Firm Capabilities, Technological Dynamism and Innovation Internationalisation – a Behavioural Approach

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INTRODUCTION

Following the internationalisation of less knowledge-intensive activities, in recent years firms have increasingly begun to internationalise also innovation activities (Manning et al., 2008, Pyndt & Pedersen, 2006, Bardhan & Jaffe, 2005, Contractor et al., 2010; Criscuolo et al., 2010; Nieto & Rodríguez, 2011; D'Agostino et al., 2013). Although some authors have started to discuss the strategic drivers of the internationalisation of innovation (Lewin et al., 2009; Mudambi & Venzin, 2010; Ambos & Ambos, 2011), a standing critique of the literature has been that it abstracts from the decision-maker (Hutzschenreuter et al., 2007) and therefore largely ignores behavioural insights on decision-making under uncertainty and bounded rationality (Aharoni, 2010; Harvey et al., 2011). Uncertainty and bounded rationality, however, are highly relevant in internationalisation processes due incomplete information resulting e.g. from differences in culture, institutions, business approaches or language (Aharoni et al., 2011).

In this paper we propose a behavioural framework for the internationalisation of innovation activities, which explicitly allows for bounded rational decision-making under uncertainty. Following prospect theory we argue that, in the light of incomplete information, decision-makers will use decision heuristics based on satisficing rather than optimizing principles (Kahneman & Tversky, 1979; Fiegenbaum et al., 1996; Shoham & Fiegenbaum 2002, Aharoni, 2010). In specific, prospect theory argued that satisficing behaviour will imply discontinuous risk preferences, where high performing firms are risk-averse while low performing firms are risk-assertive.

Not belittling other environmental factors such as cultural, institutional, or market factors (see for example Hutzschenreuter et al., 2011; Kshetri, 2007), our primary goal is to analyse how the characteristics of a firm's technological environment affects its decisions about internationalisation of innovation and how the decisions differ between firms with high and low technological capabilities. Following the high velocity literature we describe the characteristics of the technological environment by the speed and the uncertainty of technological change (Bourgeois & Eisenhardt, 1988; Gustafson & Reger, 1995; Eisenhardt & Martin, 2000). A striking prediction of our model is that firms with low technological capabilities will view uncertainty about the direction of technological change as an opportunity driving international innovation activities, while firms with high technological capabilities are expected to be more risk-averse leading to centralisation of innovation at the home base.

We test the predictions of our framework based on data from the German Innovation Survey in 2011, which is part of the Community Innovation Surveys (CIS) co-ordinated by the European Commission. Our results show that speed of technological change and uncertainty about its direction increase incentives for innovation activities in general. However, while high speed of technological change c.p. also increases the propensity to innovate internationally, the effects of uncertainty are highly conditional on the firms' internal technological capabilities. Uncertainty reduces the propensity to conduct innovation internationally for firms with high technological capabilities and increases it for firms with low technological capabilities. We, however, also show that the negative effect of technological uncertainty for firms with strong technological capabilities disappears when firms invest in their transfer capability (Kuemmerle, 1999) by engaging in personnel exchange between headquarters and its subsidiaries.

THEORY

A core task of strategic management is to align the firm's capabilities with the characteristics of the environment it faces (Andrews, 1971; Drazin & de Ven, 1985; Zajac et al., 2000). Based on prospect theory (amongst others Kahneman & Tversky, 1979; Tversky & Kahnemann, 1983; Kahnemann 2003) authors have argued that decision alternatives aiming at aligning firm capabilities with environmental characteristics can be expressed in terms of their associated risks and returns (Fiegenbaum et al., 1996; Shoham & Fiegenbaum, 2002). While potentially many external factors affect the implied risk-return-trade-off associated with international innovation, based on the high-velocity literature we will focus on the characteristics of the technological environment in terms of uncertainty about technological developments and the speed of technological change (Bourgeois & Eisenhardt, 1988; Gustaffson & Reger, 1995; Wirtz et al., 2007). In the next subsection we will discuss how technological speed and uncertainty will affect both returns and risks to innovation in general and international innovation in specific. Based on prospect theory, we then argue that the firms' technological capabilities govern their risk preferences, i.e. how firms weight risks and returns.

Uncertainty and speed of technological change

With the increasing importance of innovation and new technology for firm competitiveness in globalised markets (Porter, 1986; Scherer, 1992; Tushman & Murmann, 2003; Schiavone, 2011), the motives for the internationalizing firm activities have shifted from reducing costs (Bardhan & Jaffe, 2005, Winkler, 2009) to seeking access to knowledge (Lewin & Peeters, 2006; Bunyaratavej et al., 2007; Meyer 2015) and scarce highly-qualified human capital (Lewin et al., 2009). Several authors have argued that one source of the trend towards globalised knowledge seeking is the increased technological dynamism resulting, for example, from shorter product life cycles (Tassey, 2008; Seppälä, 2013). Nonetheless, technological dynamism has not been a core topic in the IB literature, aside from very specific studies on the role of advances in IT (Abramowsky & Griffith, 2006; Blinder, 2006; Ernst, 2002; MacDuffie, 2007).

A theoretical treatment of environmental dynamism can be found in the high-velocity literature (Eisenhardt 1989, Eisenhardt & Bourgeois 1988, Bourgeois & Eisenhardt 1988; McCarthy et al. 2010). While the high-velocity literature has taken a broad stance on dynamism by discussing the role of general economic, competitive and strategic factors, the role technological dynamism has been emphasised in particular. The literature has made a distinction between speed of technological change and the uncertainty about its direction (see Bourgeois & Eisenhardt, 1988; Gustaffson & Reger, 1995; Wirtz et al., 2007). Although speed and uncertainty of technological change are often correlated, they are conceptually not the same. In specific, while uncertainty about technological change is the result of the instability of the technological trajectory, speed of technological change is a result of the richness of technological opportunities the trajectory offers (Dosi, 1982; compare also Eisenhardt & Burgeois, 1988). As a consequence, we will argue that speed and uncertainty can affect the risk-return-trade-off associated with innovation internationalisation differently.

Typically, at the inception of a trajectory the knowledge bases underlying innovation activities are weakly developed (Dosi, 1982). As a consequence, in the early stages of the trajectory innovation activities are often based on trial-and-error approaches and build on tacit knowledge rather than well-understood cause-and-effect relationships as summarised by codified scientific principals (Asheim & Coenen, 2005; Grillitsch et al., 2016). The lack of codified and transferable knowledge leads to uncertainty about the direction of technological change, because firms will follow differing innovation strategies. This also implies that knowledge bases across firms will be very heterogeneous. However, as firms accumulate experience, knowledge about stable cause-and-effect relationships increases and technological trajectories become more stable. In addition, also dominant designs emerge, which increases predictability of the market response (Abernathy & Utterback, 1978; Klepper, 1996; Beise, 2004). As a result, uncertainty about the direction of technological change declines and eventually also the heterogeneity in the firms' knowledge bases decreases. The degree of technological uncertainty thus strongly appeals to the stability of the technological trajectory.

Speed of technological change, however, does not genuinely refer to the stability of the trajectory but the richness of the technological opportunities it offers (Robin & Schubert, 2013), where rich trajectories will allow for high speed of technological change. It is true, that speed and uncertainty are often correlated because as the trajectory matures not only uncertainty decreases but also technological opportunities deplete (Fagerberg & Verspagen, 2002). However, there is no a priori reason to assume that high uncertainty is unambiguously tied to high speed. In fact, technological opportunities can remain abundant for quite some time already after trajectories have stabilised. An example is the development of micro-processors between in the period 1990 to 2005. Moore's law predicted that processor speed would double approximately every 18 months. Yet, despite the enormous increases in processing power, the direction of technological progress was guided by the principal of miniaturisation. Radically differing approaches to increase the processing power did not emerge, giving an example of low uncertainty about the direction of technological change despite high speed. Likewise, uncertainty can be high in situations where speed is low. This can happen when basic technological obstacles to achieve the desired solution are not overcome. An example refers to the development of brain-machine interfaces. Since the knowledge about the functioning of the brain is still limited, interfaces developed so far work, despite some progress for example as concerns the development of reactive prostheses, with a low degree of accuracy. Speed of technological progress is therefore still low. Nonetheless, uncertainty is high because path-breaking insights can strongly affect the direction of innovation (Wolpaw & Wolpaw 2012; Hochberg et al., 2006).

We will now discuss how speed of technological change and uncertainty about its direction affect the incentives for innovation and its internationalization. Although speed and uncertainty are continuous (and will be treated as such in the empirical part) for expositional reasons we base our discussion here on the four archetypes summarised in Figure 1. Quadrant III and Quadrant IV are characterised by high technological uncertainty usually resulting from limited understanding of the scientific principals. The two quadrants differ by the richness of their technological opportunities realisable in the short to medium term. Innovation in both quadrants will rely on highly tacit knowledge. The knowledge bases will thus differ greatly between firms as tacit knowledge is often locally bound. Effectively absorbing it often requires localised interactions (Breschi & Lissoni, 2001; Asheim & Isaksen, 2002). The gains to conduct international innovation are high because innovation-relevant knowledge will be globally dispersed (Bathelt et al. 2004). At the same time international innovation will bear considerable risks in terms of knowledge leakage in the foreign locations (Kotabe et al., 2008; Criscuolo, 2009; Jensen et al., 2013). Quadrant III and IV are therefore characterised by simultaneously high risk and high returns. The incentives to conduct innovation internationally will eventually depend on how firms trade off risks and returns.

