FACULTEIT ECONOMIE EN BEDRIJFSWETENSCHAPPEN

Management, Strategy and Innovation (MSI)

When does it pay off to participate in markets for technology?

The interplay between the mode of technology acquisition, internal R&D and the nature of technology

Adrián Kovács

MSI_1907

When Does It Pay Off to Participate in Markets for Technology?
The Interplay Between the Mode of Technology Acquisition, Internal R&D and the Nature of Technology*

Adrián Kovács+

+Department of Management, Strategy & Innovation, KU Leuven, Leuven, Belgium, adrian.kovacs@kuleuven.be.

Abstract

This paper examines the contribution of different technology acquisition strategies to the market value of firms. I exploit a large consolidated dataset on publicly listed US-firms to distinguish between the contributions of patented inventions that these firms acquired via acquisitions of other firms – embodied technology acquisition – and via the outright purchase of standalone technology – disembodied technology acquisition. I develop hypotheses relating firms ability to benefit from both strategies to the size of their internal knowledge stock and their degree of familiarity with the acquired technology. In line with my predictions, I find a positive contribution of embodied technology acquisition on market value, which increases with the size of firms' internal knowledge stock as well as their familiarity with the acquired technology. Contrary to my predictions, I find a negative contribution of disembodied technology acquisition, except for firms having the largest internal knowledge stocks in my sample. Interestingly, my results reveal that firms are most likely to benefit from the acquisition of familiar technology via the embodied mode whilst at the same time indicating that the negative association between market value and the acquisition of standalone technology is most pronounced when this technology is novel to the acquiring firm. Overall, my findings suggest that the benefits associated with acquiring technology from external sources are only realized when firms possess a minimum degree of absorptive capacity, with the minimum needed to benefit from technology acquisition being significantly higher for technology acquired via the disembodied mode.

Keywords; Markets for Technology, Patent Assignments, Mergers and Acquisitions, Market Value

JEL Classification; O32; O34.

*Working paper draft, version June 2019. Please do not cite or redistribute without permission of the author. All errors are my own.

Introduction

External technology is universally recognized as an important source of technological inputs for firms in high-tech industries (Laursen and Salter, 2006; Arora *et. al.*, 2014; Stettner and Lavie, 2014). Because the knowledge sources for innovation are nowadays more widely distributed than ever before, even the largest and most technologically advanced firms cannot rely solely on internally developed technology. They must also tap into complementary knowledge sources situated beyond their boundaries when developing their innovations (Chesbrough, 2003; Cassiman and Veugelers, 2006). In view of this there is an extensive scholarship on the different modes that firms can rely upon to access external technology. Although this scholarship has considerably advanced our understanding of firms' 'make, buy or ally' decisions, it is predominantly confined to mergers and acquisitions (M&As) (*i.a.* Hitt *et. al.*, 1996; Ahuja and Katila, 2001; Puranam and Srikanth, 2007), R&D alliances (*i.a.* Robertson and Gatignon, 1998; Wang and Zajac, 2007; Yin and Shanley, 2008) and technology licensing (Arora *et. al.*, 2001; Arora and Ceccagnoli, 2006; Agrawal *et. al.*, 2015). As a result, another obvious and potentially more favorable mode of technology acquisition – the outright purchase of standalone technology – has so far been overlooked in existing literature. This is surprising given the large amount of attention that has been devoted to 'markets for technology' in recent times in both scholarly and academic circles (*i.a.* Federal Trade Commission, 2011).

Analyzing firms' activities on markets for technology is important for at least three reasons. First, even though historic accounts of 'markets for technology' – where trading activity refers to intermediate technological outputs that are disembodied from goods and services – date back to the late 19^{th} century (Lamoreaux & Sokoloff, 1998; Burhop, 2010), recent studies suggest that they have rapidly expanded since the beginning of the 1990s (Arora *et. al.*, 2001). Their growth is not only manifested in increased levels of technology trade, but also in the economic rents that such trade generates. For example, in 2011 Google Inc. acquired Motorola LLC for a reported $12.5 billion to, in the words of CEO Larry Page "*... strengthen its patent portfolio and to enable it to better protect Android from anti-competitive threats from Microsoft, Apple and other companies...*".[1] Similarly, Microsoft Inc. purchased a portfolio of 800 patents from AOL in 2012 for $1.1 billion which amounts to a lofty price of $1.3 million per patent.[2] Whereas in the past patents were primarily acquired by specialist patent firms, these examples indicate that large firms are increasingly involved in technology trade and are willing to spend big amounts on the acquisition of technology. Furthermore, these examples illustrate that firms rely on multiple modes to acquire external technology. Whereas Google Inc. acquired an entire firm to leverage

[1] https://www.reuters.com/article/industry-us-media-motorolapatents/behind-googles-12-5-billion-motorola-gamble-patents-idUSTRE77F00O20110816, accessed on January 25th, 2019.

[2] https://www.nytimes.com/2012/04/10/technology/microsoft-to-buy-aol-patents-for-more-than-1-billion.html, accessed on January 25th, 2019.

that firm's technology portfolio, Microsoft Inc. directly acquired a specific bundle of patents.

Second, markets for technology are relevant phenomena from a policy perspective because they have the potential to generate positive welfare effects. Essentially, these markets allow for a division of labor between the entities that invent and the entities that manufacture most efficiently (Allain *et. al*, 2016; De Marco *et. al.*, 2017). By providing a viable pathway for invention without commercialization, such specialization renders incentives to inventors who do not have access to the complementary assets required to manufacture, market and distribute their inventions (Teece, 1986). Lower entry barriers not only result in a greater supply of technology to be further developed and incorporated into products, but also to a greater level of competition among these technologies (Federal Trade Commission 2011). This competition in turn benefits consumers by speeding up the rate of innovation and resulting in better and cheaper products. In addition to shaping innovation incentives, efficient markets for technology also limit duplicative R&D investments (Gans and Stern, 2003) and costly patent litigation cases (Galasso *et. al.*, 2013).

Third, the study of markets for technology is also meaningful from a private perspective in the sense that the standalone acquisition of technology may, albeit only under specific circumstances, have distinct benefits over other modes of technology sourcing. To the extent that these markets are efficient and hence transaction costs are low, the acquisition of a single or small bundle of technologies may in principle be faster, cheaper and less risky than the acquisition of an entire firm whilst simultaneously offering a higher degree of control over the technology than R&D alliances and licensing. Markets for technology provide firms with the option to selectively choose the technologies they need, without facing the challenges associated with integrating entire firms and the potential contractual hazards of dealing with alliance partners and licensors. Although these potential benefits are certainly compelling in theory, to the best of my knowledge, no study has empirically examined firms' ability to realize them in practice.

In fact, empirical studies of markets for technology have traditionally been hampered by the lack of comprehensive datasets on technology transactions and their contractual terms. The limited number of studies that have empirically explored standalone technology acquisitions mainly focus on: (i) the characteristics of technologies, buyers and sellers that determine the likelihood that a transaction materializes (Serrano, 2010; Caviggioli and Ughetto, 2013; De Marco *et. al.*, 2017), (ii) theoretically model the gains from trading patented inventions (Serrano, 2018) or (iii) study patents as collateral in business financing (Hochberg *et. al.*, 2018). Whilst generating valuable insights with respect to the dynamics of technology trade, these studies leave unanswered the important question of whether, to what extent and under which conditions firms can profit from standalone technology transactions.

It is the pursuit of these questions that motivates this paper. By exploiting a novel firm-level dataset, I explore whether and under which conditions firms benefit from both outright purchases of standalone technology – *disembodied technology acquisition* – and the acquisition of entire firms – *embodied technology acquisition*. I propose that firms can benefit from both acquisition modes, but that their ability to do so depends on the presence of absorptive capacity as well as the nature of the acquired technology. In an important advance to the existing literature, I construct a consolidated panel of 682 publicly traded US-firms that allows me to distinguish between (i) the stock of patented inventions developed by the focal firm and its subsidiaries, (ii) the stock of patented inventions acquired by the focal firm and its subsidiaries through M&As and (iii) the stock of patented inventions acquired by the focal firm and its subsidiaries via standalone technology acquisitions. This setup also makes it possible to identify and disregard transactions – both embodied and disembodied – between entities that are part of the same parent firm at the date of acquisition. It turns out that such 'intra-firm' transactions make up a large share of all technology acquisitions and may therefore have significantly influenced the results of existing studies of technology transactions.

The findings both confirm and extend the findings of existing scholarship. First, I find that the mode of technology acquisition by itself is an important determinant of firms' ability to benefit from external technology. Whereas embodied technology acquisition positively contributes to firms' market value there is an overall negative association between market value and disembodied technology acquisition. Second, I find that internal R&D positively moderates the contribution of both modes of technology acquisition to market value. The results clearly indicate that the contribution of both modes is only positive for firms that possess a stock of internally developed technology that exceeds a certain minimum threshold, with this threshold being significantly higher for the disembodied mode. Whereas the top-40% of firms in terms of internally developed stock can benefit from embodied technology acquisition, the same only holds for the top-20% in case of disembodied technology acquisition. Thus, although absorptive capacity aids both the acquisition of entire firms and the acquisition of standalone technology, it is more critical to the success of the latter activity than it is for the former. Lastly, I find that the relationship between both modes of technology acquisition and market value also depends on the nature of the acquired technology. Surprisingly, only the acquisition of familiar technology via the embodied mode is associated with higher market values. There is no association between market value and the acquisition of novel technology via the embodied mode nor the acquisition of familiar technology via the disembodied mode whereas I find a negative association between market value and the acquisition of novel technology via the disembodied mode. Combined, the results suggest that the benefits of technology acquisition are most likely to be realized by firms having large internally developed knowledge stocks that acquire familiar technology by buying entire firms rather than standalone technology. Although the empirical setting does not permit to establish a particular causal structure, the study provides a first step towards a richer understanding of the performance implications of embodied and disembodied technology acquisition by highlighting previously unexplored relationships.

Theory and Hypotheses

Background

Scholarship has generally advanced two sets of arguments to explain why firms increasingly rely on external sources of technology. A first set of arguments is based on the premise that a single firm *cannot* develop its entire technology portfolio internally. In this scenario the acquisition of technology from external sources is thus *inevitable*. On the one hand, scholars suggest that the cross-sectoral nature of novel technologies and the interwovenness of scientific disciplines and technological fields requires firms to integrate an increasingly wide range of knowledge components (Hagedoorn, 1993; Laursen and Salter, 2006). On the other hand, it is well-established in the organizational behavior literature that organizational learning is path-dependent and confines firms' expertise to a limited number of technological fields (Rosenkopf and Nerkar, 2001). Furthermore, the capabilities needed to develop technology are less likely to be co-located with the capabilities needed to commercialize them (Teece, 1986). It is, therefore, more and more unlikely for even the largest and most diversified of firms to develop all their technologies internally (Cassiman and Veugelers, 2006).

As firms mature, they naturally develop a greater expertise in certain technological domains than in others. And once they become more familiar with a set of technologies, developing an even deeper expertise in these technologies is more likely to yield immediate returns than exploring new ones because organizational learning happens via a virtuous cycle that exists between gaining experience with a technology and becoming competent with that technology (Ahuja and Lampert, 2001; Argote and Miron-Spektor, 2011). As experience and competence in a specific set of technologies accrue, successful routines for solving specific problems solidify (Henderson and Clark, 1990). Over time these routines can become increasingly rigid and inert to an extent that solutions for specific problems evolve into dominant solutions to all problems (Leonard-Barton, 1992). However, a given set of routines and competences can only be effective in addressing a limited number of problems. A continuous dependence on familiar technologies biases firms towards favoring incremental improvements and sub-optimal solutions at the expense of exploring unfamiliar, yet potentially more promising, technological opportunities (Levinthal and March, 1993; Rosenkopf and Nerkar, 2001). Given that there is ample empirical evidence suggesting that firms develop more impactful technologies when they (re)combine technological components from otherwise decoupled knowledge domains, a fixation on familiar technologies may be detrimental to firms' sustained competitive advantage (Fleming, 2001; Yayavaram and Ahuja, 2008).

A second set of arguments conveys that even if a single firm could hypothetically develop all its technologies internally, it *should not* do so. In this scenario the acquisition of technology is a matter of *choice* and is an *attractive alternative* to internal technology development. First, sourcing technologies from external entities may enable firms to exploit technologies faster. In industries characterized by a high degree of technological change and frequently changing customer needs, current technological competences can quickly become obsolete whilst the development of new ones requires a depth of experience and cumulative knowledge that cannot be quickly nurtured internally (Dierickx and Cool, 1989); Uotila *et. al.*, 2009; Wu *et. al.*, 2014). Access to technologies developed by entities that already have these competences in place can, therefore, significantly shorten the time-to-market of firms' products. Second, acquiring technologies externally may be cheaper than developing them internally, especially when the supply of such technology is large, the technology is general-purpose rather than specific and legal appropriation mechanisms are effective (Teece, 1986; Arora *et al.*, 2001). To the extent that they function efficiently, markets for technology allow for a specialization of inventive activity that results in significant gains to be made from the trade of technology (Arora and Nandkumar, 2012). Third, the alternative to acquire technologies externally mitigates the risk of firms not being able to recoup their sunk cost investments when new technologies appear. It provides them with the option to spot promising technological opportunities in an early stage whilst committing financial resources only at a later stage (Kogut and Zander, 1992; McGrath and Nerkar, 2004).

