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by

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Role of Human Resource Practices in Absorptive Capacity and R&D Cooperation

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Abstract

While significant attention is given to the concept of absorptive capacity as a source of competitive advantage in firms, a major drawback exists in the way it is unidimensionally defined in micro-level analysis. The paper addresses this limitation and reconceptualizes absorptive capacity as a strategic human resource construct in firms, which in turn, provide important conditions for R&D cooperation and innovation. I begin by providing a "beyond-R&D" definition of absorptive capacity constituting employment practices and incentive-based compensation programs. Next, I exploit the relationship between these practices and heterogeneity in firms' R&D cooperation and partner selection strategies distinguishing between different types of external collaboration partners- horizontal, institutional and consulting-based. Further, I examine the impact of such cooperative R&D on incremental product, process and radical innovation. Employing the IAB Establishment Panel Survey on about 1200 German innovation-based establishments during 2007-2011, findings demonstrate that adoption of employment practices positively affects R&D cooperation irrespective of the type of collaboration partner, while compensation programs positively affect only horizontal R&D cooperation. Significant differences in the patterns of research collaboration are found between manufacturing and service sector firms, with respect to importance of human resource management, educational structure of the workforce and internal R&D. Finally, cooperative R&D with research institutes and consulting firms are found to have significantly positive impact on the likelihood of coming up with incremental product, process and radical innovation, but the effect is relatively weak in case of horizontal R&D cooperation.

Keywords: *Absorptive capacity; strategic human resource; employment practices; compensation programs; R&D cooperation; innovation*

JEL Classification: J21, J24, J33, L20, M12

1 Introduction

The resource-based view of the firm attributes differences in performance across firms to the heterogeneity in their resources and capabilities (Wernerfelt 1984, Barney et al. 2001). Beside investments in physical and tangible assets like machinery, infrastructure and other financial assets, firms' resource endowments may vary with regard to investment in intangible assets like R&D, expenditures that underlie organizational practices, and investments with respect to human capital. On the micro level, human capital is extensively discussed as the basis for firms' competitive advantage, performance and technological innovation and measured in terms of recruitment of high-skilled workers, career paths of employees, mobility of star scientists and geography of labor inputs (Kim and Marschke 2001, Song et al. 2003, Audretsch and Stephan 1996, Almeida and Kogut 1999, Breschi and Lissoni 2001, Simonen and McCann 2008, Boschma et al. 2009). Human capital is also linked to the literature on "absorptive capacity" (Cohen and Levinthal 1990) showing that firms' innovative capabilities and learning abilities are enhanced by their existing stock of human capital (Lofstrom 2000, Minbaeva et al. 2003, Hatch and Dyer 2004).

Although the importance of human capital is greatly acknowledged in the above studies, in a world with rapidly changing knowledge boundaries, firms cannot rely solely on internal human capital stock to be on par with latest technological requirements. Efficient interaction with external knowledge networks, and successfully broadening the scope of acquisition, assimilation and absorption of external knowledge are equally important. Building on this cue, several authors examine the complementarity between human capital and external collaboration to explain firms' performance, by estimating human capital using stock-based indicators such as share of hired experts in total workforce (Song et al. 2003), share of employees in R&D or with high level of qualification and skill (Rothwell and Dodgson 1991), share of trained employees (Muscio 2007) and accumulation of on-the-job experience (Cooper et al. 1994). Most of these studies verify that greater human capital stock combined with external knowledge is a *necessary* condition for greater firm performance. However, the very mechanism through which access to external knowledge results in greater performance is seldom discussed. To be able to successfully "integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece et al. 1997, p. 516), firms are required to continuously develop and upgrade their knowledge base, that is, the knowledge embedded in the minds of their human resources. External acquisition of R&D experts can be one aspect, the other may work through implementation of human resource management (HRM) practices that aim at increasing employees' competencies, learning, creative-thinking (Huselid 1995, Lane and Lubatkin 1998), motivation and commitment (Lawler 1971, Lazear 1999), their ability to effectively absorb and utilize external knowledge and promote knowledge sharing within and between organizations (Laursen and Mahnke 2001). Such practices not only increase the absorptive capacity of the employees, thereby firms' overall knowledge stock and internal capabilities, but also provide conditions for building and managing social capital and increasing firms' innovative capabilities. Yet, research in this direction has been surprisingly scarce.