Quadrant I and Quadrant II are characterised by low technological uncertainty resulting from stable technological trajectories. The gains to international innovation are most likely lower because the knowledge bases are less heterogeneous between firms implying that knowledge is less dispersed globally. Thus the gains to international innovation will be lower. At the same time risks associated with internationalisation will also be lower, because the greater homogeneity in the knowledge sources reduces the risk that unique knowledge leaks out. Quadrants I and II thus represent low-risk-low-returns situations, again implying that the decision to conduct innovation internationally will depend on the firms' risk preferences. Based on prospect theory, we will discuss how the firms' risk preferences are endogenously determined by their internal technological capabilities.

Figure 1: Archetypes of technological velocity

uncertaintiy about the direction of technological change	low — speed of technological change	high

high	**III. Unpredictable technological environment**
	– Instable trajectories with poor technological opportunities
	    – High risks of knowledge leakage because of great knowledge heterogeneity between firms
	    – Medium to high gains of internationalisation by access to dispersed knowledge
	– Example: brain-machine interfaces
		IV. Highly volatile technological environment
		– Instable trajectories with rich technological opportunities
		    – Very high risks of knowledge leakage because of great knowledge heterogeneity between firms
		    – Very high gains of internationalisation by access to dispersed knowledge
		– Example: cancer drug development

low	**I. Stable technological environment**
	– Stable trajectories with poor technological opportunities
	    – Low risk of internationalisation because of very low knowledge heterogeneity between firms
	    – Low gains to internationalisation
	– Example: textiles
		II. Predictable technological environment
		– Stable trajectories with rich technological opportunities
		    – Low risk of internationalisation because of low knowledge heterogeneity between firms
		    – Low to medium gains to internationalisation
		– Example: miniaturisation of computer chips

Risk preferences and technological capabilities

In Figure 1 we explained how speed and uncertainty of technological change drive the returns and risks associated with international innovation. To complete our theory we need to determine how firms weight returns and risks against each other.

Standard theory in most rational choice models treat risk preferences as an invariable parameter exogenous to the model. The invariability of risk preferences is however not consistent with empirical observations, that the very same decision-maker sometimes act risk-aversely and sometimes risk-assertively (Fiegenbaum et al., 1996). Trying to explain this behaviour, prospect theorists proposed that decision-makers benchmark their current outcomes against certain reference points, which they perceive as satisfacing (Kahneman & Tversky, 1979; Shoham & Fiegenbaum, 2002; Harvey et al., 2011). Positions below the reference point are perceived as losses and positions above the reference point are perceived as gains, where losses are weighted higher than gains of the same magnitude (March & Shapira, 1987; Miller & Chen, 2004, Figuera-de-Lemos & Hadjikhani, 2014). As a result, decision-makers perceiving their current position to be below the reference point (a loss situation) act risk-assertively in order to avoid the loss situation. Well-performing decision-makers perceiving their current position as being above the reference point (a gain situation) act risk-aversely in order to avoid falling below the satisficing threshold (Fiegenbaum et al., 1996; Shoham & Fiegenbaum, 2002). In line with the theory, several works have indeed shown that poor performers are usually more risk-taking than high performers (Bowman, 1982; Bromiley, 1991)

While performance can be defined on many scales, we take the firms internal technological capabilities as the performance benchmark. The reason is that by internationalising innovation firms often seek to improve their technological capabilities (Dunning & Narula 1995; Narula & Zanfei, 2004; Meyer et al., 2009; Nieto & Rodriguez, 2011; Meyer, 2015, Cuervo-Caruzza et al. 2015). Furthermore, several authors have argued that internationalisation of innovation will, even if initially associated with market or efficiency seeking motives (e.g. lower costs of innovation), lead to increasing emphasis of asset seeking motives in the long-run (Zanfei, 2000, Le Bas & Sierra, 2002, Narula & Zanfei, 2004, Castellani et al., 2015). By using the technological capabilities as the performance scale, an implication of prospect theory is that firms with low technological capabilities (firms in a loss-situation) will be risk-assertive while firms with high technological capabilities (firms in a gain situation) will be risk-averse.

The hypotheses

In Figure 1 we argued that high speed of technological change necessitates innovation because high speed is indicative of large technological opportunities (compare Vega-Jurado et al., 2008; Robin &

Schubert, 2013). In general speed of technological change will imply short product-life cycles (Tassey, 2008; Seppälä, 2013), which increase the need for constant innovation. As concerns internationalisation of innovation, we have to consider how speed of technological change affects risks and returns associated with innovation. We have also argued that high speed of technological change is often correlated with high uncertainty. However, it can prevail in fairly predictable environments because it is causally linked to the richness of technological opportunities, not the stability of the trajectory (see Quadrant II in Figure 1). As a consequence, higher speed of technological does not causally imply a great increase in knowledge heterogeneity between firms. An increase in speed of technological speed will therefore c.p. not strongly increase the risks of international innovation in terms of leakage of knowledge (Kotabe et al., 2008; Criscuolo, 2009) Yet, as speed of technological increases, internationalisation of innovation can be associated with high returns because of localization advantages – e.g. lower costs of innovation as an example of efficiency-seeking motives (Dunning, 1993, Cuervo-Caruzza & Narula, 2015). Consistent with our reasoning that increasing speed of technological change implies higher returns of international innovation but does not considerably increase risks, the literature confirms that firms performing innovation internationally cluster in sectors with fast technological progress (Castellani et al.; 2015). We conclude:

H1a: High speed of technological change increases the innovation intensity for firms with both high and low technological capabilities.

H1b: High speed of technological change increases the propensity to conduct innovation internationally for firms with both high and low technological capabilities.

High technological uncertainty results from instable technological trajectories. Continuous innovation is necessary in technologically instable environments because existing knowledge bases are constantly at risk of eroding (Figuera-de-Lemos & Hadjikhani, 2014). The erosion of existing knowledge bases implies that firms with high technological capabilities need to renew their technology base constantly in order to avoid situations where their technological capabilities become outdated by unanticipated technological developments. In fact, authors have argued that in volatile markets competitive advantage usually cannot be sustained for long (Johanson & Vahlne, 1977; Figuera-de-Lemos & Hadjikhani, 2014). By innovating firms thus can reduce the risk of lock-out (Schilling, 2002). Also for firms with low capabilities high incentives for innovation will prevail because uncertainty increases the chances of developing leap-frogging innovations by adopting novel solution paths (compare Lee et al., 2005).

H2: High uncertainty about the direction of technological change increases the innovation intensity for firms with both high and low technological capabilities.

Because uncertainty increases heterogeneity of the firms' knowledge bases, it is much more likely that unique and valuable knowledge sources are globally dispersed. Globally dispersed knowledge sources makes access to global knowledge bases (Bardhan & Jaffe, 2005; Barthélemy & Quélin, 2006) or specialised human capital (Lewin et al., 2009) more important. While uncertainty increases the returns to international innovation, also the risks associated with knowledge leakage (Criscuolo, 2009) and loss of control of strategic assets (Kedia & Lahiri, 2007; Ceci & Prencipe, 2013) increase. Based on prospect theory (Fiegenbaum et al., 1996; Shoham & Fiegenbaum, 2002) we have already argued that firms with high technological capabilities will be risk-averse while firms with low technological capabilities will be risk-assertive. A large literature shows that risk-aversity will make firms more inclined to apply familiar solutions and to centralise decision making to avoid loss of control (Staw et al., 1981; Dutton & Jackson, 1987; Shoham & Fiegenbaum 2002). In consequence we expect that firms with high technological capabilities will centralise innovation activities in order to keep tight control of the innovative activities representing their core competences (Granstrand, 1999; Baier et al., 2015). Low competence firms, on the contrary, will be risk-assertive and thus more likely to be willing to take the risks of international innovation.

H3a: High uncertainty about the direction of technological change decreases the propensity to conduct innovation internationally for firms with high technological capabilities.

H3b: High uncertainty about the direction of technological change increases the propensity to conduct innovation internationally for firms with low technological capabilities.

So far we have treated the firm's technological capabilities as affecting the firms' risk preferences but not the risks and returns associated with international innovation themselves. This assumption neglects important insights from innovation studies and international business which suggest that internal technological capabilities also determine the firms' absorptive capabilities (Cohen & Levinthal, 1990; Caloghirou et al., 2004, Soosay & Hyland, 2008). In particular, Betrand & Mol (2013) argue that high R&D capabilities allow firms to absorb knowledge from their international subsidiaries more effectively. Thus, while high technological capabilities will make a firm more risk-averse, they will also increase the expected gains from internationalising innovation. While the net effect on the propensity to conduct innovation internationally is theoretically indeterminate, we argue that the returns-increasing effect of higher absorptive capabilities will be the stronger the higher the effective mutual knowledge flows between the parent and its international subsidiaries are. Without such knowledge flows the knowledge produced by the subsidiaries remains stuck locally (Gupta & Govindarajan 2000). An important and often studied organizational mechanism to increase knowledge flows is the coordinated exchange of personnel between parents and subsidiaries (Rycroft, 2003; Buckley et al., 2005; Persson, 2006; Li et al. 2013). Personnel exchange is particularly important in the case of innovation because it helps transferring also tacit knowledge (Kim, 2001). The ability to absorb the knowledge sources from the subsidiaries does therefore not only require that a parent firm has high technological capabilities. It will also require the parent to make organizational efforts to actually transfer the knowledge, e.g. via exchange of personnel.