The relevance of the mode of technology acquisition

Although the benefits ascribed to external technology acquisition are universal in nature, it is well-established that there is considerable variation in firms' ability to realize these benefits in practice. A key aspect that has received a great deal of attention from both economic and managerial scholars in this respect is the choice of technology acquisition mode. Whereas the traditional transaction cost literature has portrayed firms' technology sourcing decisions as a dichotomous choice between making and buying, more recent contributions have extended this view by adding collaborative R&D arrangements to the mix of viable sourcing modes (*i.a.* Robertson and Gatignon, 1998; Van de Vrande, 2013; Stettner and Lavie, 2014; Lungeanu *et al.*, 2016). Rather than focusing on the choice between 'make, buy or ally', I focus exclusively on the choice between two variants of 'buy'; (*i*) *embodied technology acquisition* – the acquisition of technology that is embedded in an asset – and (*ii*) *disembodied technology acquisition* – the acquisition of standalone technology. More specifically, I define embodied technology acquisition as the acquisition of an entire firm via an M&A-deal and disembodied technology acquisition as the outright acquisition of a single technology or a small bundle of technologies.[3] I argue that

[3] Most studies of markets for technology have focused exclusively on the licensing of technology and have overlooked the acquisition of standalone technology. The main difference between licensing and acquiring a technology is that in a license, the owner of the technology (the licensor) grants permission to 'utilize' the technology to another entity (the licensee) whilst retaining ownership of the technology being licensed, whilst in an acquisition the owner of the technology (the assignor) transfers all of his rights to the technology to another entity (the assignee). Whereas licensing

firms can benefit from both modes, whilst recognizing that both modes have their own distinct benefits that make them more suitable over the other mode under certain conditions.

Although embodied technology acquisitions can be motivated by a variety of considerations other than the acquisition of technology – *e.g.* (i) to increase market power, (ii) to enter new geographic and/or product markets, (iii) to achieve synergies, economies of scale and economies of scope and (iv) to get access to valuable complementary assets – empirical evidence suggests that the great majority of such acquisitions in high-tech industries is inspired by technological motives (Ahuja and Katila, 2001; Choi and McNamara, 2018). Pharmaceutical firms regularly acquire small biotechnology ventures to gain access to their drug compounds, machinery and/or key personnel (Higgins and Rodriguez, 2006; Allain *et. al.*, 2016) and some of the world's largest semiconductor firms have expanded their technology portfolio almost exclusively via M&As (Grindley and Teece, 1997; Kapoor and Lim, 2007). By acquiring an entire target firm, the acquiring firm not only gains access to all the technologies of the target, but also to the unique capabilities that the target relied on to develop them. These capabilities are often embedded in the tacit and socially complex knowledge of target firms' individual and collective human capital and are therefore difficult to transfer via disembodied technology acquisition (Ranft and Lord, 2000). At the core, embodied technology acquisition enables an acquiring firm to leverage both what the target firm *knows* – its knowledge base – and what the target firm *does* – its capabilities (Puranam and Srikanth, 2007). Whereas a target's knowledge base can serve as an input to the innovative process of the acquiring firm, its capabilities can function as an independent source of ongoing future innovation.

In contrast, when a firm acquires technology via the disembodied route, it only gains ownership of a single technology or a small bundle of technologies without getting access to the seller's capabilities and resources. It can thus only leverage that part of the seller's knowledge base that is embedded within the acquired technology. In essence, the choice between embodied and disembodied technology acquisition comes down to a trade-off between the need for *commitment* and *coordination* on the one hand and *flexibility* on the other hand. Compared to disembodied technology acquisition, a firm can tap into a larger pool of external knowledge and has a greater potential to leverage this knowledge via embodied technology acquisition because it acquires the entirety of another firm's knowledge sources, including the holders of tacit knowledge. At the same time, acquiring and leveraging a larger pool of external knowledge is more costly and time-consuming than acquiring standalone technology. Even if the acquired firm operates as an independent unit of the acquiring firm, leveraging its knowledge requires a degree of communication and coordination between the acquiring firm and the new unit that

comprises a long-term, exclusive or non-exclusive contractual agreement between licensor and licensee that may be limited to fields of use, acquisition involves an irrevocable and permanent transfer of ownership from assignor to assignee. The acquisition of standalone technology thus shows a greater resemblance to a traditional seller-buyer market relationship than licensing.

requires a high-level of commitment. Furthermore, by acquiring an entire firm, the acquiring firm might not only be paying for the acquisition of knowledge and capabilities that it values but also for those that it doesn't.

In comparison to embodied technology acquisition, disembodied technology acquisition requires less commitment from the acquiring firm. Although it is prone to substantial transaction costs stemming from the search of external technology and the negotiation, execution and enforcement of agreements between buyers and sellers, these costs are likely to be lower on average than the costs associated with acquiring and integrating an entire organization. Furthermore, because there is less knowledge that needs to be leveraged, disembodied technology acquisition is arguably a faster means to ensure access to a certain technology than the acquisition of an entire firm. At the same time, leveraging knowledge might be more challenging via disembodied knowledge acquisition because there is no transfer of knowledge sources, such as key R&D personnel, that the acquiring firm can learn from.

In sum, embodied technology acquisition presents firms with more options than disembodied technology acquisition but this comes at a greater cost. It is thus not obvious whether one mode is universally more profitable than the other. At this stage, I therefore posit that firms can benefit from both embodied- and disembodied technology acquisition and hypothesize that:

H_1: The acquisition of technology contributes positively to firms' market value both via embodied- and disembodied technology acquisition.

The relevance of internal technology development

Although I expect an overall positive effect of both embodied- and disembodied technology acquisition on firms' financial performance, there is a rich body of literature suggesting that firms vary greatly in their potential to recognize the value of external knowledge, assimilate it and apply it to commercial ends. This potential is known as *absorptive capacity* and is based on the believe that, like individuals, firms require a stock of prior related knowledge to be able to assimilate and use new knowledge (Cohen and Levinthal, 1989). Firms' ability to identify, screen, transform and integrate external knowledge is dependent upon the richness of their pre-existing knowledge base in the sense that organizational learning is more straightforward when the object of learning is related to what is already known (Cohen and Levinthal, 1990, Lane and Lubatkin, 1998). Considering that firms' knowledge base is mostly a product of their internal R&D activities, these activities are important sources of absorptive capacity. As noted by Rosenberg (1990) "*...it requires a substantial research capability to understand, interpret and to appraise knowledge... whether basic or applied*" and "*...the cost of maintaining this capability is high...*" *(p. 171)*.

Whereas external technology sourcing has almost exclusively been described as a substitute for internal R&D investment in the classic make-or-buy literature, more recent studies emphasize that firms' internal and external R&D activities are *complementary* in nature. Most notably, Veugelers and Cassiman (1999) formally deduce that firms' creation of internal knowledge increases their marginal return to external knowledge acquisition and provide empirical evidence for a complementarity between the two activities. They find this complementarity to be context-specific in the sense that the extent of firms' activities that is directly related to basic research positively affects the complementarity between internal and external R&D. Rothaermel and Alexandre (2009) extend these findings by quantifying the 'optimal' technology sourcing mix. They derive that the best-performing firms in terms of financial performance are the ones that balance internal development and external sourcing in a 60-to-40 percent ratio.

Firms' ongoing investments in internal R&D contribute to the development of absorptive capacity in two ways. First, by investing a substantial amount in internal R&D, firms create a stock of specific knowledge that allows them to be more sensitive to opportunities that present themselves in their technological environments (Rothaermel and Alexandre, 2009; Stettner and Lavie, 2014). Second, higher levels of R&D investment also enable firms to be more proactive in exploiting the spillovers between internal and external sources of knowledge. In this regard, it is not only the size of firms' knowledge base that determines the degree of absorptive capacity but also its diversity. As stated by Cohen and Levinthal (1990) *"... a diverse background provides a more robust basis for learning because it increases the prospect that incoming information will relate to what is already known..." (p. 131)*. A higher knowledge diversity allows firms to make more novel and fruitful associations between internal and external knowledge because the variety of knowledge components increases the number of possible new (re)combinations (Rosenkopf and Nerkar, 2001; Fleming, 2001).

Whilst the above arguments suggest that absorptive capacity, as an important by-product of internal technology development, increases firms' ability to benefit from both embodied- and disembodied technology acquisition, I propose that absorptive capacity is more important for disembodied technology acquisition than it is for embodied technology acquisition. Whereas the capability to scan the external environment for technological opportunities is important for both technology acquisition modes, the capability to integrate acquired knowledge may only be important for disembodied technology acquisition. Leveraging external knowledge acquired via disembodied technology acquisition requires that the acquiring firm integrates this knowledge with its internally developed knowledge base, whilst this is not the case for knowledge acquired via the embodied mode. Although leveraging knowledge acquired via embodied technology acquisition requires a degree of coordination between the acquiring firm and the acquired firm on the organizational level, this does not imply per se that the acquired knowledge needs to be integrated within the acquiring firm. Hence, in case of disembodied technology acquisition, the acquired knowledge *needs* to be exploited within the confines of the acquiring firm, whereas in case of embodied technology acquisition the acquired knowledge can also be exploited within the confines of the acquired firm. In line with this reasoning I hypothesize that:

H_2: The contribution of embodied and disembodied technology acquisition to firms market value depends on the size of their internal knowledge stock, whereby the presence (absence) of internally developed knowledge is most crucial for disembodied technology acquisition.

The relevance of the nature of technology

In case of embodied technology acquisition, an acquiring firm's ability to successfully leverage the knowledge base of the target depends to a large extent on how *familiar* the acquiring firm is with the technological domain(s) in which the target is active. The consensus in the strategic management literature is that acquiring firms are more likely to realize positive post-acquisition innovation outcomes when their and their targets' knowledge bases are *sufficiently different* to expose them to novel and diverse knowledge, yet sufficiently related to provide ample opportunities for learning (Kapoor and Lim, 2007; Sears and Hoetker, 2014). The intuition is that a high degree of relatedness between the acquiring and target firm's technology portfolio makes it easier to identify and integrate technology developed by the target, but that a too high degree of relatedness limits the exposure to new knowledge domains and thus the potential for recombination and cross-fertilization. The middle ground is thus a moderate level of technological relatedness which is achieved when the acquiring and target firm focus on different narrowly defined knowledge domains that are situated within a broader core knowledge domain that they have in common (Rosenkopf and Almeida, 2003; Makri *et. al.*, 2010; Phene *et. al.*, 2012).

Familiarity with the target's technology is of lesser importance when the main objective of an M&A is to leverage the target firms' capabilities to generate future technologies rather than leveraging its existing knowledge base. Recent studies indicate that the exploitation of known and exploration of novel technologies are distinct activities that should be balanced across rather than within technology sourcing modes (Phene *et. al.*, 2012; Stettner and Lavie, 2014). When such a balance exists, exploration enhances firms' performance more via M&As than via internal development because *"...acquisitions enable a firm to gain immediate control of knowledge that is entirely different from its internal knowledge without calling for relatedness, resemblance or combination of knowledge..." (Stettner and Lavie, 2014, p. 191)*. In other words, M&As permit the separation of exploitation and exploration activities, because it is not necessary and often not even desirable for an acquiring firm to fully integrate a target firm whose business is only remotely related to its own business.

Although the acquisition of standalone technology gives the acquirer more rights and thus a higher degree of control than licensing, it offers less opportunities for learning. Via acquisition the assignee only gets access to the knowledge that is embedded in, and thus specific to, the acquired technology whereas via licensing the licensee can negotiate access to additional know-how that is not embedded in the technology per se. Evidently, the opportunities for learning via standalone technology acquisition are even more limited when compared to embodied technology acquisition as the latter provides access to a target firm's entire knowledge base and all of its resources and capabilities. Given the minimal opportunities for learning that the acquisition of standalone technology offers, it is more likely to provide benefits when the acquiring firm is familiar with the acquired technology than when it is not. As noted by Karim and Mitchell (2000), when obtaining tacit resources, such as know-how, is an objective of the acquisition, 'the market for firms' may be more robust than 'the market for discrete exchange'. The exchange of tacit resources often fails in the market for discrete exchange because these resources are not codifiable and are subject to appropriability concerns. This view is confirmed by Figueroa and Serrano (2018) who find that a patented invention is more likely to be acquired by entities that have patented in the same technological domain(s) as the selling entity prior to the acquisition.

Hence, embodied technology acquisition can be a viable strategy for the acquiring firm to leverage both technology it is familiar with and technology it is unfamiliar with. The acquisition of another firm not only provides the acquiring firm access to this firm's knowledge base and intellectual property but also presents the acquiring firm with an additional unit that has the capabilities to produce future technologies by itself. On the contrary, disembodied technology acquisition is only beneficial towards the exploitation of familiar technology and not towards the exploration of unfamiliar technology. In line with this reasoning I therefore hypothesize that:

H_3: Via the embodied mode, both the acquisition of familiar and novel technology contributes positively to market value, whereas via the disembodied mode only the acquisition of familiar technology contributes positively to market value.

