Discussion Paper No. 16-044

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Centre for European
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June 2016

Abstract: In this paper we analyze the conditions under which firms decide to offshore innovation. We consider the role of internal technological capabilities and technological dynamism in the firm environment, distinguishing speed and uncertainty of technological change. Using unique data from the German Innovation Survey we find that while high speed of technological change tends to drive innovation offshoring, high uncertainty about future technology developments results in more innovation offshoring only for firms with low internal technological capabilities. Firms with high technological capabilities instead are less likely to offshore innovation when uncertainty is high. We argue that these differences in offshoring behaviour reflect differing strategic objectives. We show that for firms with low technological capabilities asset augmentation is more important while for firms with high technological capabilities asset exploitation is more important. When faced by high technological uncertainty firms with low technological capabilities offshore innovation strategically in order to reduce uncertainty by augmenting their asset base. For firms with high technological capabilities asset augmentation is less important. When faced by high technological uncertainty they prefer to innovate onshore in order to keep stronger control of their key assets.

JEL: O32, F21, F23, L22

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1 Introduction

Following the surge in offshoring activities over the last 20 years a large body of literature has emerged analyzing the strategic drivers of offshoring. Both firm characteristics like size (Roza et al. 2011) and export intensity (Gassmann and von Zedtwitz 1999) as well as characteristics of the environment have been analyzed. Environmental characteristics for example include global trends such as advances in computing power or the digital transformation (Abramowsky and Griffith 2006, Blinder 2006, Brynjolfsson and McAfee 2012, Brynjolfsson and McAfee 2014), or differences in the institutional framework (Kshetri 2007). In addition to the increase in general offshoring, in recent years firms have increasingly engaged in innovation offshoring, i.e. building up innovation capacities outside the firms' home base (Håkanson and Nobel 1993, Manning et al. 2008, Pyndt and Pedersen 2006, Bardhan and Jaffe 2005). Although some authors have begun to discuss the strategic drivers of innovation offshoring (compare Ambos and Ambos 2011, see also Lewin et al. 2009 arguing for factor shortages in S&T personnel), the research in this field is much less comprehensive.

Because firms increasingly compete over technology (Porter 1986, Scherer 1992, Schiavone 2011) we argue that technological factors became particularly important as drivers of innovation offshoring. We follow the literature and analyse both firms' internal technology capabilities and the external technological environment. For the latter, we distinguish between speed and uncertainty of technological change (compare the high-velocity literature, in particular Bourgeois and Eisenhardt 1988, Gustaffson and Reger 1995, Eisenhardt and Martin 2000).

In this paper we intend to demonstrate that the internal technological capabilities and technological dynamism in the firms' environments have considerable influence on both the actual offshoring strategies as well as the strategic goals of firms, i.e. their motives for innovation offshoring. Our research contributes both to the literature of strategic drivers of offshoring (Manning et al. 2008, Roza et al. 2011, Massini et al. 2010, Mudambi and Venzin 2010, Ambos and Ambos 2011) by highlighting the particular role of technology-related contingencies both in terms of internal technological capabilities and external technological dynamism. We also contribute to the literature on offshoring motives highlighting the specific importance of asset augmenting versus asset exploiting motives (Dunning and Narula 1995, Patel and Vega 1999, Kuemmerle 1999, Lewin et al. 2009) by showing how internal technological capabilities and external technological dynamism shape the firms' strategic goals.

In our empirical analysis we use data from the German Innovation Survey. The German Innovation Survey is the German contribution to the Community Innovation Surveys (CIS) coordinated by the European Commission. In 2011, the German questionnaire went beyond the standard CIS questionnaire and included a question on innovation activities outside the home country, distinguishing four types of innovation activities (R&D, design, product innovation, process innovation) and asking about the motives for innovation offshoring. At the same time, the survey also asked firms to assess characteristics of their market environment, including speed and predictability of technological change. Together with information on the firms' technological capabilities, this data provides a unique opportunity to investigate the role of internal technological capacities and external technology environment for offshoring activities of innovative firms.

Our results show that high uncertainty about the direction of technological change tends to reduce the propensity to offshore innovation for firms with high internal technological capabilities while low-capability firms increase their offshoring activities. This result suggests that when technological uncertainty is high, internal technological capabilities create a strategic option to innovate onshore in order to keep flexibility high and allow for rapid adjustment of innovation strategies in case technological developments change suddenly. Our results also indicate that a high speed of technological change increases the propensity to offshore for both types of firms. The importance of strategic goals for offshoring varies considerably depending on firms' internal capabilities, the speed of technological change, and technological uncertainty. High capabilities and high uncertainty tend to be associated with a greater importance of asset exploitation. High speed of technological change tends to increase the importance of both asset augmentation and exploitation relative to situations when technological change is slow.

2 Theory

In order to explain and understand the conditions under which firms opt for offshoring as a strategic choice, it is necessary to take into account the specific situation in which a firm makes there choices. It has a long tradition in managerial thinking that appropriate strategic decisions are not universal but contingent upon certain factors (Schoonhoven 1981, Fry and Schellenberg 1984). Which choices are best well depend both on the internal and the external context in which a decision is taken. This idea has been made precise through the notion of strategic fit, which posits that firms must align their organizational structure and their abilities with their specific external environment (Andrews 1971, Hofer and Schendel 1978, Drazin and de Ven 1985, Zajac et al. 2000). Strategic fit is reached to the degree that this alignment is successful. While characteristics of the firm determine whether a certain choice can actually be implemented by a specific firm, the environmental characteristics determine the (expected) pay-off associated with each choice.

In this paper, we argue that particularly important contingencies are the firm's internal technological capabilities and how dynamic the firms' technological environment is. We show that internal capabilities and the external technological environment do not only drive actual innovation offshoring decisions but also shape the strategic intent behind innovation offshoring.

