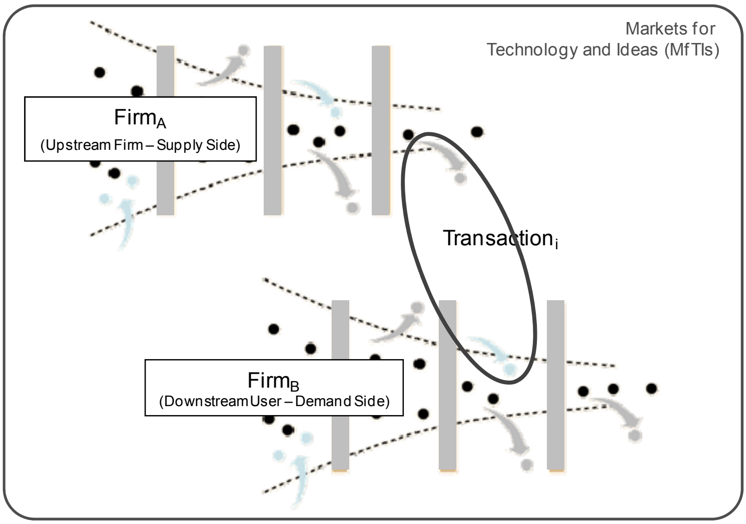
The increasing complexity of many technical products and systems makes it economically impossible for a single firm to internally develop all the technologies necessary for an innovation and particularly the IP assets required to enable freedom-to-operate in order to prevent costly litigation. Specifically with regard to IP assets firms – particularly those in highly competitive industries – often face an IP assembly problem that might be substantial, especially if important strategic patents are scattered across competing firms.[5] Hence, such an IP assembly problem can create hold-up problems, slowing down development processes, for instance 'when a patent owner refuses to allow a technology developer the use of a patent after the technology has already been developed' and it is difficult and costly to invent complementary parts for that technology (Aggarwal and Walden, 2009: 24).[6] In addition, where an innovation requires several complementary patents, fragmented property rights can limit firms' willingness to invest in R&D (Clark and Konrad (2008), Ziedonis (2008)). In contrast, firms often undertake redundant research and develop technologies that are valuable to other firms as well. Even if they are actively used by their inventors, technologies could also be embedded into other firms' products (for example, because they have been established as an industry standard). Moreover, technologies that are not used by their inventors might still be valuable to other firms that could then avoid own R&D efforts.[7]

Thus, mainly due to the growing complexity of many technical products and systems, firms not only need to manage the innovation process (that is their R&D activities), but also draw increasing attention to the management of their IP assets.[8] While firms should at least manage their IP portfolio to eliminate the risk of litigation, they can furthermore realize benefits for the more efficient creation of innovations through successful IP management. While a firm can conduct internal R&D efforts to develop its own solution to a technical problem, taking a license from another firm that has already developed a solution, might not only save resources but also accelerate the firm's innovation activities.

As a result, firms have recently started to innovate more openly in (international) networks, often even together with competitors that own technologies or IP assets relevant for industry standards.[9] Technology trade on the markets for technologies and ideas (MfTI)[10], for example, through licensing and particularly cross licensing, becomes increasingly necessary as a means to solve the IP assembly problem and holds advantages for both the technology owner and the firm willing to acquire or license it (Granstrand, 2003a). Firms that own a technology can generate additional revenues, thereby increasing their own R&D return ratio through the external exploitation of those technologies.[11] According to the European Commission (2008: 32), nowadays, 'firms increasingly diffuse intellectual property beyond firm and even country boundaries, as firms innovate more openly.' Lichtenthaler (2005), referring to Cesaroni et al. (2004), Granstrand (2004a), Chesbrough (2003b) and Grindley and Teece (1997) summarizes that the increasing technological content of products accompanied by shorter product and technology lifecycles and more intense competition have encouraged stronger external knowledge exploitation. Lichtenthaler (2005) argues that this 'knowledge push effect' has been intensified by a growing knowledge convergence and fusion, which has led to higher numbers of knowledge components from different areas being incorporated into a single product. In fact, there is great exploitation potential. Having investigated 867 patents (applied for between 1994 and 1997), Braunerhjelm and Svensson (2010) find that, on average, 39 per cent of all patents are 'fallow patents.' Nevertheless, a firm's 'willingness-to-exploit' (for example, license or sale) a technology depends mainly on the purpose of the technology in the portfolio (for example, strategic, fencing, blocking, evergreening).[12] However, firms on the supply side as well as on the demand side turn beyond the own firm boundaries to source technologies from the MfTI. Investigating 133 technology licensees and an equal number of matched non-licensees, Reichstein (2009) proves that licensed technology indeed acts as a catalyst for accelerating innovation speed. Moreover, Laursen and Salter (2006) documented the positive effects of externally sourced knowledge on innovation outcomes in an empirical study.

