Innovation diffusion, licensing and corporate entrepreneurship – a conceptual review

Gerd Schuster* and Peter Rueck

University of Erlangen-Nuremberg,
School of Business and Economics,
Lange Gasse 20, 90403 Nuremberg, Germany
E-mail: gerd.schuster@fau.de
E-mail: peter.rueck@fau.de
*Corresponding author

Abstract: The diffusion process of technology and innovation has become increasingly complex. In times of great technological leaps of emerging economies, diffusion mechanisms have changed. To cope with this change, this article reviews technology diffusion and patent licensing literature to develop robust theory that allows providing future research directions. Based on the analysis of scholarly work published in top-tier peer-reviewed management journals between 1960 and 2013, the authors find that research strongly lacks the analysis of intra-firm diffusion mechanisms. In this context, the role of corporate entrepreneurship is unclear and the density-dependent growth model, the information cascade model and game theory approaches hardly received attention. The authors build innovation diffusion theory and provide a conceptual overview as a stimulus for future research covering intra-firm and inter-firm diffusion, licensing as a specifically important diffusion mechanism and the role of corporate entrepreneurship in established companies.

Keywords: innovation management; technology diffusion; innovation diffusion; knowledge diffusion; patent licensing; corporate entrepreneurship; intra-firm diffusion; inter-firm diffusion; technology transactions; technology adoption.


Biographical notes: Gerd Schuster holds a Master of Science in Business Administration and Chinese Studies from the University of Erlangen-Nuremberg and the University of International Business and Economics Beijing. He has work experience as a strategy consultant and research assistant working for fortune 500 companies in the fields of operations strategy, product development and innovation. His research interests are determinants of innovation performance, intellectual property strategies, innovation management in emerging markets and the management of technology transactions.

Peter Rueck holds a Master of Business Administration from the Technical University of Munich and a Master of Science in Engineering from the University of Applied Sciences in Aalen. He is working for a multinational technology company in the field of technology and innovation management. His research interests are open innovation, supplier innovation and network management, primarily focusing on the identification, selection, conversion and diffusion of new technologies.
1 Introduction

As in recent years, technological innovation has become one of the most important driving factors for the development of human society, the diffusion of technological innovation is one of the inevitable parts in the process of growth. To keep up with the speed of global technology development, large multinational companies in technology-based industries are keen to diffuse technologies with pace (Abrahamson and Rosenkopf, 1993; Banbury and Mitchell, 1995; Glaser et al., 1992) and certainty (Dasgupta and Stiglitz, 1980; Ethier and Markussen, 1996). The diffusion process of new technology and innovation has become increasingly complex. Much research effort has been done on the diffusion of innovation between companies (inter-firm diffusion) in both innovation (e.g., Rogers, 1995; Wonglimpiyarat and Yuberk, 2005) and marketing research (e.g., Peres et al., 2010). However, companies still struggle to share inventions and technology in a global reach within the company (intra-firm diffusion) and research strongly lacks studies about intra-firm diffusion (Battisti and Iona, 2009).

To close this gap and recap the research, which was done on the process of innovation diffusion from the perspective of a rapidly changed and much more complex business environment, starting from the initial work by Mansfield (1968), Bass (1969) and Rogers (1983) to very recent studies on diffusion mechanisms through licensing by companies in emerging economies (e.g., Li-Ying et al., 2012; Wang et al., 2013; Wang and Zhou, 2013), we theorise by conceptualising the constructs and variables used in prior studies to show white spots in technology transaction and diffusion research as well as indicate future research directions. In detail, this paper will review innovation diffusion research about both intra-firm and inter-firm diffusion, summarise the findings in a comprehensive overview of constructs and variables used in literature, enhance prior frameworks by emphasising the role of licensing and corporate entrepreneurship and draw conclusions for future research.

In the attempt to do so and reliably update theory, we need to consider the latest key developments in global economy. Following the discussions at the World Economic Forum’s annual meeting, the main themes of the last five meetings included: ‘Resilient Dynamism’ (2013), coming out of the crisis and build a stable grounding with a strong basis of technology and innovation; ‘The Great Transformation’ (2012), i.e., how developed countries will deleverage without falling back into recession and how emerging countries will curb inflation and avoid future economic bubbles; ‘Shared Norms For Reality’ (2011), how to foster global economic growth; ‘Rethink, Redesign, Rebuild’ (2010), i.e., rethink business models, redesign policies and regulations, rebuild trust; and “Shaping the post-crisis World” (2009), i.e., stabilise and relaunch global economy after the global economic crisis of 2009 (all themes have been derived from the website of the World Economic Forum, 2013). All of the topics above include certain aspects, which are highly relevant for innovation management practice and research. Among others that is: the importance of emerging economies and the rise of new technology leaders, as well as the fact that governments have increasingly recognised the importance to support radical technical breakthroughs and started to standardise science and technology as governments themselves are actually very heavy users of new technologies (Branscomb, 2001). The sheer size of a government makes them important agents in the innovation diffusion process (Geroski, 2000). Anyway, policy makers need to take care of more than the concerns of a single company. For example, even if the ICT industry became the most dynamic sector in China’s economy, the Chinese government...
Innovation diffusion, licensing and corporate entrepreneurship

was first reluctant to take measure to foster information and communication industry mainly due to the ‘displacement effect’, i.e., the effect in emerging economies that large scale technology adoption could lead to high unemployment due to highly-skilled labour demand but low-skilled labour supply (Meng and Li, 2002). In the attempt to respond and enhance the studies of Da Silveira (2001) and Wonglimpiyarat and Yuberk (2005) and meet the need for research around the topics mentioned before, we will review innovation diffusion research and theorise key management aspects, which will contribute to explain diffusion how it happens today.

2 Literature review

To conceptually review the effort, which was recently made to analyse technology and innovation diffusion mechanisms, we will provide an overview of innovation diffusion literature covering the processes of intra-firm and inter-firm diffusion. Further, we discuss the role of licensing and very recent empirical studies about technology transfer and learning mechanisms in emerging economies and emphasise the role of corporate entrepreneurship.