Data and Methods

Sample

My dataset comprises information on 682 publicly traded US-firms, representing nine industries: (i) Pharmaceuticals & Biotechnology, (ii) Chemicals, (iii) IT-Hardware, (iv) Electronics & Electrical Machinery, (v) Engineering & General Machinery, (vi) Software, (vii) Automotive & Other Vehicles, (viii) Other Manufacturing and (ix) Other Industries (see Table 1 for a breakdown of industries according to NACE-REV.2 codes). These firms are drawn from the 2016-edition of the European Commission's Worldwide R&D Scoreboard, which lists the top 2,500 firms that spend the most on R&D activities worldwide. I selected all firms from this list that were incorporated in the US, are the ultimate owner of their corporate group and have been publicly traded for a minimum of three years between 2000 and 2016. For these firms I constructed a panel dataset comprising 7,827 firm-year observations for the period 2000-2016 by combining ownership-, accounting- and patent information from several sources. Specifically, I retrieve (i)

Table 1: An overview of industries according to NACE-REV.2 codes.

Industry	Tag	NACE Code	NACE Code Description	#Firms	#Observations
Automotive & other vehicles	AUTH	29	Manufacture of motor vehicles, trailers and semi-trailers.	45	575
		30	Manufacture of other transport equipment.		
Chemicals	CHEM	01	Crop and animal production, hunting and related service activities.	58	787
		19	Manufacture of coke and refined petroleum products.		
		20	Manufacture of chemicals and chemical products.		
		22	Manufacture of rubber and plastic products.		
Electronics & electrical machinery	ELEC	27	Manufacture of electrical equipment.	28	351
Engineering & general machinery	ENGI	28	Manufacture of machinery and equipment nec.	46	644
It-hardware	ITHW	26	Manufacture of computer, electronic and optical products.	137	1,769
Other manufacturing	OTHM	17	Manufacture of paper and paper products.	53	659
		23	Manufacture of other non-metallic mineral products.		
		24	Manufacture of basic metals.		
		25	Manufacture of fabricated metal products, except machinery and equipment.		
		31	Manufacture of furniture.		
		32	Other manufacturing.		
Pharmaceuticals & biotech	PHAR	21	Manufacture of basic pharmaceutical products and pharmaceutical preparations.	86	819
Software	SOFT	58	Publishing activities.	79	793
		62	Computer programming, consultancy and related activities.		
		63	Information service activities.		
Other industries	OTHI	06	Extraction of crude petroleum and natural gas.	150	1,430
		07	Mining of metal ores.		
		08	Other mining & quarrying.		
		09	Mining support service activities.		
		10	Manufacture of food products.		
		11	Manufacture of beverages.		
		12	Manufacture of tobacco products.		
		13	Manufacture of textiles.		
		14	Manufacture of wearing apparel.		
		15	Manufacture of leather and related products.		
		35	Electricity, gas, steam and air conditioning supply.		
		38	Waste collection, treatment and disposal activities; materials recovery.		
		41	Construction of buildings.		
		42	Civil engineering.		

Table 1: An overview of industries according to NACE-REV.2 codes (continued).

Industry	Tag	NACE Code	NACE Code Description	#Firms	#Observations
Other industries	OTHI	45	Wholesale and retail trade and repair of motor vehicles and motorcycles.	150	1,430
		46	Wholesale trade, except of motor vehicles and motorcycles.		
		47	Retail trade, except of motor vehicles and motorcycles.		
		49	Land transport and transport via pipelines		
		51	Air transport.		
		52	Warehousing and support activities for transportation.		
		53	Postal and courier activities.		
		55	Accommodation.		
		56	Food and beverage service activities.		
		59	Motion picture, video and television programme production, sound recording and music publishing activities.		
		60	Programming and broadcasting activities.		
		61	Telecommunications.		
		64	Financial service activities, except insurance and pension funding.		
		65	Insurance, reinsurance and pension funding, except compulsory social security.		
		66	Activities auxiliary to financial services and insurance activities.		
		68	Real estate activities.		
		71	Architectural and engineering activities; technical testing and analysis.		
		72	Scientific research and development.		
		73	Advertising and market research.		
		74	Other professional, scientific and technical activities.		
		77	Rental and leasing activities.		
		78	Employment activities.		
		79	Travel agency, tour operator reservation service and related activities.		
		82	Office administrative, office support and other business support activities.		
		85	Education.		
		86	Human health activities.		
		93	Sports activities and amusement and recreation activities.		
		94	Activities of membership organisations.		
		96	Other personal service activities.		
Full sample				**682**	**7,827**

ownership information from 10-K filings at the Securities and Exchange Commission (SEC), (ii) information on M&As from Thomson Reuters' EIKON database (previously known as SDC Platinum), (iii) patent information from the United States Patent and Trademark Office's (USPTO) Historical Patent Data Files and the 2018 Spring Edition of PATSTAT, (iv) patent assignment information from the USPTO Patent Assignment Data File and (v) accounting information from

COMPUSTAT.

For the 682 sample firms I obtained the names of all subsidiaries listed in Exhibit-21 of yearly 10-K filings at the SEC for all years between 2000 and 2016. Pursuant to item 601(b)(21) of Regulation S-K of the SEC, public firms are required to list all of their subsidiaries which, considered in the aggregate or as a single subsidiary, constitute a significant subsidiary as defined in Rule 1-02(w) of Regulation S-X.[4] I retrieved a total of 131,389 unique subsidiaries which amounts to an average of 193 subsidiaries per firm. To identify M&As and divestments, I complemented the subsidiary information from SEC-filings with records of M&A deals from EIKON that list the corporate name of sample firms as 'ultimate acquirer' or 'ultimate target'. I identified and dropped records of 'intra-firm' deals between entities that were part of the same corporate group at the time the deal was finalized. The sample firms were listed as ultimate acquirer in 15,801 M&A deals and as ultimate target in 7,623 divestments during the sample period. The compilation of parent names, subsidiary names, names of acquired entities and names of divested entities allows me to track changes in the ownership structure of firms over time, which is an important first step towards distinguishing between technologies developed internally and technologies acquired via M&As.

To identify the patents held by sample firms I matched the yearly lists of entity names as they appear in SEC-filings and EIKON to the names of assignees as they appear on publications of patent applications published by the USPTO. I retrieved the names of patent assignees from the USPTO Historical Patent Data Files and PATSTAT 2018 and applied several name cleaning procedures to standardize them. Subsequently, I developed an algorithm, that computes the similarity between the names of firms and assignees, based on a weighted function of (i) the number of overlapping characters, (ii) the sequence of characters and (iii) string length, to denote the similarity between pairs of text strings. After a manual validation of a random sample of potential name-matches I set the threshold for 'correct' matches such that it would limit both the number of false positives and false negatives.

To account for changes in the ownership structure of firms, I only retrieved patent records for the years in which matched entity names were part of a sample firm. For example, if Subsidiary A has been part of Firm B between 2001 and 2006, I only retrieved patent applications having earliest filing years between 2001 and 2006. In case of acquired entities, I assigned all patents filed prior to the acquisition date to the stock of acquired patents and assigned those

[4] Under rule 1-02(w) of Regulation S-X, a significant subsidiary is one that meets any of the following conditions; (i) The value of the investments in and advances to the subsidiary by its parent and the parent's other subsidiaries, if any exceed 10 percent of the value of the assets of the parent or, if a consolidated balance sheet is filed, the value of the assets of the parent and its consolidated subsidiaries. (ii) The total investment income of the subsidiary or, in the case of a non-investment company subsidiary, the net income exceeds 10 percent of the total investment income of the parent or, if consolidated statements are filed, 10 percent of the total investment income of the parent and its consolidated subsidiaries. (iii) The subsidiary is the parent of one or more subsidiaries and, together with such subsidiaries would, if considered in the aggregate, constitute a significant subsidiary.

filed thereafter to the stock of patents developed internally by the acquired firm. To illustrate, if Firm B acquires a Target Firm C on 01/01/2001 I consider all patents filed by Target Firm C prior to 01/01/2001 as being acquired by Firm B and all patents filed after that day as being developed by Firm B. This logic is reversed for divestments, in these cases I assign patents filed prior to the divestment date to the stock of internally developed patents and consider patents filed thereafter as being developed by the new owner of the divested entity.

I rely on patent assignment records from the USPTO Patent Assignment Database (UPAD) to identify technologies acquired via the disembodied mode. [5] A patent assignment is a transfer by a party of all or part of its right, title and interest in a patent or patent application for which an application to register has been filed. For an assignment to take place, the transfer to another party must include the entirety of the bundle of rights that is associated with the ownership rights. A patent assignment is in effect thus an acquisition of a patented invention by a designated assignee from a designated assignor. I retrieved all patent assignment records from UPAD that list the sample firms or their subsidiaries as assignees by using the same name-matching approach that I used to link parent-, subsidiary- and acquired firms' names to patent records.

Recognizing that patent assignments can be the result of M&As – the acquiring firm can decide to assign all or some of the patents of the acquired entity to its own name – I identified and dropped all assignment records involving patents that I assigned in the previous step to the stock of patents that were acquired via M&As. Furthermore, I disregarded all 'intra-firm' assignment records that have a listed assignor and assignee that were both part of the same corporate group at the execution date of the assignment. Lastly, I followed the procedure described by Marco *et. al.* (2015) to drop assignments whereby the assignor is an inventor-employee of the assignee.[6]

Ultimately, I matched at total of 1,915,752 patent applications filed at the USPTO to the 682 sample firms. Of these patents 1,697,533 were developed internally by sample firms of which 645,063 were developed by 15,595 subsidiaries, 81,101 were acquired via 3,449 M&A deals and 137,118 were acquired via 34,678 patent assignments deals. These numbers highlight that establishing the ownership structure of firms over time is essential for understanding the entirety of firms' technological activities. First, without taking into account the subsidiaries of

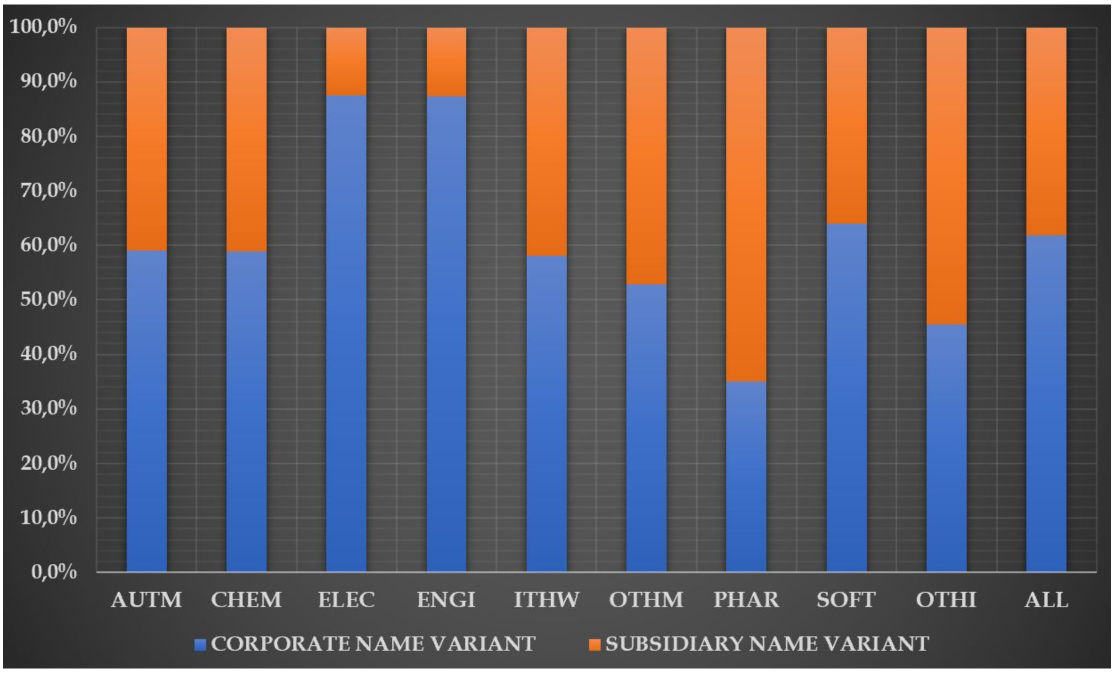
---

[5] See Marco *et. al.* (2015) for an elaborate description of the USPTO Patent Assignment Dataset.

[6] This issue exists because *"...for all applications filed before September 16, 2012, the patent must issue to a human inventor, requiring a legal assignment to an employer-owner. Inventor-employees are typically under some contractual obligation to transfer ownership of an application or resulting patent to their employers. Thus, before the recent enactment of the America Invents Act (AIA), in order to take action in a patent matter, an assignee had to establish ownership of the patent or patent application in compliance with 37 CFR 373 (pre-AIA), which generally required submitting or specifying the location of documentary evidence of a chain of title from the inventor to the assignee in the assignment records of the Office..." (Marco et. al., 2015, p. 7).* Marco *et. al.* (2015) classify an assignment record as "employer assignment" when the record meets the following conditions: (i) the record is the earliest transaction recorded for the property, (ii) the property was transferred alone, (iii) the execution date is prior to the patent application disposal date and (iv) keyword searching identifies the conveyance text as an "assignment".

firms, I would miss out on about 38% of patents that were filed under subsidiary name variants rather than corporate name variants. An even greater concern is that there are stark differences between industries with respect to the allocation of patent ownership. As shown by Figure 1 below, in some industries, such as Pharmaceuticals & Biotechnology, the majority of patents is filed under subsidiary names whereas in other industries such as Electronics & Electrical Machinery and Engineering & General Machinery more than 90% of patents are filed under corporate name variants. Second, by not taking into account the ownership structure of firms,

Figure 1: The share of corporate and subsidiary patents per industry.