The present paper addresses this caveat of existing research by considering HRM as an important strategic asset in organizational value creation and development of absorptive capacity, that is necessary for systematically managing external knowledge embedded in R&D cooperation relationships and stimulating innovation performance. By definition

(Ichniowski et al. 1995), human resource management encompasses employment practices such as access to training, quality workshops, job rotation and departmental restructuring, skill-adaptation, self-learning, as well as incentive and compensation schemes in the form of profit sharing, stock and bonuses. On this basis, the main implication of the paper is that existing literature underestimates the extensive construct of organizational absorptive capacity by considering only R&D and stock-based human capital indicators to analyze conditions for benefiting from external collaboration. Therefore, drawing inspiration from the resource-based view of firm (RBV), strategic management (SM) and industrial organization (IO) literature, I provide a broader definition of absorptive capacity incorporating firms' human resource practices and address the following two research questions for private-sector German establishments during 2007-2011.

- Do human resource practices determine the likelihood of having external knowledge linkages in the form of R&D collaboration and the choice of cooperation partners?
- Do such cooperative R&D have a significant impact on firms' incremental and radical innovation performance?

The remainder of the article is organized as follows: Section 2 gives the conceptual background and formalization of the hypotheses. Section 3 introduces the data and construction of the variables. Section 4 describes the empirical strategy used to test the hypotheses. Section 5 summarizes main results and Section 6 concludes the paper with implications for policy intervention.

2 Background

2.1 Human resource practices and absorptive capacity

Successful innovation requires development of new knowledge that can be acquired through external sources, developed internally or both. In the context of internal knowledge building and knowledge management, firms' human resource practices present an important attribute. Human resource practices are typically defined in the strategic management and human resource management literature as organizational programs that allow employees to draw on knowledge and competencies inside and outside the firm in an efficient way (Lado and Wilson 1994, Huselid 1995, Ichniowski et al. 1999, Baron and Kreps 1999, Vinding 2006, Bontis and Fitz-enz 2002, Collins and Smith 2006, Laursen and Mahnke 2001). Usually, they constitute a) employment practices like internal and external training programs, delegation of responsibility, job rotation, provision of quality workshops, and b) performance related incentive and compensation schemes. These human resource practices are found to enhance employee trust and loyalty, increase their productivity, abilities to cooperate and exchange knowledge and foster intra- and inter-organizational learning (Lane and Lubatkin 1998). Subsequently, these studies have examined the economic impact of such practices, applied in isolation or in various combinations, on individual and firm performances, measured in terms of productivity, turnover, sales growth and innovation among others.

Even though the aforementioned studies enhance our understanding on internal organizational settings and their effect on various firm characteristics, they are constrained on two major grounds. The first criticism relates to a methodological limitation, while the

second considers a conceptual drawback. The methodological issue is based on the fact that most of the existing studies are cross-sectional in nature and therefore do not take into account the potential simultaneity between adoption of human resource practices and performance indicators. In other words, better performing firms are more likely to adopt relatively better human resource practices than low performing firms which might systematically bias the estimation results. In order to account for this identification problem, it is therefore essential to take into account a time horizon and then estimate the relationship between the two.

The second limitation lies in the fact that although human resource practices and occupational relations contribute to the internal human capital development and value creation in firms, they are not explicitly considered as determinants of firm-level absorptive capacity in explaining its relationship with various economic variables (profitability, cooperation decisions). Prior research incorporating human resource practices looks at factors that affect the degree and extent to which these practices are adopted and implemented across firms; such as differences in the types of manufacturing-technology used in firms (Jackson et al. 1995), the sectors they belong to (Laursen and Mahnke 2001), workforce size, education and skill structure (Osterman 1995), gender (Veum 1996), presence of employee representation like works councils or trade unions (Roy et al. 2014, Addison et al. 2004), geographic location (Simonen and McCann 2008), social networks of top management teams (Collins and Clark 2003; Williamson and Cable 2003; Kase, Paauwe and Zapan 2009) and employer networks (Erickson and Jacoby 2003). Looking next at the literature on absorptive capacity, following Cohen and Levinthal's (1990) seminal paper, researchers have come up with different variants of the concept in explaining organizational knowledge stock and performance. Absorptive capacity is defined in terms of traditional R&D variables such as in-house R&D expenditure (Cohen and Levinthal 1990), new product development (Stock et al. 2001), publications and co-authorship (Cockburn and Henderson 1998), patents (Zhang et al. 2007), external sources of knowledge such as R&D cooperation relationships (Tsai 2001), years of experience (Cooper et al. 1994) or optimal cognitive distance (Nooteboom et al. 2007). It is also related to human capital indicators such as acquisition of research personnel (Song et al. 2003), share of trainees in total workforce and firm's prior knowledge base and education-skill composition (Rothwell and Dodgson 1991). Studies in strategic management have shifted focus from the traditional indicators to organizational forms and routines, social integration mechanisms and potential and realized absorptive capacity (Lane and Lubatkin 1998, Van Den Bosch et al. 1999, Zahra and George 2002, Vinding 2006). Lane and Lubatkin (1998), for example, define absorptive capacity as a dyad-level learning phenomenon and claim that a firm's ability to absorb and learn from external knowledge depends not only on R&D-related activities but on the extent to which its knowledge-processing systems, organizational structures and dominant ideologies are similar to the partner firm. Van Den Bosch et al. (1999) consider organization forms (functional form, divisional form, matrix form) and combinative capabilities (system capabilities, coordination capabilities, socialization capabilities) as main determinants of absorptive capacity, *ceteris paribus* the level of prior knowledge. Zahra and George (2002, p. 198) propose a multi-dimensional definition of absorptive capacity based on the dynamic capabilities view of the firm and highlight the importance of "organizational routines and strategic processes by which firms acquire, assimilate, transform and exploit knowledge by transforming acquired knowledge". Murovec and Prodan (2009) provide a direct measure of organizational absorptive capac-

