Profiling Sustainable Innovators: Not Ready to Make Nice?

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Abstract

Over the past decade, sustainable or "green" innovation has occupied a top-ranking position on the agenda of many firms. Sustainable innovation can be broadly defined as an innovation that has to consider environmental and social issues. Particularly multinational companies have come under the spotlight of stakeholder groups since these companies are operating in a diverse landscape of regulatory, cultural or ecological conditions. Although sustainable innovation provides considerable new opportunities it hence goes along with an increased complexity. This in turn requires certain organizational routines and capabilities to deal with the upcoming challenges. We explore the driving forces leading firms to innovate in a sustainable development domain and towards a build-up of sustainable innovation capabilities. We test them empirically for more than 1,100 firms in Germany and find that firms need to invest in internal absorptive capacities and draw both broadly and deeply from external impulses for innovation.

1 Introduction

Sustainability has been an important topic for scholars and practitioners in innovation management for a long time. It was traditionally associated with a firm's long-term orientation and planning that ensure a continuous stream of new products and process. This notion of sustainability is changing towards a reconciliation of the interests of various firm stakeholders (employees, government, environment, local communities) with shareholder interests as the basis for truly long-lasting firm success. We will use the term "sustainable innovation" for innovation activities with sustainable outcomes.

Over the past decade, this form of sustainable or "green" innovation has occupied a top-ranking position on the agenda of many firms. This has partly been driven by prominent failures like Shell's Brent Spar experience or Nike and the Asian "sweatshops". Sustainable innovation can be broadly defined as an innovation that considers environmental and social issues, as well as the needs of future generations. Particularly multinational companies have come under the spotlight of various stakeholder groups, since these companies are operating in a diverse landscape of regulatory, cultural or ecological conditions. Therefore, sustainable innovation is generally perceived to be more challenging than market innovation (Hall and Vredenburg, 2003). In this respect, sustainable innovation turns out to have two facets. The first is pressure-driven: Companies are adopting responsible corporate behavior as a result of the increasing pressures that they are facing from their stakeholders, including governments or non-governmental organizations (NGOs) (Christmann and Taylor, 2002; Ottman et al., 2006). The second facet is demand-driven: Various stakeholders - and most importantly customers - are increasingly demanding products that have been produced in a sustainable way, i.e. in an eco-efficient process, consuming less resources and energy, reducing environmental stress and improving health and safety conditions for employees as well as for customers, the local community or society in general. In this context, customers can react with extreme aggressiveness, even resulting in boycotts of certain products or services. At the same time, customers seem to clearly appreciate the firms that are known for their sustainable development strategies or for their reputation for sustainable conduct. Many studies, such as Rindova et al. (2005), have shown that a firm's reputation can create competitive advantage since reputation constitutes a substantial part of the perceived utility of a product or service. An indication for this might be the development of the Dow Jones Sustainability Index, which tracks the financial performance of the leading multinational sustainability-driven companies worldwide. Since 2001, the index has constantly outperformed a global reference index.[1]

In order to comply with pressure from stakeholders on the one hand, and to satisfy new customer demands on the other hand, many firms are starting to consider an integration of sustainable development practices and a review of their established business models. Early attempts directed at an improvement of corporate reputation included the establishment of sustainability offices and the publication of sustainability reports (Hall and Vredenburg, 2003). Apart from public relations efforts, companies have also increasingly switched from conforming with regulations to becoming environmentally proactive (Berry and Rondinelli, 1998). They want to become more environmentally responsive. Whereas during the 1960s and 1970s companies undertook major efforts to repair environmental damages, they had to try to keep up with ever-increasing environmental regulation during the 1980s. In the nineties, companies began to adopt more proactive environmental policies. Nowadays, sustainable innovation practices are considered an integral part of successful management (Ketata and McIntyre, 2006). But this also implies that a simple public relations-driven approach to

[1] See http://www.sustainability-indexes.com

sustainable innovation might not be enough as it does not provide sufficient clues for differentiation in the marketplace.