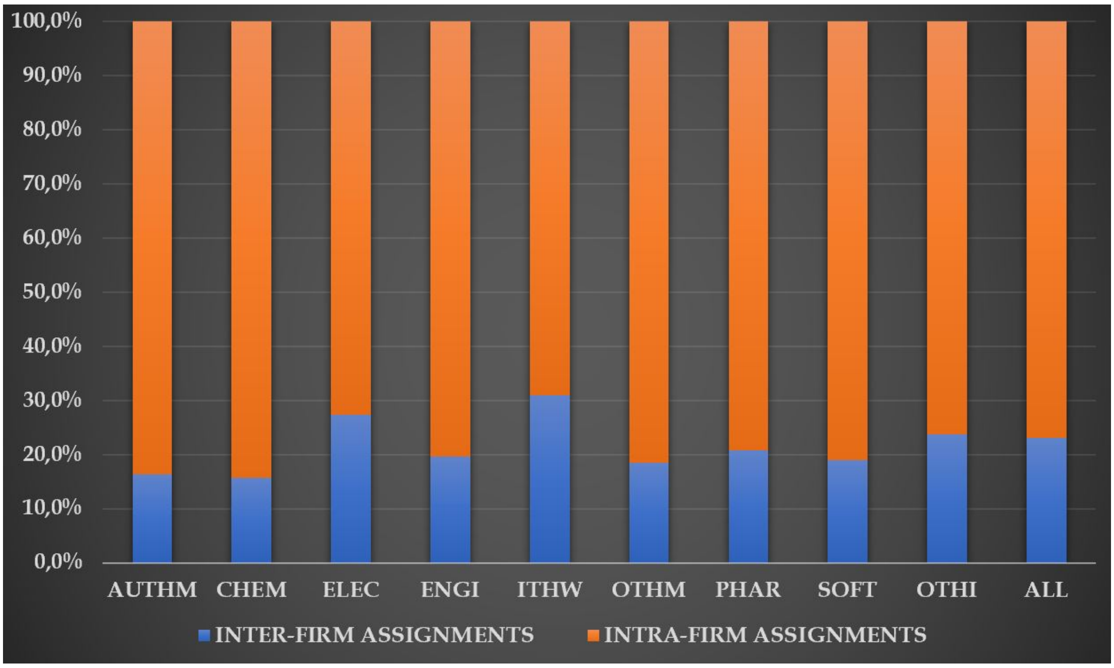
I would not have been able to identify and disregard technology transactions between entities belonging to the same corporate group. As it turns out, about 78% of all assignments listing the sample firms or their subsidiaries as beneficiary of a patent assignment happen within rather than across firm boundaries. As illustrated by Figure 2, this finding is pretty consistent across industries. Without consolidation I would thus vastly overestimate the prominence of disembodied technology acquisition.

Variables

Dependent Variable

The dependent variable in the analyses is the annual financial performance of firms, reflected by their market value at the end of each fiscal year. In line with a longstanding tradition in

Figure 2: The share of intra-firm and inter-firm assignments per industry.



the economics of innovation literature I compute market value as the sum of common stock, preferred stock and total debt minus current assets whereby the book value of current assets includes net plant, property and equipment, inventories and investments in unconsolidated subsidiaries (*i.a.* Hall *et. al.*, 2005; Czarnitzki *et. al.*, 2006; Arora *et. al.*, 2014). The main rationale for using market value is that it is a far sighted measure of financial performance. Existing studies that use market value as dependent variable implicitly assume that firms' stock price at any point in time fully reflects all information available to the market up to that point (Fama, 1998; Borah and Tellis, 2014). Every announcement of a new decision by a focal firm provides new information to the market that may affect its stock price positively or negatively. Fluctuations in the stock price reflect the discounted cash flows that the market anticipates as a result of the decision, thereby considering the focal firm's past performance and its future potential.

Pursuant to this logic, I assume that the stock market returns to different technology acquisition strategies reflect their discounted expected returns in the future. Analyzing these returns, then permits me to assess the payoff from embodied and disembodied technology acquisitions as well as the factors that drive this payoff. This forward-looking feature of market value is paramount to this study, given that the returns from firms' technological activities often become apparent only several years after they ensued (*i.a.* Czarnitzki *et. al.*, 2006; Belderbos *et. al.*, 2010). An additional advantage of relying on market value as the dependent variable is that it makes the results comparable to the results of existing studies (e.g. Hall *et. al.*, 2005; Arora *et. al.*, 2014). I collected all relevant accounting information to compute the market value from COMPUSTAT. The market value is given by:

$$MARKETVALUE_{i,t} = CSHO_{i,t} * PRCC\_F_{i,t} + PSTKL_{i,t} + LCT_{i,t} + DLTT_{i,t} \\ - PPEGT_{i,t} - INVT_{i,t} - ESUB_{i,t}$$

where $MV_{i,t}$ is the market value of firm i at the end of fiscal year t, $CSHO_{i,t}$ is the number of outstanding common shares, $PRCC\_F_{i,t}$ is the share price at the end of the fiscal year, $PSTKL_{i,t}$ is the preferred stock at liquidating value, $LCT_{i,t}$ is the sum of current liabilities, $DLTT_{i,t}$ is the sum of long-term debt, $PPEGT_{i,t}$ is the total book value of property, plant and equipment, $INVT_{i,t}$ is the total book value of inventory and $ESUB_{i,t}$ is the total investment in unconsolidated subsidiaries.

Patent Stocks

There are two opposing views with regards to the computation of patent stocks that have dominated the economics of innovation literature. On the hand, there are scholars who take the view that the economically relevant lifetime of a patent exceeds its legal lifetime. Most notably, Cantwell and Andersen (1996) and Cantwell and Piscitello (1998) calculate patent stocks over a 30-year period and use a straight-line depreciation method that resembles those included in vintage capital models. The underlying rationale is that new technological knowledge is embodied, at least in part, in capital equipment that has an average age of 30 years and depreciates steadily over time. On the other hand, there are scholars who contend that the economically relevant lifetime of a patent is much shorter than the maximum legal age of 20 years. These scholars generally employ a perpetual inventory method and use constant annual depreciation rates that vary between a conservative 15%, which corresponds to an average patent age of 6.6 years (*i.a.* Gambardella and Torrisi, 2000; Hall *et. al.*, 2005), and a more progressive 30%, alluding to an average patent age of 3.3. years (*i.a.* Cockburn and Griliches, 1988; Blundell *et. al.*, 1999).

I adopt the latter view and apply a constant annual depreciation rate of 15% in all the calculations of patent stocks. To account for differences in observation periods between sample firms, I follow the approach outlined by Jungmittag (2004) and compute patent stocks in a moving six-year time-window using the perpetual inventory method. I also account for the heterogeneity in the quality of patents by computing citation-weighted patent counts as introduced by Hall *et. al.* (2005). Specifically, I count the number of citations that a focal patent receives in a fixed time-window of three years after its earliest publication date and normalize this count by the average number of citations received in the same period by patents that are classified into the same technology classes and have the same earliest filing year as the focal patent. As an example, consider a focal patent that is classified simultaneously into technology classes ‘A61B’, ‘A18G’ and 'C12F' and has been filed in 2005. For this patent I derive the number of citations that it receives in a three-year period and divide this number by the average number of citations in the same time window received by all patents classified simultaneously into technology classes 'A61B', 'A18G' and 'C12F' that were filed in 2005.

I compute patent stocks based on patent information from the USPTO Historical Patent Data Files, PATSTAT and UPAD. The generic formula for patent stocks is given by:

$$PATENT\ STOCK_{i,t} = \sum_{\tau=t-5}^{t} (1-\delta)^{(t-\tau)}\ PATENT\ COUNT_{i,\tau}$$

where $PATENT\ STOCK_{i,t}$ is the patent stock of firm i at the end of fiscal year t, δ is the annual depreciation rate of 15% and $PATENT\ COUNT_{i,\tau}$ is the count of citation-weighted and normalized patent applications with earliest filing year τ. To test my hypotheses, I disaggregate firms' overall patent stock into several parts. To test Hypotheses 1 and 2 I distinguish between the stock of patents that have been filed by firm i and its subsidiaries, the $INTERNAL\ STOCK_{i,t}$, the stock of patents that firm i has acquired either via M&As, the $EMBODIED\ STOCK_{i,t}$ and the stock of patents that firm i has acquired via patent assignments, the $DISEMBODIED\ STOCK_{i,t}$. All three stocks are computed via the generic formula as defined above. To test hypotheses 3a and 3b I develop measures that indicate how familiar a firm is with the acquired technology. To this end, I apply the 'novelty in recombination' indicator developed by Verhoeven *et. al.* (2016) to the firm-level.

Verhoeven *et. al.* (2016) propose that an invention has novelty in recombination if the combination of components and principles applied to serve its purpose are different from those embodied in previous technologies. They operationalize this intuition by relying on the International Patent Classification (IPC) system and identify patents that are the first to make a combination of IPC-4 classes as those having novelty in recombination. This means, for example, that only the first patent that is classified into both class A61B and A18G will 'score' on the novelty in recombination indicator. I apply the same logic to the firm level and impose a fixed time window of ten years. For every patent that a focal firm acquires via M&As and patent assignments, I derive all combinations of IPC4-classes listed on the patent and check whether these combinations are present on patents filed by the focal firm or its subsidiaries in the ten years prior to the acquisition date. If an acquired patent makes at least one combination of IPC4-classes that is not present on any of the patents filed by the focal firm or one of its subsidiaries, I classify this patent as 'novel' and otherwise as 'familiar'. This allows me to distinguish between the stock of patents acquired via M&As that is novel to the focal firm, the $EMBODIED\ STOCK(novel)_{i,t}$, and the stock that is not novel, the $EMBODIED\ STOCK\ (familiar)_{i,t}$. Likewise I can make the same distinction between the stock of patents acquired via assignments that is novel, the $DISEMBODIED\ STOCK(novel)_{i,t}$, and the stock that is not novel, the $DISEMBODIED\ STOCK\ (familiar)_{i,t}$.

Ultimately, my approach allows me to delineate the technology sourcing mix of sample firms over time. To illustrate, Figure 3 presents the profiles of three sample firms – Apple Inc., Comtech Telecommunications Corporation and Twitter Inc. – to highlight markedly different technology sourcing mixes. From the figure it can be observed that Apple Inc. developed the vast majority of its technologies internally and filed most patents under its parent name, Comtech Telecommunications Corporation acquired the majority of its patent portfolio via the embodied route – primarily the acquisition of Telecommunications Systems Inc. in 2015 – and Twitter Inc. acquired the bulk of its technologies via the disembodied route – primarily a patent assignment deal with IBM Corporation in 2014. To illustrate that the technology sourcing mix of firms can be subject to considerable changes over time, consider the technology sourcing mix of Twitter Inc. prior to 2014, presented in Figure 4. It is clear that prior to the patent assignment deal with IBM Corporation, the majority of Twitter Inc.'s patent portfolio was developed internally. It is the effect of changes such as this in the technology sourcing strategies of firms on their market value that is the focal point of the analysis.

Control Variables

I introduce several variables that may be correlated with firms' market value as control variables in the analysis. First, I include the total assets of a firm – $ASSETS_{i,t}$ – to account for the fact that market values may vary considerable between firms of different sizes. Second, it is well-established in the economics of innovation literature that the stock market value of firms is related to the size of their investments into R&D *(i.a.* Blundell *et. al.*, 1999; Hall *et. al.*, 2005). Therefore, I include the R&D expenditures of firms as a control variable. To be consistent with the computation of patent stock variables, I compute the stock of R&D expenditures using a perpetual inventory method with a constant 15% annual discount rate in a fixed six-year window. Relying on accounting information from COMPUSTAT, the R&D stock is given by:

$$R\&D\ STOCK_{i,t} = \sum_{\tau=t-5}^{t} (1-\delta)^{(t-\tau)}\ XRD_{i,\tau}$$

where $R\&D\ STOCK_{i,t}$ is the stock of R&D expenditures of firm i in fiscal year t, δ is the annual depreciation rate of 15% and $XRD_{i,\tau}$ is the amount of R&D expenditures in millions in year τ. Lastly, I include time fixed effects to control for differences in macroeconomic trends across time and include industry fixed effects to account for differences in market value across industries. Hence, firms in different industries may face different competitive pressures and opportunities, which may ultimately translate into performance differences across industries.

I do not include firm fixed effects for multiple reasons. First, analyses of variance indicate that most of the variation in the measures of interest is between firms rather than over time within firms. The between-firm variation of *PATENT STOCK*, *INTERNAL STOCK*, *EXTERNAL STOCK*, *EMBODIED STOCK* and *DISEMBODIED STOCK* accounts to 86, 87, 83, 82 and 79

Figure 3: The technology sourcing mix of Apple Inc. (top), Comtech Telecommunications Corporation (middle) and Twitter Inc. (bottom).