2.1 Technology diffusion in innovation management

Due to matters of market demand or technology push, new ideas are brought up in or outside a company’s environment. The generic process will then guide that ideas are properly screened - neither too softly, nor too strictly - so that an idea or invention could be transferred into revenue-generating products and services. Most importantly, the final products must be accepted not only by consumers but also by insiders within the company. Innovation management literature teaches that this is the way innovations need to diffuse through different regions and organisations and finally get to customers (Comin and Hobijn, 2004; Mu and Lee, 2005; Rogers, 1995; Todo and Miyamoto, 2002). In this context innovation can be defined in many ways. However, many agree with the definition of Rogers (2001, p.12), who defined innovation as “an idea, practice, or object that is perceived as new by an individual or other units of adoption”. This article will focus on the analysis of technological innovation, which can be considered as a commercialised idea in any of the three areas: product, production processes or work organisations (Whipp and Clark, 1986). Besides other definitions of the innovation process (e.g., by Ergas, 1989), we follow the definition of Hansen and Birkinshaw (2007), who stated that the innovation value chain could be divided into three steps: idea generation, conversion and diffusion. Similar to Hansen and Birkinshaw (2007), Hall (2004) described diffusion as one of the three main process steps for the successful implementation of new products, processes and practices. In this paper we focus on the diffusion part of the innovation process.

2.2 Many definitions, one principle

Before we elaborate discussions around different diffusion models and the evolution of diffusion research, we will provide an overview of the most common definitions of technology diffusion. We distinguish between definitions related to the different types of
diffusion (‘definitions by content’) and time-specific determinations (‘definitions by time’).

2.2.1 Definitions by content

Rogers (1995) described diffusion as the process for multiplying an innovation within a social system using specific channels. In addition to the definitions of Rogers, technological diffusion is defined as “a process by which the market of a new technology changes over time and from which product and usage patterns of new products and production processes result” [Battisti and Stoneman, (2010), p.734]. To define the individual steps of the entire diffusion process, we generally agree with other authors that a more precise fragmentation is necessary. Hereby, technology diffusion can be decomposed into two elements: the inter-firm diffusion and the intra-firm diffusion of technology. Inter-firm diffusion describes the first adoption (e.g., the first use) of a new technology by the firms in the market (e.g., Fuentelsaz et al., 2003; Hollenstein and Woerter, 2008) and intra-firm diffusion encompasses the extent of use by companies after already having adopted a new technology (Hollenstein and Woerter, 2008). The overall use of technologies involves therefore both inter- and intra-firm levels.

Battisti and Stoneman (2005) provided a slightly different definition. In their perspective the diffusion at the inter-firm level covers the extensive margin (international, national, industrial) of the innovation diffusion, whereas the intra-firm level of diffusion indicates the application extent of innovation within an individual company. Thus, we can conclude that inter-firm diffusion concentrates on the process of the original adoption of a new technology across firms, whereas intra-firm diffusion focuses on the penetration of a technology within firms.

2.2.2 Definitions by time

In Roger’s theory ‘time’ matters a lot in the diffusion process. He divided individuals or other units of adopters into five categories on the basis of the adoption speed: innovators, early adopters, early majority, late majority and laggards (Rogers, 2001). Furthermore, it should be pointed out, that the initial adoption decision is just the first step of a more complex diffusion process within the firm until the beneficial effects of a new technology are fully reached (Fuentelsaz et al., 2003). Rogers (2003) complemented that the diffusion process starts after the initial adoption of an invention. Also, Fuentelsaz et al. (2003) correctly stated that intra-firm diffusion is explained as the speed with which firms fully employ a new technology.

On the other hand, Battisti and Stoneman (2005, p.3) illustrated the diffusion process with the time profile of the use of new technologies and differentiate between “the time profile of the number of firms using the technology (inter-firm diffusion) and the time profile of the extent of use by individual firms (intra-firm diffusion)”’. Battisti and Stoneman added that the spread of technology across firms is far before that within firms as well as inter-firm diffusion proceeds much faster than intra-firm diffusion (Battisti, 2000; Battisti and Stoneman, 2003). Following this logic, they pointed out that the diffusion process across households and within firms always fall behind their international diffusion, which reinforces the relevance and importance of this research object. Finally, Battisti (2000) and Battisti and Stoneman (2003) emphasised that the inter-firm mechanisms are related to the early phases of the whole technology diffusion
process whereas the intra-firm mechanisms much stronger affect the later phases of the overall process.

2.3 Diffusion models

Following Geroski (2000), there are four main categories of diffusion models, which have been discussed in the past research: epidemic, probit, density-dependent growth and information cascade models. The epidemic model, which is the most commonly used model, states that the use of new technologies over time follows the S-curve (the principle which gained broad currency in the early 1960s when Stanford professor Everett Rogers first published *Diffusion of Innovations*) (Rogers, 1962). The speed of adoption is hereby limited by the lack of information about the use and functionality of a new technology (Geroski, 2000). But there are alternative models which can be used to generate an S-curve which are not based on information diffusion. By contrast the probit model is the second most deployed model perishing that different companies with different objectives and capabilities probably want to introduce the new technology at different times. Therefore diffusion happens due to gradual adoption of individual types of firms (Geroski, 2000). The density-dependent growth model is based on the forces of legitimation and competition to accelerate the diffusion of new technologies and to limit their usage. Information cascade models on the other hand incorporate the approach that the subsequent diffusion speed of the chosen technology is affected by the initial choice between different variants of a new technology. These kinds of models rely on bandwagon effects, induced by imitation due to information cascades (Geroski, 2000).

Bocquet et al. (2007) classified the various technology diffusion models in a similar way. But they described three theoretical approaches: epidemic, rank and game theory approaches. Chang et al. (2009) pointed out, that the rank approach is identical to the probit approach discussed by Geroski (2000). The epidemic and rank/probit approaches are widely studied in literature, whereas the density-dependent growth, the information cascade and the game theory approach have been hardly analysed in diffusion research (Chang et al., 2009).