> *H4: For firms with high technological the higher the personnel exchange the more positive is the effect of uncertainty about technological change on the propensity of conducting international innovation activities.*

DATA, VARIABLES AND IDENTIFICATION

Data

The data used to test the hypotheses are taken from the Mannheim Innovation Panel (MIP). The MIP is an annual survey of innovation activities of German enterprises and the German contribution to the Community Innovation Surveys (CIS) of the European Commission. It fully complies with the methodological standards laid down for the CIS. The MIP is based on a stratified random sample of firms located in Germany with 5 or more employees having their main economic activity in mining, manufacturing, energy and water supply, sewerage and environmental remediation, wholesale trade, transportation and storage, information and communication services, financial and insurance activities, and other business-oriented services. More details on the MIP can be found in Peters & Rammer (2013).

We use data from the MIP survey conducted in 2011, which collected information on innovation activities of firms conducted during the years 2008 and 2010. The MIP survey provides information on the core variables described in our theory (innovation internationalisation, technological dynamism, internal technological capabilities) as well as general information about the firms. Note that the questions we use for our core variables were not part of the harmonised questionnaire for the CIS 2010 but have been added only to the survey in Germany.

We follow the approach of Baier et al. (2015) and restrict our sample to firms with headquarters in Germany. With these restrictions we have a sample of 6,589 firms. Due to the item non-response for some of the model variables the sample used in the regressions consisted of approximately 4,500 firms.

Core Variables and Identification Strategy

Our aim is to explain the internal and external conditions that drive a firm's decision to conduct international innovation activities and the general incentives for innovation measured by the innovation intensity. For the innovation intensity we use two alternative variables. First we create a measure of innovation expenditures as a share of turnover. Second we use R&D expenditures as a share of turnover. As concerns international innovation, the MIP 2011 survey gives information on whether a firm engaged in activities related to R&D, manufacturing of new products, design, or implementing new processes internationally during the three year period 2008 to 2010. We rely on the standard concepts and definitions of R&D, design and innovation as proposed in the respective OECD manuals (OECD & Eurostat, 2005; OECD, 2015). R&D and design refer to activities related to the development of innovations and involve the creation of new knowledge or the creative use of existing knowledge.

Although manufacturing a new product at a foreign location or implementing a new process technology need not be linked to creative work performed at the foreign location, e.g. if the new product or new process technology has been transferred from the parent company, in line with international definitions, we still regard these activities as innovation since they constitute a new activity at the foreign location, requiring changes to existing routines and usually also adaptations of technologies and practices to the specific situation at the foreign location. In order to obtain a fine-grained insight into how technological capabilities and technological dynamism affect offshoring decisions we report the effects on each of the four internationalisation variables (R&D, design, product, process) separately in Table 3, Table 4, and Table 5.

A firm's internal technological capability as well as technological uncertainty and the speed of technological change in a firm's market are measured through an assessment made by managers. Firms were asked to rate their internal technological capabilities ("Ability to develop new technological solutions") on a Likert scale from 1 (very low) to 5 (very high).[1] We create a dummy for high technological capabilities if managers rated their technological capabilities at 4 (high) or 5 (very high), while it takes a value of 0 for all classes up to 3 (intermediate). In addition, firms were asked to characterise their market environment on a 4-point Likert scale ranging from 1 (item does not apply) to 4 (item fully applies). Two items most referred to technological dynamics of the environment: "Technological development is difficult to predict" and "Products are rapidly outdated". We use the first item as an indicator for technological uncertainty and the latter one for speed of technological change. To measure the degree of personnel exchange we make use of four dummy variables indicating whether a firm sent personnel from the parent to the subsidiary a) on short-term basis or b) on a long-term basis or whether the subsidiary has sent personnel to the parent c) on a short-term basis or d) on a long-term

[1] We perceive technological capabilities as the sum of the firms' internal competences ranging from the production, use, adaption and improvement of new technological knowledge, value chain technologies and product development technologies, competences in technology forecasting and technology assessment as well as the ownership of patents and licenses.

basis. We sum up the four variables and leading to an index taking values between 0 and 4.[2] The exact wording of the core survey items are shown in the supplementary material accompanying this article.

In order to test H1a and H2 we use Tobit regressions because both the innovation and the R&D intensity are strictly positive and continuous. In order to test H1b, H3a/b, and H4 we use Probit regressions taking the four types of innovation internationalisation activities as the key dependent variables to analyse the effect of speed of and uncertainty about technological change. In all cases, in order to grasp the potentially differing effects between firms with low and high internal technological capabilities we split our sample and report the results for the firms with high and low capabilities separately.

Confounding Factors

Based on earlier findings, we identify a set of confounding factors. We differentiate between size, group structure, export activities, and characteristics of the appropriability regime. We also discuss the role of innovation expenditures as well as the sector a firm belongs to. While we discuss these variables with respect to internationalisation of innovation, they can also be expected to be relevant for innovation in general.

Size: Although some authors find support that also smaller companies engage in innovation internationalisation (Roza et al., 2011), the literature has frequently discussed the phenomenon as being most relevant for large companies. Reasons are that large companies usually have greater financial resources, more complementary assets and greater managerial capacities (see Bardhan & Jaffe, 2005). Although small companies may have an advantage in coping with increased organizational complexity associated with innovation internationalisation, most authors find that the propensity to conduct innovation internationally strongly increases with size (Baier et al., 2015). We include the number of employees and its square as a functionally flexible control for size.

Group structure: Belonging to a group can contribute to making firms more accustomed to managing multi-site processes (Bartlett & Ghoshal, 2002). Furthermore, to the degree that parts of the group are

[2] The Cronbach's Alpha was with 0.86 sufficiently high to warrant the creation of an index.

based abroad, strong global links and thus opportunities for internationalisation activities may exist (Berry, 2006). Firms in a group structure may therefore be more likely to conduct international innovation. We include a dummy indicating whether the firm is part of a company group.

Export activities: The Uppsala model argues that firms gradually intensify their internationalisation activities (Johanson & Vahlne, 1977). In this model export activities are usually one of the first steps and act as the originator for more advanced types of internationalisation as described by Dunning (1980, 1988). In particular, specificities in local demand may induce firms to internationalizing innovation in an attempt to adapt products to foreign consumer preferences. Furthermore, exposure to international markets can create learning potentials (Gassmann & von Zedtwitz, 1999; Macharzina et al., 2001), which allow firms to handle their internationalisation activities more efficiently (Ørberg Jensen, 2009). We therefore expect that export activities and innovation internationalisation are positively related. We include a variable which measures exports as a share of turnover (export intensity).

Intensity of product market competition: Alcácer et al. (2013) argue that the type of competition and internationalisation are strongly related, because industries dominated by MNEs are oligopolistic in nature. In oligopolistic markets competitive interaction is an important source of strategic behaviour. Intensity of competition may for example induce a race for human capital (Lewin et al., 2009). In addition, firms may try to escape competition by moving to geographically distant places. Furthermore, by internationalising innovation firms may reduce costs bestowing them with a competitive advantage. We thus expect that intensity of competition and innovation internationalisation are positively related. We include a variable measuring the intensity of price competition rated by managers on a Likert scale from 1 (low) to 4 (high).

Innovation intensity and sector dummies: The innovation intensity is a strong driver of international innovation at the firm level (Baier et al., 2015), because it measures the firms' overall orientation on innovation. Also the sectors set important incentives for or against international innovation. We thus include both sector dummies according to the OECD classification of technology levels and the innovation intensity as control variables. We include the innovation intensity for obvious reasons only in the internationalisation regressions.

Patents: The strength of patent protection may considerably affect the appropriability and knowledge leakage risks associated with the internationalisation of innovation (Teece, 1986; Park, 2008). Including patents is highly relevant for internationalisation decisions because major costs of international innovation are seen in the loss of control over core technologies resulting from the inability to prevent key know-how to spill-over to competitors in the foreign location (Kirner et al., 2009; Contractor et al., 2010; Hoecht & Trott, 2006). We therefore use an indicator on whether a firm used patents to protect its intellectual property.

Location in Eastern Germany: Since industrial structures, productivity and management practices are still different in the Eastern and the Western parts of Germany it is important to control for the firm location. We use a dummy for Eastern Germany.

Endogeneity Issues

Testing H1-H4 can be subject to endogeneity issues. For example, firms investing heavily in innovation both domestically and abroad may perceive a higher speed of technological change because they are better informed about technological advances on a global scale. In this case, the reported technological change is not exogenous, but positively depends on the degree of innovation investment presumably leading to an upward bias of our estimates. We therefore test for the possibility of endogeneity. To implement such a test, in a first step we create a variable measuring the firms' ratings of speed and uncertainty about technological change averaged at NACE 2-digit sectors, where we exclude the rating of the focal firm. For the Probit models we use this as an instrumental variable for individual firms' rating regression in a first step. The intuition behind this is that the sector averaged ratings are on the one hand correlated with the true speed of technological change in the sector. On the other hand any individual firm decision will not have an effect on the sector average ratings about the speed and uncertainty of technological change. From each of these two first step regression we obtain the residuals and include them in the second step Probit regression as additional explanatory variables. Endogeneity prevails if these two residuals are jointly significant (see Wooldridge, 2002). For the Tobit regressions we simply employ a full-maximum likelihood IV-Tobit estimator and check for endogeneity using a direct test. All the tests remain insignificant at 5%-level indicating that endogeneity is not a big issue in our regressions.