Although sustainable innovation provides considerable new opportunities for companies it is accompanied by an increased complexity and possible “traps” (Hall and Vredenburg, 2003). This in turn requires certain organizational routines and capabilities to deal with the upcoming challenges. Rooted in the capability based view of the firm, we hypothesize that firms capable of realizing such innovation will have developed certain skills and competencies. These enable them to respond to stakeholders’ pressures and demands and – as a consequence – to gain a head start over competitors (Eisenhardt and Martin, 2000; Hoopes *et al.,* 2003). It remains unclear, however, how these sustainable innovation capabilities are developed. We investigate these processes and propose that sustainable innovation capabilities are the result of external demands and fitting internal absorptive capacities to leverage them.

The objective of this paper is twofold: We extend the existing literature by investigating this research question both theoretically and empirically. As Helfat and Peteraf (2003: 997) noted that “it is difficult to fully explain how firms use resources and capabilities to create a competitive advantage”, we will provide recommendations on how to develop sustainable innovation capabilities. Important findings in the field have been derived from case studies or based on small samples (see for example Christmann, 2000; Hall and Vredenburg, 2003; Kreikebaum, 1999). We are able to provide empirical evidence for more than 1,100 German firms and their innovation activities, most of them being multinationally operating companies. The remainder of this paper is designed as follows. Section 2 presents our conceptual considerations, focusing on the specifics of sustainable innovation and how sustainable innovation capabilities emerge. The subsequent section 3 develops a set of hypotheses that will be tested in our empirical study (section 4). Section 5 presents the results of this quantitative analysis followed by discussion and recommendations in section 6. Section 7 closes, acknowledging some limitations of this research and providing an outlook on future research on this topic.

2 Deliberate learning and sustainable innovation capabilities

2.1 The specifics of sustainable innovation

Unique knowledge can be considered a firm's most valuable asset for generating competitive advantage (Liebeskind, 1996) as it provides firms with the necessary platform to decide which resources or capabilities to deploy, develop or discard as their environment changes (Ndofor and Levitas, 2004). This perspective is typically summarized as the knowledge based view of the firm (Grant, 1996). We suggest that the specific knowledge required for sustainable innovation entails additional layers of complexity and uncertainty.

Complex knowledge differs from simple knowledge in the amount of additional factual information that is required to transfer and understand it fully and accurately (Bhagat et al., 2002). Sustainable innovation is related to environmental, social and economic domains (Hall and Vredenburg, 2003). In that sense, sustainable innovation adds a broader, systematic perspective to the meaning of "sustainable" competitive advantage by incorporating the interests and needs of all parties involved; including not just shareholders but also employees, customers, local communities, regulators and advocacy groups (Gable and Shireman, 2004). The latter is an important aspect of sustainable innovation. The ability of non-governmental organizations to mobilize and publicize through modern communication technology worldwide has given them considerable clout on various issues ranging from food standards to child labor (Brugmann and Prahalad, 2007). These organizations have often resorted to public attacks on individual market-leading firms, with indirect repercussions for the industry as a whole. According to Hall and Vredenburg (2003), society’s opinion of a technological innovation are extremely subjective, depend upon various stakeholder groups and change constantly. Some authors have captured this multidimensionality of sustainable innovation as a shift from the traditional one-dimensional profit target system towards a “triple bottom line” (Elkington, 1998). The latter adds social/ethical and environmental performance measures to traditional profit maximizing goals (Vanclay, 2004). In its simplest form this change in paradigm has the potential to save resources and hence costs, reduce a company’s exposure to risks from publicized cases of malpractice (e.g. resulting in consumer boycotts) and build a favorable reputation that materializes as respect, trust and confidence (Dowling, 2004; Edelstein, 2004). However, this comprehensive target system is not very precise. Vanclay (2004), for example, presents 11 different descriptions of the triple bottom line ranging from “profit, people, planet” to “landscapes, lifestyles, livelihoods.” Hence, the complexity of sustainable innovation stems from a multitude of external demands from various stakeholders with varying agendas. This makes it challenging to access and assess relevant stakeholder knowledge comprehensively because knowledge creation, organization and transfer depends heavily on the commitment and belief patterns of both holders and recipients (Nonaka, 1994).