2.1 The Role of Technological Dynamism

With the increasing importance of innovation and new technology for firm competitiveness in globalised markets (Porter 1986, Scherer 1992, Tushman and Murmann 2003, Schiavone 2011), the motives for offshoring have shifted from reducing costs (Bardhan and Jaffe 2005, Winkler 2009) to seeking access to knowledge (Lewin and Peeters 2006, Bunyaratavej et al. 2007, Deloitte 2004, Farrell et al. 2006) and scarce highly-qualified human capital (Lewin et al. 2009). Several authors have argued that one source of the trend towards globalized 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 international business (IB) literature, aside from studies on the role of advances in IT (Abramowsky and Griffith 2006, Blinder 2006, Ernst 2002, MacDuffie 2007).

Several authors have highlighted that technological dynamism is a multifaceted phenomenon impacting firm environments (Tushman and Anderson 1986). The high-velocity literature has emphasized that research should not only focus on speed of technological change as evidenced by shorter product life cycles but also on the uncertainty about the direction of technological change (see Bourgeois and Eisenhardt 1988, Gustaffson and Reger 1995, Eisenhardt and Martin 2000, Wirtz et al. 2007). In fact, high speed and high uncertainty may coincide, but not necessarily. An interesting example is the enormous increase in CPU computation speed up over the past two decades. The well-known (now deprecated) Moore's law states that based on the miniaturization of transistors CPU speed would double every 1-2 years. The very fact that there existed a valid law predicting the direction of technological progress indicates that uncertainty was low, although the speed of technological progress was without doubt high.

Linking these insights to the IB literature on technological dynamism, we argue that high speed of technological change and high technological uncertainty both determine the expected benefits that are associated with a certain competitive strategy. For example, high speed of technological change may favour strategies aiming at staying technologically ahead of competition by gaining faster access to knowledge about new technological trends.

2.2 The Role of Internal Technological Capabilities

While technological dynamism has a role to play, strategic decisions about offshoring cannot be fully understood with pure reference to a firm's technological environment. The strategic fit framework suggests that also the internal technological, organizational, and managerial capabilities play a decisive role, because internal capabilities determine the firms' ability to implement a certain strategy (Teece et al. 1997). Several authors have highlighted that managerial capabilities develop over time and help firms to offshore innovation successfully (Johanson and Vahlne 1977, Levy 2005). Likewise, Baier et al. (2015) show that past experience in innovation offshoring considerable raises organizational adaptability in offshoring firms also in later periods. A second strand of literature focuses on the role of IT-based capabilities. The importance of IT-based capabilities is usually justified by the fact that information systems can reduce the costs of geographically dispersed firm activities. But for effectively using this potential, employees need to have high IT-related capabilities (Ranganathan and Balaji 2008, Feeny and Willcocks 1998).

While admittedly the reference to IT capabilities may capture some part of technology, little research has been performed on the role of firms' technological capabilities. Only occasionally authors have established a link between technology-related capabilities and offshoring. For example, Demirbag and Glaister (2010) argue that R&D capabilities represent a form of ownership advantage (in the sense of Dunning 2000) allowing firms to apply their core technology abroad.

We extend the argument of Demirbag and Glaister (2010) in two respects. First, technological capabilities —in contrast to R&D capabilities— should be considered broader. They are the sum of various firm internal competences ranging from technology forecasting, technology assessment, the ownership of patents and licenses, the production, use, adaption and improvement of new technological knowledge, production technologies, value chain technologies and product development technologies. Second, we do not consider technological capabilities being an ownership advantage that drives innovation offshoring per se. Instead we propose that strategic decision making regarding innovation off-shoring intertwines internal technological capabilities and technological dynamism. Thus it is part of the managerial challenge to align internal capabilities and (expected) changes in the technological environment in such a way as to accommodate speed and uncertainty of technological change as well as developments on global markets. The outcomes from this process are refined innovation offshoring strategies which reflect technological dynamics and internal capabilities at the same time. Based on the level of internal technological capabilities and on the extent of technological dynamics, both home-base-exploiting and home-base-augmenting motives can be viable strategic options.

2.3 The Hypotheses

The discussion so far suggested that the interplay between internal technological capabilities on the one hand, and speed and uncertainty of technological change on the other jointly affect a firm's decision on innovation offshoring. In this section we analyze the actual mechanisms behind the interplay. In order to create a strong link to the existing literature on strategic drivers of innovation offshoring, we will also analyze how technological capabilities and technological dynamism shape the firms' strategic intent. We argue that technological capabilities and dynamism have a strong effect on whether firms follow asset augmenting or asset exploiting motives (Ambos and Ambos 2011).

Both technological uncertainty and high speed of technological change cause problems of incomplete information, though often in a quite different way. High speed of technological change implies that existing knowledge about technologies and markets become soon depreciated. In such environments it is a key challenge for firms to increase the speed of knowledge absorption in order to maintain competitive advantage. Lewin et al. (2009) argue that one important effect of having access to globally distributed human capital and unique knowledge is to shorten time to market. Likewise, many authors have argued that access to new or broader knowledge bases increases firm performance (Rosenkopf and Nerkar 2001, Laursen and Salter 2006). Other authors highlighted the importance of tapping new knowledge bases as a major incentive for innovation offshoring (Bardhan and Jaffe 2005, Barthélemy and Quélin 2006). Furthermore, offshoring innovation can help firms to exploit their asset base by making them aware of local demand characteristics and technological developments outside the domestic market (Vernon 1966, Doh 2005). We assume that the benefits of innovation offshoring should become larger the higher the speed technological change.

Technological uncertainty can have two distinct sources. First, firms with low technological capabilities will tend to rate uncertainty higher, because they find it harder to anticipate correctly the direction of technological change. If low technological capabilities are the source of perceived uncertainty, innovation offshoring can be viable strategy to reduce uncertainty by augmenting the home base (Dunning 2000) through access to new knowledge and human capital. Second, uncertainty can result from inherent unpredictability of the technological trajectory. Life-cycle models of innovation have shown that unpredictability is frequent when new markets emerge as a wide variety of technological solutions and innovation designs exist but no standard has arrived yet (Abernathy and Utterback 1978, Klepper 1996, Beise 2004). After a certain time of experimentation dominant designs emerge as quasi-standards which reduce the number of rival solutions, stabilize future technological trajectories and hence reduce uncertainty (Tushman and Anderson 1986). Several authors have highlighted that even thorough technology assessment and forecasting cannot reduce uncertainty substantially caused by the emergence of discontinuous patterns of technological change (Christensen 1997, Utterback 1994). Innovation offshoring, although increasing the access to new knowledge, will not imply a greatly increased ability to anticipate the direction of future technological change. If at all, such an increase could be expected for firms with low technological capabilities.