ity by distinguishing between demand-pull and science-push theories and test this using a cross-national structural model. Similar studies are conducted by Jensen et al. (2007), Jansen et al. (2005), Vega-Jurado et al. (2008), Camisón and Forés (2010) who redefine absorptive capacity in terms of organizational mechanisms, coordination capabilities, informal processes of learning, managerial knowledge and social integration mechanisms.

Building on the above discussion, the current paper goes beyond the traditional conceptualization of absorptive capacity and considers human resource practices as a crucial element of knowledge creation in firms. Human resource practices in the form of internal and external training programs influence learning capabilities in employees through upgrading of skills and competencies regarding latest technological developments and market needs, contributing significantly to organizational knowledge stock. Employment restructuring programs such as quality workshops and job rotation allow for decentralization of responsibilities, integration of functions and distribution of localized knowledge across individuals and departments (Ichniowski et al. 1999, Jensen and Meckling 1992, Inkpen 1996, Kase et al. 2009). Cross-functional teams result in interactive learning, open communication, social integration and greater combinative capabilities of firms (Kogut and Zander 1992). This is one side of the story, which henceforth I refer to as employment practices. On the other side, performance-based reward system such as bonus or stock options foster employee satisfaction and curb opportunistic behaviors (Coriat and Dosi 1998), providing incentive for greater efforts, increased efficiency and organizational knowledge building (Bollinger and Smith 2001). Taken together, these practices enhance employee abilities as well as employee motivation and contribute significantly to individual as well as organizational absorptive capacities. However, this very link between organizational absorptive capacity and human resource practices has remained vastly unexplored, both in theory and practice.

2.2 R&D cooperation and human resource practices

Over the past few decades, there is a steady growth in the number of studies on inter-firm relationships in the form of strategic alliances, supply-chain cooperation, public-private collaborations, research joint ventures, and virtual company networks. Openness towards knowledge sharing usually involves two levels of commitment; one being the willingness to participate in strategic alliances, which can include marketing, sales or other non-R&D related functions, and the other being collaboration in product and process development or completion of an innovation. Prior studies find that firms with external knowledge linkages benefit from exploiting similar/complementary knowledge and internal resources (Shan et al. 1994, Lee et al. 2001, Becker and Dietz 2004, Cantner and Meder 2007), positive internalization of spillovers (Kaiser 2002), increased efficiency through economies of scale and scope (D'Aspremont and Jacquemin 1988), reduced transaction and organizational costs and increased capabilities and strategic endowments (Prahalad and Hamel 1993), which subsequently influence their innovative performance (Nooteboom et al. 2007).