2.4 The evolution of diffusion theory

2.4.1 Inter-firm diffusion

The literature on inter-firm diffusion is extensive (e.g., Geroski, 2000; Hall, 2004; Karshenas and Stoneman, 1993) and it comprises many different research fields. The research on diffusion theory started in the 1960s with the studies of Mansfield, Rogers and Bass. Bass (1969) focused on the marketing perspective of diffusion. He stated, that mass media plays an important role in the early stage of the diffusion process to reach as many potential adopters as possible, whereas interpersonal communication is more important in the later phase, when the degree of adoption, following the S-curve, accelerates slower. It should be pointed out that the Bass model is partly based on two former diffusion models (Chang et al., 2009) established by Fourt and Woodlock (1960) and Mansfield (1961). Fourt and Woodlock outlined, that the diffusion process was basically affected by mass media (‘external effect’), whereas the studies of Mansfield (1961) described the diffusion process as mainly influenced by ‘word of mouth’, related to the number of people using the innovation in the early phases (‘internal effect’). Later
Rogers (1983, 1995) provided a diffusion model which was ascertained from a sociological and organisational perspective. He summarised five categories of innovation attributes that influence the decision of potential adopters of an innovation: relative advantage of the innovation, compatibility with current ways of doing (social norms), complexity of innovation, trialability and observability. With respect to the speed of the diffusion process, he additionally emphasised the use of external and social influence factors: i.e. decisions made by individuals, collectively or by a central authority; used communication channels; nature of social systems in terms of norms and interconnectedness; and the extent of promotion effort of change agents. In addition, Rogers used the Bass model to prove that interpersonal communication is a lot more important in the diffusion process than media is (Rogers, 1983). As the Bass model was often used as basis for further research, several new versions of the model have been developed by modifying and enhancing the original version (Mahajan et al., 1990). Moore (1991) extended the approach of Rogers by introducing the so-called technology adoption lifecycle concept (TALC), in which firms adjust their marketing strategies at different stages as a result of the respective characteristics of adopters. The flow of technological innovation between 'productive units' (Abernathy, 1978) within firms differs depending on various characteristics in the technology life-cycle (which is defined as a four-stage model including the product phase, transition phase, process phase and mature phase). Information sources and network elements vary in each of the four technology life-cycle stages. For example, in the product phase the crucial information comes from customers and technological researches, whereas in the transition phase information is mainly absorbed from competitors and suppliers (De Meyer, 1985).

Summarising, one of the main differences among the discussed diffusion models of Fourn and Woodlock (1960), Mansfield (1961), Bass (1969), Rogers (1995) and Moore (1991) is that the object of diffusion switched from product to technology (Chang et al., 2009). Yet, further research was conducted. According to Miller and Garnsey (2000) diffusion research of technological innovation lacks an integrated approach which includes all influence factors regarding technology progress. Therefore they studied the role of entrepreneurs in the diffusion process and highlighted, that “diffusion of technological innovation can be strongly influenced by the capacities of the early entrepreneurs to match resources and opportunities” [Miller and Garnsey, (2000), p.460]. Further research on technology diffusion generally outlined a variety of relevant factors, which have an enormous impact on the diffusion process itself. Following Da Silveira, innovation diffusion “depends on three contextual aspects that are economy and government, technology strategies and innovation paths of firms and managerial practices, capabilities and resources to innovate” [Da Silveira, (2001), p.767]. On the contrary, Hall (2004) additionally outlined the main determinants of diffusion from an economic, social and institutional point of view. He derived an overview of potential factors, which influence the external diffusion of innovations, classified into four categories: Factors influencing the expected benefits from a new technology after the adoption decision, those affecting the costs of adoption, factors with respect to the industrial and social environment as well as critical factors relating to uncertainty and information problems.

Therefore, we agree with Peres et al. (2010) that diffusion processes have turned out to be more and more complex and multifaceted in the last years. Nowadays, adopters are not only influenced by word of mouth communication, but also by network externalities and social signals. Peres et al. (2010) claimed that the traditional diffusion theory based
Innovation diffusion, licensing and corporate entrepreneurship

2.4.1 Interpersonal communication should be revised and extended to comprise social interdependence of all kinds, including network externalities (which occur, when the usage of a product to a consumer increase with the rising number of adopters of the new product (Rohlfs, 2001)) and social signals (social information that individuals infer from adoption of an innovation by others). Moreover, the influence of media and social communication are effective factors which play a distinctive role in promoting the transformation between various use types and different adopter roles (Shih and Venkatesh, 2004). The empirical studies of Motohashi et al. (2012) recently proved that Roger’s adoption-diffusion model is not anymore as capable as the use-diffusion (UD) model provided by Shih and Venkatesh (2004) in explaining the diffusion of innovation under today’s real-world conditions.

2.4.2 Intra-firm diffusion

Whereas there were numerous research activities about inter-firm diffusion (e.g., Geroski, 2000; Hall, 2004; Hollenstein and Woerter, 2008; Karshenas and Stoneman, 1993), intra-firm diffusion has been largely neglected in literature (Battisti and Stoneman, 2005; Bryson et al., 2007; Fuentelsaz et al., 2003). It is remarkable that past research mainly focused on inter-firm diffusion, even though Stoneman (1981), three decades ago, already pointed out that the research of the extend of use of a technology within a firm (intra-firm diffusion) is at least as important as the general number of adopters of a technology (inter-firm diffusion). Due to the high number of people influencing the adoption decision and the diffusion throughout the company, further research on intra-firm diffusion processes is crucial, especially in the case of large and complex multinational companies (Stoneman, 1981).