H1: High technological uncertainty fosters offshoring of innovations in firms with low levels of technological competences.

H2: The effect in H1 is smaller for firms with high technological capabilities.

H3: High speed of technological change increases the probability to offshore innovation both for firms with high and low levels of internal technological competences.

The preceding discussion has already pointed to the fact that the interplay between technological capabilities, speed of technological change and uncertainty about technological change influences innovation offshoring decisions through their impact on firms' strategic choice. Several authors have emphasized a distinction between asset augmentation and asset exploitation (Dunning 1993, Kuemmerle 1999, Ambos and Ambos 2011). We will now explore how technological capabilities and technological dynamism may affect firms' strategic goals as drivers of their offshoring decisions.

Starting with the role of technological capabilities we expect that for firms with low technological capabilities, asset exploiting motives are of less relevance than asset augmenting motives. Having high technological capabilities represents an ownership advantage that is a prerequisite for asset exploitation (Demirbag and Glaister 2010). Firms without such strong capabilities in technology almost by definition lack the possibility to exploit their asset base in foreign markets (Gerpott 2005). At the same time, if capabilities are low the learning potential of innovation offshoring is particularly large, provided that firms are able to absorb the knowledge they can access at offshore locations. On the contrary, firms with strong technology capabilities will have higher incentives to engage in asset exploitation, because their capability to offer superior goods and services at offshore locations is higher. Likewise their expected learning potential compared to their already existing capabilities is smaller.

> *H4: a) For firms with high technological capabilities the asset exploiting motive is a more important driver of innovation offshoring than for firms with low technological capabilities. b) For firms with high technological capabilities the asset augmenting motive is less important than for firms with low technological capabilities*

As concerns the speed of technological change, we have already argued that a higher rate of technological turnover is associated with a need to get access to new knowledge fast. This implies that asset augmentation motives are more important in the case of high speed of technological change. Likewise, asset exploitation will be more important because benefits stemming from the existing asset base wither fast. Firms thus are required to exploit their asset base as broadly as possible.

> *H5: Both asset exploitation and asset augmentation are more important drivers for offshoring when the technology changes fast.*

The above discussion showed that high technological uncertainty differs from pure high speed of technological change. This implies that investments into the augmentation of the asset base become uncertain in the sense that the benefits are not easy to assess in advance. At the same time high technological uncertainty will increase the incentives to exploit the existing asset base because its value may be lost if the technology changes into a direction that does not fit well to a firm's existing assets. Thus the exploitation incentive should be stronger when the technological uncertainty is high. On the contrary, low technological uncertainty is often associated with relatively mature product markets. Fast and aggressive market penetration is often neither necessary nor very likely to be successful because market shares are distributed and protected by entry barriers (Utterback and Suarez 1993, Klepper 1996). That is why asset exploitation abroad may become much more difficult in cases of low technological uncertainty.

> *H6: a) For firms operating under high technological uncertainty the asset augmenting motive is less important than for firms operating under low technological uncertainty. b) For firms operating under high technological uncertainty the asset exploiting motive is a more important driver of innovation offshoring than for firms operating under low technological uncertainty.*

3 Data, Variables and Identification

3.1 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. It is 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 enterprises located in Germany with 5 or more employees that have their main economic activity in mining, manufacturing, energy and water supply, sewerage and 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 and 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 and which was the German contribution to the CIS 2010. The MIP survey provides information on the core variables (innovation offshoring activities, technological dynamism, motives for offshoring, internal technological capabilities) described in our theory as well as well as general information about firms.. Note that the questions we use for our core variables have not been part of the harmonized 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 and exclude firms which are German subsidiaries of companies with headquarters outside Germany. This approach guarantees a clear meaning of the terms ‘onshore’ and ‘offshore’. Additionally, we exclude all firms with no onshore innovation activities because the decision to offshore innovation is by definition only relevant for firms that have innovation activities at their home base. With these restrictions we have a sample of 3,889 firms. Due to item non-response for some of the model variables the effective sample size of the regressions hovers however around 2,300.

3.2 Core Variables and Identification Strategy

Our aim is to explain the internal and external conditions that drive a firm’s decision to offshore innovation activities. Based on data from the 2011 MIP survey, we know whether a firm offshored R&D, design activities, product innovation or process innovation during the three year period 2008 to 2010. However, we do not know the significance of innovation offshoring in terms of personnel or funds involved. The exact wording of the question as well as of the other questions used for our core variables are shown in the Appendix.

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. As part of a question on internal capabilities of firms that contained a total of 12 items, 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). 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 for 11 items on a 4-point likert scale ranging from 1 (item does not apply) to 4 (item fully applies). We choose two the two most suitable items from the group of 11, able to represent 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 high speed of technological change. Dummies for these variables take the value 1 if managers rated 3 (mainly applies) or 4 (fully applies) and 0 otherwise.

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 offshoring variables (R&D, design, product, process) separately in Table 2 and Table 3. In order to economize on space, we also generate a compound measure labelled offshoring breadth by summing up these four variables. The resulting measure therefore ranges from 0 (no type of innovation activity offshored) to 4 (all four types of innovation activity offshored).

In order to test H1-H3 we use Probit regressions taking the four types of innovation offshoring activities as the key dependent variables to analyze the effect of speed of and uncertainty about technological change. 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. Assuming that H1 and H3 apply, the coefficient on the speed of technological change and the coefficient on the uncertainty of technological change variable should increase the likelihood to offshore any kind of innovation for firms with low technological capabilities. Furthermore, speed of technological change should also increase the likelihood to offshore innovation for firms with high technological capabilities. If H2 applies, the coefficient on the uncertainty of technological change variables is expected to be significantly lower for firms with high technological capabilities.