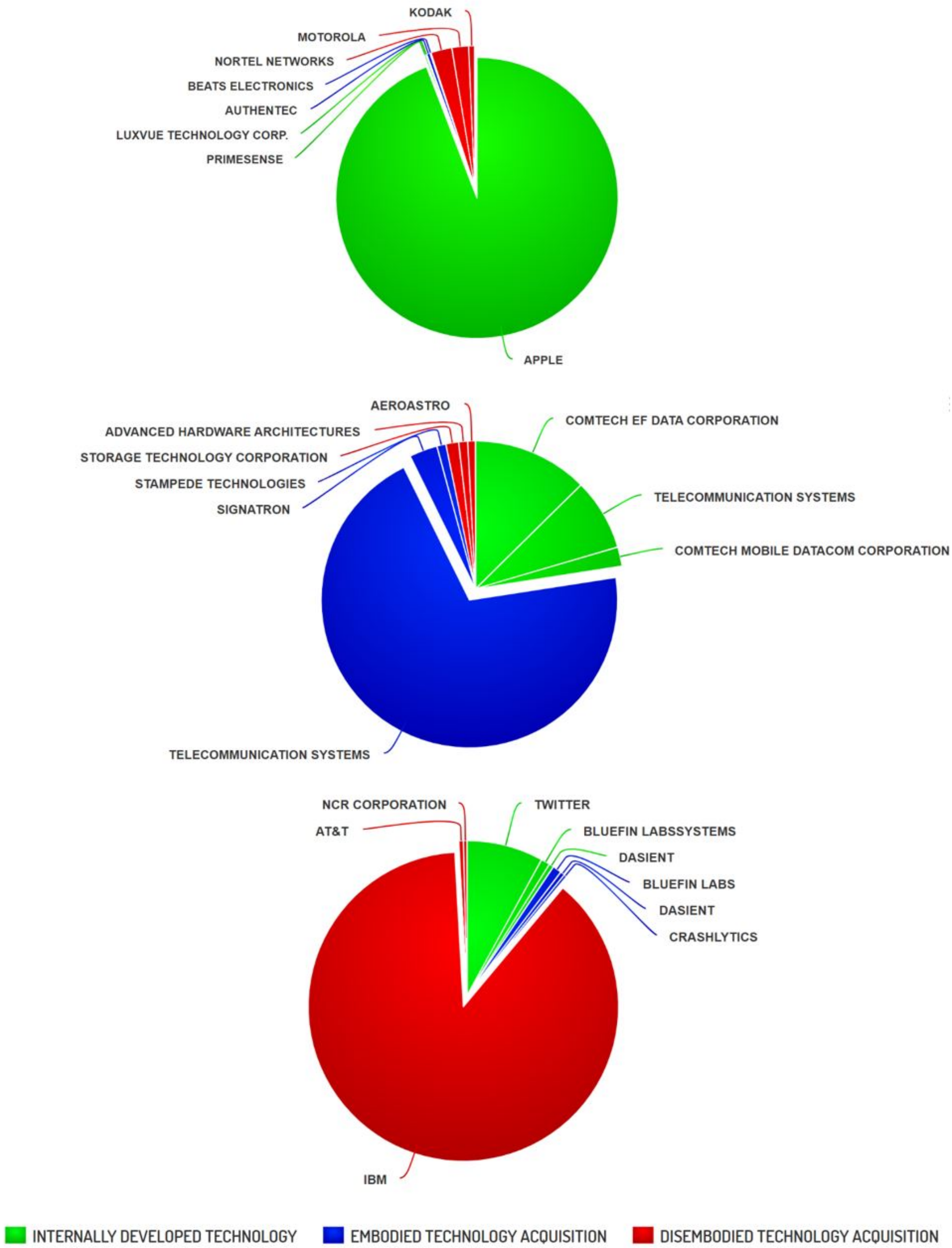
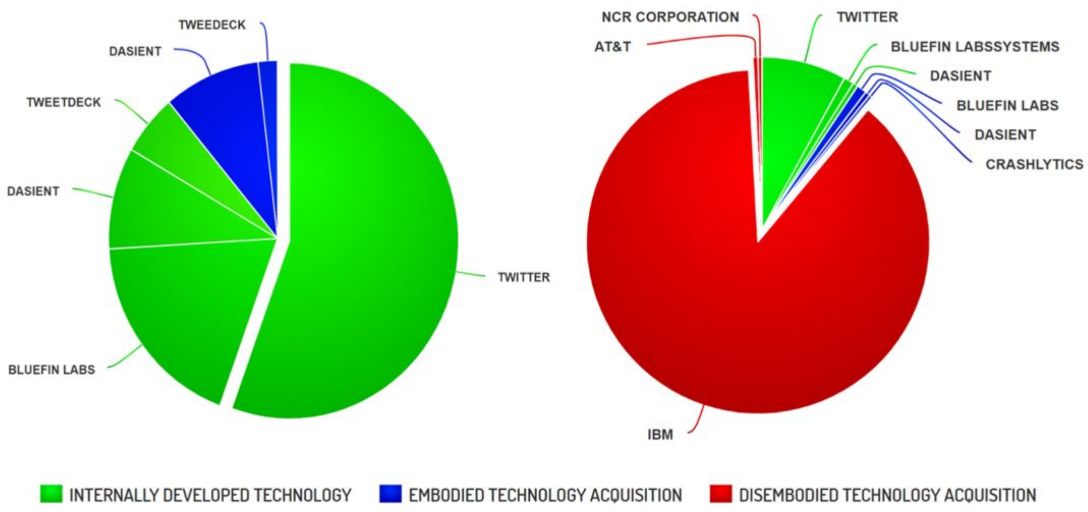


Figure 4: The technology sourcing mix of Twitter Inc. prior to (left) and after 2014 (right).



percent of the variation respectively. This observation is in line with existing studies that use patent stock measures in a firm-level setting (Arora *et. al.*, 2014). Second, by construction the stock-variables change slowly over time which implies that *"...even small amounts of measurement error may lead to a substantial downward bias in the coefficient estimates when differenced estimators are used..."*, *(Hall et. al., 2005, p. 26)*. Lastly, 'fixing' differences across firms may not be sensible in the sense that firms are likely to adapt their strategies in response to changing market conditions (Hall *et. al.*, 2005).

Estimation

I estimate a multiplicative and non-linear relationship between market value and the patent-stock variables because I have reason to believe that both dependent and independent variables of interest exhibit the characteristics of exponential growth over time. Under these circumstances, multiplicative models have been shown to produce substantially improved statistical specifications compared to additive models. Most notably, a recent study by Falta and Willett (2013) that estimates the relationship between market value and a large set of accounting variables in a panel of US-firms over a 50-year period, suggests that most accounting variables – including the model variables market value, total assets and R&D-expenditures – exert exponential growth over time. The study also highlights the importance of giving recognition to time lags when estimating a 'market-accounting' relationship because the effects of most accounting variables are long-run rather than short run. Following this logic, I estimate the following base regression equation:

$$ln(Y)_{i,t} = \alpha + \beta ln(X)_{i,t-1)} + \epsilon_i$$

In the resulting models, coefficients should be interpreted as an elasticity in the sense that the effect of a one-unit change in X on Y refers to a percentage change rather than an absolute one. In the above equation, β, thus, refers to the percentage increase in $ln(Y)_{i,t}$ for every 1% increase in $ln(X)_{i,t}$. This approach is in line with recent studies that estimate the contribution of firms' R&D activities on their market value, most notably the study of Arora *et. al.* (2014), which makes my results directly comparable with their results.

Results

Nonparametric Analysis

I present summary statistics for core constructs in Table 2. From the table one can observe that the average market value of firms in the sample is $13.8 billion of which $11.8 billion is vested in physical assets. On average, sample firms spend $351 million on R&D and have a patent stock of 516 patents. At the firm level, an average of 85 percent of the patent stock is developed internally by parent firms and their subsidiaries, whilst 15 percent is acquired externally. Of the externally acquired patents, 40 percent is acquired via the embodied route and 60 percent is acquired via the disembodied route, which amounts to 6 percent and 9 percent respectively out of the total patent stock. The sample firms thus acquire a greater number of patents via patent assignments than via the acquisition of firms. On average, the share of novel patents within firms' patent stock is 9 percent, although there is a notably difference between the share of novel patents in the internally and externally developed stocks. Whereas the share of novel patents is 9 percent for the internally developed stock, it amounts to 14 percent for the externally developed stock, with only a 1 percent difference between the embodied and disembodied stocks. This suggests that sample firms are more likely to acquire technologies that belong to technological domains they are not familiar with than to develop these technologies internally.

Table 3 breaks downs the descriptive statistics by industry to highlight key differences in average values of core constructs across industries. From the table it can be observed that the average market value of sample firms is the greatest in the *Chemical* and *Pharmaceutical & Biotech* industries, with the value of assets being the greatest in the *Electronics & Electrical Machinery* and *Automotive & Other Vehicles* industries. Not surprisingly, the most R&D intensive firms are active in the *Pharmaceutical & Biotech*, *Software* and *IT-Hardware* industries. *Pharmaceutical & Biotech* firms spend a whopping 57 percent of the value of their assets on R&D, which is more than five times the sample average of 11 percent. Also in line with expectations, firms in manufacturing industries generate the most patents on average. An average firm in *Engineering &*

Table 2: Summary statistics for main constructs.

	#Observations	#Firms	Mean	S.D.	Distribution				
					Min	10th perc.	50th perc.	90th perc.	Max
Market value ($m)	7,827	682	13,782	40,029	0.04	236	2,165	30,176	626,550
Assets ($m)	7,827	682	11,781	42,949	0.10	167	1,738	23,818	797,769
R&D expenditures ($m)	7,827	682	351	1,102	0	2	52	654	16,085
R&D stock ($m)	7,827	682	1,301	4,042	0	9	189	2,406	46,903
Sales ($m)	7,827	682	10,000	31,795	0	101	1,462	19,616	483,521
Number of employees	7,827	682	28,694	104,025	2	341	5,550	66,663	2,300,000
Patent stock	7,827	682	516	1,725	0	2	77	1,016	31,789
R&D expenditures/assets	7,827	682	0.11	51.95	0	0.002	0.04	0.19	93.09
Patent stock/R&D stock	7,827	682	0.71	1.01	0	0.047	0.40	1.66	19.69
Internal stock	7,827	682	438	1,560	0	1	59	889	30,922
External stock	7,827	682	77	373	0	0	9	146	10,581.
Embodied stock	7,827	682	31	236	0	0	0	38	8,534
Disembodied stock	7,827	682	46	270	0	0	5	99	10,379
Share internal stock	7,827	682	0.85	0.23	0	0.446	0.89	1	1
Share external stock	7,827	682	0.15	0.23	0	0	0.11	0.55	1
Share embodied stock	7,827	682	0.06	0.16	0	0	0.0028	0.24	1
Shared disembodied stock	7,827	682	0.09	0.18	0	0	0.0547	0.37	1
Patent stock (familiar)	7,827	682	467	1,650	0	0.73	59	928	31,288
Patent stock (novel)	7,827	682	49	106	0	0.52	16	111	1,622
Internal stock (familiar)	7,827	682	401	1,501	0	0.52	45	818	30,423
Internal stock (novel)	7,827	682	38	83	0	0	12	88	967
External stock (familiar)	7,827	682	66	342	0	0	6	121	9,490
External stock (novel)	7,827	682	11	43	0	0	2	25	1,251
Embodied stock (familiar)	7,827	682	26	213	0	0	0	30	8,108
Embodied stock (novel)	7,827	682	5	33	0	0	0	8	1,243
Disembodied stock (familiar)	7,827	682	40	248	0	0	3	83	9,319
Disembodied stock (novel)	7,827	682	6	25	0	0	1	16	1,060
Share novel in patent stock	7,827	682	0.09	0.20	0	0.048	0.19	0.48	1
Share novel in internal stock	7,827	682	0.09	0.19	0	0.042	0.17	0.45	1
Share novel in external stock	7,827	682	0.14	0.26	0	0	0.21	0.64	1
Share novel in embodied stock	7,827	682	0.15	0.31	0	0	0.20	0.78	1
Share novel in disembodied stock	7,827	682	0.14	0.27	0	0	0.17	0.63	1

Table 3: Summary statistics for main constructs broken down per industry.