First, there are a couple of studies about intra-firm diffusion mechanisms in general which need to be discussed. Prior intra-firm literature mainly focused on learning based or epidemic approaches, like the study of Mansfield (1963). He states that the diffusion of new technologies increases by learning effects. Because technology will be spread ‘naturally’ throughout an organisation over time, Mansfield assumed that the utility of a new technology is higher the longer the first adoption dates back. Following the results of Stoneman and Battisti (1997), time since initial adoption can however determine the entire intra-firm diffusion mechanisms only to a minimal extent, what implies that previous approaches have not sufficiently explained learning effects. Karshenas and Stoneman (1995) structured intra-firm literature not only into epidemic approaches, but also into decision-theoretic approaches, which extend former approaches with theoretical links between the individual firm’s adoption decision and the diffusion of innovation.

Also few research activities were performed to analyse relevant research gaps and influencing factors associated with the intra-firm diffusion process. In this context Bryson et al. (2007) emphasised that there is a limited number of research activities dealing with the speed of adoption within and across companies and how they are related with firm performance. Fuentelsaz et al. (2003) also attempted to fill the gap of lacking intra-firm diffusion literature by analysing the factors that influence the speed of an overall adoption of a new technology within a company (from first adoption to full internal diffusion). The results of their analysis show that the rate of intra-firm diffusion depends on innovation, firm and market characteristics (Fuentelsaz et al., 2003). For firm characteristics, research initially showed that company size positively impacts the adoption decision (Karshenas and Stoneman, 1993; Mansfield, 1968; Noteboom, 1993),
yet Battisti and Stoneman (2003) proved the finding of Oster (1982), that the size or the age of a company has a negative relationship with the number of adopted innovations. As the global business environment strongly changed in comparison to the 1960s, when Rogers established the diffusion theory, a variety of things must be reconsidered. If the diffusion process must go through rather many distribution channels, which happens more likely in larger companies, the whole process will be slower and more difficult in comparison with that in smaller companies. However, large companies might have obvious advantages when it comes to technological innovations, owing to their financial strength and process know-how (Teece, 1986). This logic could also be applied to explain why incumbents are slower in adopting new technology: new entrants have nothing to cannibalise, while incumbents have to give up some existing activities, which usually makes the adoption more expensive (Geroski, 2000).

Meanwhile different researches put attention to the subsequent intra-firm diffusion process by developing new (empirical) models. Shih and Venkatesh (2004) have noticed, that the adoption diffusion (AD) theory of Rogers failed in observing the diffusion process as an organic whole. They argued that the diffusion process cannot be fully understood without paying attention to the UD process. Unlike AD, the UD model classifies users as four types (intense, specialised, unspecialised and limited) considering the type and the variety of use as relevant criteria. They stressed that innovation diffusion is not supposed to only focus on the timing or rate of adoption, but also on the degree of the product usage and the further development of the adopted innovation. Moreover, Battisti and Stoneman (2005) outlined an approach where intra-firm diffusion represents the profitability of new technology adoption as proxied by company characteristics. Profit gain from adoption of a new technology in the context of intra-firm research can be assigned by rank effects and stock effects, whereas stock effects have minor relevance in contrast to inter-firm diffusion literature (Karshenas and Stoneman, 1993). The extent of intra-firm diffusion and hence the degree of use of the technology within a firm depend on the cost-benefit ratio of adoption of the new technology. Battisti and Stoneman (2005) emphasised the relevance of innovation, R&D strength, export intensity, company size, and the usage of managerial techniques and complementary technologies as important factors for the intra-firm rate of diffusion. They conclude that the internal diffusion would be more likely to reach a high level if the firm does R&D itself (Battisti and Stoneman, 2005). And there might also be a positive impact on intra-firm diffusion, the higher the core competences in processing and operationalising information of the firm are. Moreover, Battisti and Stoneman (2005) pointed out, that there is no direct positive correlation between the initial adoption (inter-firm diffusion) and the degree of usage of a new technology (intra-firm diffusion). Inter- and intra-firm diffusion have different drivers, which imply that being an adopter does not necessarily suggest being an expanded user (Hollenstein and Woerter, 2008). Further research on intra-firm diffusion was recently conducted by Battisti and Iona (2009). They analysed the diffusion of complementary innovations in comparison to the diffusion of a single innovation and their respective intensity of usage.

Finally, several studies (e.g., Bresnahan et al., 2002; Carlsson, 1984; Caroli and Van Reenen, 2001; Colombo and Mosconi, 1995; Hollenstein, 2004; Hollenstein and Woerter, 2004; Jaikumar, 1986) implied that in order to understand thoroughly the value creation patterns of a firm, and thus to know its innovation capability and potential, it is necessary to get a better understanding of the operation and function models of its internal organisations.
2.5 Technology diffusion by patent licensing

Among the existing indicators one can use to forecast the rise of technology and innovation, patents and patent citations are considered to be a very useful instrument (Chang et al., 2009). The more often a patent is cited by another subsequent patent, the more likely the technology that is patented is diffused within a company or industry. The process of patent citation is somewhat like the epidemic model of technology diffusion. Even if there are many other possibilities for technology diffusion (for both inbound and outbound diffusion), e.g., product exhibitions or expositions, technology conferences, research collaborations and joint ventures, the diffusion effect of other methods than patent licensing cannot be observed or measured clearly. Also, we see that large companies from emerging economies like China actually strongly use patent licensing as an instrument to adopt technology and develop technological capabilities (Wang et al., 2013; Wang and Zhou, 2013).