H4 to H6 explore how the asset augmenting and exploiting motives to innovation offshoring change as a function of the interplay between technological dynamism and internal technological capabilities. In addition to the already described variables on speed and uncertainty of technological change on the one hand, and internal technological capabilities on the other, we can use information on the firms' offshoring motives. In particular, firms were asked to rate the importance of asset augmentation (measured by the rated importance of gaining "access to knowledge/technology") and asset exploitation (measured by the firms rated importance of "gaining new customers") on a Likert scale ranging from 1 (not relevant) to 4 (high) (see the Appendix for the exact wording of the question).

We test these hypotheses based on regression approaches taking the offshoring breadth (for definition see discussion above) as dependent variable. To test H4a we create an interaction between the asset augmenting variable and the internal technological competences. If H4a applies, the coefficient would be negative. For H4b we create an interaction between the asset exploitation variable and the internal technological capabilities. To corroborate this hypothesis, the coefficient on this interaction would be positive. With respect to H5, we interact the variables measuring the augmentation and exploitation motive with the speed of technological change. If H5 applies, both interactions should be positive. Finally, to test H6a and H6b we interact these variables with the firms' rating of the uncertainty about the technological change. If H6a applies, we would expect a positive coefficient on the exploitation interaction and negative one on the augmentation interaction.

3.3 Confounding Factors

Based on earlier findings, we identify a set of confounding factors. We differentiate between size, group structure, export activities, and characteristics of appropriability regimes. We also discuss the role of R&D expenditures, location of headquarters, as well as the sector a firm belongs to.

Size: Although some authors find support that also smaller companies engage innovation offshoring (Roza et al. 2011), the literature has frequently discussed offshoring as a large company phenomenon. Reasons are that large companies usually have greater financial resources, more complementary assets and greater managerial capacities (see Bardhan and Jaffe 2005). Although small companies may have in advantage in coping with increased organizational complexity associated with offshoring, most authors find that indeed to propensity to offshore 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 management of multi-site processes (Bartlett and Ghoshal 2002). Furthermore, to the degree that parts of the group are based abroad, there may also exist stronger links and thus opportunities for offshoring activities (Berry 2006). Such firms may therefore be more likely offshore innovation. We include a dummy of whether the firm is part of a company group.

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

Intensity of product market competition: Alcácer et al. (2013) argue that the type of competition and internationalization 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). Also firms may try to escape competition by moving to geographically distant places. Furthermore, by offshoring firms may reduce costs bestowing them a competitive advantage. We thus expect that intensity of competition and offshoring innovation 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 predictor of innovation offshoring at the firm level (Baier et al. 2015). Since R&D intensity varies according to sector affiliation, but also from firm to firm, sector and firm differences in R&D are important. We thus include both sector dummies according to the OECD classification of technology levels (OECD 2007) and innovation intensity as control variables.

The role of patents: The strength of patent protection may considerably affect the appropriability and knowledge leakage risks associated with innovation offshoring (Teece 1986, Park 2008). Including patents is highly relevant for offshoring decisions because major costs of offshoring innovation are seen in the loss of control about core technologies resulting from the inability to prevent key know-how to spill-over to competitors in the offshore location

(Kirner et al. 2009, Contractor et al. 2010, Hoecht and Trott 2006). We therefore use an indicator on whether a firm used patents to protect its intellectual property. Although this indicator does not give direct information about the strength of patents, it can serve as a proxy because patents are costly to obtain. In this respect, if a firm is willing to invest in this protection mechanism, this may be an indication of the relative strength of patents in this particular sector.

A dummy for a location in Eastern Germany: The rationale for the inclusion of Eastern Germany dummy stems from the origin of the data used for testing the hypotheses. 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 this.

3.4 Endogeneity Issues

Estimations to test hypotheses H1-H3 could be subject to endogeneity issues. It could for example be the case that offshoring firms 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 offshoring strategy leading to an upward bias of our estimation. We therefore test for the possibility of endogeneity. To implemented such a test, in a first step we create a variable measuring the firms' ratings of speed of and uncertainty about technological change averaged at NACE 2-digit sectors. We use this as an instrumental variable for individual firms rating in a first step regression. The intuition behind 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 would prevail if these two variables are jointly significant (see Wooldridge 2002). All the tests remain insignificant indicating that endogeneity is not a big issue in our regressions. In addition to these two tests we also provide the first stage F-statistic of the instrument variable regressions (IVs) to show that the first stage is identified. These tests are well above 10, implying a very good quality of the IVs in terms of explanatory power.

4 Results

In Table 1 we present the summary statistics of the main variables used throughout this paper. Even within the subset of innovation active firms, offshoring 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 5% offshoring product innovation activities was still the most common practice. This was followed with 4% each by offshoring R&D and offshoring design activities. About 3% of innovation active firms offshored parts of their activities related to process innovation.

Table 1: Summary statistics

Variable	*# Obs.*	*Mean*	*Std. Dev.*	*Min*	*Max*
Offshored R&D	3,505	0.040	0.195	0	1
Offshored product innovation	3,505	0.046	0.209	0	1
Offshored design	3,505	0.044	0.206	0	1
Offshored process innovation	3,504	0.035	0.183	0	1
Offshoring breadth	3,504	0.164	0.701	0	4
Speed technological change	3,427	2.058	0.868	1	4
Uncertainty about future technological change	3,427	2.153	0.795	1	4
Internal technological capabilities	3,313	3.571	1.063	1	5
Motive: asset exploitation	3,495	1.206	0.718	1	4
Motive: asset augmentation	3,495	1.146	0.566	1	4
Patents used	3,220	0.395	0.489	0	1
Intensity of competition	3,428	2.556	0.620	1	4
Employees	3,888	999	5623	1	163,835
Export intensity	3,546	0.179	0.256	0	1
Innovation intensity	2,894	0.169	1.787	0.00006	75
Eastern Germany	3,889	0.291	0.454	0	1
Member of a company group	3,889	0.350	0.477	0	1
High-tech manufacutring	3,889	0.104	0.306	0	1
Medium high-tech manufacutring	3,889	0.174	0.379	0	1
Medium low-tech manufacutring	3,889	0.123	0.328	0	1
Low-tech manufacutring	3,889	0.199	0.399	0	1
Knowledge intensive services	3,889	0.301	0.459	0	1
Other services	3,889	0.099	0.299	0	1