Hence, in order to maintain competitiveness in the innovation race (for example, by accelerating its innovation speed) and generate sustainable firm growth, an increasing number of firms extend their innovation processes beyond their own firm boundaries (Gassmann (2006), Rosenkopf et al. (2001)) – a trend labeled by Chesbrough (2003c) as open innovation.[13] Following successful firms like Procter and Gamble, more and more firms have started innovating in networks, trying to exploit and source ideas, technologies and IP assets on the MfTI. Consequently, 'with a shift towards "open innovation" … contributors to innovations are more likely to come from different types of organizations' including universities, other firms (for example, start-ups), leading clients and users (Murray and O'Mahony (2007: 1008), Owen-Smith and Powell (2003)).[14]

With the paradigm changing from 'closed' to the 'open' innovation, the 'classical' (closed) innovation process (for example, according to Cooper (2008)), is now being split up and divided among different actors and innovation is carried out cooperatively (for example, in joint ventures, alliances, and R&D cooperations) where technology transactions among the involved actors play an important role. Figure 1.1 illustrates a technology transaction[15] on the MfTI within open innovation processes of two firms ($Firm_A$ and $Firm_B$). $Firm_A$ is exploiting a technology in an advanced stage of the innovation process to $Firm_B$ who acquires the technology in an early innovation process stage. While transactions can take place directly between $Firm_A$ and $Firm_B$, they can also involve technology market intermediaries (TMIs)[16] supporting the transactions.



Notes: Own illustration with depiction of open innovation processes adapted from Chesbrough (2003c)

Figure 1.1 - Inter-firm technology transactions on the MfTI

Empirical studies have proven the trend towards open innovation. For instance, Sheehan et al. (2004) show that there has been an increase in the importance of out-licensing in 51.4 per cent of their surveyed firms in the preceding 10 years. Furthermore, 63 per cent of the respondents in their study expected this trend to continue and anticipated that the out-licensing of patented inventions would become more important for their firms in the following five years. This trend was also confirmed in a survey by PWC (2007) who reported that 54 per cent or their respondents expected the importance of out-licensing to increase in the following three to five years. There are also various firm examples. Among the most cited cases is IBM. While IBM is among the top patent holders in the world, its licensing revenues until 1993 amounted to approximately US$300 million a year. This changed drastically in 1993 when, under the newly appointed CEO Lou Gerstner, IBM adopted an active licensing program that was expected to yield US$1.4 billion to US$1.5 billion in 2000 according to Salomon Smith Barney (1999). Owing to the substantially higher gross margin on licensing revenues than on other IBM revenues, the patent royalty contribution to IBM's bottom line can be regarded as considerably larger than of those from other revenue sources. According to Shulman (2003) and Lang (2001), IBM's licensing revenues accounted for 20 per cent of their total profits in 1999 and in the last decade a total of almost €8.2 billion. Dow Chemicals is another example often cited. According to Roos et al. (1997), the company set up an 'Intellectual Asset Function' in 1993 and obtained licensing revenues of €110 million in 2000 compared to €22 million in 1994. Another example is the Denmark-based healthcare firm, Novo Nordisk A/S. According to Reitzig (2004), the firm gained a dominant market position in Europe with a diabetes drug since it had a license to a technology for manufacturing insulin from animal sources. From 197 survey responses and 30 interviews with senior executives in the five principal regions across the world, PWC (2007) reported that above 80 per cent of all surveyed top managers agreed or strongly agreed with the statement that IP management is important for the success of a firm.

The increased adoption of open innovation approaches is also well reflected by the growth in the MfTI. Although MfTI have existed for decades,[17] empirical data from various sources indicate that they have grown sizably since the 1990s[18], especially in some high-technology areas.[19] Arora et al. (2001: 40) compare estimates at an aggregated level from three different data sources that were 'subject to numerous caveats' but led to rather consistent results. Limiting their analysis to technological knowledge, Arora et al. (2001: 40) estimates indicate that the annual worldwide 'markets for technology ' were worth between US$35 billion and US$50 billion in 2000. In addition, Elton et al. (2002) and Kline (2003) estimated that the overall US patenting licensing revenues have skyrocketed from below US$15 billion per year in the early 1990s to around US$100 billion per year in 2002. Results from a survey by Sheehan et al. (2004) indicate that a majority of 81% of the responding firms expected an increasing number of out-licensing transactions from 2005 to 2010, while 54% of the respondents had experienced a growth of out-licensing since 1995. A study by the Institut der deutschen Wirtschaft Köln (2006) estimates that the German MfTI has a potential size of €8 billion. Gambardella et al. (2006) estimated the market for the EU-8 countries at €9.4 billion from 1994 to 1996, €12.7 billion from 1997 to1999 and €15.6 billion from 2000 to 2002, which corresponds to 0.16 per cent, 0.19 per cent and 0.20 per cent of the GDP and a total growth of 65 per cent between the third and the first period. According to Gambardella et al. (2006: V), 'the total value of patents licensed has increased considerably in the… industries [they included in their study] in the 1990s, suggesting that the markets for technology are growing in these sectors at a significant pace.' Athreye and Cantwell (2007) have compared the growth of non-US patents and worldwide licensing receipts and came to conclude that the growth of patenting coincided with the growth of MfTI after the 1980s. Moreover, the growth is expected to continue in the future. Gambardella et al. (2006) estimate that the MfTI in Europe could increase by 50 per cent, that is the potential has grown from US$14.8 billion to US$24.4 billion. As noted earlier, the market potential suggests that there are notable untapped opportunities for enhancing the MfTI in Europe and subsequently for using this means in order to increase the utilization rate of patented technologies.