In the context of R&D cooperation, four main areas of interest are highlighted in the literature (Veugelers 1997, Becker and Peters 2000, Hagedoorn 2002, Cassiman and Veugelers 2002, Kaiser 2002, Vinding 2006): a) what factors determine a firm's R&D collaboration strategies, that is, whether or not to form cooperation networks for research and development, b) what determines the choice of appropriate cooperation partners, c)

how to efficiently manage external knowledge networks, and d) how efficient utilization of cooperation networks is complemented by absorptive capacity and how that subsequently affects firm performance. With regard to determinants of firms' R&D cooperation strategies and partner selection, industrial organization literature suggests own R&D activities, magnitude of research spillovers, appropriability mechanism and presence of high-skilled researchers (D'Aspremont and Jacquemin 1988, Kaiser 2002, Belderbos et. al 2004, Cassiman and Veugelers 2002, Simonen and McCann 2008) as major determinants of research collaboration. D'Aspremont and Jacquemin (1988) employ a theoretical model to show that investment in own R&D builds absorptive capacity, maximizes incoming spillovers and minimizes outgoing spillovers, thereby ultimately affecting R&D cooperation decisions. Kaiser (2002) empirically tests whether R&D expenditures affect the propensity of firms to form a research joint venture and finds that on average cooperating firms invest more in R&D than non-cooperating firms. However, there exists significantly weak but positive effect of horizontal spillovers, on the probability of R&D cooperation but no effect on the choice of vertical or mixed cooperation. Similarly, Franco and Gussoni (2010) find that firms who are better able to maximize incoming spillovers and minimize knowledge leakage will prefer a mix of heterogeneous collaboration partners over a single partner relationship. Belderbos et al. (2004) explore the heterogeneity in firms' partner-selection strategies and find significant differences with respect to incoming spillovers and R&D intensity between horizontal, vertical and institutional cooperation. Other studies on the choice of R&D cooperation partners are conducted by Mowery et al. (1996), Boschma (2005), Cantner and Meder (2007) who find technological proximity/overlap, managerial tools and individual incentives as main determinants of R&D cooperation partners. Miotti and Sachwald (2003) find complementary R&D resources to be the determining factor, and, Muscio (2007) finds significant effects of R&D employment, skilled human capital and innovative activities on the choice of cooperation partner in firms.

The literature mentioned above indicate that different kinds of R&D cooperation partners reflect different appropriation mechanism and differences in the extent of spillovers with respect to R&D activities. In contrast, studies in strategic management literature emphasize on the importance of 'relative' absorptive capacity (Prahalad and Bettis 1986, Lane and Lubatkin 1998) and organizational similarities among partner firms as the most important criteria for alliance-formation. By similar arguments, one could expect significant differences in the type of collaboration partners with regard to the human resource construct in firms. Looking first at employment practices such as job-training, restructuring of responsibilities and external acquisition of labor, it is sensible to think that firms providing greater training and employability conditions are more willing to engage in cooperation relationships to be better able to exploit and absorb complementary knowledge of their partners than firms with lower investment in human capital. This argument is equally valid for all types of cooperation partner, since investment in human resources stimulate employee as well as organizational competencies in general and, consequently, derive greater benefits from collaboration agreements. Therefore, such employment practices are expected to be an important determinant of firms' R&D cooperation strategies, irrespective of the type of collaboration partner. Based on this consideration, the paper draws distinction between three types of R&D cooperation relationships (Tether 2002)- cooperation with other private establishments (horizontal), cooperation with universities and research institutes (institutional), and cooperation with consulting firms (consultation-based), and propose the following hypothesis:

Hypothesis 1: Adoption of employment practices positively affects R&D cooperation with competitors and other private firms, research institutes and universities as well as with consultation-based firms.

With respect to incentive and compensation-based programs as determinants of cooperation, however, significant differences are expected between R&D cooperation with private establishments, with research institutes and with consulting firms. The literature on outgoing spillovers provides mixed reviews on the effect of firms' appropriability conditions on the probability of cooperation. While on the one hand, greater protection in the form of intellectual property rights, patents and copyrights serves as a shield against value misappropriation (Cassiman and Veugelers 2002), it also reduces the scope of acquisition and assimilation of external knowledge on the other (Lopez 2008). Therefore firms often resort to employment protection in the form of bonuses and performance-based incentives to ensure job-loyalty on part of the employees. However, such a reward system is likely to have different effects on the probability of R&D cooperation relationships depending on the types of partners. For example, in case of private cooperation or cooperation with competitors having symmetric knowledge profile and innovation activities, employee protection is crucial given the high risks associated with employee turnover and poaching. This might not be relevant when the cooperation partner is a research institute or consulting firm, who have significantly different organizational settings, employment portfolio and appropriation mechanism. Therefore, provision of flexible performance-based compensation is more likely to be associated with research cooperation with private establishments but not necessarily with research institutes or consulting firms. Accordingly, the following hypothesis is put forward:

Hypothesis 2: Compensation programs positively affect R&D cooperation only with competitors and other private firms.