These layers of complexity resonate inside the company. Sustainable innovation activities typically require a broader scope as they are related to different functional dimensions, i.e. spanning the human resource department, the R&D department, procurement, production and sales (Noci and Verganti, 1999). In fact, they can involve nearly all organizational functions as well as the whole supply chain. Management expertise is of particular importance as sustainable innovation projects and conventional innovation management strategies are not fully applicable (Hall and Vredenburg, 2003). This involves adequate communication with and training of employees as this domain needs to be integrated into their daily activities in order to avoid resistance and frustration. Ketata and McIntyre (2006) find that a lack of understanding for the benefits of innovating in the sustainable development domain among employees leads them to resist these projects.

Dealing with complex knowledge leads to causal uncertainty (Bhagat et al., 2002) which implies more frequent mistakes in sustainable innovation activities. Irrevocable investments into the wrong projects exhibit a considerable economic risk (Balachandra and Brockhoff, 1995). Besides, sustainability management is associated with a significant financial commitment (Walley and Whitehead, 1994). Sustainable innovation is likely to be more expensive than traditional innovation since the former involves almost the whole company structure, and implies investing in a whole set of different technologies that might considerably exceed the scope of a firm's competencies (Shrivastava, 1995). Moreover, the pay-offs from sustainable innovation may not immediately translate into monetary benefits but are often intangible and related to long-term objectives (e.g. reputation building). In contrast, the pressures to make the innovation process efficient and profitable are very direct, immediate and specific.

2.2 Learning processes and capability development

Looking at the length of time that it took companies to start developing capabilities for dealing with sustainable innovation concerns, it becomes clear that the creation of such capabilities necessarily involves a deliberate learning process. Firms obviously first need to understand the challenges of regulation and new demands in order to develop targeted capabilities that leverage competitive advantage. The knowledge (and capability[2]) based view

[2] Capabilities are organizational processes which bundle strategic knowledge resources into unique combinations and constitute superior performance themselves. This follows the basic rationale that competitive advantage does not only arise from the possession of such resources but also from the way in which they are used (Penrose, 1959).

of the firm complements traditional industry analysis in that internal and external factors have to be considered to understand the sources of such competitive advantage (Amit and Schoemaker, 1993; Sirmon et al., 2007). Several studies argue that capabilities cannot be investigated without considering their context (Atuahene-Gima and Haiyang, 2004; Brush and Artz, 1999): the "when, where and how" knowledge resources and capabilities translate into competitive advantage (Priem and Butler, 2001). We follow this stream of literature by discussing the roots of sustainable innovation capabilities and their relevant context.

We argue that the mechanism behind the build-up of sustainable innovation capabilities can be regarded as a continuous and deliberate learning process (Zollo and Winter, 2002). This process describes the systematic methods a firm uses to modify its operating routines. Such routines constitute stable patterns of organizational behavior and reaction to internal or external stimuli. On the one hand, routines define predictable as well as interrelated organizational actions e.g. the production process at globally dispersed production sites. On the other hand, a routine may also initiate the introduction of certain environmental or health standards in global production processes. Routines of this second type are typically referred to as search routines (Nelson and Winter, 1982). They deal with changes in the existing set of operating routines and can hence be seen as constitutive of sustainable innovation capabilities.

In a relatively stable environment, operating routines superior to those of competitors can be a source of competitive advantage. It may even be sufficient to rely on discrete and sporadic changes and improvements in the set of operating routines that may result from a tacit accumulation of experience. However, when the environment turns more demanding, in that new regulation is imposed from different regulatory bodies or stakeholders assert certain claims regarding the adoption of sustainable development practices, a stable set of routines might no longer be sufficient. Systematic efforts are needed to track the environment and dynamically adjust routines. This is where sustainable innovation capabilities enter the game.