A considerable number of researchers recently studied the licensing activities of large multinationals in Asian economies (Han and Park, 2006; Nelson, 2009; Tsai and Wang, 2007; Wang and Zhou, 2013), e.g., by analysing license contracts and included patents per contract in the database of the Chinese Intellectual Property Office (Li-Ying et al., 2012; Wang et al., 2013). Wang and Zhou (2013) found that Chinese local sites enhance firms’ technological-capability building by international technology licensing-in activities. Further the effect seems to be moderated by three things: the enrolment of sufficient R&D personnel from local sites, the collaborations with local universities and research institutes and the collaborations with local industrial community, while the collaboration with universities has the biggest impact followed by the enrolment of local R&D personnel. The study of Wang et al. (2013) further explores performance implications of such in-licensing decisions in the same Chinese context. They explain the performance differences not only by the amount of in-licensing, but mainly by the differences in the firms’ absorptive capacity. Thus, they emphasise the importance of licensing capabilities as technology diffusion mechanism. Interestingly they find that firms that license-in foreign technologies outperform those that predominantly license-in technologies from domestic sources, which illustrates one of the major goals of Chinese multinationals building up subsidiaries and research centres in developed countries such as the USA and Germany. Anyway, the scale of in-licensing as well as the diversity of the portfolio seems to be inverted U-shaped, which can easily be explained by the increased effort companies have to make when licensing in more knowledge in both amount and complexity. So, we see that patent licensing is an important mechanism for Chinese companies to learn from incumbent firms on their journey to become world market leaders. And in some industries they already managed to do so, e.g., in the ICT industries with companies like Huawei and ZTE. Certainly, this journey is supported by the plan of the Chinese Government to turn the Chinese economy into a technology powerhouse by 2020 and a global leader by 2050. Chinese firms are encouraged to co-innovate and re-innovate imported technology, and grow their own technology. Anyway, we have also seen that licensing-in will not guarantee the development of increased technological capabilities. Thus the study of Li-Ying et al. (2012) explores if Chinese firms have learned from prior in-licensing. And indeed they did as Li-Ying et al. (2012) examined with subsequent patent citations made by the Chinese licensee firms to their licensed patents.
As recent studies strongly relied on the analysis of licensing-activities as an indicator for technology diffusion, the study of Nelson (2009) has to be highlighted. Nelson suggests that studies of knowledge diffusion can be strongly strengthened by drawing upon multiple indicators. The major point for innovation research is that different measures provide different patterns and that, ceteris paribus, more measures are better since they capture a greater amount of activity. Nelson emphasises the aspect that diffusion is a concept in need of specification and elaboration. Depending on the type of study, diffusion can refer to the knowledge of the existence of a technique to the application of the technique in scientific experiments or in product development, or to the sale of products based upon the technology.3

2.6 The role of corporate entrepreneurship

Audretsch and Feldman (2004) and Audretsch et al. (2008) suggest that entrepreneurship is a crucial factor during innovation selecting, and it serves as a mechanism of knowledge spillover (Audretsch and Feldman, 2004; Grossman and Helpman, 1991; Lucas, 1988; Romer, 1986). As Gries and Naudé (2011) commented, an entrepreneur is often seen as an innovator, risk-taker and arbitrageur who introduces new technology, competition and markets, and thus contributes to economic growth (Kirzner, 1973; Schumpeter, 1934). Further there is a clear processual link between entrepreneurship and innovation, which was discussed in a prior article of this journal (Brem, 2011). And Miller’s scale to measure entrepreneurship contains items that measure a firm’s tendency toward innovation, risk-taking, and proactiveness, which he describes as the sub-dimensions of corporate entrepreneurship (Miller, 1983). So, if entrepreneurship seems to have a clear correlation with innovation, then what is the role of entrepreneurship in the diffusion of innovation?

Corporate entrepreneurship, or the entrepreneurial orientation of a firm, according to Chen et al. (2005), is not only the entrepreneurship of leaders or any particular individual in a corporation, but also the entrepreneurship of all employees as a whole. Chen et al. provides four measures to cultivate corporate entrepreneurship through enhancing corporate performance, among which setting up a special department and fostering innovation-oriented culture are considered necessary. In the late 1970s Khandwalla (1977) initially developed a measurement scale for corporate entrepreneurship. Other authors have later refined Khandwalla’s measurement scale (e.g. Miller and Friesen, 1982; Covin and Slevin, 1986). Today, the original scale is anyway a very prominent scale to measure firm-level entrepreneurship (Merz et al., 1990; Zahra et al., 1999). A slightly different approach was recently provided by Chen et al. (2005, p.540ff) who measured corporate entrepreneurship with four constructs (each construct represented by a set of different variables): “Reasonably adjusting the system of the director board and the management”, “Developing senior executive’s entrepreneurial ability”, “Developing the individual’s entrepreneurial personality”, “Improving corporate strategic management and corporate circumstances”.

As we have discussed above, the study of Wang and Zhou (2013) reveals that international ventures, i.e., foreign subsidiaries of focal firms, have a technological capability fostering role, which is determined by the quantity and quality of local R&D personnel and the collaboration with universities and the industry community. Thus, the general importance of measure 4 is supported. In this context, Burgelmann (1984) offers
an organisational design for corporate entrepreneurs, which distinguishes several options in relation to operational relatedness and strategic importance. And McFadzean et al. (2005) and Shaw et al. (2005) provide further approaches to determine corporate entrepreneurship. Also, recent studies on licensing as well as the discussion around intra-firm diffusion show that measure 2 has a crucial role on the company performance, e.g., by seizing opportunities from patent licensing (Li-Ying et al., 2013; Wang et al., 2013). For measure 1 and measure 3, we have not been able to find any examination in literature yet. Anyway, we can see a clear but incomplete investigation of the role of corporate entrepreneurship in the process of technology diffusion.

As a summary, Table 1 gives an overview of the variables and respective measures discussed in this article. The variables are derived from a selection of peer-reviewed empirical studies from 1977 to 2013. The list is not intended to be exhaustive, but provides an overview of variables used in studies about the topics discussed above. We encourage other researchers to use this overview as a repository for further research on the evolution of technology diffusion.