In addition, distinction is drawn between manufacturing and service sectors, and firms' R&D cooperation strategies are re-estimated. Due to unavailability of empirical data on various aspects of innovation in service sector firms, studies in innovation economics focus mostly on manufacturing firms for explaining R&D, cooperation and innovation patterns. However, given the rising importance of service sectors in today's knowledge-intensive economy (Drejer 2004, Hipp and Grupp 2005), it is essential to consider both manufacturing and service sectors to provide an integrated theory of industry behavior. The third hypothesis therefore tests if there exist significant differences between manufacturing and service firms with regard to adoption and diffusion of human resource practices, and consequently, on R&D cooperation strategies and partner-type. The intuition here is that manufacturing firms differ from firms belonging to the service sector with respect to organizational and employment structures, spillover conditions and appropriability mechanisms, and therefore there should be important variation in their respective cooperation and partner selection strategies.

Hypothesis 3: There exist significant differences with respect to R&D cooperation strategies between manufacturing and service firms.

2.3 Human resource practices, R&D cooperation and innovation performance

The effect of human resource practices on firm performance has been subjected to extensive discussion in the past few decades. Previous literature in the fields of industrial organization and strategic management claim that human resource practices in the form of high-performance work practices improve employee skills and competencies, their motivation to perform and reduce turnover by ensuring loyalty and commitment. This in turn encourages greater individual and firm performance, measured mostly in terms of productivity (Huselid 1995, Datta et al. 2005), turnover and financial performance (Huselid 1995), sales growth and stock growth (Collins and Clark 2003), and innovation performance (Laursen and Foss 2003, Vinding 2006, Chen and Huang 2009).

Digging deeper into the relationship between human resource practices and firm performance, the following issues arise. Employment practices in the form of external and internal training programs continuously upgrade employee skills and combinative capabilities, allowing them to keep up with latest technological developments. Given that investment in human resources is not easily imitated, firms often provide continuous training to employees in the form of technical workshops and skill improvement programs that increase functional efficiency and produce greater returns in the long run. New hiring allows firms to select from a pool of qualified personnel a set of employees that provide perfect fit to organizational requirements and innovation strategies. Employment restructuring such as job rotation, quality workshops and cross-functional teams ensure open communication between department leaders and regular employees thereby encouraging involvement, cooperation and knowledge exchange among employees. Additionally, such practices increase discretionary efforts of employees (Becker and Huselid 1998) by allowing them to be responsible for planning and controlling their own tasks, thereby significantly improving individual and firm productivity and performance. Incentive and compensation schemes such as bonuses and profit sharing, on the contrary, align the interests of employees with that of the firm and motivate workers to put additional efforts into tasks and individual performance. This increases overall performance of the firm, measured among others in terms of productivity, turnover or innovation outcome.

With regard to R&D cooperation and firm performance, theoretical predictions and empirical evidence suggest that R&D cooperation enables firms to internalize incoming spillovers (D'Aspremont and Jacquemin 1988, Kaiser 2002), reduce cognitive distance between partners (Nooteboom et al. 2007), lower operational risks and maximize market control (Teece 1980), increase efficiency (Kogut 1988) and consequently innovation performance. Most of these studies find a positive impact of R&D cooperation relationships on firm performance, with significant differences within industries (Fritsch and Lukas 2001), between types of cooperation partners (Belderbos et al. 2004, Cassiman and Veugelers 2005), and measures of performance used (Becker and Dietz 2004, Okamuro 2007).

While existing literature analyzes in isolation the role of human resource practices on the one hand and R&D cooperation on the other hand in firm performance and innovation, no attempt is made so far to consider the predictive capability of human resource practices in determining the effect of cooperative R&D on innovation performance. What is investigated so far is the interplay between firms' absorptive capacity measured in terms of R&D activities and external knowledge sources and how they affect development and