Obstacles preventing efficient transactions

As a result, when a growing number of firms started expanding their innovation processes, they needed to acquire dedicated knowledge to establish competences and capabilities for an effective management of transactions on the MfTI. While firms that source technologies externally need to establish acquisition competences, those firms who own technologies and are willing to exploit them to those sourcing them (for example, to generate additional R&D returns through outlicensing or technology sales) need to establish competences to efficiently manage the exploitation process.[20]

However, according to Lichtenthaler and Ernst (2006a), the management approaches developed so far are still in their infancy. Firms face various obstacles when managing transactions on the MfTI including the not-invented-here-syndrome (NIH)[21], valuation difficulties to assess market prices, identifying buyers, etc.[22] In addition to internal obstacles related to management processes and firms' innovation cultures, further obstacles relate to the interfirm relations or the institutional structures of the MfTI in which the transactions take place. Most of the studies that were conducted to better understand MfTI transactions on firm level either from the seller's perspective (for example, Lichtenthaler (2006a), Escher (2005)), the buyer's perspective (for example, Granstrand et al. (1992)) or on a national level (for example, Gambardella (2002); Granstrand (2004a)) came to similar conclusions. The market design and the institutional structure are far from optimal. There are many obstacles that inhibit MfTI from clearing efficiently. According to Troy and Werle (2008: 3), the 'well-functioning market for patented new technological knowledge is confronted with several obstacles… [and the]…markets are far from functioning smoothly.' Teece (1998b: 545), referring to his early work in Teece (1981), noted that he had already recognized the 'first signs of an emerging market for know-how' nearly twenty years prior to his 1998 research. However, at the same time, he had stated that 'much technology does not enter it … either because the firm is unwilling to sell or because of difficulties in transacting in the market for know-how.' Teece (1998b: 62) further noted that 'the market for knowledge is riddled with imperfections…' and 'one class of assets that is especially difficult, although not impossible, to trade involves knowledge assets.' Owing to various obstacles on the MfTI, transaction difficulties and high transaction costs ultimately prevent efficient market clearing, which leads to market failure or constitutes a transaction challenge for firms.[23] Consequently, firms facing the transaction challenge have lower incentives to engage in technology transactions that could actually facilitate the more efficient creation of innovations.

Technology market intermediaries

Recently specialized market actors started to enter the MfTI using transaction obstacles as business opportunities.[24] These technology market intermediaries (TMI) develop novel transaction models offering them to firms willing to acquire or exploit technologies and IP assets of the MfTI.

OECD et al. (2005: 10) point out that 'market intermediaries have become more numerous and diverse as the demand for technology transfer and patent valuation has grown.' According to the EPO et al. (2006: 1) the 'marketplace is nowadays in a probe and learn period in which the number of intermediaries is rising.' EPO et al. (2006) draw further attention to the rise of new models that intermediaries apply. Examples of such models include partnerships, technology pools, special purpose investments vehicles, auctions, publicly traded IP indexes, as well as patent value funds which aim at taking care of IP logistics issues (for example, finding and negotiating with potential licensees). According to EPO et al. (2006: 1) these new models 'make one step towards the development of a market… [and]… contribute to the maturation of the IP market.'

Aside from governmental organizations, scholars from this field have also recognized the emergence of TMI. Koruna (2004) observes that, with new services and instruments on the market, the process of externally exploiting technologies is getting easier and thus will probably also gain more acceptance among firms. Chesbrough (2006: 3) reported 'that a small number of intermediary firms has arisen in recent years to assist in the process of identification, negotiation and the transfer of patents from one firm to another.' Troy and Werle (2008: 20) note that 'the number of intermediaries is growing, as is the propensity of firms to employ specialized intellectual property professionals. These and other actors potentially involved in patent transactions gain trading experience, experiment with different modes of trade and invent ways to cope with uncertainty.'[25] However, for the purpose of this study only few statistics documenting this trend were available. Subsequently, I collected own data by means of a pre-study done in December 2006. Based on interviews with a range of industry experts, about 70 TMI were identified. The growth rate of those firms was calculated since the year of their foundation. The results of this pre-study confirm the trend. An approximated exponential curve fit indicates an annual growth rate of 8 per cent since 1980.[26]

Today, TMI have developed a number of novel transaction models that are characterized by different transaction governance structures (TGS). However, it remains insufficiently understood whether the different models are equally suitable for every technology transaction or which factors determine the choice of preferred model. Among the various novel transaction models, technology auctions have gained particular interest since the first, widely recognized public technology auction was organized in San Francisco, US in spring 2006. Since then, subsequent technology auctions were held not only in the US but also in Europe and Asia. However, whether all or only certain technologies can and should be auctioned remains an open question in the literature and motivated this study.