RESULTS

Descriptive statistics

In Table 1 we present the summary statistics of the main variables used throughout this paper. Internationalisation of any kind of innovation activities is a phenomenon observed only in a minority of the firms. In particular, we find that with a sample share of 2.6% international product innovation activities was still the most common practice. This was followed with 2.5% internationalisation of design activities. 2.2% had international R&D activities. About 2.0% of the firms had internationalised parts of their activities related to process innovation. As a point of reference we present the correlations in Table 2.

Main results

Table 1 goes about here

Table 2 goes about here

In H1-H4 we have argued that the speed of technological change and uncertainty about its direction can have distinct impacts on the firms' propensity to invest in innovation and their internationalisation patterns given the firms' technological capabilities. We first start with the analysis of the general incentives for innovation, which we present in Table 3.

Table 3 goes about here

Our results show that both technological uncertainty and speed of technological change drive innovation as well as R&D activities irrespective of the level of the technological capabilities. For all cases (except for one) the coefficients are positive and highly significant. This confirms our baseline hypotheses that both speed of technological change and technological uncertainty create strong incentives for innovation. While the confirmation of H1a and H2 is well in line arguments from the high-velocity literature, the more interesting question is if and under which conditions increasing incentives for innovation in general also translate into higher incentives for international innovation. As argued in Section "Core Variables and Identification Strategy", we test the hypotheses relating to internationalisation of innovation for each type (R&D, manufacturing of new products, design, and process innovation) separately. Using a sample splitting technique to avoid multicollinearity which may result fro a high number of interaction terms, the main results are presented in Table 4 (for R&D internationalisation and internationalisation of product innovation) and Table 5 (for design internationalisation and internationalisation of process innovation).

Table 4 goes about here

Table 5 goes about here

As concerns speed of technological change, we expected that firms both with high and low competences become more likely to conduct innovation internationally (H1b). The positive effect on the likelihood of innovation internationalisation is indeed corroborated for all types of innovation, with the exception of R&D internationalisation for low-competence firms. We thus are able to corroborate H1b for almost all cases.

As concerns uncertainty about the direction of technological change, for high-capability firms the effect of high uncertainty is negative on internationalisation of innovation. As predicted, firms with low technological capabilities differ from this pattern. For them the effect is positive. The differential pattern between low and high-capability firms corroborates H3a and H3b.

Moving to H4 we have extended our discussion of prospect theory underlying H1-H3, where we assumed that the technological capabilities only affect the firm's risk preferences. As already highlighted the concept of absorptive capacity suggests that technological competences will also affect the expected returns of internationalisation, because firms with high technological competences will be better able to absorb the knowledge from their international subsidiaries. While the mechanism based on absorptive capacity may confound the predictions that high-competence firms are less likely to conduct international innovation activities when technological uncertainty is high, we argued that the role of absorptive capacity is more relevant when the firms have effective knowledge transfer mechanisms in place. We further argued that if firms with high technological competences actively engage in personnel exchange, we would expect the negative effect of high technological uncertainty on internationalisation to fade out as high competence firms increasingly engage in personnel exchange. Table 6 corroborates this argument for all types of international innovation activities. A graphical representation (Figure 2) indeed demonstrates a statistically significant overcompensation of the negative effect of technological uncertainty for firms making intense use of personnel exchange.

Table 6 goes about here

Figure 2 goes about here

Robustness checks

We performed two major robustness checks. First, in order to deal with problems of endogeneity we have instrumented the speed and uncertainty of technological change by their sector means on the NACE 2 digit level. Because the endogeneity tests were mostly far from significant (see statistics in Table 3-Table 6, where only two cases with mildly significant results emerged), we are reasonably confident that the results are not strongly plagued by simultaneity and endogeneity issues. We also checked the strength of the identification by inspecting the F-statistics of the first stage regressions. The statistics were for all instrumented variables with above 20 very high, so that weak identification should not be an issue.

Second, we probed our sample selection. In our analyses we included firms irrespective of whether they innovate at all. On the one hand, this allows us to include firms which only innovate internationally – a phenomenon consistent with the hallowing-out hypothesis (Ghauri & Santangelo, 2012). On the other hand we may misleadingly include firms which do not innovate at all, rendering an analysis of internationalisation of innovation problematic. We have therefore rerun the analyses in Table 4-Table 6 excluding all non-innovators. The results remained quite robust, though at times, slightly less significant due to the reduced sample size.

DISCUSSION

In this paper we provided a predictive framework analysing the internal and environmental technological factors driving firms' decision to conduct innovation internationally. In doing so we moved beyond the discussion about the motives for firms to perform certain activities abroad (for a recent review see Cuervo-Cazzura & Narula, 2015). Instead of discussing the classical set of market-seeking, efficiency-seeking, resource-seeking or strategic asset-seeking motives (Kuemmerle, 1999, Dunning 1993, 2000, von Zedtwitz & Gassmann 2002) we have developed a predictive approach suitable to explain the internationalisation of innovation activities by firms in different technological environments. Similar to the work by (Cuervo-Cazzura et al., 2015) our framework builds on behavioural theory emphasising bounded rationality of decision-makers (March & Simon, 1958; Cyert & March, 1963). In specific, we applied prospect theory (Kahneman & Tversky, 1978; Kahneman, 2003) and characterised the decision for innovation internationalisation as a risk/return trade-off. In our model the risks and returns are determined by the dynamics of the technological environment (i.e. the speed of technological change and uncertainty about its direction), while the firms' risk preferences (i.e. how firms weight risks and returns) are determined by the firms' internal technological capabilities.

On a general level we contribute to an emerging literature emphasizing the need to integrate behavioural aspects of decision-making into theory development in the IB literature (Aharoni, 2010; Aharoni et al., 2011, Cuervo-Caruzza et al., 2015). Although, elements of behavioural theorizing have left some footprints in IB (Aharoni, 1966; Johanson & Vahlne 1977, 2009) the analysis of the influence of key behavioural concepts such as bounded rationality, satisficing behaviour, or decision-making under risk and uncertainty is still in its infancy (compare Figueira-de-Lemos et al., 2011; Harvey et al., 2011; Figuera & Hadjikhani, 2014; Cuervo-Cazurra et al., 2015). By applying prospect theory we were able to provide a structural model on how bounded rationality, risk and uncertainty, and satisficing behaviour play out with respect to internationalisation of innovation by firms. We believe that the integration of satisficing decision-making under risk und uncertainty is crucial to improve our understanding of firms' internationalisation decisions because the high complexity of fast changing globalised markets renders the conception of the rational fully-informed and optimizing decision-makers increasingly problematic (Johanson &Vahlne, 1977; Eisenhardt & Martin, 2000; Teece, 2007).

While there is an agreement in the IB literature that firms when internationalizing activities face a risk-turn trade-off (Hahn et al., 2009; Massini et al., 2010; Jensen et al., 2013), the existing works do not pay much attention to the stochastic meaning of the term risk. Rather risk often used is in the sense of anticipatable costs resulting from threats such as leakage of knowledge (Criscuolo, 2009; Kotabe et al. 2008; Lei & Hitt, 1995), higher organizational complexity (Bartlett & Goshal, 2002; Fifarek et al., 2008, Baier et al. 2015, Castellani et al. 2016), or loss of control (Nakatsu & Iacovou, 2009; Mudambi, 2008). We emphasise that we need to include risk and uncertainty explicitly because optimizing and satisficing agents respond differently to risk issues. In particular, optimizing agents will transform the decision problem into a quasi-deterministic problem expressed in terms of expected returns and costs. In addition, if at all, risk preferences are incorporated as an invariable trait (Jensen et al., 2013). This is problematic, because behavioural insights into actual risk-coping strategies are effectively moved outside the explanatory boundaries of the frameworks treating decision-makers as optimising. Our model instead explicitly includes risk preferences and suggests that high-capability firms will be more risk-averse in order to avoid falling below their satisficing reference point (Shoham & Fiegenbaum, 2002). We therefore contribute to the literature on strategic drivers of international innovation (Mudambi &Venzin, 2010; Manning et al., 2008; Ambos & Ambos, 2011) by explicitly incorporating behavioural issues of decision-making under uncertainty and bounded rationality.