Based on the discussion in the theory section we distinguish two different characteristics of the technological environment, speed of technological change and uncertainty about future technological development. In H1-H3 we have argued that these variables can have distinct impacts on the firms' propensity to offshore innovation given the firms' technological capabilities. As argued in Section 3, we test these hypotheses for each type of offshored innovation. Thus, we analyze whether they hold for R&D, product innovation, design, and process innovation. Using a sample splitting technique to avoid multicollinearity which may result from too many interaction terms, the main results are presented in Table 2 (for R&D offshoring and product innovation offshoring) and Table 3 (for design offshoring and process innovation offshoring).

Table 2: The impact of technological change and competition on R&D and product innovation offshoring

	High technological capabilities Offshored R&D	Low technological capabilities Offshored R&D	High technological capabilities Offshored product innovation	Low technological capabilities Offshored product innovation
Speed of technological change	0.34984***	0.10298	0.36765***	0.38465**
	(4.21)	(0.57)	(4.00)	(2.37)
Uncertainty about future technological change	-0.30028***	0.40844*	-0.27671***	0.34955*
	(-3.12)	(1.91)	(-2.63)	(1.85)
Patents used	0.51854***	0.43487	0.55741***	0.47632*
	(3.26)	(1.33)	(3.18)	(1.66)
Intensity of competition	0.06996	0.07507	0.15622	0.03610
	(0.60)	(0.25)	(1.21)	(0.14)
Employees	0.00016***	0.00091***	0.00024***	0.00092***
	(4.44)	(3.15)	(5.69)	(2.71)
Employees^2	-0.00000**	-0.00000**	-0.00000***	-0.00000**
	(-2.35)	(-2.53)	(-3.82)	(-1.97)
Export intensity	0.88714***	1.24335**	1.07046***	1.56566***
	(3.76)	(2.27)	(4.09)	(2.99)
Innovation intensity	0.00343	2.66640***	-0.31414	0.92222
	(0.07)	(2.68)	(-0.75)	(1.56)
Eastern Germany	-0.38107**	-0.14263	-1.11945***	-0.39916
	(-2.33)	(-0.38)	(-4.14)	(-1.06)
Member of a group	0.70617***	0.85309**	0.80850***	0.89669***
	(5.07)	(2.51)	(5.26)	(2.98)
Constant	-2.97219***	-4.57488***	-2.86003***	-4.85858***
	(-5.62)	(-4.23)	(-5.37)	(-4.80)
Sector dummies	YES	YES	YES	YES
Observations	1,464	576	1,464	832
Pseudo R^2	0.306	0.404	0.401	0.398
AIC	0.56	0.31	3.08	0.08
Alt spec.: endog. test	14.16***	11.47***	14.16***	11.47***
Alt spec.: ident. test	High tech. cap.	Low tech cap.	High tech. cap.	Low tech cap.

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

Table 3: The impact of technological change and competition on design and process innovation offshoring (marginal effects based on probit regressions)

	High technological capabilities Offshored design	Low technological capabilities Offshored design	High technological capabilities Offshored process innovation	Low technological capabilities Offshored process innovation
Speed of technological change	0.27805***	0.43768**	0.21681**	0.34755*
	(3.30)	(2.44)	(2.28)	(1.81)
Uncertainty about future technological change	-0.17399*	0.36610*	-0.31992***	0.39262*
	(-1.83)	(1.90)	(-2.84)	(1.75)
Patents used	0.40958***	0.32423	0.57922***	0.36879
	(2.66)	(1.15)	(3.14)	(1.15)
Intensity of competition	0.17553	-0.08588	0.35263***	-0.14563
	(1.49)	(-0.33)	(2.61)	(-0.49)
Employees	0.00022***	0.00075**	0.00016***	0.00134***
	(5.62)	(2.35)	(4.95)	(3.74)
Employees^2	-0.00000***	-0.00000	-0.00000***	-0.00000**
	(-3.75)	(-1.55)	(-3.02)	(-2.58)
Export intensity	0.80183***	1.16106**	1.03469***	0.91150
	(3.29)	(2.25)	(3.78)	(1.58)
Innovation intensity	-0.19711	-0.61796	-0.14268	-0.06301
	(-0.63)	(-0.43)	(-0.44)	(-0.04)
Eastern Germany	-0.62011***	-0.85513*	-0.66005***	-0.31236
	(-3.35)	(-1.79)	(-2.98)	(-0.74)
Member of a group	0.81813***	0.43570	1.03696***	0.53543
	(5.81)	(1.53)	(5.99)	(1.62)
Constant	-3.07044***	-4.18250***	-3.46559***	-4.29853***
	(-6.03)	(-4.47)	(-5.97)	(-4.04)
Sector dummies	YES	YES	YES	YES
Observations	1,464	832	1,464	832
Pseudo R^2	0.337	0.369	0.373	0.441
AIC	515.7	146.3	410.3	120.3
Alt spec.: endog. test	0.83	1.93	3.10	0.64
Alt spec.: ident. test	14.16***	11.47***	14.16***	11.47***

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

We find that firms with high technological capabilities react quite consistently to speed and uncertainty of technological change. In all cases for firms with high technological capabilities the likelihood of offshoring innovation activities increases with speed of technological change. However, if uncertainty about the future direction of technological change is high, firms are less likely to offshore R&D. As predicted, firms with low technological capabilities differ from this pattern as concerns uncertainty about technological change. For them the effect is positive instead of negative as was the case for firms with high technological capabilities. This corroborates H1 and H2. In fact, concerning H2, the effect is not only smaller but even negative.