To summarize, firms have nowadays widely realized the importance of innovation, while recent market developments force them to continuously innovate (for example, by accelerating their innovation speed). However, to maintain competitiveness, particularly for the development of (increasingly) complex technical products, firms need to combine internally developed technologies with externally acquired ones as innovation is often a cumulative process. Hence, firms no longer only use internal resources to innovate but there is an increasing tendency to innovate openly, sourcing from and exploiting technologies outside of the own firm's boundaries on the MfTI. Hence, these firms become more dependent on rigorous management of the interfirm innovation process as well as on the management of transactions to acquire or exploit technologies. These firms need to acquire knowledge to establish competences and capabilities for the efficient management of technology and IP asset transactions on the MfTI.

However, various obstacles prohibit efficient clearing on the MfTI (for example, through high transaction costs). Those obstacles present a transaction challenge for firms that engage in technology transactions or open innovation. TMI have started entering the MfTI (that is as organizational innovation in the institutional structure). They develop and offer novel transaction models (service innovations) to firms in order to facilitate the more efficient creation of innovations.

However, each novel transaction model is characterized by a different TGS and is – most likely – not equally suitable for any technology transaction. Among these various novel transaction models, firms have to choose the best suited model with the most favorable TGS for each transaction. Thus, firms need to understand how they can best utilize the currently emerging TMI or the transaction models they offer. Technology auctions are among these new models. The question addressed in this study is whether and, if so, for which technologies auctions represent a suitable TGS for conducting efficient transactions.

1.2 FIELD OF RESEARCH AND FOCUS OF THE STUDY

This study is of an interdisciplinary nature and combines concepts from both management science and industrial organization literature. Figure 1.2 illustrates the main research fields that are related to this study and which are further discussed in the following section. The research fields that are closely related to the present research are highlighted with bold frames.

In terms of management science, this study is primarily grounded in the innovation management literature with a focus on the firm.[27] In this study, innovation is considered a result of an iterative, interacting and cumulative process, in which various pieces of complementary knowledge (tacit and explicit)[28] as well as related IP assets[29] are assembled from different sources. These sources are either inside the own firm (including other business units) or, to an increasing extent, from outside the own firm's boundaries. This definition builds on the notions of various scholars. For instance, Murray and O'Mahony (2007: 1008) argue that 'for innovation to occur … innovators must have the ability to actually combine or accumulate knowledge.' Aghion et al. (2001: 470), subscribing to endogenous growth theory, argue along the lines of Harris and Vickers (1987) and Budd et al. (1993) that technological progress is 'emerging from a dynamic process of "step-by-step" innovation.' Green and Scotchmer (1995: 20) note that 'knowledge and technical progress are cumulative in the sense that products are often the result of several steps of invention, modification and improvement.' Nelson (1994: 50), subscribing to evolutionary growth theory, also observes that 'in many fields, technological advance … [is]… "cumulative" in the sense that today's technological advances tend to proceed from yesterday's, building on and from what had previously been achieved and improving it in various directions. In many cumulative technologies … "natural trajectories" tend to appear, with the cumulative improvements proceeding along particular lines of advance that reflect both what technologists understand they likely can achieve and what entrepreneurs believe customers will buy.'[30]

In management science, following the introduction of the innovation concept by Schumpeter (1912), systematic research on innovation management began in the 1960s and has since then exploded (Hauschildt and Salomo, 2007: X).[31] Innovation management has nowadays grown into a complex research stream combining a wide range of topics including, for instance, different generations of innovation processes (for example, distributed, open, linear, and interactive) with its different phases / stages,[32] innovation strategies, project management, organizational structures (for example, patent and licensing departments), incentive systems, sources of innovation,[33] actors in innovation projects, knowledge management approaches, corporate entrepreneurship, product lifecycle models, diffusion process models, various management tools, innovation types (for example, radical, incremental, cumulative), and system innovations.[34]