A failure to develop such capabilities, which leverage the value of a firm's resources in a more demanding environment, would turn once established core competencies into core rigidities (Leonard-Barton, 1992). A simple accumulation of experience and knowledge resulting from a repeated execution of routines combined with a process of trial-and-error will therefore not be enough for a build-up of sustainable innovation capabilities. The whole process must necessarily culminate in knowledge articulation and knowledge codification. The following section centers around these two aspects within the learning process to derive our hypotheses.

3 Hypothesis development

Knowledge articulation evolves from discursive actions between individuals and groups in the execution of organizational tasks (Levitt and March, 1988; Levinthal and March, 1993). Expressing opinions and individual viewpoints, challenging them and mutually understanding causal linkages – especially in the presence of ambiguities – are pre-requisites for making implicit or tacit knowledge explicit and hence for enabling collective learning efforts. Knowledge from relevant stakeholders has to be made available throughout the company in order to adjust operating routines accordingly and to spread successful action-performance links within the whole organization. Sirmon et al. (2007) have suggested that the effectiveness of this step also depends on environmental munificence. The varying munificence of environments might critically affect the potential value of a firm's resources and capabilities. Moreover, munificent environments can support the growth of resources within firms by providing access to complementary, external resources (Baum and Wally, 2003). We argue that sustainable innovation capabilities stem from investments in internal absorptive capacities that reflect the munificence of the environment.

3.1 Absorptive capacities for sustainable innovation

Learning processes are built around a firm's ability to extract relevant market knowledge and integrate it into new products and services as well as into the whole organization. While market impulses are generally available to all competitors, firms can differentiate themselves through their expertise in synthesizing this information, integrating and combining it with existing knowledge (Henderson and Cockburn, 1994; Kogut and Zander, 1992). An important stream of literature has summarized these capabilities as absorptive capacity (Cohen and Levinthal, 1989, 1990): a firm's ability to identify, assimilate and exploit knowledge from the environment. This differentiation corresponds with the three learning mechanisms in organizational capability development – experience accumulation, knowledge articulation and knowledge codification – but puts a stronger emphasis on exploiting and capitalizing acquired knowledge. Several studies have linked absorptive capacity to superior firm performance (Landry, 2006; Love and Roper, 2004; Nadiri, 1993). Absorptive capacities are typically accumulated as a by-product of firms' innovation activities and hence difficult to acquire, imitate or substitute (Amit and Schoemaker, 1993).

Cohen and Levinthal, 1989, 1990 follow the rationale that absorptive capacities are developed by performing R&D activities, which stresses the technological aspect of absorptive capacity. Technological advance is an obvious driver of innovation. However, absorptive capacities are especially relevant for sustainable innovation activities as they often appear outside of a firms' traditional field of technological expertise (Shrivastava, 1995). Other studies have extended the absorptive capacity concept to include employees' level of education and academic achievement (Rothwell and Dodgson, 1991). In addition, motivational factors have been found to be important for activating these capacities (Lane and Lubatkin, 1998; Lord and Ranft, 2000). The discussion on the specifics of sustainable innovation has shown that it has both a technological and social facet. Hence we develop two hypotheses:

> Hypothesis Ia: Investments in technological absorptive capacities increase the likelihood of sustainable innovation.
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> Hypothesis Ib: Investments in the education of employees and their individual absorptive capacities increase the likelihood of sustainable innovation.

3.2 Munificent environments for sustainable innovation

Sustainable innovation activities add new layers of complexity to a firms' innovation process (Noci and Verganti, 1999). As the pool of relevant stakeholders from various geographical or cultural backgrounds and therefore knowledge sources increases, firms need to broaden their spectrum for potential innovation impulses. Zahra and George (2002) introduce the distinction between potential and realized absorptive capacity. Put simply, they envision absorptive capacity as a funnel with a large opening for taking in a broad variety of diverse ideas with potential value. These have to be narrowed down, prioritized and codified to facilitate efficient assimilation and exploitation processes (Jansen et al., 2005). Complex knowledge requires the transfer and processing of additional knowledge that puts it into perspective. It may stem from technological, market or regulatory factors. This necessitates their integration in existing products and processes which depends heavily on available competencies. Early customer involvement has been found to be especially important for the market success of sustainable innovations (Hall and Kerr, 2003; Heiskanen et al., 2005). However, important impulses for innovation can also be technologically or legally induced. Certain companies are more open to new ideas than others. Indeed, specific features related to the company help it to be more open to these ideas. In this context, the culture of the company and its customs have an important influence. In fact, an open culture for innovation is a necessary condition for the firm to recognize the need to innovate (Ekvall and Ryhammar, 1998; Lester, 1998; van der Panne et al., 2003). Openness prevents firms from missing important dynamics in their environment (Chesbrough, 2003) and enables them to predict future trends more accurately (Cohen and Levinthal, 1994). We propose:

> Hypothesis IIa: As the diversity of external knowledge inside the firm increases sustainable innovation becomes more likely.

However, Laursen and Salter (2006) contrast the concept of breadth in knowledge sourcing with the necessary depth. There is a need for focus as company's information processing capacities are limited. A vast amount of ideas impedes selection and exploitation processes (Koput, 1997). Hence, we derive:

> Hypothesis IIb: As the depth of external knowledge inside the firm increases sustainable innovation becomes more likely.

After all, it would be shortsighted to perceive sustainable innovation as a purely voluntary endeavor. Governmental and regulatory agencies play an important role in influencing sustainable innovation. Hall and Vredenburg (2003), stress this aspect when discussing the introduction of new laws that sanction those that are harmful to the environment and to the population. Following the munificence rationale, we argue that regulations can be supportive in nature, i.e. in the form of subsidies, or based on sanctioning mechanisms (Abdul-Gafaru, 2006). We therefore suggest:

> Hypothesis IIIa: As regulatory demands increase sustainable innovation becomes more likely.

> Hypothesis IIIb: As financial support from the government increases sustainable innovation becomes more likely.

4 Empirical study

4.1 Data

For the empirical part of this analysis we use cross section data from a survey on the innovation activities of German enterprises called the “Mannheim Innovation Panel” (MIP) The survey is conducted annually by the Centre for European Economic Research (ZEW) on behalf of the German Federal Ministry of Education and Research. The methodology and questionnaire used by the survey, which is targeted at enterprises with at least five employees, are the same as those used in the Community Innovation Survey (CIS), conducted every four years under the coordination of Eurostat. For our analysis we use the 2005 survey, in which data was collected on the innovation activities of enterprises during the three-year period 2002-2004. About 5,000 firms in manufacturing and services responded to the survey and provided information on their innovation activities.[3] We utilize this data to operationalize the concepts presented above. Non-innovating firms were excluded from our analysis, because most variables can only be constructed for firms with innovation activities. In addition, we narrow our analysis to the manufacturing sector. As a result we retain a final sample of 1,124 innovative manufacturing firm observations.

CIS surveys are self-reported and largely qualitative which raises quality issues with regards to administration, non-response and response accuracy (for a recent discussion see Criscuolo et al., 2005). First, our CIS survey was administered via mail which prevents certain shortcomings and biases of telephone interviews (for a discussion see Bertrand and Mullainathan, 2001). The multinational application of CIS surveys adds extra layers of quality management and assurance. CIS surveys are subject to extensive pre-testing and piloting in

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3 The sample was drawn using the stratified random sample technique. For a more detailed description of the dataset and the survey see Spielkamp and Rammer, 2006.

various countries, industries and firms with regards to interpretability, reliability and validity (Laursen and Salter, 2006). Second, a comprehensive non-response analysis of more than 4,200 firms showed no systematic distortions between responding and non-responding firms with respect to their innovation activities. Third, the questionnaire contains detailed definitions and examples to increase response accuracy. Longhand questions (e.g. “Please describe your most important product innovation briefly”) allow robustness checks for multiple choice answers.

In conclusion, the major advantages of CIS surveys are that they provide direct, importance-weighted measures for a comprehensive set of sources (Criscuolo et al., 2005). On the downside, this information is self-reported. Heads of R&D departments or innovation management are asked directly if and how they are able to generate innovations. This immediate information on processes and outputs can complement traditional measures for innovation such as patents (Kaiser, 2002; Laursen and Salter, 2006).