	AUTM	CHEM	ELEC	ENGI	ITHW	OTHM	PHAR	SOFT	OTHI	ALL
#Observations	575	787	351	644	1,769	659	819	793	1,430	7,827
#Firms	45	58	28	46	137	53	86	79	150	682
Market value ($m)	10,708	22,676	15,528	9,506	10,170	8,375	19,156	10,738	17,191	13,782
Assets ($m)	22,572	19,070	32,292	8,560	6,189	6,008	9,903	5,049	14,235	11,781
R&D expenditures ($m)	687	219	217	290	387	173	839	342	110	351
R&D stock ($m)	2,747	867	818	1,123	1,434	658	3,046	1,149	361	1,301
Sales ($m)	17,978	18,594	8,966	7,084	4,621	4,681	4,843	2,413	19,898	10,000
Number of employees	45,023	19,821	25,980	25,858	12,583	15,875	9,562	7,727	77,376	28,694
Patent stock	716	454	582	978	782	432	291	361	168	516
R&D expenditures / assets	0.04	0.02	0.04	0.04	0.10	0.05	0.57	0.11	0.03	0.11
Patent stock / R&D stock	0.80	0.81	0.99	0.97	0.81	0.99	0.27	0.26	0.65	0.71
Internal stock	655	383	523	920	635	374	226	252	155	438
External stock	60	71	59	58	148	58	64	109	13	77
Embodied stock	16	42	18	21	52	17	37	56	3	31
Disembodied stock	44	29	41	37	96	41	27	53	10	46
Share internal stock	0.92	0.84	0.90	0.94	0.81	0.87	0.78	0.70	0.92	0.85
Share external stock	0.08	0.16	0.10	0.06	0.19	0.13	0.22	0.30	0.08	0.15
Share embodied stock	0.02	0.09	0.03	0.02	0.07	0.04	0.13	0.15	0.02	0.06
Share disembodied stock	0.06	0.06	0.07	0.04	0.12	0.10	0.09	0.15	0.06	0.09
Patent stock (familiar)	611	398	512	907	715	383	272	337	152	467
Patent stock (novel)	105	56	70	71	67	49	19	24	16	49
Internal stock (familiar)	565	339	463	863	587	334	213	238	142	401
Internal stock (novel)	91	45	60	58	48	40	13	14	13	38
External stock (familiar)	46	60	48	45	128	49	59	99	10	66
External stock (novel)	14	11	11	14	20	9	6	10	3	11
Embodied stock (familiar)	11	37	14	16	43	14	34	52	2	26
Embodied stock (novel)	5	5	5	5	9	3	3	4	1	5
Disembodied stock (familiar)	35	23	35	28	85	35	25	47	8	40
Disembodied stock (novel)	9	6	6	9	11	6	2	6	2	6
Share novel in patent stock	0.15	0.12	0.12	0.07	0.09	0.11	0.06	0.07	0.09	0.09
Share novel in internal stock	0.14	0.12	0.11	0.06	0.07	0.11	0.06	0.06	0.08	0.09
Share novel in external stock	0.24	0.16	0.18	0.23	0.13	0.15	0.09	0.09	0.22	0.14
Share novel in embodied stock	0.34	0.12	0.25	0.22	0.18	0.15	0.08	0.07	0.32	0.15
Share novel in disembodied stock	0.20	0.21	0.15	0.24	0.11	0.15	0.09	0.12	0.18	0.14

General Machinery, *IT-Hardware* and *Automotive & Other Vehicles* has a patent stock of 978, 782 and 715 patents respectively.

Interestingly, there are stark differences across industries with respect to the relative shares of internally developed and externally acquired technologies. The share of externally acquired patents is the largest in the *Software*, *Pharmaceuticals & Biotech* and *IT-Hardware* industries, whilst being the lowest in the *Engineering & General Machinery* and *Automotive & Other Vehicles* industries. The share of externally acquired patents amounts to 30 percent for an average *Software* firm, which is twice the sample average of 15 percent, whilst amounting to only 6 percent for an average *Engineering & General Machinery* firm, which is less than half of the sample average. Except for the *Chemical*, *Pharmaceutical & Biotech* and *Software* industries, sample firms acquire a larger share of patents via patent assignments than via M&As. For firms in these industries the share of externally acquired technologies via M&As far exceeds the sample average of 6 percent. The standalone acquisition of technology is especially prominent in the *Software*, *IT-Hardware* and *Other Manufacturing* industries.

The differences between industries are also apparent when it comes to the share of novel technologies within the internally developed and externally acquired stock of patents. With respect to the entire patent stock it is notable that firms in the *Automotive & Other Vehicles*, *Chemical*, *Electronics & Electrical Machinery* and *Other Manufacturing* industries have the largest share of novel patents on average. It is also the firms in these industries that both develop the largest share of novel patents internally and acquire the largest share of novel patents externally. Lastly, firms in the *Automotive & Other Vehicles* and *Electronics & Electrical Machinery* and *Engineering & General Machinery* have the highest novelty shares within the stocks of patents acquired via both the embodied and disembodied mode.

Parametric Analysis

The results of the regression models estimating the contribution of different technology acquisition strategies to the market value of firms are presented in Table 4. I begin with a baseline regression in Model 1 that estimates the contribution of firms' assets, cumulative R&D investments and internal technology development efforts to their market value. As expected, the signs of *ASSETS* , *R&D STOCK* and *INTERNAL STOCK* are all positive and highly significant. Furthermore, the high value of the R-squared indicates that the control variables account for a large share of the variation in *MARKET VALUE*. To test Hypothesis 1, I include the *EMBODIED STOCK* and *DISEMBODIED STOCK* in Model 2. Interestingly, I find that the coefficient of *EMBODIED STOCK* is positive and significant whilst the coefficient of *DISEMBODIED STOCK* is negative and significant. The results, thus, suggest a positive contribution to market value of technology acquired via the embodied mode whilst revealing a negative relationship between market value and technology acquired via the disembodied mode. This finding not only rejects

Table 4: Regression results: contributions from internal, embodied and disembodied stocks to market value.

	Dependent Variable: ln(Market value)				
	(1)	(2)	(3)	(4)	(5)
ln(*ASSETS*)$_{t-1}$	0.825***	0.829***	0.833***	0.822***	0.830***
	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)
ln(*R&D STOCK*)$_{t-1}$	0.020***	0.022***	0.025***	0.021***	0.019**
	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)
ln(*INTERNAL STOCK*)$_{t-1}$	0.085***	0.095***	0.097***	0.077***	0.092***
	(0.006)	(0.007)	(0.007)	(0.008)	(0.009)
ln(*EMBODIED STOCK*)$_{t-1}$		0.015**		-0.082***	
		(0.007)		(0.018)	
ln(*DISEMBODIED STOCK*)$_{t-1}$		-0.035***		-0.064***	
		(0.007)		(0.016)	
ln(*EXTERNAL STOCK*)$_{t-1}$			-0.013*		
			(0.007)		
ln(*INTERNAL STOCK # EMBODIED STOCK*)$_{t-1}$				0.017***	
				(0.003)	
ln(*INTERNAL STOCK # DISEMBODIED STOCK*)$_{t-1}$				0.005*	
				(0.003)	
ln(*EMBODIED STOCK FAMILIAR*)$_{t-1}$					0.026***
					(0.010)
ln(*EMBODIED STOCK NOVEL*)$_{t-1}$					-0.020
					(0.014)
ln(*DISEMBODIED STOCK FAMILIAR*)$_{t-1}$					0.002
					(0.010)
ln(*DISEMBODIED STOCK NOVEL*)$_{t-1}$					-0.063***
					(0.014)
Constant		0.581***	0.546***	0.732***	0.567***
		(0.078)	(0.077)	(0.082)	(0.080)
#Observations	7,827	7,827	7,827	7,827	7,827
#Firms	682	682	682	682	682
R-squared	0.822	0.826	0.826	0.828	0.825
Industry Dummies	Yes	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes

Standard errors are robust to arbitrary heteroskedasticity and allow for serial correlation via clustering on the firm-level.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

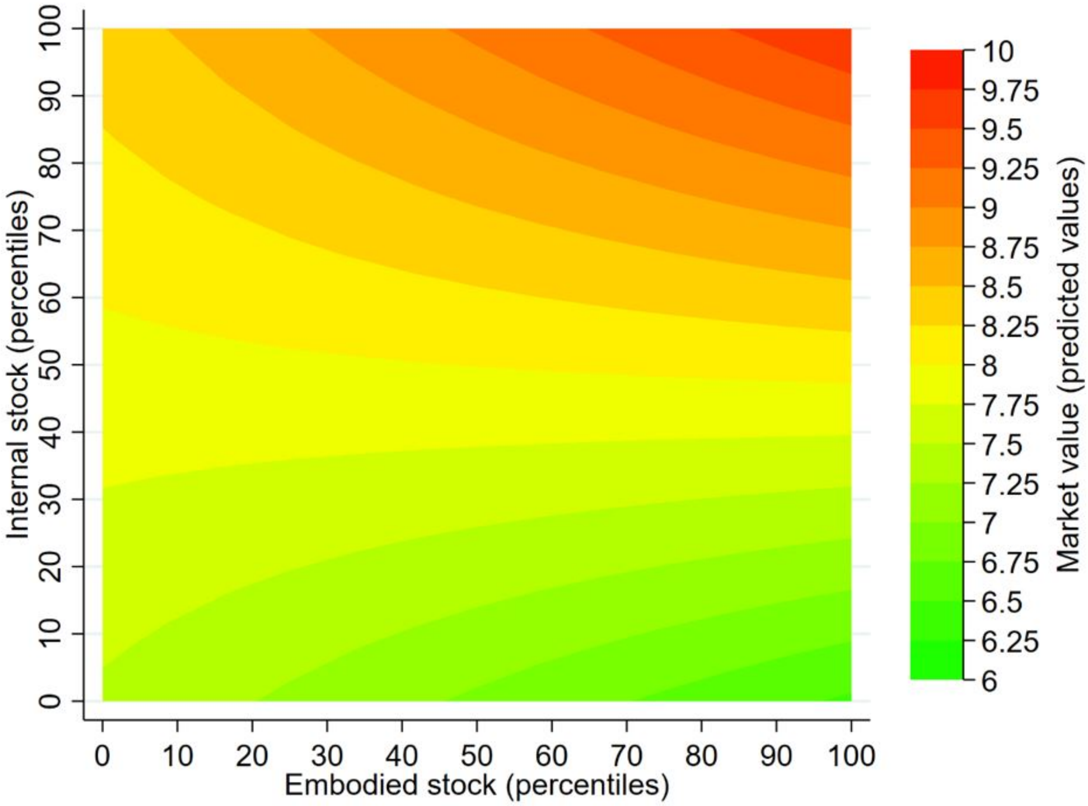
Hypothesis 1, but also highlights the importance of disentangling different modes of technology acquisition. To further illustrate this point, I include the sum of *EMBODIED STOCK* and *DISEMBODIED STOCK* in Model 4 instead of including both stocks separately. The coefficient of *EXTERNAL STOCK* is negative and significant, albeit only at the 10%-level. This means that U would have found an overall negative relationship between technology acquisition and market value without explicitly distinguishing between the different modes of technology acquisition.

To explore whether the contribution of the two modes of technology acquisition to market value differs across different levels of internal technology development, I include the interaction term of *INTERNAL STOCK* and *EMBODIED STOCK* and the interaction term of *INTERNAL STOCK* and *DISEMBODIED STOCK* respectively in Model 4. Both interaction terms are positive and significant, albeit only at the 10%-percent level for the interaction between *INTERNAL STOCK* and *DISEMBODIED STOCK*, but are difficult to interpret because the coefficients of *EMBODIED STOCK* and *DISEMBODIED STOCK* are negative whilst the coefficient of *INTERNAL STOCK* is positive. This signals that the direction of the relationship between *EMBODIED STOCK* and *MARKET VALUE* and *DISEMBODIED STOCK* and *MARKET VALUE* differs across levels of *INTERNAL STOCK*.

To get a clearer view of the interaction between *INTERNAL STOCK* and the two modes of technology acquisition I visualize the predicted values of *MARKET VALUE* across the distribution of *INTERNAL STOCK* and *EMBODIED STOCK* in Figure 5 and across the distribution of *INTERNAL STOCK* and *DISEMBODIED STOCK* in Figure 6. The interaction between *INTERNAL STOCK* and *EMBODIED STOCK* is apparent in the curvature of the contour lines in the figure. This curvature clearly shows that the relationship between *EMBODIED STOCK* and *MARKET VALUE* differs across levels of *INTERNAL STOCK*. Hence, if this would not be the case the contour lines in the figure would all be straight. The presence of both upward and downward curves confirms that for part of the distribution of *INTERNAL STOCK* the relationship between *EMBODIED STOCK* and *MARKET VALUE* is negative whereas for another part it is positive. More specifically, one can observe a clear pattern whereby (i) up to the 30^{th} percentile of the distribution of *INTERNAL STOCK*, firms acquiring even a low volume of technology via the embodied mode have a lower market value on average than firms that do not acquire any technology, (ii) between the 30^{th} and 60^{th} percentile of the distribution of *INTERNAL STOCK*, there is no significant difference between the market value of firms acquiring any level of technology and firms acquiring no technology at all and (iii) above the 60^{th} percentile of the distribution of *INTERNAL STOCK*, firms acquiring any level of technology have a higher market value on average than firms acquiring no technology. This suggests that the acquisition of technology via the embodied mode only contributes positively to market value for firms having the top-40% largest stocks of internally developed technologies.