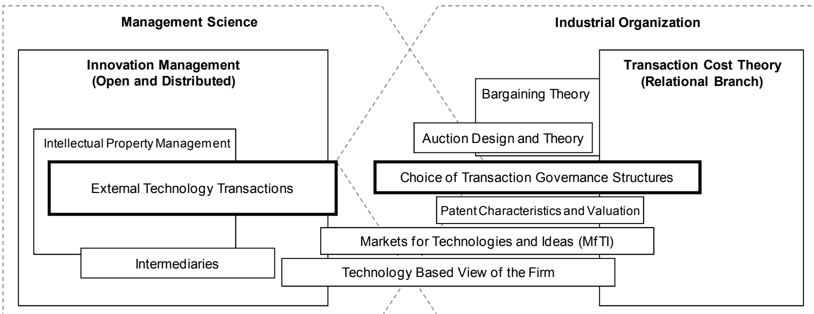


Figure 1.2 - Scope of the study and related research fields[35]

In terms of innovation literature, this study analyses the transactions of the firm's (patented) technologies. Similarly, this study looks into the management (exploitation and acquisition) of a firm's 'technology base'[36] supporting the creation of innovations. Firms that transact and recombine technologies for the creation of innovations are considered to be 'technology-based' in this study. Technology-based firms (TBF) are the primary actors that engage in transactions with their innovation and IP (IIP) managers who manage these transactions. Although this study focuses on transactions in general I apply the perspective of firms exploiting technologies rather than of those acquiring them. More specifically, this study focuses on the organizational structures and the management of technology transactions that take place beyond the boundaries of firms on the MfTI.

Each technology transaction is assumed to happen within the overarching frame of an innovation process. It has often been assumed that the firm who develops an invention and eventually files for patent protection will be the same actor to complement the patented invention with all necessary resources to carry it all the way through the different stages of the innovation process up to the market launch, that is turn the patented invention into an innovation. However, a significant share of patents is not used directly by its inventors. To facilitate innovation, it is thus necessary to ensure that patented inventions are owned by the market actors who can and are willing to exploit them. The interacting innovation process across firm boundaries has recently been labeled as open or distributed innovation. Those distributed, inter-firm innovation processes, particularly when TMI are involved, are related to this study.[37]

As this study is primarily concerned with patented technologies as the transaction object, it is closely linked to the IP management literature. While – in light of the above mentioned developments – previous studies of patents have been mainly addressed by the legal discipline and only to a minor extent by economists[38], the traditional view on patents has changed gradually since the early 1990s, which is reflected by the increasing attention scholars have drawn to this field.[39] Based on some early contributions (for example, as often cited Teece (1998a), Grindley and Teece (1997), Nonaka and Takeuchi (1995)), patent management and more broadly IP management is currently widely accepted and integrated into the innovation management literature, particularly with importance to open and distributed innovation. Within IP management research, scholars have been concerned with processes, tools, strategies, and structures of technology acquisition and exploitation[40] transactions and the marketing of technologies.[41] However, the role of the increasing number of TMI influencing transactions has so far been neglected to a large extent.[42] This study focuses particularly on how TMI influence transactions (particularly those conducted via technology auctions). To enhance the readers' understanding of TMI, this research borrows different concepts from the literature on brokers and intermediaries in innovation systems (see Chapter 3.2). A large stock of the IP management literature focuses on licensing. Although this topic is closely related to this study, I rather take an organizational perspective, focusing on the structure of transactions, and thus hardly refer to the licensing literature which often rather focuses on, for example, contract design and royalties.[43]

As previously mentioned, to achieve an economically efficient resource allocation along the (open) innovation processes from inventors of technologies to those best equipped to exploit them, MfTI represent the institutional framework as part of the innovation system[44] in which transactions take place (see Figure 2.1). Thus, applying this outside, inter-firm perspective involving different market actors and their relationships during transactions within this institutional framework, this study is also related to the industrial organization literature (for example, Carlton and Perloff (2008), Tirole (2008)). In the industrial organization literature, a particular stream is concerned with the patent valuation.[45] Those studies investigate properties of patents and particularly the determinants of patent value. For the quantitative analysis of factors that influence sales probability and sales prices, measures are applied to operationalize the variables developed primarily in this research stream.

This study adopts transaction cost theory's overarching theoretical concept, which is reflected in the main research question (see Chapter 2) and combines the choice of governance structures of transactions with properties of the traded asset. As this study is concerned with transactions between a technology owner and an acquirer, that is with the relation between these actors, it is related to the relational branch of transaction cost theory as opposed to 'organizational governance.' The relational branch of transaction cost theory provides this study's theoretical basis. According to Shelanski and Klein (1995), the relational branch of transaction cost theory aims to explain how trading partners choose from a set of feasible institutional alternatives, that is this theory is concerned with make-or-buy as well as keep-or-sell decisions. In the open innovation literature, a number of empirical studies have applied the transaction cost theory in a similar way to this study in that they investigate 'relational governance' structures. In terms of technology acquisition, these studies include, for instance, (Van de Vrande et al. (2006), Delmas (1999)), make-or-buy decisions (Klein (2005)), licensing contracts (Bessy et al. (2008), Brousseau et al. (2007)), and alliances (Colombo (2003), Oxley (1999)). According to some authors, for instance Leiblein (2003), closely related concepts also include contracting for innovation, contractual relations, vertical disintegration, and interfirm collaboration.