For the speed of technological change the effects are positive for the firms with low technological competences, although we observe no effect for offshored R&D activities. This may stem from the fact that low technological competences are themselves the results of the absence of R&D, which would imply that these firms in general experience a lower stimulus from higher speed of technological change to offshore R&D. In any case, we are able to corroborate also H3, with the exception of offshored R&D for firms with low technological capabilities.

In order to exclude problems of endogeneity we have also tried to instrument the key dependent technology variables by their sector means on the NACE 2 digit level. The results are shown in the appendix and largely corroborate our findings. Thus, we are reasonably confident that the results are not obviously plagued by simultaneity and endogeneity issues.

Moving to H4a, we have argued that the importance of asset exploitation increases with the quality of the technological competences. If this hypothesis is true, we would expect a positive coefficient for the interaction term of asset exploitation and technological competence. Likewise in H4b we argued that the importance of asset augmentation should be reduced, which would imply a negative interaction with technological capabilities. In Table 4 (column) we present the estimation results. Graphical representations of the marginal effects are in **Figure 1**. In fact, we find a positive interaction between the asset exploitation motive and internal technological capabilities, corroborating H4a. However, no significant effect can be found for the interaction between the asset augmentation motive and technological capabilities. Thus, the results suggest that the importance of the asset augmentation motive not clearly depends on the internal technological capabilities. We therefore find no support for H4b.

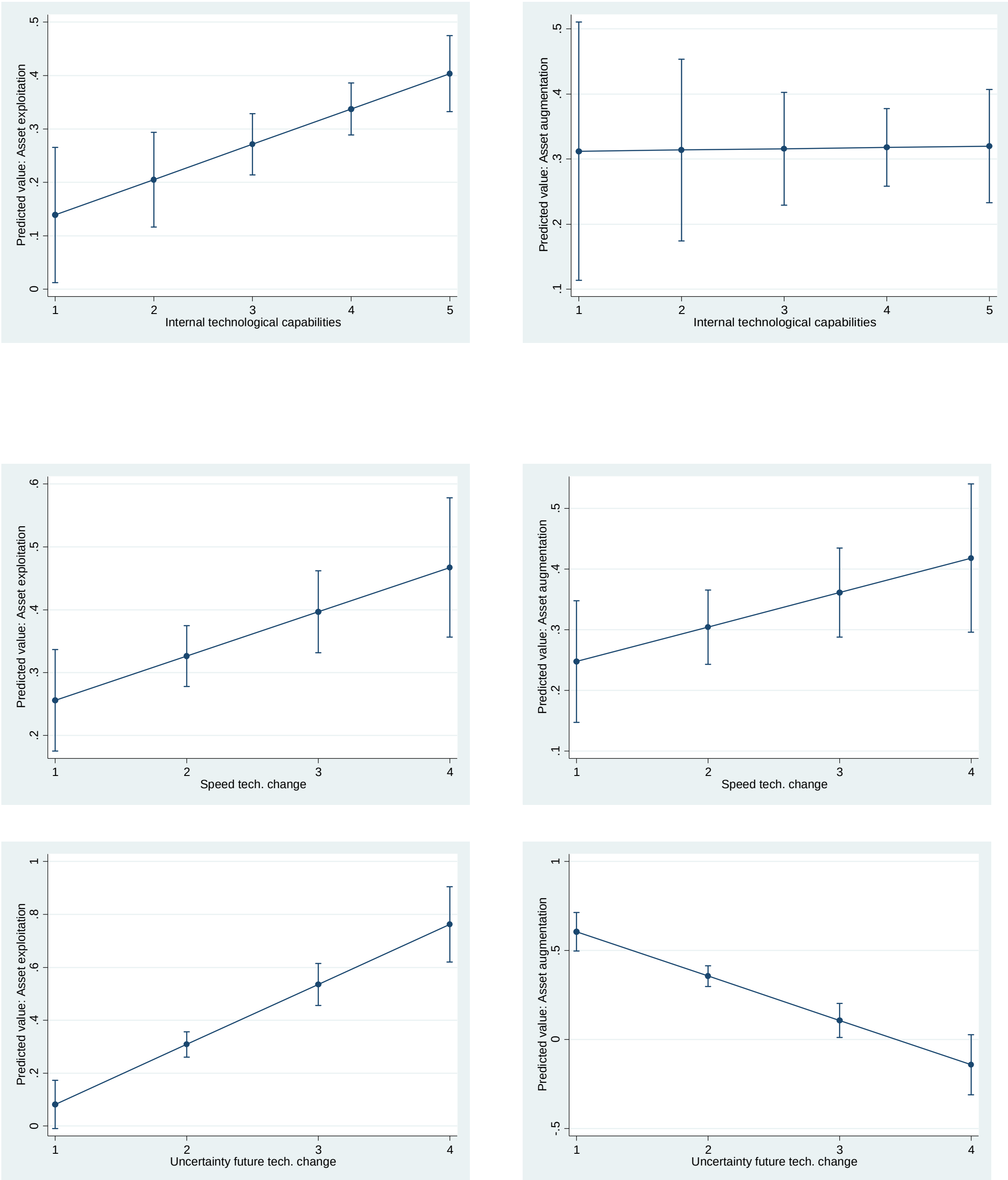
H5 suggested that high speed of technological change increase the need to simultaneously exploit and augment the technology base. The third and the fourth graphical presentations give support of this expectation. In the case of high speed of technological change, the effect of asset exploitation and asset exploration on the breadth of innovation offshoring is higher as compared to a situation of low speed of technological change.