4.2 Variables and method

Measuring sustainable innovation

The previous theoretical discussion made it clear that our research question touches a multi-faceted construct. It cannot be readily observed. Hence we rely on qualitative, self-reported but importance-weighted answers to a question on the outcomes of a firm’s innovation activities. Respondents are asked to assess the importance of these outcomes on a 4 point Likert scale ranging from “not relevant” to “high”. We rely on three different outcomes: Reduction in resource/energy consumption (per unit of output), reduction of economic stress and improvement of health/safety. We construct a sustainability scale based on these ratings through principal factor analysis and retain a single factor with an eigenvalue larger than one (2.16; Cronbach’s alpha scale reliability coefficient: 0.71; Kaiser-Meyer-Olkin measure of sampling adequacy: 0.71). A higher scale value indicates that firms assign higher importance to all three sustainable components of their innovation activities and vice versa. It will serve as the dependent variable in our empirical study.

Measuring absorptive capacity

Absorptive capacities are not a tangible concept but rather a combination of different competencies and capabilities. Hence, companies cannot be easily surveyed to estimate the degree to which they possess these absorptive capacities. Cohen and Levinthal, 1989, 1990, follow the rationale that absorptive capacities are developed by performing R&D activities. We follow their suggestion and introduce R&D intensity (R&D expenditures as a share of sales) to our model. Besides, investment in employees' level of education and academic achievement have been recognized as an important indicator for a firms' absorptive capacity (Rothwell and Dodgson, 1991). We capture this item through the training expenditure per employee. Absorptive capacities are generally accumulated over time. Hence, consistent R&D engagements should produce superior results to sporadic ones. We therefore include a dummy variable indicating whether the firm performs continuous R&D activities.

Measuring environmental munificence

Laursen and Salter (2006) suggest a differentiation between breadth and depth of external innovation impulses by relying on the importance weighted information obtained through surveys. We are able to obtain information on a comprehensive list of potential sources for innovation and their importance. These nine options are suppliers, customers, competitors, consultancies, universities, public research institutions, conferences, scientific journals and trade associations. Following Laursen and Salter (2006), we measure a firm's breadth of external innovation inputs as the number of different sources used (from 0 to 9) and depth as the number of sources they assigned a high importance to.

With regards to governmental support/pressure, we add dummy variables indicating whether the firm received public funding for their innovation activities and whether it perceived regulatory pressure as an important obstacle to its innovation activities.

Control variables

We control for several other factors that may influence the estimation results of our core variables. These control variables capture regional differences (whether the firm is located in East Germany) and a firm's size (number of employees in logs). We capture the effects from internationalization (share of exports of sales) and remaining industry effects through variables on whether a firm operates in medium high-tech manufacturing (e.g. automotives) or high-tech manufacturing (e.g. medical equipment). A detailed industry breakdown is provided in Appendix A. "Other manufacturing" (e.g. food and tobacco) will be the comparison group for all subsequent steps of the analysis.

Model and method

We choose a standard ordinary least squares regression model for estimation. One might argue that the investments in absorptive capacities are already reflected in the sources used (breadth and depth). We add absorptive capacity and munificence variables stepwise to the model and present both results. Effects should be consistent in both models.

Appendix B provides a detailed overview on the characteristics of firms that conduct sustainable innovation activities divided by the median of the sustainable innovation scale. On average, these firms focus on resource and energy saving sustainable innovation activities followed by health and safety and environmental ones. They rely on a broad set of external sources for innovation (roughly 7) but high importance is assigned to just a single one. Firms with high sustainable innovation scale values invest more into the training of their employees and R&D. They feel more pressured by regulatory demands but are not more likely recipients of public R&D funding.

While this prima facie comparison is an early indication for the accuracy of our theoretically derived hypotheses these firms also differ in other important characteristics. They are on average larger, less frequently located in East Germany and less likely to be found in high-tech manufacturing industries. Hence, a multivariate analysis is required.