Investigating technology auctions as a specific transaction model, this study is clearly related to the theoretical and empirical stream of the auction literature (see Chapter 5), which in turn is part of game and bargaining theory. This study borrows a theoretical auction process model from the auction literature. For my discussion on the choice of technology auctions, particularly when and under which circumstances they should be preferred to bargaining negotiations, I also refer to the fundamental principles of bargaining theory. Furthermore, to some extent, this study also draws on the market design literature.

NOTES

[1] Rycroft and Kash (1999) provide a comprehensive examination of the complexity phenomenon. Schmookler (1966: x) regards the cumulative nature of technical knowledge for inventions as 'the "bits" that are added to the existing stock of knowledge.' According to Pénin (2008), similar concepts discussed in the literature are 'step-by-step innovation,' 'multi-invention products,' 'collective learning process,' 'collective mode of innovation,' 'combinative capabilities and replication,' 'evolutionary innovation,' 'sequential innovation,' and 'multi-stage innovation.' However, sequential innovation does not appear to be a suitable term, since it can be confused with the rather early generations of sequential innovation processes. Moreover, cumulative innovation should not to be confused with collective innovation. For a discussion comparing open, user, and cumulative innovation, see West and Bogers (2010).

[2] Related concepts in the literature are multi-invention products (Somaya and Teece, 2008) and modularity (Campagnolo and Camuffo, 2010).

[3] Also see Ernst and Unctad (2005) and Lindmark (2002).

[4] Nevertheless, determining the boundaries of a firm is not trivial. Within industrial organization a related stream of literature investigates what determines the firm's size (firm scope). A review of the related literature can be found in Holmström and Roberts (1998).

[5] The notions of the 'IP assembly problem' and the hold-up problem further relate to the theory of the anti-commons originally referring to the difficulties of assembling lease rights for buildings in Russia (for example, Granstrand (2003c) and Aggarwal and Walden (2009)) or in biomedical research (Heller and Eisenberg, 1998).

[6] Nevertheless, patents do not necessarily create hold-up problems in cumulative innovation processes as demonstrated by Granstrand (2006) in mathematics as an extreme case of cumulative innovation.

[7] It is a common assumption that, along the innovation process, the market actor who files for the patent protection of a technical invention is the same one who ultimately exploits the patented invention on the market, turning it into an innovation. Empirical evidence however proves that this is not the case. A considerable share of patents is not used directly by its inventors. Gambardella et al. (2006) reported that 36 per cent of the patents in their 'huge' sample of EU patents are not used internally or for licensing. While about half of these patents (18.7 per cent) may even assume a potentially high value as they help block competitors, the other half (17.4 per cent), labeled 'sleeping patents,' are left virtually unexploited. The Institut der deutschen Wirtschaft Köln (2006) proved that in Germany a quarter of patents (24.6 per cent) is not used at all. Chesbrough (2006: 5) reported that in the 'US over 95 per cent of issued patents are unlicensed and over 97 per cent never generate any royalties.'

[8] Granstrand (2004b) provides further arguments for the shift from R&D and technology management towards IP and intellectual capital management.

[9] Parker et al. (1996) provides further arguments explaining this trend. They point out that, through marketing, firms who intentionally or unintentionally find that their internal R&D efforts are limited to line extensions, can gain access to the breakthrough ideas created by inventors who are not confined to the corporate context. Moreover, Somaya and Teece (2000: 1) argue that 'inventions may be combined into … multi-invention products using three alternative organizational modes - viz., licensing of inventions, trade in components that embody inventions or by integrated production.'

[10] Various notions are applied in the literature. Troy and Werle (2008) and Gambardella et al. (2007) use the term 'market for patents' as a narrow definition. Chesbrough (2006) uses the term 'markets for IP,' Lichtenthaler and Ernst (2006b) use 'market for knowledge,' Arora et al. (2001) use the term 'markets for technology,' and Gu and Lev (2000) use 'markets in intangibles.' Recently, however, a special issue of ICC (Volume 19 Issue 3) summarizes the

different notions as markets for technologies and ideas (MfTI) that cover not only technologies but also ideas that are traded in the rather early stages of innovation processes (for example, Innocentive.com).

[11] According to March (1991: 71), the relation 'between the exploration of new possibilities and the exploitation of old certainties … is of central concern' in economic studies. While exploration includes aspects captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, and innovation in contrast, exploitation includes aspects such as refinement, choice, production, efficiency, selection, implementation, and execution. Bessy and Brousseau (1998: 452) argue that 'when an innovator is allowed to license his technology, he spreads it in the economic system, while at the same time he increases his return on innovation investments and efforts.'