A key result from our analysis is that when technological uncertainty is high firms with high internal technological capabilities will tend to avoid the risks associated with internationalisation and will be more likely to innovate at the home-base. We find the opposite patterns for firms with low technological capabilities. Our theory explains these findings, which proved to be robust across a variety of different specifications, in terms of risk preferences differing between high and low performing firms. We stress that the findings are hard to explain within a more traditional theoretical framework. First, with few exceptions – e.g. Roza et al., 2011 argue that risk preferences vary in the firms' size – existing theories provide very little guidance on the reasons why firms differ in their risk preferences. Thus, there is hardly any obvious risk-related argument that could explain that high-capability firms are less likely to innovate internationally. In fact, treating risk preferences as given as suggested by rational choice models, would be consistent rather with the opposite pattern: since returns and risks must be positively related in the long-run (i.e. when all possibilities for arbitrage have been eliminated) more risk-assertive firms will perform better on average. By backward induction, a higher observed performance level will be the result of greater risk tolerance of the past (Aharoni et al., 2011; Harvey et al. 2011), which implies that high-capability firms should be more likely to accept the risks of internationalizing innovation. A similar prediction would in fact result from the OLI framework (see e.g. Dunning, 2000), arguing that strong capabilities represent ownership advantages, which can be exploited abroad to outcompete local firms. The implicit assumption of home-base exploiting strategies thus would suggest that high-capability firms are more likely to serve international markets. For home-base exploiting activities the argument is clearly convincing. However for home-base augmenting activities like innovation, it is less so. In fact, an argument can be made, that low-capability firms have more to gain in terms improving own capabilities (Kedia & Lahiri, 2007; Meyer et al., 2009) or accessing foreign technologies/knowledge sources (Manning et al., 2008; Lewin et al., 2009) but much less to loose in terms of knowledge leakage (Kotabe et al., 2008, Jensen et al. 2013). The emphasis on behavioural approaches to risk thus seems crucial for understanding our findings.

We however stress that we regard our approach as complementary to established models based on rational choice frameworks (for an overview compare e.g. Castellani et al., 2015). In particular, if risks associated with internationalisation are low in a specific situation, rational models can provide very good approximations. As an example, in this paper we have argued that speed of technological change is related to the richness of technological opportunities and, although often correlated with uncertainty, does not per se imply high uncertainty. Giving support of this argument, we have shown that speed of technological change increases the incentives to internationalise innovation for all firms, irrespective of their technological capabilities.

A second reason why we think that our approach complements existing studies hints at some limitations. In particular, we have argued that our assumption that internal technological capabilities affect only the risk preferences (we relaxed this assumption in our last hypothesis) is too rigid and neglects some well-understood mechanisms. A leading example is the role of absorptive capacity which allows firms to benefit more from internationalising innovation (Kotabe et al., 2011; Bertrand & Mol, 2013). In the context of our model, the absorption mechanism means that technological capabilities do not only affect risk preferences (as assumed in H1-H3) but also incentives to conduct innovation internationally (which we allowed in H4). We have provided evidence that the effect that high-capability firms can counteract their inward orientation resulting from high technological uncertainty by employing personnel exchange and thereby configure their capabilities (Kuemmerle, 1999). We thus conclude that the focus on risk behaviours as proposed by prospect theory cannot be a stand-alone program. Rather we argue that a fruitful line of research could open up by integrating behavioural as well as more established concepts in IB and innovation studies.

REFERENCES

Abernathy, W. J. & Utterback, J. M. 1978. Patterns of industrial innovation. *Technology Review*, 80: 40-47.

Abramowsky, L. & Griffith, R. 2006. Outsourcing and offshoring of business services: How important is ICT? *Journal of the European Economic Association*, 4: 594-601.

Aharoni, Y. (1966). *The foreign investment decision process*.

Aharoni, Y. 2010. Behavioral elements in foreign direct investments. *Advances in International Management*, 23: 73-111.

Aharoni, Y., Tihanyi, L., & Connelly, B. L. 2011. Managerial decision-making in international business: A forty-five-year retrospective. *Journal of World Business*, 46: 135-142.

Alcácer, J., Dezsö, C. L. & Zaho, M. 2013. Firm rivalry, knowledge accumulation, and MNE location choices. *Journal of International Business Studies*, 44: 504–540.

Ambos, B. & Ambos, T. C. 2011. Meeting the challenge of offshoring R&D: an examination of firm- and location-specific factors. *R&D Management*, 41: 107–119.

Andrews, K. R. 1971. *The Concept of Corporate Strategy*. Homewood, IL: Dow Jones Irwin.

Asheim, B. T., & Coenen, L. 2005. Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research policy*, 34: 1173-1190.

Asheim, B. T., & Isaksen, A. 2002. Regional innovation systems: the integration of local 'sticky' and global 'ubiquitous' knowledge. *The Journal of Technology Transfer*, 27(1): 77-86.

Baier, E., Rammer, C. & Schubert, T. 2015. The impact of captive innovation offshoring on the effectiveness of organizational adaptation. *Journal of International Management*, 21: 150-165.

Bardhan, A. & Jaffe, D. 2005. *Innovation, R&D and Offshoring, Fisher Center for Real Estate and Urban Economics.* Berkeley: University of California.

Barthélemy, J. & Quélin, B. V. 2006. Complexity of outsourcing contracts and ex post transaction costs: an empirical investigation. *Journal of Management Studies*, 43: 1775-1797.

Bartlett, C. A. & Ghoshal, S. 2002. *Managing Across Borders. The Transnational Solution*. Cambridge, MA: Harvard Business School Press.

Bathelt, H., Malmberg, A., & Maskell, P. 2004. Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography*, 28(1): 31-56.

Beise, M. 2004. Lead markets: country-specific drivers of the global diffusion of innovations. *Research Policy*, 33: 997-1018.

Benito, G. R. G. 2015. Why and how motives (still) matter. *The Multinational Business Review*, 23: 15-24.

Berry, J. 2006. *Offshoring Opportunities: Strategies and Tactics for Global Competitiveness.* Hoboken: Wiley.

Bertrand, O., & Mol, M. J. 2013. The antecedents and innovation effects of domestic and offshore R&D outsourcing: The contingent impact of cognitive distance and absorptive capacity. *Strategic Management Journal*, 34: 751-760.

Blinder, A. S. 2006. Offshoring: The next industrial revolution? *Foreign Affairs*, 85: 113-128.

Bourgeois, L. J. & Eisenhardt, K. M. 1988. Strategic decision processes in high velocity environments: four cases in the microcomputer industry. *Management Science*, 34: 816–835.

Bowman, E. H. 1982. Risk seeking by troubled firms. *Sloan management review*, 23: 33.

Bromiley, P. 1991. Testing a causal model of corporate risk taking and performance. *Academy of Management journal*, 34: 37-59.

Breschi, S., & Lissoni, F. 2001. Knowledge spillovers and local innovation systems: a critical survey. *Industrial and Corporate Change*, 10: 975-1005.

Buckley, P. J., Carter, M. J., Clegg, J., & Tan, H. 2005. Language and social knowledge in foreign-knowledge transfer to China. *International Studies of Management & Organization*, 35: 47-65.

Bunyaratavej, K., Hahn, E. D. & Doh, J.P. 2007. International offshoring of services: a parity study. *Journal of International Management*, 13: 7–21.

Caloghirou, Y., Kastelli, I., & Tsakanikas, A. 2004. Internal capabilities and external knowledge sources: complements or substitutes for innovative performance? *Technovation*, 24: 29-39.

Castellani, D., Mancusi, M. L., Santangelo, G. D., & Zanfei, A. 2015. Exploring the links between offshoring and innovation. *Economia e Politica Industriale*, 42: 1-7.

Castellani, D., Montresor, S., Schubert, T., & Vezzani, A. 2016. Multinationality, R&D and productivity: Evidence from the top R&D investors worldwide. *International Business Review*, forthcoming

Ceci, F., & Prencipe, A. (2013). Does distance hinder coordination? Identifying and bridging boundaries of offshored work. *Journal of International Management*, 19: 324-332.

Cohen, W. M., & Levinthal, D. A. 1990. Absorptive capacity: A new perspective on learning and innovation. *Administrative science quarterly*, 35: 128-152.

Contractor, F. J., Kumar, V., Kundu, S. K. & Pedersen, T. 2010. Reconceptualizing the firm in a world of outsourcing and offshoring: the organizational and geographical relocation of high-value company functions. *Journal of Management Studies*, 47: 1417-1433.

Criscuolo, P. 2009. Inter-firm reverse technology transfer: the home country effect of R&D internationalization. *Industrial and Corporate Change*, 18: 869-899.

Criscuolo, C., Haskel, J. E., & Slaughter, M. J. 2010. Global engagement and the innovation activities of firms. *International Journal of Industrial Organization*, *28:* 191-202.

Cuervo-Cazurra, A. & Narula, R. 2015. A set of motives to unite them all? Revisiting the principles and typology of internationalization motives. *The Multinational Business Review,* 23: 2-14.

Cuervo-Cazurra, A., Narula, R. & Un, C. A. 2015. Internationalization motives: sell more, buy better, upgrade and escape. *The Multinational Business Review*, 23: 25-35.

Cyert, R. M., & March, J. G. 1963. *A behavioral theory of the firm*. Englewood Cliffs, NJ, 2.

Dosi, G. 1982. Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change. *Research Policy*, 11: 147-162.

Drazin, R. & de Ven, A. H. V. 1985. Alternative forms of fit in contingency theory". *Administrative Science Quarterly*, 30: 514-39.

Dunning, J. H. 1980. Toward an eclectic theory of international production: some empirical tests. *Journal of International Business Studies*, 11: 9-31.

Dunning, J. H. 1988. The eclectic paradigm of international production: a restatement and some possible extensions. *Journal of International Business Studies*, 19: 1-31.

Dunning, J. H. 1993. *Multinational enterprises and the global economy*. Wokingham: Addison-Wesley Publishing Company.

Dunning, J. H. & Narula, R. 1995. The R&D activities of foreign firms in the United States. *International Studies of Management & Organization*, 25: 39-73.