The interpretation of figure 6 is analogous to the interpretation of Figure 5. The overall pattern in Figure 6 is similar to the one in Figure 5, although the threshold of *INTERNAL STOCK*

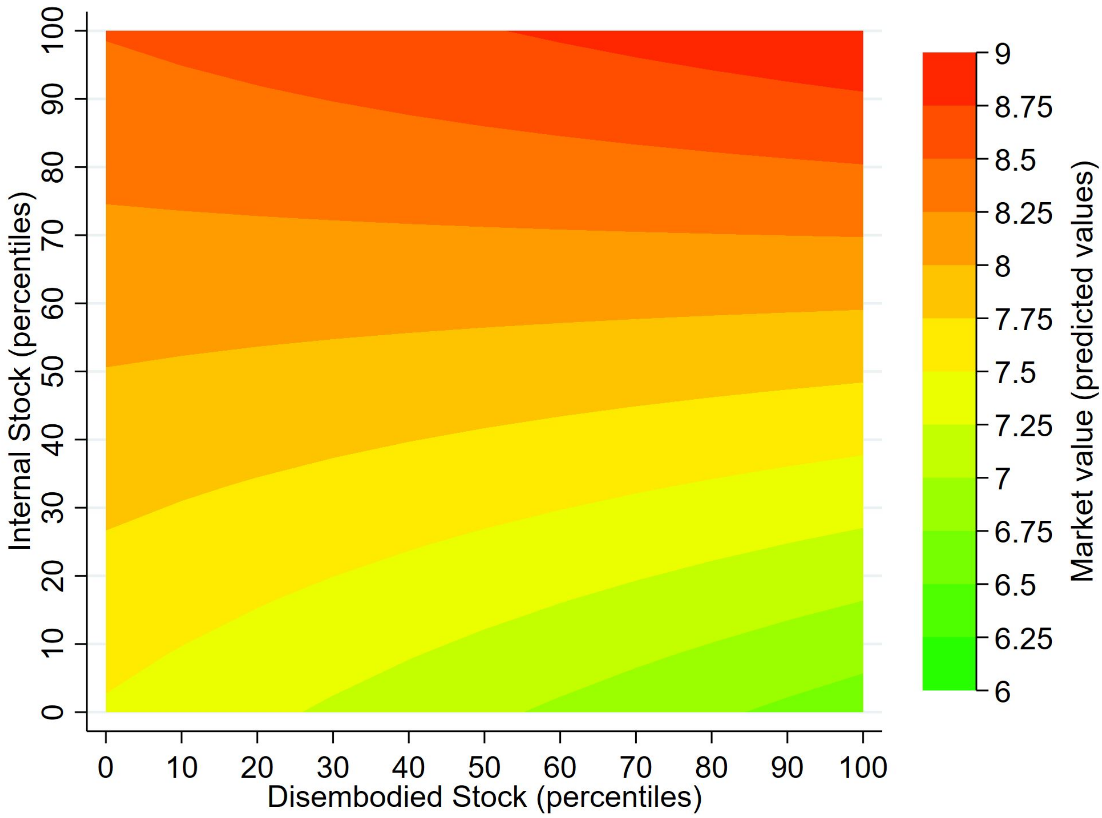
Figure 5: Predicted values of market value across the distribution of internal and embodied stocks.



at which higher levels of *DISEMBODIED STOCK* are associated with higher values of *MARKET VALUE* is considerably greater than the threshold of *INTERNAL STOCK* at which higher levels of *EMBODIED STOCK* are associated with higher values of *MARKET VALUE* in Figure 5. Interestingly, this indicates that acquiring technologies via M&As contributes positively to the market value of a larger share of firms than acquiring technologies via standalone acquisitions. In sum, the patterns in Figures 5 and 6 suggest that the size of firms' internally developed knowledge stock positively moderates the relationship between market value and both modes of technology acquisition. At the same time a comparison of both patterns suggests that absorptive capacity is more important for acquiring technology via the disembodied route than via the embodied route. This is conform the predictions of Hypothesis 2.

In a final specification in Model 5 I further disaggregate the embodied and disembodied stocks into stocks of patents that the acquiring firm is familiar with and those that are novel to the acquiring firm. The coefficient of *EMBODIED STOCK FAMILIAR* is positive and significant whilst the coefficient of *EMBODIED STOCK NOVEL* is not significant. These results suggest

Figure 6: Predicted values of market value across the distribution of internal and disembodied stocks.



that there is a positive relationship between embodied technology acquisition and market value for acquired technologies that are familiar to the acquiring firm but not for the technologies that the acquiring firm is unfamiliar with. This finding rejects the prediction of Hypothesis 3a that acquiring technology from external sources via embodied technology acquisition is positively associated with firms' financial performance, regardless of whether the acquiring firm is familiar or unfamiliar with the acquired technology. The results suggest that for acquisitions via M&As it does matter whether firms are familiar with the technologies that they acquire. Interestingly, the coefficient of *DISEMBODIED STOCK FAMILIAR* is not significant whilst the coefficient for *DISEMBODIED STOCK NOVEL* is negative and significant. These results signal that there is no contribution of familiar technology acquired via standalone acquisition to market value but that there is a negative appraisal of the market of novel technology acquired via the disembodied route. One can thus reject Hypothesis 3b which predicted that the acquisition of technology via the disembodied mode has a positive effect on firms' financial performance, only when the acquiring firm is familiar with the acquired technology. The results suggest that there is no positive contribution of technology acquired via the disembodied mode, regardless of whether the acquiring firm is familiar with the technology or not.

Discussion

Main Findings

To the best of my knowledge, this study is the first to consider the performance implications of standalone technology acquisitions on the firm-level. As a result, the findings extend the existing scholarship on the sourcing of external technology in multiple ways. First, the findings clearly suggest that the mode of technology acquisition is a key determinant of firms' ability to generate value from technology developed outside their boundaries. I find that whilst the acquisition of technology via the embodied mode is associated with higher market values the same does not hold for technology acquired via the disembodied mode. In fact, the findings point to a negative relationship between market value and the acquisition of standalone technology. This implies, that despite all the benefits that are ascribed to the acquisition of standalone technology in the literature on markets for technology, the acquisition of technology alone does not necessarily translate into value creation on the firm-level, at least not in the eyes of the stock market.

Second, the findings strongly emphasize that absorptive capacity is a requisite for firms to derive value from technologies acquired via both embodied- and disembodied technology acquisition. I find that the size of firms' internally developed knowledge stock positively moderates the relationship between market value and both modes of technology acquisition respectively. I thus find support for the notion that firms can only be 'good buyers' when they are also 'good makers', irrespective of the mode of acquisition. For firms that develop little to no technology themselves buying even the lowest volumes of technology is associated with lower market values on average whilst firms having large internal knowledge stocks can derive additional value from acquiring large volumes of external technology. Although I do not formally test for it, these findings hint at a complementary rather than substitutive relationship between internal technology development and external technology acquisition. Furthermore, they seem to suggest that above a certain threshold of internal knowledge production, the marginal cost of identifying, screening, assimilating, integrating and exploiting technology is likely to decrease whilst the opportunities for the fruitful recombination of internal and external knowledge are likely to increase. Interestingly, the analyses reveal that this threshold is considerably higher for the acquisition of technology via the disembodied mode than via the embodied mode. This implies that firms require a greater absorptive capacity to generate value from external technology if technology is the only thing they acquire.

Third, the findings highlight that the nature of technology shapes firms' ability to benefit from technology acquired via both modes, albeit in different ways. The distinction between the acquisition of technologies that firms have prior experience with and those that are novel to them reveals that firms are most likely to benefit from the acquisition of familiar technology via the embodied mode. Although I find a positive relationship between market value and the acquisition of familiar technology via the embodied mode, I do not find any relationship between market value and the acquisition of novel technology via this mode. This suggests that the positive overall contribution of embodied technology acquisition that I reported above is mainly attributable to the acquisition of technology that is related to what the acquiring firm already knows. Interestingly, I find a negative relationship between market value and the acquisition of novel technology via the disembodied mode whilst finding no effect for the acquisition of familiar technology via this mode. On the one hand, this suggests that it is challenging to derive value from technology that is new to a firm, even if this firm acquires the entire firm that developed this technology. On the other hand, it implies that acquiring technology only may not be sufficient to leverage external technology even if this technology is related to what the acquiring firm already knows.

Implications

Although the finding of a negative association between the acquisition of standalone technology and market value is somewhat surprising, given that it goes against all the arguments provided in favor of markets for technology, other studies have reported negative stock market responses to firms' buying decisions. Most notably, in an event study of stock market reactions to firms general 'make, buy and ally' decisions, Borah and Tellis (2014) find that make and ally decisions generally provoke a positive stock market reaction, whilst buy decisions generally prompt a significant negative reaction. This finding is robust even after controlling for a variety of confounding variables, applying different estimation methods and testing for both pure and mixed strategies. As an explanation for the negative stock market reaction towards buying, Borah and Tellis advance that, when buying firms often incur high financial, management and reputation costs that outweigh its benefits in large part because buying often involves a bidding game with rivals that results in a price that exceeds the 'real' value of the object of purchase. Although their study is not specifically concerned with making or buying technology, Borah and Tellis' explanations may also hold in this setting.

Another explanation, that is more specific to the setting of technology acquisition, relates to the inefficiency of markets for technology in overcoming the information asymmetry between buyers and sellers of technology. Although most market exchanges are subject to a level of information asymmetry, the level of information asymmetry is greater for intangible assets than for tangible assets because intangibles exert the characteristics of a public good. Whereas a buyer requires a certain level of detail about a technology in order to decide whether to acquire it or not, a seller does not have an incentive to provide such a level of detail because doing so would *de facto* result in a transfer of the technology without any financial compensation. As a result, there is considerable uncertainty about the potential applications and, hence value of a technology, and there may be high costs associated with negotiating, executing and enforcing agreements between buyers and sellers. These costs are likely to be especially high for technologies that the acquiring firm is not familiar with. This might explain, at least in part, why the negative relationship between disembodied technology acquisition pertains to technologies that acquiring firms are not familiar with. An acquiring firm simply knows less about the potential applications of technologies that it has no experience with than it knows about the applications of technologies that it has experience with. As a result, it faces higher uncertainty and transaction costs when acquiring novel technology than it faces when acquiring familiar technology.

Alternatively, the negative association between standalone technology acquisition and market value might also be explained by the fact that the acquisition of standalone technology signals strategic motives that the stock market perceives as negative. Whereas the acquisition of an entire firm might be perceived by the stock market as a signal that the acquiring firm is serious about expanding its stock of technologies, resources and/or capabilities, the acquisition of a bundle of patents might be perceived as a signal that the acquiring firm is facing some kind of adversity. For example, Facebook Inc.'s acquisition of 750 patents from IBM Corporation in 2012 was perceived by analysts as a signal that the firm was preparing itself for a major patent litigation battle with Yahoo!. As a result, the stock market reaction to Facebook Inc.'s announcement of the patent acquisition deal was negative.[7] At the same time though, Twitter Inc.'s acquisition of 943 patents from IBM Corporation for $36 million was perceived as a bargain to avoid litigation with IBM Corporation, resulting in a positive stock market reaction following the announcement.[8] It is likely that there is a great deal of heterogeneity among disembodied technology acquisition deals with some provoking negative and others provoking positive stock market responses.

Limitations

My study is subject to a number of noteworthy limitations that can serve to highlight fruitful avenues for future research. First, although I took great caution in retrieving and combining information from several publicly available data sources to establish firms' ownership structure and technology sourcing strategies, I should note that firms may have strategic motives for not disclosing information pertaining to their ownership of other companies and their ownership of intellectual property. A study by Gramlich and Whiteaker-Poe (2013), for example, reveals

[7]https://www.reuters.com/article/us-facebook-ibm-patents/facebook-buys-750-patents-from-ibm-source-idUSBRE82L13O20120322, accessed on February 11th, 2019.

[8]https://www.bloomberg.com/news/articles/2014-03-06/twitter-paid-36-million-for-900-ibm-patents-to-build-portfolio, accessed on February 11th, 2019.

that in 2010 Oracle Corporation and Google Inc. disclosed significantly less subsidiaries in SEC-filings than in the years prior, with the list of Google Inc.'s subsidiaries going down from 118 to two and the list of subsidiaries of Oracle Corporation going down from 428 to six from 2009 to 2010. Another study by Ewing and Feldman (2012) found that the mass patent aggregator Intellectual Ventures has made use of over 1,000 shell companies to conduct its intellectual property acquisitions. Furthermore, the limitations of relying on publicly available patent assignment records as highlighted in papers 2 and 3 of this dissertation certainly apply. To the extent that existing regulations do not warrant the adequate disclosure of changes in patent ownership rights, I may only selectively observe firms' disembodied technology acquisition activities. Although I rely on inventory measures that moderate sudden fluctuations in patent stocks, I cannot rule out that the results are biased due to the fact the I may not observe the full extent of intellectual property ownership by the sample firms.

Second, it is important to note that I simply observe mere counts of patents acquired via M&As and patent assignment deals without observing the terms of these deals. Most notably, I do not observe the amount of transaction costs that the sample firms incurred to acquire firms and standalone technologies. Clearly, the price paid to acquire technologies via both M&As and patent assignment deals is likely to be an important, if not the most important, determinant of how the stock market reacts to such deals. Although I attempt to partially capture the value of internally developed and externally acquired technologies by weighing patents by the number of forward citations that they receive – which is in line with several existing studies that suggest that forward citations are associated with economic value (see for example Hall *et. al.*, 2005 and Kogan *et. al.*, 2017) – it is very likely that the contribution of technology acquisition deals to market value is attributable to the specific terms of these deals rather than the occurrence of deals themselves. Any future research endeavor that would incorporate the cost of acquiring technology into the analysis would undoubtedly be a valuable addition to existing scholarship.