Table 4: The role of strategic motives for innovation offshoring

	Offshoring breadth	Offshoring breadth	Offshoring breadth
Motive: asset exploitation	0.07279 (0.85)	0.18527*** (2.80)	-0.14497* (-1.82)
Motive: asset augmentation	0.30990** (2.34)	0.19078** (2.40)	0.85456*** (9.14)
(Motive: asset exploitation)*(Internal technological capabilities)	0.06613*** (3.04)		
(Motive: asset augmentation)*(Internal technological capabilities)	0.00199 (0.06)		
Internal technological capabilities	-0.08044*** (-2.74)		
(Motive: asset exploitation)*(Speed of technological change)		0.07050** (2.50)	
(Motive: asset augmentation)*(Speed of technological change)		0.05682* (1.77)	
(Motive: asset exploitation)*(Uncertainty about future technological change)			0.22685*** (6.27)
(Motive: asset augmentation)*(Uncertainty about future technological change)			-0.24916*** (-5.89)
Speed of technological change	0.03905*** (2.65)	-0.11484*** (-3.96)	0.03873*** (2.64)
Uncertainty about future technological change	-0.01470 (-0.92)	-0.01809 (-1.13)	-0.00063 (-0.02)
Patents used	0.08055*** (3.18)	0.08791*** (3.51)	0.07760*** (3.10)
Intensity of competition	-0.00499 (-0.25)	-0.00255 (-0.13)	0.00065 (0.03)
Employees	0.00010*** (9.81)	0.00010*** (9.92)	0.00010*** (9.85)
Employees^2	-0.00000*** (-6.24)	-0.00000*** (-6.36)	-0.00000*** (-5.89)
Export intensity	0.24071*** (4.64)	0.24027*** (4.65)	0.24458*** (4.74)
Innovation intensity	0.00064 (0.10)	0.00072 (0.11)	0.00092 (0.14)
Eastern Germany	-0.05532** (-2.26)	-0.05472** (-2.24)	-0.05592** (-2.29)
Member of a group	0.13796*** (5.20)	0.13892*** (5.24)	0.14615*** (5.52)
Constant	-0.44116*** (-3.22)	-0.43734*** (-4.74)	-0.81520*** (-8.39)
Sector dummies	YES	YES	YES
Observations	2,275	2,287	2,287
R^2	0.496	0.502	0.502
AIC	3629.2	3654.8	3653.3

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

Figure 1: Graphical representations of the interactions



Finally, we also find evidence for H6a and H6b, which stated that technological uncertainty tends to be associated with asset exploitation rather than augmentation because the value of investment in existing assets becomes very uncertain. Like in the case of high technological capabilities this would suggest that the coefficient of the exploitation variable is higher than the coefficient of the augmentation variable in the case of high technological uncertainty. As expected the interaction terms with technological uncertainty are positive and significant for the exploitation motive and negatively significant for the augmentation motive.

5 Discussion

On a general level we have portrayed innovation offshoring as a strategic decision which is shaped by the simultaneous interplay between firms' internal technological capabilities and their technological environments. This is an important observation because most analyzes so far have either focused on the role of firm characteristics/capabilities or aspects of the external environment in isolation (compare Roza et al. 2011, Massini et al. 2010, Ambos and Ambos 2011, see also Manning et al. 2008). In this respect, a contingency approach for understanding innovation offshoring decisions has to take into account a dual contingency spanned by both internal and external characteristics working simultaneously. This is in line with the strategic fit perspective propagated in strategic management (Andrews 1971, Hofer and Schendel 1978, Drazin and de Ven 1985, Zajac et al. 2000), which highlights that strategy is the act of aligning internal characteristics with the characteristics of the external environment.

On a more specific level, our results show that uncertainty about the direction of technological change tends to reduce the propensity to offshore innovation for firms with high technological competences, while low-competence firms increase their offshoring activities. We argue that this result stems from the fact that in the light of severe uncertainty high internal technological competences create a strategic option to concentrate innovation activities onshore. This option is only available to firms with high technological competences. Innovation offshoring seems to be a viable strategic option for firms with low internal technological capabilities. High uncertainty about technological change in fact can be the very result of low technological capabilities. Offshoring innovation can serve as an asset augmenting strategy which both increases technological learning through accessing internationally dispersed knowledge sources (Bardhan and Jaffe 2005, Barthélemy and Quélin 2006) while at same time it reduces the firm's technological uncertainty. On the contrary, we observed that high technological uncertainty makes firms with high technological capabilities much less likely to offshore innovation. We explain this by the presumable existence of objective uncertainty of the direction of technological change. In such a situation, firms with high technological capabilities may choose to draw on their internal capabilities to execute innovation projects. Innovating onshore may also have the advantage to keep tighter control over core activities (Mudambi 2008). In this respect we argue that high internal technological capabilities create a strategic option to innovate onshore.

Our results also show that high speed of technological change increases the propensity to offshore for all firms. If technology changes rapidly, that creates a need to react fast to changing environments. Therefore, speed to market becomes an essential criterion (Lewin et al. 2009). In fact, by showing that the effects of high technological uncertainty differ for firms with high and low technological capabilities, while they do not for high speed, we provide additional evidence that the distinction between uncertainty and speed common in e.g. the high-velocity-literature (see Burgeois and Eisenhardt 1988, Gustaffson and Reger 1995, Eisenhardt and Martin 2000, Wirtz et al. 2007) is indeed essential. The reason is that high speed creates considerably differing incentives as compared to high uncertainty. High uncertainty considerably tends to make asset exploitation a more important driver of innovation offshoring, while it reduces the importance of asset augmentation. High speed of technological change increases the importance of both asset augmentation and exploitation. Firms in fast changing, though not necessarily uncertain, technological environments have to be prepared for change and have to proactively adjust and develop their technology portfolio (Neuhäusler et al. 2015). Augmenting their knowledge assets through internationalization is therefore critical, since rapid product cycles imply short periods for realizing returns from innovation (Klepper 1996). Reaching out to new geographical markets through knowledge exploitation abroad is a promising strategy in this situation.

Our findings have direct implications for managers. First, internationalizing innovation needs to be aligned with a firm's changing market environment. If firms face increasing technological uncertainty resulting from the emergence of new technologies, or because old, familiar technologies have become obsolete, managers tend to refrain from strong offshoring activities, particularly with regard to knowledge augmenting activities. While such a strategy reduces complexity in managing the innovation process, firms may miss new developments if these emerge outside their home region. Although we are not able to evaluate the success of this strategic choice, managers should a least be aware of the trade-offs.