[12] While technologies directly related to a firm's core competences and competitive advantage might not be suitable for external exploitation – or at least not to direct competitors – other technologies might not be critical to the firm's competitive advantage and may be very well suited for external exploitation. However, looking into the different strategic purposes of the technologies within technology portfolios is beyond the scope of this study. The reader might rather refer to, for example, Tschirky and Koruna (1998, chapter 4.2.10) who present different typologies and approaches to classify technologies. Granstrand (2000a) also provides a discussion of different strategic purposes of patents.

[13] According to Chesbrough (2003a), open innovation is the process of cultivating and internalizing value from opportunities external to the firm, as well as the skillful deployment of internal discoveries to external complements. Although this phenomenon has only recently been observed in certain industries, this innovation principle is not particularly new. Teece (1989: 35) argues that 'the institutional structure of innovation in capitalist economies is extremely variegated and involves a complex network of backward, forward, horizontal, lateral relationships and linkages within, among and between firms and other organizations.' Furthermore, based on an original idea published in Granstrand (1982), Granstrand and Sjölander (1990) propose a typology for technology acquisition and exploitation strategies that would nowadays be subsumed under the notion of an open innovation.

[14] Firms also actively engage and sponsor online communities (for example, Janzik et al., forthcoming) where users develop software (for example, Raasch and Herstatt, forthcoming) as well as tangible products (for example, Raasch et al. (2009)).

[15] The label 'technology trade' is avoided as it is often used in the literature for inter-country technology transactions commonly associated with the transaction of technical know-how towards developing countries for instance by Yang and Maskus (2009), Hoekman et al. (2005) and Chen et al. (1994).

[16] For a detailed definition of this concept, see Chapter 4, which refers to Schumpeter (1912). Such intermediaries can be seen as ventures started by entrepreneurs and thus as a source of change (North, 1996).

[17] Even at the beginning of the 20th century, there have been organized MfTI (Lamoreaux and Sokoloff (1998)).

[18] Explanations for this growth effect are currently under scrutiny by various scholars. However, explaining this phenomenon is beyond the scope of this study.

[19] For instance, pharma firms rely extensively on outside knowledge for their products (Ceccagnoli et al., 2009). However, it is interesting to note that the size of the MfTI, respectively for intangible assets, patents and licensing remains difficult to determine. Besides the absence of solid measures to systematically collect data, few studies have tried to approximate the market size and so far only few official statistics have been regularly collected by international authorities, for instance, EUROSTAT.

[20] In the literature, various terms are used for essentially similar processes. These include deployment, for example, by Escher (2005) and commercialization, for example, by Lichten-

thaler (2006a). For a typology of external technology sourcing strategies and a detailed discussion of them, see Chapter 3.

[21] For further readings on the NIH syndrome, see, for example, Lichtenthaler and Ernst (2006a) and Katz and Allen (1982).

[22] For details and a discussion on obstacles, see Chapter 3.

[23] For instance, Escher (2005: 75) argues that firms 'often fail to initiate such an exploitation program due to market imperfections and high initial financial commitments.'

[24] Certain specialized intermediaries, such as brokers and dealers, have been present for a long time (for example, reported in Arora et al. (2001) as 'specialized engineering firms'). The recent emergence of TMIs rather refers to those firms included in the rather narrow definition provided in Chapter 4.

[25] It is interesting to note that the emergence of intermediaries is not significant to markets for technology when markets do not clear efficiently. For example, in agricultural markets, Klerkx and Leeuwis (2008: 260) report that 'due to market and systemic failures, both supply side and demand side parties in this market have experienced constraints in effecting transactions and establishing the necessary relationships to engage in demand-driven innovation processes. To mitigate these constraints, a field of intermediary organizations has emerged to assist agricultural entrepreneurs to articulate demand, forge linkages with those that can provide innovation support services and manage innovation processes.'

[26] Founding dates could be identified for only 60 TMIs of the sample. Counting for 80 per cent of the TMIs, by far the majority of the TMIs is based in the US clustering around two centers at the west and east coasts. While a considerable number of them are concentrated around Silicon Valley at the west coast, another cluster can be found at the east coast, including New York and Massachusetts. The non-US based TMIs are mainly European and Canadian firms. In Europe, the majority of TMIs are British and German. Several TMIs hold regional offices in Europe, Japan, China and East Asia.

[27] Schumpeter (1912: chapter 2) introduces the innovation concept to the economic literature and defines it as the 'introduction of new goods …, new methods of production …, the opening of new markets …, the conquest of new sources of supply …, and the carrying out of a new organization of any industry.' Since then, various definitions have been developed. For instance, Drucker (1954: xi) defines innovation as 'change that creates a new dimension of performance' and Nelson and Winter (1982: 130) define innovation as the 'the creation of any sort of novelty in art, science or practical life that consists – to a substantial extent – of a recombination of conceptual and physical materials that were previously in existence.' Nowadays, it is widely accepted that innovations comprise a variety of domains (for example, organizational, financial, social or service) and nowadays different typologies have been proposed (for example, Granstrand, 2000). The OECD (2005: 46) defines innovation as 'the implementation of a new or significantly improved product (good or service) or process, a new marketing method or a new organizational method in business practices, workplace organization or external relations.'