Third, in addition to not observing the terms of M&A and patent assignment deals I also know little to nothing about the motivations for completing such deals. Although I implicitly assume that M&As and patent assignments are at least partly motivated by technological considerations, I cannot rule out that these considerations are not the main motive to conduct such deals. M&As might, for example, primarily be an entry mechanism to access new geographic and/or product markets and patent assignments may be a means to initiate or fend off patent litigation cases. As a result, I also know little about the choices that firms face when deciding between M&As and standalone technology acquisitions and between patent assignments and technology licensing. A better understanding of the motives underlying different modes of technology acquisition is arguably the most important advance towards a richer understanding of the dynamics of firms' technology acquisition strategies.

Finally, whilst the empirical strategy allows me to generate new insights on the relationship between different technology sourcing strategies and firms' market value, it does not allow me to establish a particular causal structure. Although I believe that this study provides a valuable first step towards a richer understanding of the performance implications of embodied and disembodied technology acquisition, I fully acknowledge the need for future causal explorations of the proposed relationships.

References

Agrawal, A, Cockburn, I, Zhang, L. 2015. Deals not done: sources of failure in the market for ideas. *Strategic Management Journal* **36**(7): 976–986.

Ahuja G, Katila R. 2001. Technological acquisitions and the innovation performance of acquiring firms: a longitudinal study. *Strategic Management Journal* 22(3): 197–220.

Ahuja G, Lampert CM. 2001. Entrepreneurship in the large corporation: a longitudinal study of how established firms create breakthrough inventions. *Strategic Management Journal*, Special Issue 22(6–7): 521–542.

Allain ML, Henry E, Kyle M. 2016. Competition and the efficiency of markets for technology. *Management Science* **62**(4): 1000–1019.

Argote L, Miron-Spektor E. 2011. Organizational learning: from experience to knowledge. *Organization Science* **22**: 1123–1137.

Arora A, Belenzon S, Rios LA. 2014. Make, buy, organize: the interplay between research, external knowledge, and firm structure. *Strategic Management Journal* **35**(3): 317–337.

Arora A, Ceccagnoli M. 2006. Patent protection, complementary assets, and firms: incentives for technology licensing. *Management Science* **52**: 293–308.

Arora A, Fosfuri A, Gambardella A. 2001. *Markets for Technology: The Economics of Innovation and Corporate Strategy*. MIT Press: Cambridge, MA.

Arora A, Nandkumar A. 2012. Insecure advantage? Markets for technology and the value of resources for entrepreneurial ventures. *Strategic Management Journal* **33**(3): 231–251.

Belderbos R, Faems D, Leten B, Van Looy B. 2010. Technological activities and their impact on the financial performance of the firm: exploitation and exploration within and between firms. *Journal of Product Innovation Management* **27**(6): 869–882.

Blundell R, Griffith R, Van Reenen J. 1999. Market share, market value and innovation in a panel of British manufacturing firms. *Review of Economic Studies* **66**: 529–554.

Borah A, Tellis G. 2014. Make, buy, or ally? Choice of and payoff from announcements of alternate strategies for innovations. *Marketing Science* **33**(1): 114–33.

Burhop C. The transfer of patents in Imperial Germany. *The Journal of Economic History* **70**(4): 921–939.

Cantwell JA, Andersen B. 1996. A statistical analysis of corporate technological leadership historically. *Economics of Innovation and New Technology* **4**: 211–234.

Cantwell JA, Piscitello L. 2000. Accumulating technological competence – its changing impact on corporate diversification and internationalisation. *Working Paper University of Reading*.

Cassiman B, Veugelers R. 2006. In search of complementarity in innovation strategy: internal R&D and external knowledge acquisition. *Management Science* **52**(1): 68–82.

Caviggioli F, Ughetto E. 2013. The drivers to patent transactions: corporate views on the market for patents. *R&D Management* **43**(4): 318–332.

Chesbrough H. 2003. *Open Innovation*. Harvard University Press: Cambridge, MA.

Choi S. McNamara G. 2018. Repeating a familiar pattern in a new way: The effect of exploitation and exploration on knowledge leverage behaviors in technology acquisitions. *Strategic Management Journal* **39**(2): 356–378.

Cockburn I, Griliches Z. 1988. Industry effects and appropriability measures in the stock market's valuation of R&D and patents. *American Economic Review* **78**(2): 419–423.

Cohen WM, Levinthal DA. 1989. Innovation and learning: the two faces of R&D. *Economic Journal* **99**: 569–596.

Cohen WM, Levinthal DA. 1990. Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly* **35**(1): 128–152.

Czarnitzki D, Hall BH, Oriani R. 2006. The market valuation of knowledge assets in US and European firms. In: *The Management of Intellectual Property*. Bosworth DL, Webster E (eds). Edward Elgar, Cheltenham, UK.

De Marco A, Scellato G, Ughetto,E, Caviggioli F. 2017. Global markets for technology: evidence from patent transactions. *Research Policy* **46**(9): 1644–1654.

Dierickx I, Cool K. 1989. Asset stock accumulation and sustainability of competitive advantage. *Management Science* **35**(12): 1504–1512.

Ewing T, Feldman R. 2012. The giants among us. *Stanford Technology Law Review* **15**(1): 1-61.

Falta M, Willett, MJ. 2013. The impact of exponential growth variables on regression models of the marketaccounting relation. *Journal of Accounting, Auditing and Finance* **28**(3): 243–272.

Fama EF. 1998. Market efficiency, long-term returns, and behavioral finance. *Journal of Financial Economics* **49**(3): 283–306.

Federal Trade Commission, 2011. *The evolving IP marketplace: aligning patent notice and remedies with competition*. Washington, DC, Government Printing Office.

Figueroa N, Serrano CJ. 2018. Patent trading flows of small and large firms. *NBER Working Paper 18982*.

Fleming L. 2001. Recombinant uncertainty in technological search. *Management Science* **47**(1): 117–132.

Galasso A, Schankerman M, Serrano CJ. 2013. Trading and enforcing patent rights. *RAND Journal of Economics* **44**(2): 275–312.

Gambardella A, Torrisi S. 2000. The economic value of knowledge and interfirm technological linkages: an investigation of science-based firms. Paper prepared for the Dynacom TSER Project (Contract No. SOE1-CT97-1078).

Gans JS, Stern S. 2003. The product market and the market for 'ideas': commercialization strategies for technology entrepreneurs. *Research Policy* **32**(2): 333–350.

Gramlich J, Whiteaker-Poe J. 2013. Disappearing subsidiaries – the cases of Google and Oracle. Working Paper. Available at: https://ssrn.com/abstract=2229576.

Grindley PC, Teece DJ. 1997. Managing intellectual capital: licensing and cross-licensing in semiconductors and electronics. *California Management Review* **39**(2): 8–41.

Hagedoorn J. 1993. Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral differences. *Strategic Management Journal* **14**(5): 371–385.

Hall B, Jaffe A, Trajtenberg M. 2005. Market value and patent citations. *RAND Journal of Economics* **36**(1): 16–38.

Henderson RM, Clark KB. 1990. Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly* **35**(1): 9–30.

Higgins MJ, Rodriguez D. 2006. The outsourcing of R&D through acquisitions in the pharmaceutical industry. *Journal of Financial Economics* **80**(2): 351–383.

Hitt M, Hoskisson R, Johnson R, Moesel D. 1996. The market for corporate control and firm innovation. *Academy of Management Journal* **39**(5): 1084–1119.

Hochberg Y, Serrano C, Ziedonis R. 2014. Patent collateral, investor commitment, and the market for venture lending. *Journal of Financial Economics* **130**(1): 75–94.

Jungmittag A. 2004. Innovations, technological specialisation and economic growth in the EU. *International Economics and Economic Policy* **1**(2): 247–273.

Kapoor R, Lim K. 2007. The impact of acquisitions on the productivity of inventors at semiconductor firms: a synthesis of knowledge-based and incentive-based perspectives. *Academy of Management Journal* **50**(5): 1133–1155.

Karim S, Mitchell W. 2000. Path-dependent and pathbreaking change: reconfiguring business resources following acquisitions in the U.S. medical sector, 1978–1995. *Strategic Management Journal* **21**(10–11): 1061–1081.

Kogan L, Papanikolaou D, Seru A, Stoffman N. 2017. Technological innovation, resource allocation, and growth. *The Quarterly Journal of Economics* **132**(2): 665-712.

Kogut B, Zander U. 1992. Knowledge of the firm, combinative capabilities, and the replication of technology. *Organiza-*

tion Science **3**(3): 383–398.

Lamoreaux NR, Sokoloff KL. 1998. Inventors, firms, and the market for technology in the late nineteenth and early twentieth centuries. *NBER Historical Working Paper No. 98*.

Lane PJ, Lubatkin M. 1998. Relative absorptive capacity and interorganizational learning. *Strategic Management Journal* **19**(5): 461–477.

Laursen K, Salter A. 2006. Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal* **27**(2): 131–150.

Leonard-Barton D. 1992. Core capabilities and core rigidities: a paradox in managing new product development. *Strategic Management Journal* **13**(35):111–125.

Levinthal DA, March JG. 1993. The myopia of learning. *Strategic Management Journal*. Winter Special Issue **14**: 95–112.

Lungeanu R, Stern I, Zajac, EJ. 2016. When do firms change technology-sourcing vehicles? The role of poor innovative performance and financial slack. *Strategic Management Journal* **37**(5): 855–869.

Makri M, Hitt MA, Lane PJ. 2010. Complementary technologies, knowledge relatedness, and invention outcomes in high technology mergers and acquisitions. *Strategic Management Journal* **31**(6): 602–628.

Marco AC, Myers AF, Graham SJ, D'Agostino PA, Apple K. 2015. The USPTO patent assignment dataset: descriptions and analysis. *USPTO Working Paper* **2015-2**.

McGrath RG, Nerkar A. 2004. Real options reasoning and a new look at the R&D investment strategies of pharmaceutical firms. *Strategic Management Journal* **25**(1): 1–21.

Phene A, Tallman S, & Almeida P. 2012. When do acquisitions facilitate technological exploration and exploitation? *Journal of Management*. **38**: 753–783.

Puranam P, Srikanth K. 2007. What they know vs. what they do: how acquirers leverage technology acquisitions. *Strategic Management Journal* **28**(8): 805–825.

Ranft AL, Lord MD. 2002. Acquiring new technologies and capabilities: a grounded model of acquisition implementation. *Organization Science* **13**(4): 420–442.

Robertson TS, Gatignon H. 1998. Technology development mode: a transaction cost conceptualization. *Strategic Management Journal* **19**(6): 515–531.

Rosenberg N. 1990. Why do firms do basic research (with their own money)? *Research Policy* **19**(2): 165–174.

Rosenkopf L, Almeida P. 2003. Overcoming local search through alliances and mobility. *Management Science* **49**(6): 751–767.

Rosenkopf L, Nerkar A. 2001. Beyond local search: boundary-spanning, exploration, and impact in the optical disk industry. *Strategic Management Journal* **22**(4): 287–306.

Rothaermel FT, Alexandre MT. 2009. Ambidexterity in technology sourcing: the moderating role of absorptive capacity. *Organization Science* **20**(4): 759–780.

Sears J, Hoetker G. 2014. Technological overlap, technological capabilities, and resource recombination in technological acquisitions. *Strategic Management Journal* **35**(1): 48–67.

Serrano CJ. 2010. The dynamics of the transfer and renewal of patents. *RAND Journal of Economics* **41**(4): 686–708.

Stettner U, Lavie D. 2014. Ambidexterity under scrutiny: exploration and exploitation via internal organization, alliances, and acquisitions. *Strategic Management Journal* **35**(13): 1903–1929.

Teece DJ. 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. *Research Policy* **15**(6): 285–305.

Uotila J, Maula M, Keil T, Zahra S. 2009. Exploration, exploitation, and financial performance: analysis of S&P 500 corporations. *Strategic Management Journal* **30**(2): 221–231.

Van de Vrande V. 2013. Balancing your technology-sourcing portfolio: how sourcing mode diversity enhances innovative performance. *Strategic Management Journal* **34**(5): 610–621.

Verhoeven D, Bakker J, Veugelers R. 2016. Measuring technological novelty with patent-based indicators. *Research Policy* **45**(3): 707–723.

Veugelers R, Cassiman B. 1999. Make and buy in innovation strategies: evidence from Belgian manufacturing firms. *Research Policy* **28**(1): 63–80.

Wang L, Zajac EJ. 2007. Alliance or acquisition? A dyadic perspective on interfirm resource combinations. *Strategic Management Journal* **28**(13): 1291–1317.

Wu B, Wan Z, Levinthal DA. 2014. Complementary assets as pipes and prisms: innovation incentives and trajectory choices. *Strategic Management Journal* **35**(9): 1257–1278.

Yayavaram S, Ahuja G. 2008. Technological search and decomposability in knowledge structures: impact on invention utility and knowledge-base malleability. *Administrative Science Quarterly* **53**(2): 333–362.

Yin X, Shanley M. 2008. Industry determinants of the 'merger versus alliance' decision. *Academy of Management Review* **33**(2): 473–491.

MANAGEMENT, STRATEGY AND INNOVATION (MSI)
Naamsestraat 69 bus 3535
3000 LEUVEN, Belgium
tel. + 32 16 32 67 00
msi@econ.kuleuven.be
https://feb.kuleuven.be/research/MSI/