High speed of technological change on the contrary, consistently increases the likelihood to offshore innovation. The overall less ambiguous effect of technological speed on offshoring could imply that innovation offshoring is particularly effective when speed of change is high, irrespective of the level of technological capabilities.

While we were able to shed some new light on a few issues in firms' innovation offshoring decision, we explicitly highlight that analyzing the interplay between technological capabilities and technological dynamism is only one part of the puzzle. One important aspect of innovation offshoring relates to its impacts on innovation activities at the home base. On the one hand, offshored innovation may strengthen a firm's home base innovation by contributing complementary assets and access to new markets. On the other hand, it may reduce innovation output by increasing managerial complexity (Bartlett and Goshal 2002, Fifarek et al. 2008, Baier et al. 2015).

We also ignored the heterogeneity of offshoring locations and other firm characteristics which may have significant impacts on the success of offshoring activities (Sartor and Beamish 2014). The analysis of the specific locational factors is there a prerequisite of beneficial offshoring activities. In addition, offshoring success may also be linked to the quality of internal processes, especially with respect to (reverse) knowledge transfer capabilities of the firm (Kuemmerle 1999). Finally, we did not look at the actual way how firms organize offshoring of innovation and the integration of offshored activities into the innovation process along the entire value chain (Mudambi and Venzin 2010).

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7 Appendix

a) Question on innovation offshoring

Did your enterprise conduct any <u>innovation activities</u> (incl. R&D) at <u>foreign facilities</u> of your company during 2008 to 2010?

Yes	☐ 3	
No, enterprise does <u>not have any foreign facilities</u>	☐ 2	Please continue with the next section.
No, foreign facilities were <u>not used for innovation activities</u>	☐ 3	

What type of <u>innovation activities</u> did your enterprise conduct <u>abroad</u> during 2008 to 2010?

	Yes	*No*
<u>R&D</u> (internal R&D) at foreign facilities	☐ 1	☐ 2
<u>Design, industrial engineering or feasibility studies</u> for new products or processes at foreign facilities	☐ 1	☐ 2
<u>Manufacture of new products</u> or <u>launch of new services</u> at foreign facilities	☐ 1	☐ 2
Introduction of <u>process innovations</u> at foreign locations	☐ 1	☐ 2

In which <u>countries other than Germany</u> did your enterprise conduct innovation activities during 2008 to 2010?

Foreign locations (<u>country code</u>) with innovation activities 2008-2010, ordered by the <u>importance</u> for your enterprise:

How important were each of the following <u>objectives</u> in your decision to conduct innovation activities abroad and how successful have you been in meeting each objective?

(Please make at least one tick in every line)	*importance* high	*importance* medium	*importance* low	*not relevant*	***successful?*** *completely*	***successful?*** *partially*	***successful?*** *no*	***successful?*** *not able to determine*
Decrease of <u>development costs</u>	☐ 1	☐ 2	☐ 3	☐ 4	☐ 1	☐ 2	☐ 3	☐ 4
Decrease of <u>production costs</u>	☐ 1	☐ 2	☐ 3	☐ 4	☐ 1	☐ 2	☐ 3	☐ 4
Reach new <u>clients</u>	☐ 1	☐ 2	☐ 3	☐ 4	☐ 1	☐ 2	☐ 3	☐ 4
Respond to <u>clients' needs</u>	☐ 1	☐ 2	☐ 3	☐ 4	☐ 1	☐ 2	☐ 3	☐ 4
Contact to <u>clients / markets</u> at the forefront of innovative trends	☐ 1	☐ 2	☐ 3	☐ 4	☐ 1	☐ 2	☐ 3	☐ 4
<u>Access to knowledge / technology</u>	☐ 1	☐ 2	☐ 3	☐ 4	☐ 1	☐ 2	☐ 3	☐ 4
Access to <u>skilled labour</u>	☐ 1	☐ 2	☐ 3	☐ 4	☐ 1	☐ 2	☐ 3	☐ 4

b) Question on technological dynamism

Please indicate to what extent the following characteristics describe the competitive situation of your enterprise.

(Please mark an X for each line)

	applies fully	*applies somewhat*	*applies very little*	*applies not at all*
Products / services become outdated quickly	☐ 1	☐ 2	☐ 3	☐ 4
The technological development is difficult to predict	☐ 1	☐ 2	☐ 3	☐ 4
Products / services from competitors are easily substitued for those of your enterprise	☐ 1	☐ 2	☐ 3	☐ 4
Major threat to market position because of entry of new competitors	☐ 1	☐ 2	☐ 3	☐ 4
Competitor's actions are difficult to predict	☐ 1	☐ 2	☐ 3	☐ 4
Strong competition from abroad	☐ 1	☐ 2	☐ 3	☐ 4
Crowding out among the main competitors in the market	☐ 1	☐ 2	☐ 3	☐ 4
Price increases lead to immediate loss of clients	☐ 1	☐ 2	☐ 3	☐ 4
Clients have difficulties to assess the quality of your products before purchasing them	☐ 1	☐ 2	☐ 3	☐ 4
Switching to other suppliers is easy	☐ 1	☐ 2	☐ 3	☐ 4
The products / services of your suppliers are of high quality	☐ 1	☐ 2	☐ 3	☐ 4

c) Question on internal technological capabilities

How distinct are the following capabilities in your enterprise?

(Please make at least one tick in every line)

	strongly distinct	*distinct*	*medium*	*weakly distinct*	*not existing*
Detecting new client's needs	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Development of new technical solutions	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Scope for development via 'trial and error'	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Strong individual responsibility of employees	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Creativity of employees	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Incentive schemes for employees to innovate	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Stimulation of internal competition between projects	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Internal co-operation between departments / firm units	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Inclusion of external partners	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Quick implementation of new ideas to market launch	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Quick imitation of competitor's innovations	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5