Table 1: Overview of constructs, key variables and measures used in studies that regress firm-level, macro-level and knowledge-level variables on technology characteristics, corporate entrepreneurship and R&D outcome

<table>
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<th>Construct</th>
<th>Key variable</th>
<th>Measures</th>
<th>Key citations</th>
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<td></td>
<td>Success with product innovations, i.e., share of sales from products new to the market or alternatively share of sales from products new to the firm.</td>
<td>Cockburn et al. (2010)</td>
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<td></td>
<td>Number of patents that led to new product, e.g., for a new drug launch in the pharmaceutical industry.</td>
<td>Guler and Nerkar (2012)</td>
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<td></td>
<td>Taking the value of 1 if the firm obtains any new or significantly improved products and/or process during a selected year, otherwise the value is 0.</td>
<td>Diaz-Diaz et al. (2008)</td>
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<tr>
<td>Outcome</td>
<td>Technological diversity</td>
<td>Herfindahl index, which takes into consideration the counts in different patent classes as weights. Counts in different patent classes.</td>
<td>Trajtenberg (1990), Cloodt et al. (2006), Singh (2008)</td>
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<td>Proportion of patent technology subclasses to measure.</td>
<td>Katila and Ahuja (2002)</td>
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<td>Number of new classes in a firm’s patent portfolio within five years of its in-licensing experience compared with the five years preceding the licensing year. Derived from the International Property Classification.</td>
<td>Guellec and van Pottelsberge (2000), Fleming (2001), Silverman (1999), Wang et al. (2013)</td>
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<td></td>
<td></td>
<td>Natural log of a measure of breadth of the firm’s patent stock. Observed citation count and projecting future citations following the procedure of Hall et al. (2001).</td>
<td>Miller (2006), Hall et al. (2001)</td>
</tr>
<tr>
<td>Outcome</td>
<td>Learning status</td>
<td>0 = not learned, 1 = learned. Measures whether the licensee firm has learned from their previously in-licensed technologies within the five-year period after the licensing year. A licensee firm is regarded as ‘has learned’ if any of its patent applications cited any of its previously in-licensed patents.</td>
<td>Li-Ying et al. (2012)</td>
</tr>
<tr>
<td>Licensing capabilities</td>
<td>Licensing experience</td>
<td>Number of patents covered by a license agreement between firm A and B in each year.</td>
<td>Wang et al. (2012)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total number of prior licenses held by licensee.</td>
<td>Kotha et al. (2013)</td>
</tr>
<tr>
<td>Licensing capabilities</td>
<td>Licensed patents</td>
<td>Number of licensed patents of a firm per year.</td>
<td>Li-Ying et al. (2012), Wang and Zhou (2013), e.g., Wang et al. (2013)</td>
</tr>
<tr>
<td>Licensing capabilities</td>
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Table 1  Overview of constructs, key variables and measures used in studies that regress firm-level, macro-level and knowledge-level variables on technology characteristics, corporate entrepreneurship and R&D outcome