5 Results

Table 1 provides the results of the estimation. Our sample consists solely of firms with successful innovation activities. One should bear in mind that we measure differences between them with regards to sustainable aspects of innovation but not their general propensity to innovate. Focusing on the model specifications (Model I and its extension II), significant effects are consistent. Adding munificence variables increases the overall fit of the model considerably.

- Table 1 about here -

The estimation results reveal that investments into absorptive capacities for sustainable innovation are focused on investing in employees (positive effect of training expenditures) while investments in R&D (negative effect) are detrimental. This result holds both on the firm and the industry level (negative, significant effect on high-tech industry dummy). Therefore, Hypothesis Ia has to be rejected while Ib is supported. Continuous R&D activities, often associated with having a dedicated R&D department as a nexus of innovation engagements and learning, show no significant effect. This may be an indication for the multi-functional nature of sustainable innovation (Hall and Vredenburg, 2003).

With regard to the munificence of the environment both the breadth and depth of external innovation sources have a positive significant effect. Hypotheses IIa and IIb can be accepted. Interestingly, the effect of breadth is stronger. Direct regulatory pressure has a significant positive effect on sustainable innovation engagements while public funding produces no significant effect. Hypothesis IIIa is supported while IIIb has to be rejected. Control variables have no significant impact, except for firm size, which propels sustainable innovation, and the already mentioned negative effect in high-tech manufacturing. The degree of internationalization as measured by the share of exports of total turnover turns out to have no effect either. This indicates that multinational companies are not per se more likely to develop sustainable innovation capabilities although they face a much more diverse pressure from their environment.

6 Discussion and implications

This analysis focuses on the processes that allow firms to develop sustainable innovation capabilities. We suggest conceptually that the knowledge required for successful sustainable innovation is both more complex and more uncertain than for traditional innovation engagements. We argue that this needs to be reflected in a firm's investments in absorptive capacities and the breadth and depth of their learning engagements.

Our findings directly translate into management recommendations on how to strengthen or develop sustainable innovation capabilities. We find strong benefits of investing in the training of employees as opposed to technological R&D. We suggest that the merits of internal R&D may be limited as important technological impulses for sustainable innovation appear outside a firm's traditional fields of technological expertise (Shrivastava, 1995). Technological breakthroughs in energy storage and batteries for fuel efficient hybrid car production may be a fitting example. Motivated and well trained employees may give firms broader interfaces to deal with a multitude of potential stakeholders in the environment. This includes not only the ability to collect impulses but also to set priorities and choose the crucial ones.

This line of reasoning resonates immediately with our findings on the breadth and depth of innovation impulses. The former represents the potential of ideas for a company while the latter implies boiling them down to a few important ones to act on efficiently (Jansen et al., 2005). Both are important for sustainable innovation capabilities. Apparently, breadth is even more important than depth. We suggest that the dangers from blind spots or betting on the wrong horse are especially pronounced in sustainable innovation. Firms may hedge against long-lasting reputation effects from individual failures or cases of malpractice. Finally, we find that firms respond to the traditional mechanisms of regulatory intervention when it comes to sustainable innovation. In that sense, sustainable innovation may not just be a chosen capability but also a mandatory one.

7 Limitations and further research

Our analysis is constrained by certain limitations which may in turn provide opportunities for further research. First, our empirical analysis is limited to Germany. The country has a large tradition of societal, political and regulatory awareness for environmental challenges. In fact, Germany has been frequently characterized as a lead market for sustainable innovation (Beise-Zee and Rennings, 2005). However, it may not be representative for other countries with different backgrounds and structures. Hence, we encourage comparative studies, for which harmonized European CIS data may be an excellent platform. Second, our findings on the link between openness to external ideas, internal absorptive capacities and successful sustainable innovation beg more in-depth analysis. Third, we capture only a single point in time. Sustainable innovation, however, follows long-term orientations that should be explored through longitudinal data.