Dunning, J. H. 2000. The eclectic paradigm as an envelope for economic and business theories of MNE activity. *International Business Review*, 9: 163-190.

Dutton, J. E., & Jackson, S. E. 1987. Categorizing strategic issues: Links to organizational action. *Academy of Management Review*, 12: 76-90.

Eisenhardt, K. M. 1989. Making fast strategic decisions in high-velocity environments. *Academy of Management Journal*, 32(3): 543-576.

Eisenhardt, K. M., & Bourgeois, L. J. 1988. Politics of strategic decision making in high-velocity environments: Toward a midrange theory. *Academy of Management Journal*, 31(4): 737-770.

Eisenhardt, K. M. & Martin, J. A. 2000. Dynamic capabilities: what are they? *Strategic Management Journal*, 21: 1105-1121.

Ernst, D. 2002. Global production networks and the changing geography of innovation systems. Implications for developing countries. *Economics of Innovation and New Technology*, 11: 497-523.

Fagerberg, J., & Verspagen, B. 2002. Technology-gaps, innovation-diffusion and transformation: an evolutionary interpretation. *Research Policy*, 31: 1291-1304.

Farrell, D., Laboissiere, M. A. & Rosenfeld, J. 2006. Sizing the emerging global labor market: rational behavior from both companies and countries can help it work more efficiently. *Academy of Management Perspectives*, 20: 23-34.

Feeny, D. F. & Willcocks, L. P. 1998. Core IS capabilities for exploiting information technology. *Sloan Management Review*, 39: 9-21.

Fiegenbaum, A., Hart, S., & Schendel, D. 1996. Strategic reference point theory. *Strategic Management Journal*, 17: 219-235.

Fifarek, V., Veloso, F. M. & Davidson, C. I. 2008. Offshoring technology innovation: a case study of rare-earth technology. *Journal of Operation Management*, 26: 222-238.

Figueira-de-Lemos, F., Johanson, J., & Vahlne, J. E. 2011. Risk management in the internationalization process of the firm: A note on the Uppsala model. *Journal of World Business*, 46: 143-153.

Figueira-de-Lemos, F., & Hadjikhani, A. 2014. Internationalization processes in stable and unstable market conditions: Towards a model of commitment decisions in dynamic environments. *Journal of World Business*, 49: 332-349.

Fry, L. & Schellenberg, D. 1984. *Congruence, contingency, and theory building. An intergrated perspective.* Unpublished Manuscript.

Gassmann, O. & von Zedtwitz, M. 1999. New concepts and trends in international R&D organsation. *Research Policy*, 28: 231-250.

Ghauri, P. N., & Santangelo, G. D. 2012. Multinationals and the changing rules of competition. *Management International Review*, 52: 145-154.

Granstrand, O. 1999. Internationalization of corporate R&D: a study of Japanese and Swedish corporations. *Research Policy*, 28: 275-302.

Grillitsch, M., Martin, R., & Srholec, M. 2016. Knowledge base combinations and innovation performance in Swedish regions. *Economic Geography:* 1-22.

Gupta, A. K. & Govindarajan, V. 2000. Knowledge Flows within Multinational Corporations. *Strategic Management Journal,* 21*:* 473-496.

Gustafson, L. T. & Reger, R. K. 1995. Using organizational identity to achieve stability and change in high velocity environments. *Academy of Management Proceedings*, 1995: 464-468.

Hahn, E. D., Doh, J. P., & Bunyaratavej, K. 2009. The evolution of risk in information systems offshoring: the impact of home country risk, firm learning, and competitive dynamics. *MIS quarterly*, 33: 597-616.

Harvey, M., Griffith, D., Kiessling, T., & Moeller, M. 2011. A multi-level model of global decision-making: Developing a composite global frame-of-reference. *Journal of World Business*, 46(2): 177-184.

Hochberg, L. R., Serruya, M. D., Friehs, G. M., Mukand, J. A., Saleh, M., Caplan, A. H., Branner, A., Chen, D., Pen, R. D. & Donoghue, J. P. 2006. Neuronal ensemble control of prosthetic devices by a human with tetraplegia. *Nature*, 442*:* 164-171.

Hoecht A. & Trott P. 2006. Outsourcing, information leakage and the risk of losing technology-based competencies. *European Business Review*, 18: 395-412

Hofer, C. & Schendel, D. E. 1978. *Strategy Formulation: Analytical Concepts.* St. Paul, MN:West.

Hutzschenreuter, T., Pedersen, T., & Volberda, H. W. 2007. The role of path dependency and managerial intentionality: A perspective on international business research. *Journal of international business studies*, *38*: 1055-1068.

Hutzschenreuter, T., Voll, J. C., & Verbeke, A. 2011. The impact of added cultural distance and cultural diversity on international expansion patterns: A Penrosean perspective. *Journal of Management Studies*, *48*: 305-329.

Jensen, P. D. Ø., Pedersen, T., & Petersen, B. (2013). Do expectations match reality when firms consider the risks of offshoring? A comparison of risk assessment by firms with and without offshoring experience. In *The offshoring challenge* (pp. 287-299). Springer London.

Johanson, J. & Vahlne, J.-E. 1977. The internationalization process of the firm – a model of knowledge development and increasing foreign market commitments. *Journal of International Business Studies*, 8: 23-32.

Johanson, J., & Vahlne, J. E. 2009. The Uppsala internationalization process model revisited: From liability of foreignness to liability of outsidership. *Journal of International Business Studies*, 40: 1411-1431.

Kahneman, D. 2003. A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist*, 58: 672697.

Kahneman, D., & Tversky, A. 1979. Prospect theory: An analysis of decisions under risk. *Econometrics*, 47: 262-291.

Kedia, B. L., & Lahiri, S. 2007. International outsourcing of services: A partnership model. *Journal of International Management*, 13: 22-37.

Kim, L. 2001. Absorptive capacity, co-opetition, and knowledge creation. In: Nonaka, I. & Nishiguchi, T. (eds.): *Knowledge emergence: Social, technical, evolutionary dimensions of knowledge creation*. New York: Oxford University Press, 13-29.

Kirner, E., Kinkel, S. & Jäger, A. 2009. Innovation paths and the innovation oerformance of low-technology firms - an empirical analysis of German industry. *Research Policy*, 38: 447-458.

Klepper, S. 1996. Entry, exit, growth, and innovation over the product life cycle. *American Economic Review*, 86: 562–583.

Kotabe, M., Mol, M. J., & Ketkar, S. 2008. An evolutionary stage model of outsourcing and competence destruction: A triad comparison of the consumer electronics industry. *Management International Review*, 48: 65-94.

Kotabe, M., Jiang, C. X., & Murray, J. Y. 2011. Managerial ties, knowledge acquisition, realized absorptive capacity and new product market performance of emerging multinational companies: A case of China. *Journal of World Business*, 46: 166-176.

Kshetri, N. 2007. Institutional factors affecting offshore business process and information technology outsourcing. *Journal of International Management*, 13: 38-56.

Kuemmerle, W. 1999. The drivers of foreign direct investment into research and development: an empirical investigation. *Journal of International Business Studies*, 30: 1–24.

Le Bas, C., & Sierra, C. 2002. 'Location versus home country advantages' in R&D activities: some further results on multinationals' locational strategies. *Research policy*, 31: 589-609.

Lee, K., Lim, C., & Song, W. 2005. Emerging digital technology as a window of opportunity and technological leapfrogging: catch-up in digital TV by the Korean firms. *International Journal of Technology Management*, 29: 40-63.

Lei, D., & Hitt, M. A. 1995. Strategic restructuring and outsourcing: The effect of mergers and acquisitions and LBOs on building firm skills and capabilities. *Journal of management*, 21: 835-859.

Lewin, A. Y., Massina, S. & Peeters, C. 2009. Why are companies offshoring innovation? The emerging global race for talent. *Journal of International Business Studies*, 40: 901-925.

Lewin, A. Y. & Peeters C. 2006. Offshoring work: business hype or the onset of fundamental transformation? *Long Range Planning,* 39: 221-239.

Li, X., Wang, J., & Liu, X. 2013. Can locally-recruited R&D personnel significantly contribute to multinational subsidiary innovation in an emerging economy? *International Business Review*, 22: 639-651.

MacDuffie, J. P. 2007. Modularity and the geography of innovation. Paper presented at the 2007 INFORMS Annual Meeting, Seattle.

Macharzina, K., Oesterle, M.-J. & Brodel, D. 2001. Learning in multinationals. In Dierkes, M., Berthoin Antal, A., Child, J. & Nonaka, I. (eds.) 2001. *Handbook of Organizational Learning and Knowledge*. Oxford: Oxford University Press, 631-656.

Manning, S., Massini, S. & Lewin, A. Y. 2008. A dynamic perspective on next-generation offshoring: the global sourcing of science & engineering skills. *Academy of Management Perspectives*, 22: 35-54.

Massini, S., Perm-Ajchariyawong, N. & Lewin, A. Y. 2010. Role of corporate-wide offshoring strategy on offshoring drivers, risks and performance. *Industry and Innovation*, 17: 337-371

March, J. G., & Shapira, Z. 1987. Managerial perspectives on risk and risk taking. *Management science*, 33: 1404-1418.

March, & Simon, 1958. *Organizations*. New York: Wiley.