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<tr>
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<tr>
<td>Licensing capabilities</td>
<td>Absorptive capacity</td>
<td>Number of patents applied by a licensee firm five years prior to the licensing year.</td>
<td>e.g., Wang et al. (2012)</td>
</tr>
<tr>
<td>Licensing capabilities</td>
<td>Patent application experience</td>
<td>Licensee firm’s total number of patent applications within the five-year period before the year of licensing in technology.</td>
<td>Li-Ying et al. (2012)</td>
</tr>
<tr>
<td>Technology value</td>
<td>Technological complexity</td>
<td>Number of forward and backward citations in a year.</td>
<td>Carayannopoulos and Auster (2010), Sorenson et al. (2006), Wang et al. (2012)</td>
</tr>
<tr>
<td>Technology value</td>
<td>Technological generality</td>
<td>Generality index developed by Hall et al.</td>
<td>Hall et al. (2001)</td>
</tr>
<tr>
<td>Technology value</td>
<td>Technological generality</td>
<td>Claims appearing in the front page of each patent.</td>
<td>Lanjouw and Schankerman (2004), Lerner (1994), Wang et al. (2012)</td>
</tr>
<tr>
<td>Technology value</td>
<td>Knowledge newness</td>
<td>Average years of backward citation lags of all patents covered under a firm’s license agreements each year. Extent to which a firm’s licensed patent portfolio is in a mature technological field.</td>
<td>Hall et al. (2001), Wang et al. (2012)</td>
</tr>
<tr>
<td>Technology value</td>
<td>Technology age</td>
<td>Average number of years between the time when the licensed patents is filed and the year when it is licensed to a focal firm.</td>
<td>Li-Ying et al. (2012), Wang et al. (2013)</td>
</tr>
<tr>
<td>Technology value</td>
<td>Patent value</td>
<td>Average number of forward citations in the regional patent database ten years after the patents were firstly applied.</td>
<td>Li-Ying et al. (2012)</td>
</tr>
<tr>
<td>Corporate entrepreneurship</td>
<td>Firm’s tendency towards innovation</td>
<td>Leadership’s emphasis on R&amp;D, technological leadership, and innovation; number of new product and service lines within past five years; extend of changes to product and service lines within past five years.</td>
<td>e.g., Khandwalla (1977), Miller and Friesen (1982), Miller (1983), Covin and Slevin (1986), Barringer and Bluedorn (1999)</td>
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<tr>
<td>Corporate entrepreneurship</td>
<td>Firm’s tendency towards risk-taking</td>
<td>Leadership’s emphasis on high-risk projects; leadership’s emphasis to maximise the probability of exploiting potential faced with uncertainty; leadership’s believe in bold, wide-ranging acts.</td>
<td>e.g., Khandwalla (1977), Miller and Friesen (1982), Miller (1983), Covin and Slevin (1986), Barringer and Bluedorn (1999)</td>
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<tr>
<td></td>
<td></td>
<td>Capacity to endure uncertain circumstances, ability to seize opportunities, ability to learn from failures.</td>
<td>e.g., Khandwalla (1977), Miller and Friesen (1982), Miller (1983), Covin and Slevin (1986), Barringer and Bluedorn (1999), Chen et al. (2005)</td>
</tr>
<tr>
<td>Corporate entrepreneurship</td>
<td>Firm’s tendency towards proactiveness</td>
<td>Initiating actions to which competitors respond; First mover instead of follower; extend of competitive ‘undo-the-competitor’ strategy</td>
<td>e.g., Khandwalla (1977), Miller and Friesen (1982), Miller (1983), Covin and Slevin (1986), Barringer and Bluedorn (1999)</td>
</tr>
<tr>
<td>Corporate entrepreneurship</td>
<td>Leadership system</td>
<td>Stock ownership and separation of the CEO from the board of directors.</td>
<td>Chen et al. (2005)</td>
</tr>
<tr>
<td>Corporate entrepreneurship</td>
<td>Individual’s entrepreneurial personality</td>
<td>Extend of self-efficacy and independence.</td>
<td>Chen et al. (2005)</td>
</tr>
<tr>
<td>Corporate entrepreneurship</td>
<td>Strategic management and circumstances</td>
<td>Measured by staff participation, the flexibility of strategy formulation in accordance with circumstances, strategic financial control, enterprising strategy, organisation structure, dedication of innovation and venturing, innovation-oriented corporate culture.</td>
<td>Chen et al. (2005)</td>
</tr>
<tr>
<td>Knowledge-level variables</td>
<td>Technology classes</td>
<td>Average number of patent classes (following three digital patent classes of the USPTO classification system) from all licensed patent portfolios in a firm’s yearly licenses.</td>
<td>Wang et al. (2012)</td>
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<tr>
<td>Knowledge-level</td>
<td>Ratio of foreign licenses</td>
<td>Dividing the number of foreign licenses by the total number of licenses, per year.</td>
<td>Wang et al. (2013)</td>
</tr>
<tr>
<td>Firm-level variables</td>
<td>Licensor diversity</td>
<td>Number of different licensors from which a focal firm licenses-in new technologies, per year.</td>
<td>Wang et al. (2013)</td>
</tr>
<tr>
<td>Firm-level variables</td>
<td>New technical personnel</td>
<td>Ratio of the licensee firm’s new inventors within five years after the licensing year to its whole number of inventors during this period</td>
<td>Wang and Zhou (2013)</td>
</tr>
<tr>
<td>Firm-level variables</td>
<td>Firm age</td>
<td>Number of years between a licensee’s year of establishment to the year when the licensing agreement was established. Number of corporate employees. Employee counts transformed into a categorical variable because the information is not fully reliable for all privately owned firms. 0 for firms with equal to or less than 500 employees, and 1 for companies with more than 500 employees. Capital as the number of total capital in selected year or total fixed gross assets, deflated by the gross-fixed capital index.</td>
<td>e.g., Wang et al. (2013), Diaz-Diaz et al. (2008) or Wang et al. (2012) e.g., Katila and Ahuja (2002), Artz et al. (2010) or Salomon and Jin (2010) Wang et al. (2013) Park and Lee (2011), Tsai and Wang (2007)</td>
</tr>
<tr>
<td>Firm-level variables</td>
<td>Existing technological strength</td>
<td>Cumulative number of patents successfully applied by the focal firm in five years prior to the year it licenses a technology.</td>
<td>Wang et al. (2013), Wang and Zhou (2013)</td>
</tr>
<tr>
<td>Firm-level variables</td>
<td>Ownership</td>
<td>Firm belongs to the state, nominal scale (yes, no).</td>
<td>Wang et al. (2012), Wang and Zhou (2013)</td>
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<tr>
<td>Macro-level variables</td>
<td>Collaboration with universities and research institutes</td>
<td>Licensee firm has co-patenting activities with universities and research institutes within five years before its technology in-licensings, nominal scale (yes, no).</td>
<td>Wang et al. (2012)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Licensee firm has co-patenting activities with universities and research institutes within five years after its technology in-licensings, nominal scale (yes, no).</td>
<td>Wang and Zhou (2013)</td>
</tr>
<tr>
<td>Macro-level variables</td>
<td>Collaboration with industrial community members</td>
<td>Number of different business parties with which the licensee firms co-patented within five years following their technology licensing-in</td>
<td>Wang and Zhou (2013)</td>
</tr>
<tr>
<td>Macro-level variables</td>
<td>Province patent stock</td>
<td>Number of patent applications per 10,000 residents of the province where licensee firms reside.</td>
<td>Wang et al. (2012, 2013)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Licensee’s externally technological environment, calculating the average number of patent applications per million people four years before the in-licensing.</td>
<td>Li-Ying et al. (2012), Wang and Zhou (2013)</td>
</tr>
<tr>
<td>Macro-level variables</td>
<td>Market competition</td>
<td>Number of firms who licensed-in the same technologies from the same licensor within the current year and the two subsequent years.</td>
<td>e.g., Wang et al. (2012) or Wang et al. (2013)</td>
</tr>
<tr>
<td>Macro-level variables</td>
<td>Year</td>
<td>Time between year X and year Y, using year X as the reference category.</td>
<td>e.g., Wang, Zhou and Li-Ying (2012, 2013) or Cockburn et al. (2010)</td>
</tr>
<tr>
<td>Macro-level variables</td>
<td>Industry</td>
<td>Control for industry effects using SD according to the International Standard Industrial Classification. Categories: 0 for manufacturing (SD0) and 1 for other industries (SD1).</td>
<td>e.g., Wang et al. (2013)</td>
</tr>
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</thead>
<tbody>
<tr>
<td>Macro-level variables</td>
<td>Industry</td>
<td>Control for industry effects using own categorisation depending on industry diversification of selected sample.</td>
<td>e.g., Park and Lee (2011) or Tsai and Wang (2007)</td>
</tr>
</tbody>
</table>

3 Future research directions

Our review of articles on technology diffusion with emphasis on studies recently published on licensing as a learning and diffusion mechanism and the review of articles analysing the influence of corporate entrepreneurship, reveals several notable insights. We could find a strong emphasis on the analysis of the epidemic diffusion model and the probit model (Geroski, 2000), which is also described by other authors as the rank model (e.g., Bocquet et al., 2009). Other diffusion models such as the density-dependent growth model, the information cascade model and game theory approaches hardly received attention (Chang et al., 2009). Therefore, we believe that there is a need to analyse those models in the context of the current business environment.