8 Appendix

Appendix A: Industry classification

Industry	**NACE Code**	**Industry Group**
Mining and quarrying	10 – 14	Other manufacturing
Food and tobacco	15 – 16	Other manufacturing
Textiles and leather	17 – 19	Other manufacturing
Wood / paper / publishing	20 – 22	Other manufacturing
Chemicals / petroleum	23 – 24	Medium high-tech manufacturing
Plastic / rubber	25	Other manufacturing
Glass / ceramics	26	Other manufacturing
Metal	27 – 28	Other manufacturing
Machinery and equipment	29	Medium high-tech manufacturing
Electronics	30 – 32	High-tech manufacturing
Medical, precision and optical instruments	33	High-tech manufacturing
Motor vehicles	34 – 35	Medium high-tech manufacturing
Furniture, jewellery, sports equipment and toys	36 – 37	Other manufacturing
Electricity, gas and water supply	40 – 41	Other manufacturing
Construction	45	Other manufacturing

Appendix B: Descriptive Statistics

Variables	Full sample		Above median sustainability scale		Below/equal median sustainability scale	
	Mean	*Std. Dev.*	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*
Innovation outcome: Resource/energy cost reduction (max. 3)	1.21	0.94	1.82	0.87	0.74	0.69
Innovation outcome: Reduction of environmental stress (max. 3)	0.96	0.92	1.71	0.80	0.38	0.51
Innovation outcome: Improvement of health/safety (max. 3)	1.00	0.95	1.76	0.80	0.41	0.55
Training expenditures per employee (€)	1.04	2.01	1.15	2.56	0.95	1.46
R&D expenditures as share of sales (ratio)	0.04	0.07	0.03	0.06	0.04	0.08
Continuous R&D activities (dummy)	0.47	0.50	0.52	0.50	0.43	0.50
Breadth of innovation sources (index)	6.69	2.02	7.18	1.85	6.31	2.07
Depth of innovation sources (index)	1.18	1.17	1.34	1.26	1.05	1.08
High regulatory pressure on innovation activities (dummy)	0.11	0.32	0.15	0.36	0.09	0.28
Public funding for innovation projects (dummy)	0.29	0.45	0.29	0.45	0.28	0.45
Location in East Germany (dummy)	0.30	0.46	0.27	0.45	0.32	0.47
No. of employees	276.01	637.06	370.71	771.99	202.50	496.54
Share of exports of turnover (ratio)	0.26	0.27	0.28	0.269	0.25	0.26
Other manufacturing (dummy)	0.58	0.49	0.59	0.49	0.57	0.49
Medium high-tech manufacturing (dummy)	0.27	0.44	0.30	0.46	0.25	0.43
High-tech manufacturing (dummy)	0.15	0.36	0.12	0.32	0.18	0.39
Observations	1,124		493		635	

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Table

Table 1: Estimation results

	Model I			Model II		
Variable	*Coeff.*		*Std. Err.*	*Coeff.*		*Std. Err.*
R&D expenditures as a share of sales (ratio)	-0.64	*	0.38	-1.06	***	0.34
Training expenditures per employee (€)	0.40	***	0.01	0.32	***	0.01
Continuous R&D activities (dummy)	0.10		0.07	0.02		0.06
Breadth of innovation sources (index)				0.09	***	0.01
Depth of innovation sources (index)				0.05	**	0.02
High regulatory pressure on innovation activities (dummy)				0.37	***	0.08
Public funding for innovation projects (dummy)				-0.01		0.06
Location in East Germany (dummy)	-0.16		0.59	-0.03		0.05
No of employees (logs)	0.09	***	0.02	0.05	***	0.02
Share of exports of turnover (ratio)	-0.26		0.11	0.03		0.12
Medium high-tech manufacturing (dummy)	0.45		0.06	0.05		0.06
High-tech manufacturing (dummy)	-0.21	***	0.07	-0.23	***	0.05
Constant	-0.43	***	0.07	-0.92	***	0.08
Number of obs:	1,124			1,124		
Wald chi2 (12):	113.01			233.30		
Prob > chi2:	0.00			0.00		
R-squared:	0.06			0.13		
Adj R-squared:	0.05			0.12		
Root MSE:	0.82			0.79		

***, **, * indicate significance at the 1%, 5% and 10% level; bootstrapped standard errors