Meyer, K. E. 2015. What is "strategic asset seeking FDI"?. *The Multinational Business Review*, 23(1): 57-66.

Meyer, K. E., Wright, M., & Pruthi, S. 2009. Managing knowledge in foreign entry strategies: a resource-based analysis. *Strategic Management Journal*, 30(5): 557-574.

Miller, K. D., & Chen, W. R. 2004. Variable organizational risk preferences: Tests of the March-Shapira model. *Academy of Management Journal,* 47: 105-115.

Mudambi, R. 2008. Location, control and innovation in knowledge-intensive industries. *Journal of Economic Geography*, 8: 699-725.

Mudambi, R. & Venzin, M. 2010. Strategic nexus of offshoring and outsourcing decisions. *Journal of Management Studies*, 47(8): 1510–1533.

Nakatsu, R. & Iacovou, C. L. 2009. A comparative study of important risk factors involved in offshore and domestic outsourcing of software development projects: A two-panel Delphi study. *Information and Management,* 48: 57-68.

Narula, R. & Zanfei, A. 2004. Globalization of innovation: The role of multinational enterprises. In: Fagerberg, J. & Mowery, D. C. (eds.). 2004. *Oxford Handbook of Innovation.* Oxford: Oxford University Press, 318-345.

Nieto, M. J. & Rodríguez, A., 2011. Offshoring of R&D: looking abroad to improve innovation performance. *Journal of International Business Studies*, 42: 345-361.

OECD 2015. *Frascati Manual*. Guidelines for Collecting and Reporting Data on Research and Experimental Development. Paris: OECD.

OECD & Eurostat 2005. *Oslo Manual*. Guidelines for Collecting and Interpreting Innovation Data. 3rd Edition. Paris: OECD.

Ørberg Jensen, P. D. 2009. A learning perspective on the offshoring of advances services. *Journal of International Management.* 15: 181-193.

Park, W. G. 2008. International patent protection: 1960–2005. *Research Policy*, 37: 761-766.

Persson, M. 2006. The impact of operational structure, lateral integrative mechanisms and control mechanisms on intra-MNE knowledge transfer. *International Business Review*, 15: 547-569.

Peters, B. & Rammer, C. 2013. Innovation panel surveys in Germany. In: Gault, F. (ed.): *Handbook of Innovation Indicators and Measurement*. Cheltenham: Edward Elgar, 135-177.

Porter, M. E. 1986. *Competition in Global Industries*. Princeton: Harvard Business Press.

Pyndt, J. & Pedersen, T. 2006. *Managing Global Offshoring Strategies: A Case Approach*. Copenhagen: Copenhagen Business School Press.

Robin, S., & Schubert, T. 2013. Cooperation with public research institutions and success in innovation: Evidence from France and Germany. *Research Policy*, 42: 149-166.

Roza, M., van den Bosch, F. A. J. & Volberda, H.W. 2011. Offshoring strategy: motives, functions, locations, and governance modes of small, medium-sized and large firms. *International Business Review*, 20: 314-323.

Rycroft, R. W. 2003. Technology-based globalization indicators: the centrality of innovation network data. *Technology in Society*, 25: 299-317.

Seppälä, T. 2013. Tracking offshoring and outsourcing strategies in global supply chains. In: Pedersen, T., Bals, L., Ørberg Jensen, P.D. & Larsen, M.M. (eds.). 2013. *The Offshoring Challenge.* London: Springer, 57-76.

Scherer, F. M. 1992. *International High-Technology Competition*. Princeton: Harvard University Press.

Schiavone, F. 2011. Strategic reactions to technology competition: a decision making model. *Management Decision*, 49: 801-809.

Schilling, M. A. 2002. Technology success and failure in winner-take-all markets: The impact of learning orientation, timing, and network externalities. *Academy of Management Journal*, 45: 387-398.

Shoham, A., & Fiegenbaum, A. 2002. Competitive determinants of organizational risk-taking attitude: the role of strategic reference points. *Management Decision*, 40: 127-141.

Soosay, C., & Hyland, P. 2008. Exploration and exploitation: the interplay between knowledge and continuous innovation. *International Journal of Technology Management*, 42: 20-35.

Staw, B. M., Sandelands, L. E., & Dutton, J. E. 1981. Threat rigidity effects in organizational behavior: A multilevel analysis. *Administrative science quarterly*, 26: 501-524.

Tassey, G. 2008. Globalization of Technology-Based Growth: The Policy Imperative. *Journal of Technology Transfer*, 33: 560-578.

Teece, D. J. 2007. Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, 28: 1319-1350.

Teece, D. J. 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research policy*, 15: 285-305.

Tushman, M. L. & Murmann, J. P. 2003. Dominant designs, technology cycles, and organizational outcomes. In: Garud, R., Kumaraswamy, A. & Langlois, R. (eds.). *Managing in the Modular Age: Architectures, Networks, and Organizations*. Malden: Blackwell Publishing, 316-347.

Vega-Jurado, J., Gutiérrez-Gracia, A., Fernández-de-Lucio, I., & Manjarrés-Henríquez, L. 2008. The effect of external and internal factors on firms' product innovation. *Research Policy*, 37: 616-632.

Von Zedtwitz, M. & Gassmann, O. 2002. Market versus technology drive in R&D internationalization: four different patterns of managing research and development. *Research Policy,* 31: 569-588.

Winkler, D. 2009. *Services Offshoring and its Impact on the Labour Market – Theoretical Insights, Empirical Evidence and Economic Policy Recommendations for Germany*. Heidelberg: Springer.

Wirtz, B. W., Mathieu, A. & Schilke, O. 2007. Strategy in high-velocity environments. *Long Range Planning*, 40: 295-313.

Wolpaw, J., & Wolpaw, E. W. 2012. *Brain-computer interfaces: principles and practice*. USA: Oxford University Press.

Wooldridge, J. M. 2002. *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: The MIT Press.

Zajac, E. J., Kraatz, M. S. & Bresser, R. K. F. 2000. Modeling the dynamics of strategic fit: a normative approach to strategic change. *Strategic Management Journal,* 21: 429-453.

Zanfei, A. (2000). Transnational firms and the changing organisation of innovative activities. *Cambridge Journal of Economics*, 24: 515-542.

Tables and figures

Table 1: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Int. R&D	6197	0.0229	0.1496	0	1
Int. product innovation	6197	0.0266	0.1610	0	1
Int. design	6197	0.0255	0.1576	0	1
Int. process innovation	6196	0.0200	0.1401	0	1
Innovation intensity	5579	0.0875	1.2895	0	75
R&D intensity	5681	0.0444	0.6510	0	34
Speed tech. change	5919	1.9414	0.8817	1	4
Uncertainty future tech. change	5916	2.0446	0.8215	1	4
Internal technological capabilities	5694	3.2057	1.1771	1	5
Cross-border personnel exchange	6589	0.0694	0.4427	0	4
Patents used	5522	0.2774	0.4478	0	1
Intensity of competition	5919	2.5616	0.6739	1	4
Employees	6588	619.3260	4347.0100	1	163835
Export intensity	6094	0.1245	0.2251	0	1
Eastern Germany	6589	0.3125	0.4635	0	1
Member of a group	6589	0.2744	0.4462	0	1
High-tech man.	6589	0.0748	0.2631	0	1
Med.-high-tech man.	6589	0.1278	0.3339	0	1
Med.low-tech man.	6589	0.1187	0.3234	0	1
Low-tech man.	6589	0.2340	0.4234	0	1
Knowledge intensive services	6589	0.3072	0.4614	0	1
Other services	6589	0.1375	0.3444	0	1

Table 2: Correlation table

	Int. R&D	Int. product innovation	Int. design	Int. process innovation	Innovation intensity	R&D intensity	Speed tech. change	Uncertainty future tech. change	Internal technological capabilities	Cross-border personnel exchange	Patents used	Intensity of competition	Employees	Export intensity	Eastern Germany	Member of a group
Int. R&D	1															
Int. product innovation	0.7281	1														
Int. design	0.7709	0.7983	1													
Int. process innovation	0.6806	0.7757	0.7714	1												
Innovation intensity	0.0058	0.0004	-0.0012	-0.0008	1											
R&D intensity	0.011	0.0023	0.0011	0.0017	0.9408	1										
Speed tech. change	0.0784	0.0892	0.078	0.065	0.0343	0.0307	1									
Uncertainty future tech. change	0.0297	0.038	0.0426	0.0303	0.0616	0.0658	0.4231	1								
Internal technological capabilities	0.1423	0.1314	0.1357	0.1292	0.0581	0.0672	0.1745	0.2372	1							
Cross-border personnel exchange	0.6933	0.7472	0.7587	0.7353	-0.0002	0.0017	0.0711	0.0273	0.1404	1						
Patents used	0.1993	0.2003	0.1998	0.1834	0.0691	0.0787	0.095	0.1161	0.2998	0.2038	1					
Intensity of competition	-0.0087	-0.0037	0.0016	0.01	-0.0388	-0.0489	0.1692	0.1618	-0.0224	-0.0003	-0.0505	1				
Employees	0.2772	0.3022	0.3011	0.2813	-0.0039	-0.0035	0.0375	0.028	0.083	0.337	0.0988	-0.007	1			
Export intensity	0.2421	0.2434	0.2304	0.2244	0.0072	0.0118	0.0396	0.0685	0.2593	0.2495	0.3718	-0.0381	0.1233	1		
Eastern Germany	-0.0785	-0.101	-0.0941	-0.0832	0.0273	0.0229	-0.0051	-0.0476	-0.0195	-0.0869	-0.0561	0.0155	-0.0714	-0.1102	1	
Member of a group	0.2138	0.2296	0.2328	0.2224	-0.0112	-0.0115	-0.0066	0.0071	0.1283	0.219	0.1747	-0.0003	0.1963	0.2012	-0.0801	1