Other topics identified the lack of research concerning the evolution of technology diffusion. First, we see a strong need to analyse the influence of all kinds of social interdependencies, including network externalities and social signals (Peres et al., 2010), and its interaction on technology diffusion in general, i.e. touching both processes inter-firm diffusion and intra-firm diffusion. Second, as Roger’s initial model fails to explain intra-firm aspects or aspects of the UD model (Shih and Venkatesh, 2004), an update of Roger’s model and the development of a diffusion model as an organic whole would be a fruitful contribution to diffusion research. And third, related to the second argument there is no integrated model available, which covers all possible influence factors, e.g. the integration of entrepreneurship (Miller and Garnsey, 2000) or the integration of other internal and external diffusion mechanisms such R&D collaborations, joint ventures and word-to-mouth diffusion.

Concerning the differentiation of intra-firm diffusion and inter-firm diffusion, we have clearly found that intra-firm mechanisms such as the deployment of research platforms and influence factors such as the entrepreneurial behaviour of a company have been hardly analysed. Anyway, the complex business environment, the consolidation to large multinational organisations with highly complex research and innovation systems and the technological leap of multinationals from emerging economies call for a deeper analysis of intra-firm diffusion processes. For example, by analysing the influence of R&D strength, export intensity, company size, managerial techniques and complementary technologies on firms’ intra-firm diffusion performance (Battisti and Stoneman, 2005). Or the empirical analysis of activities dealing with speed of adoption in (intra-firm diffusion) and between companies (inter-firm diffusion) and how they are related with firm performance (Bryson et al., 2007; Fuentelsaz et al., 2003).
Finally, this review has identified avenues that remain unexplored in research. Table 2 presents potential future research questions to further explore innovation diffusion and its causal mechanisms that influence firm performance.

**Table 2 Potential future research questions on innovation diffusion**

<table>
<thead>
<tr>
<th>Category</th>
<th>Potential research question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffusion models</td>
<td>Beyond the frequent analysis of the epidemic/rank/probit technology diffusion model, what implications for technology diffusion mechanisms can be drawn from other models such as the density dependent model, the information cascade model or the game theory approach?</td>
</tr>
<tr>
<td>Evolution of technology diffusion</td>
<td>How do social interdependencies including network externalities and social signals influence technology diffusion? AD (inter-firm diffusion) failed to explain the diffusion process as an organic whole, how can Roger’s initial model be extended to better explain the diffusion process in the current business environment?</td>
</tr>
<tr>
<td></td>
<td>How does an integrated diffusion model could look like, which includes influence factors such as corporate entrepreneurship and different diffusion mechanisms such as licensing, R&amp;D collaborations, joint ventures and word-to-mouth?</td>
</tr>
<tr>
<td>Intra-firm diffusion</td>
<td>How do intra-firm (use diffusion) mechanisms such as word-to-mouth and internal IT-supported research platforms as well as mediation effects such as entrepreneurial behaviour influence technological firm performance?</td>
</tr>
<tr>
<td>Intra-firm diffusion</td>
<td>How do R&amp;D strength, export intensity, company size, managerial techniques, and complementary technologies influence intra-firm diffusion? How does the speed of adoption in companies influence technological firm performance? How does the speed of adoption between companies influence technological firm performance?</td>
</tr>
</tbody>
</table>

4 Limitations

The intention of our paper was to review the most popular work about technology diffusion, show research gaps and elaborate recent activities in the field of diffusion research to identify future research directions. As most of the work in the area of innovation management emphasises the use and effectiveness of patents as a mechanism for capturing value from innovation, the latest studies we found on the topic continue to do so. Even if the research agenda is primarily shaped by the mechanisms companies actually use – as the strong use of licensing patents from companies in emerging economies to capture innovation – scholarly work lacks a deeper analysis and theory building of other possible innovation diffusion mechanisms such as technology transactions in joint ventures, R&D collaborations with companies and universities or technology buy (‘asset deals’).
Also, Li (2012) stated that inventors from the top countries regarding patent filing (except China), i.e., Japan, USA, Korea and Germany, have been more active in filing applications to the Chinese State Intellectual Property Office (SIPO) than inventors from other countries. These countries contributed more than three quarters of the total foreign invention applications in China in 2007 (Li, 2012). The statistics show that patenting filed in China by inventors from these countries has been rising much faster than patenting in their home countries, suggesting that China has indeed become a favoured destination for foreign inventors seeking patent protection. This illustrates that the motivation of licensing activities studied at the SIPO may strongly differ among the companies. This study as many others before solely studied patent licensing as a mechanism of technological capability development.

From an institutional perspective, our study mainly focuses on the analysis of research within and across companies, i.e., we focus very much on the micro-level drivers of technology diffusion. The study therefore lacks a deeper macro-level analysis. For example, as recent studies have shown (e.g., Wang and Zhou, 2013), multinational companies from emerging economies strongly use patent licensing as an instrument to build up technological capabilities and leap generic technological growth (often strongly supported by the government). Thus, a deeper analysis of goals and consequences of technology diffusion as learning mechanism is required as well as a holistic analysis of both micro-level and macro-level determinants and the interactions among them.

References


Innovation diffusion, licensing and corporate entrepreneurship


Innovation diffusion, licensing and corporate entrepreneurship


Notes
1 In course of the study we use the terms ‘knowledge diffusion’, ‘technology diffusion’ and ‘innovation diffusion’ as synonyms for the same principle, i.e., the process of the first adoption of the technology in the market to the extent of use within a company.
3 In addition to the definitions section of this article, Bozeman (2000) offers a very useful discussion of the various definitions of technology diffusion.
4 Technological capabilities can be measured by input indicators (e.g., R&D expenditure or R&D personnel) or by output indicators (e.g., new products, new processes, patents, and their share of annual sales). For more information on the various indicators see Grupp (1998).