[28] Polanyi (1966) introduced the dichotomy of tacit and explicit knowledge. At the same time 'tacit' also relates to the notion of 'sticky knowledge' as introduced by von Hippel (1994).

[29] In this study, following Pearce (1992: 18), an asset is defined as an 'entity possessing market of exchange value and forming part of the wealth or property of the owner. In economics, an important distinction is made between real assets, which are tangible resources like plant, building and land yielding services in terms of production or directly to consumers; and financial assets which include money, bonds and equities and which are claims or titles to receive income or to receive value from others.'

[30] The cumulative nature of innovation has further been on the research agenda in relation to the policy debate, for example, by Furman and Stern (2006), O'Donoghue (1998), Mazzoleni and Nelson (1998), Chang (1995), and Scotchmer (1991).

[31] In addition, see the comprehensive review of innovation research from its early inception at the beginning of the 20th century as conducted by Fagerberg and Verspagen (2009: 220).

Accordingly, 'before 1960, scholarly publications on innovation were few and far between. The main exception to this rule was the work of the Austrian-American social scientist Joseph Schumpeter. However, at least until the 1990s, most research was conducted in the economic field rather than by management scholars. For a review of the development of research on innovation and particularly on innovation processes during the last decades, see, for example, Xu et al. (2007), Teece (2006), Herstatt and Verworn (2004), and Rothwell (1994).

[32] For instance, Herstatt (2007) focuses in particular on the early stages of innovation processes, that is the 'fuzzy front end'.

[33] See von Hippel (1988) as a prominent example.

[34] For an overview of the wide range of literature within innovation management, see, for example, Hauschildt and Salomo (2007). Gerybadze (2004) and Tschirky and Koruna (1998) also illustrate the various sub-themes and interconnections of topics within technology and innovation management.

[35] Applying to the JEL classification system, this study relates to the following categories: Primarily, that is, closely connected, to O31 (Innovation and Invention: Processes and Incentives), D45 (Rationing; Licensing), M21 (Business Economics), O3 (Technological Change; Research and Development) and D44 (Auctions). To a broader extent, concepts from the following classes are embedded in this study: K11 (Property Law), D23 (Organizational Behavior; Transaction Costs; Property Rights), D43 (Oligopoly and Other Forms of Market Imperfection), L1 (Market Structure, Firm Strategy and Market Performance), L14 (Transactional Relationships; Contracts and Reputation; Networks), and L21 (Business Objectives of the Firm).

[36] Granstrand (2000a) understands technology as a resource and subsequently developed the concept of the technology base, that is the portfolio of technologies that are 'continually being acquired, combined, and exploited in various ways…' Referring to Granstrand and Sjölander (1990), Escher (2005: 44) points out that 'the main task of the technology-based enterprise is to optimize its resource base through acquisition and exploitation processes.'

[37] Among other ideas, the use of the concept of distributed innovation processes is an outcome of various discussions with colleagues from the MELT project (which synthesizes Management, Economics, Law and Technology) at Chalmers University of Technology, Sweden.

[38] According to Penrose (1951: xi), 'although the patent system was developed primarily to promote economic ends, economists have devoted very little attention to it and none at all to the international patent system.' Granstrand (2000a, ch.2.5) provides further arguments that there was no change in this attitude between the 1950s until the 1990s.

[39] Despite this 'old observation that the value of a firm as a going concern considerably exceeds the value of its physical assets' (Arrow, 1996: 126), a growing number of IP-related articles reflects the increased importance of IP management since the mid-1980s (Ziedonis, 2008). Moreover, Granstrand (2000a: ch.2.3.2) argues that the growing awareness and importance of IP is linked to the emergence of the 'pro-patent era' in the 1980s that was followed by some substantial legislative changes in the US patent jurisdiction.

[40] In the literature, various terms are used for essentially similar processes. These include deployment (for example, Escher (2005)) and commercialization (for example, Lichtenthaler (2006a)).

[41] For instance, Escher (2005: 68) provides a well-structured overview of various studies.

[42] There are a few exceptions, for instance, Escher (2005) briefly discusses the use of auctions to establish market prices.

[43] See, for instance, Anand and Khanna (2000) for an empirically-based discussion on licensing features, Lafontaine and Slade (forthcoming) for an analysis of licensing contracts, and Braun and Herstatt (2007) for a discussion on the relation between licensing activities and innovation.

[44] According to Nelson and Nelson (2002: 265), 'the development of the conception of an innovation system … has largely been the work of economists and other scholars of technological advance who adhere to an evolutionary theory of economic growth.' Within innovation systems, 'scholars of technological advance have always understood the important role of institutional structures in supporting and molding efforts to advance technology'.

[45] For instance, Giuri et al. (2007), Hall et al. (2005) and Harhoff et al. (2003).