Table 3: The effect of technological change on the innovation and R&D intensity (marginal effects based on Tobit regressions)

	High cap.	Low. cap.	High cap.	Low. cap.
	Innovation intensity	Innovation intensity	R&D intensity	R&D intensity
Speed tech. change	0.09059	0.01546***	0.09272**	0.01418***
	(1.37)	(3.03)	(1.96)	(3.14)
Uncertainty future tech. change	0.28774***	0.01692***	0.19527***	0.01272***
	(4.00)	(3.10)	(3.84)	(2.59)
Patents used	0.71455***	0.06075***	0.70398***	0.05403***
	(6.28)	(6.05)	(8.80)	(6.38)
Intensity of competition	-0.20371**	0.00072	-0.20804***	-0.00498
	(-2.41)	(0.12)	(-3.43)	(-0.86)
Employees	0.00002	0.00001	0.00001	0.00001
	(0.35)	(1.56)	(0.24)	(1.46)
Employees^2	-0.00000	-0.00000	-0.00000	-0.00000
	(-0.43)	(-0.80)	(-0.36)	(-0.64)
Export intensity	0.41066*	0.10960***	0.46739***	0.13169***
	(1.79)	(4.89)	(2.96)	(7.20)
Eastern Germany	0.30098***	0.00423	0.25281***	0.01855**
	(2.74)	(0.50)	(3.25)	(2.48)
Member of a group	0.01717	0.02356**	0.08800	0.02378***
	(0.14)	(2.35)	(1.06)	(2.77)
Constant	-1.73867***	-0.20545***	-1.72683***	-0.23335***
	(-5.34)	(-9.63)	(-7.11)	(-10.70)
Constant	2.12729***	0.15498***	1.38696***	0.11112***
	(54.08)	(38.29)	(46.34)	(26.71)
Sector dummies	YES	YES	YES	YES
Observations	2038	2408	2010	2482
Pseudo R2	0.020	0.257	0.055	0.478
AIC	7052.30917	637.10345	4637.69151	374.10756
p.val. endog. Chi-sq(2) test	0.2644	0.1921	0.1553	0.1124

Table 4: The effect of technological change on internationalization of R&D and product innovation (marginal effects based on Probit regressions)

	High cap.	Low. cap.	High cap.	Low. cap.
	Int. R&D	Int. R&D	Int. product innovation	Int. product innovation
Speed tech. change	0.32898***	0.10831	0.36637***	0.35647**
	(4.23)	(0.62)	(4.32)	(2.37)
Uncertainty future tech. change	-0.24516***	0.42962**	-0.23169**	0.37790**
	(-2.68)	(2.12)	(-2.34)	(2.12)
Patents used	0.55798***	0.59757*	0.53633***	0.65025**
	(3.75)	(1.96)	(3.38)	(2.47)
Intensity of competition	0.04419	0.06278	0.11045	0.00465
	(0.41)	(0.23)	(0.94)	(0.02)
Employees	0.00017***	0.00101***	0.00025***	0.00095***
	(4.68)	(3.49)	(5.98)	(2.87)
Employees^2	-0.00000***	-0.00000***	-0.00000***	-0.00000*
	(-2.58)	(-2.71)	(-4.08)	(-1.93)
Export intensity	0.93307***	1.24751**	1.03949***	1.53756***
	(4.07)	(2.46)	(4.12)	(3.37)
Innovation intensity	0.00744	3.08777***	-0.18618	1.23216**
	(0.19)	(3.06)	(-0.54)	(2.15)
Eastern Germany	-0.36799**	-0.06406	-1.10045***	-0.27566
	(-2.32)	(-0.18)	(-4.18)	(-0.78)
Member of a group	0.72167***	0.87823***	0.79807***	0.89193***
	(5.42)	(2.73)	(5.52)	(3.19)
Constant	-3.14929***	-12.99687	-3.01587***	-5.10748***
	(-6.60)	(-0.06)	(-6.46)	(-5.67)
Sector dummies	YES	YES	YES	YES
Observations	2029	2406	2029	2406
Pseudo R2	0.333	0.517	0.414	0.457
AIC	543.35855	124.83858	488.55514	157.62304
p.val. Endog.Chi-sq(2) test.	0.4890	0.9297	0.0689	0.8328

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: The impact of technological change on design and process innovation offshoring (marginal effects based on Probit regressions)

	High cap.	Low. cap.	High cap.	Low. cap.
	Int. design	Int. design	Int. process innovation	Int. process innovation
Speed tech. change	0.26533***	0.39355**	0.22996***	0.32884*
	(3.36)	(2.45)	(2.62)	(1.85)
Uncertainty future tech. change	-0.12453	0.33029*	-0.25867**	0.39936*
	(-1.38)	(1.93)	(-2.47)	(1.94)
Patents used	0.46524***	0.54860**	0.54458***	0.52332*
	(3.21)	(2.14)	(3.29)	(1.80)
Intensity of competition	0.14179	-0.10035	0.27427**	-0.13851
	(1.30)	(-0.44)	(2.24)	(-0.52)
Employees	0.00023***	0.00081***	0.00017***	0.00140***
	(5.92)	(2.66)	(5.19)	(3.98)
Employees^2	-0.00000***	-0.00000*	-0.00000***	-0.00000***
	(-4.04)	(-1.72)	(-3.26)	(-2.59)
Export intensity	0.86476***	1.18170***	0.97463***	1.01282*
	(3.64)	(2.59)	(3.73)	(1.91)
Innovation intensity	-0.09522	0.21352	-0.08549	0.48682
	(-0.42)	(0.20)	(-0.33)	(0.44)
Eastern Germany	-0.60791***	-0.72211	-0.67411***	-0.22903
	(-3.37)	(-1.61)	(-3.14)	(-0.58)
Member of a group	0.83572***	0.47883*	0.98330***	0.55921*
	(6.20)	(1.82)	(6.21)	(1.81)
Constant	-3.29514***	-4.34243***	-3.50913***	-4.65279***
	(-7.17)	(-5.50)	(-6.83)	(-4.91)
Sector dummies	YES	YES	YES	YES
Observations	2029	2406	2029	2406
Pseudo R2	0.363	0.429	0.380	0.502
AIC	546.88842	158.67904	449.95988	127.75325
p.val. endog. Chi-sq(2) test	0.2330	0.2233	0.0747	0.7885

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: The role of cross-border personnel exchange (marginal effects based on Probit regressions)

	High. cap.	High. cap.	High. cap.	High. cap.
	Int. R&D	Int. product innovation	Int. design	Int. process innovation
Speed tech. change	0.28475***	0.28406***	0.15660	0.07679
	(3.00)	(2.70)	(1.59)	(0.70)
Uncertainty future tech. change	-0.28579**	-0.17173	-0.06229	-0.20915
	(-2.28)	(-1.27)	(-0.50)	(-1.35)
Cross-border personnel exchange	0.30767	0.42784*	0.30883	0.48808**
	(1.40)	(1.79)	(1.31)	(2.10)
(Uncertainty future tech. change)*(Cross-border personnel exchange)	0.26631**	0.24047**	0.34042***	0.16853
	(2.53)	(2.09)	(2.92)	(1.53)
Patents used	0.45576**	0.38970**	0.35844**	0.43024**
	(2.53)	(1.99)	(1.97)	(2.06)
Intensity of competition	-0.14000	-0.06169	-0.01648	0.15500
	(-1.11)	(-0.44)	(-0.12)	(1.03)
Employees	-0.00004	0.00016***	0.00015***	0.00005
	(-0.36)	(3.01)	(2.96)	(1.11)
Employees^2	0.00000	-0.00000**	-0.00000**	-0.00000
	(0.78)	(-2.00)	(-2.28)	(-0.90)
Export intensity	0.59219**	0.82652***	0.50151	0.64190*
	(2.07)	(2.61)	(1.61)	(1.89)
Innovation intensity	0.01136	-0.12217	-0.02884	-0.01268
	(0.33)	(-0.32)	(-0.15)	(-0.06)
Eastern Germany	-0.15842	-1.00607***	-0.52845**	-0.49055*
	(-0.87)	(-3.06)	(-2.30)	(-1.84)
Member of a group	0.48681***	0.45764**	0.53019***	0.78744***
	(2.95)	(2.57)	(3.15)	(4.05)
Constant	-2.36801***	-2.31972***	-2.65042***	-2.85878***
	(-4.49)	(-4.32)	(-4.93)	(-4.71)
Sector dummies	YES	YES	YES	YES
Observations	2029	2029	2029	2029
Pseudo R2	0.561	0.640	0.625	0.619
AIC	372.68278	316.57027	339.60010	293.11916
p.val. endog. Chi-sq(2) test	0.5735	0.4299	0.9129	0.5015

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 2: Graphical representation of the interaction of effect of personnel exchange (firms with high technological competences)