introduction of new products or processes to the market. Few studies also extend the concept of absorptive capacity to a human capital framework and test the joint effect of human capital and openness to external knowledge on firm performance. Vinding (2006), for example uses data on manufacturing and service firms from the DISKO and IDA database and shows that human resource practices adopted within the firm combined with external knowledge promotes the ability to innovate. Simonen and McCann (2008) investigate innovation in firms by looking at the geography of human capital acquisition and find significant effects of inter-firm R&D cooperation on innovation on one hand and human capital inputs acquired from other regions on innovation on the other. On the same note, Lee et al. (2001), Escribano et al. (2009) and Gao et al. (2008) examine the influence of managerial networks and internal capabilities on innovation. Other studies on the importance of human capital and human resource practices in firm performance are proposed by Ichniowski et al. (1995), Huselid (1995), Laursen and Foss (2003, 2012), Collins and Clark (2003), Collins and Smith (2006), and Chen and Huang (2009), all of which find a positive relationship albeit to various degrees. This can be one aspect, the other may be related to the indirect effects of firms' human resources and organizational practices on innovation performance through cooperative R&D. Increased knowledge absorption and diffusion capabilities in employees, through implementation of human resource practices, can be expected to augment incremental and radical innovation performance of firms having external R&D collaboration relationships. This follows from the theoretical understanding that greater absorptive capacity allows for efficient utilization of external knowledge, resulting in firms' increased likelihood of introducing new or improved products or services to the market. Accordingly, the final three hypotheses explore the effects of variation in cooperative R&D strategies predicted by firms' human resource programs on innovation output, distinguishing between incremental product innovation, process innovation and radical innovation.

Hypothesis 4a: R&D cooperation positively affects incremental product innovation.

Hypothesis 4b: R&D cooperation positively affects incremental process innovation.

Hypothesis 4c: R&D cooperation positively affects radical innovation.

3 Data and variable description

The empirical analysis is based on data from the IAB Establishment Panel, which is a representative employer survey on corporate indicators of investment, employment practices and innovation activities at establishment-level. The data is carried out orally by way of personal interviews and consists of information on innovation firms across all sectors in Germany. The IAB Establishment Panel has been in existence in western Germany since 1993 and in the east since 1996 and covers information from 1993-2011. Information collected includes (1) general data on the participating establishment such as total number of employees, ownership structure, operational investments, sales, sectoral affiliation, employee representation (2) employment structure such as educational background of employees, skill mix, employment groups, vacancies, operational working hours, personnel movement and recruitment, (3) human resource practices such as training, advanced training measures, employee participation in profits and capital, vocational

traineeships, salaries and wages, and (4) innovative activities and R&D cooperation. The current analysis is conducted using survey data from 2007-2011 since information on R&D, cooperation structure and innovation activities of establishments is available for three data points (2007, 2009 and 2011). All explanatory variables used in the analysis are lagged by 2-years in the estimation, and therefore the first year of estimation is 2009. The final sample consists of about 1200 innovating firms. The following section provides an overview of the variables used in the analysis (see Table 8 in Appendix for detailed description of the variables).

3.1 Measures of absorptive capacity

Two measures of absorptive capacity are provided, the first one based on human resource practices and the second using traditional measure.

Measure 1: As previously mentioned, human resource practices are categorized into two groups: (i) Employment practices, where establishments are asked if they have supported training courses in the current year and their choice is indicated by a binary variable (yes/no). Furthermore, establishments are asked if they have offered other/advanced on-the-job training such as external or internal training courses, seminars and workshops, initial skill adaptation training, training in self-learning, employment restructuring such as job rotation and quality workshops. Each of these variables is reported with a yes/no and therefore indicated by dichotomous variables. This measure also includes information on hired personnel and is given by a binary variable indicating whether an establishment has hired qualified high-skilled personnel during the first half of the current year; (ii) Compensation programs, which indicate whether establishments offer additional financial incentives (mostly performance-based) for employees and is given by two binary variables, profit-sharing and staff sharing arrangements for employees. Since the questionnaire consists of several variables corresponding to human resource practices, a confirmatory factor analysis based on tetrachoric correlation is conducted in order to reduce the number of regressors in the estimations. Based on the factor loadings of these human resource practices, two indices for the first two factors are created and interpreted as employment practices and incentive programs (see Table 6 in Appendix). Next, the average of the scores for all items under each category is computed for each establishment and then recoded on a scale of 0-1. These two variables constitute the main variables of interest in the analysis.

Measure 2: Following existing literature, a second measure of absorptive capacity is provided that reflects firm's willingness to undertake innovation activities. In that sense, R&D intensity is calculated as the ratio of part-time and full-time R&D employees to total employees for each establishment.

3.2 Measure of skill and educational background

Skill structure and educational background of employees are given by two variables viz. share of skilled blue collar and white collar workers requiring a vocational education and share of qualified white collar employees requiring a university degree in the total workforce.

3.3 Measure of physical investments

Establishments are asked to indicate (yes/no) whether they have made operational investment in one or several of the areas such as real estate, information and communications technology, electronic data processing, production facilities and transportation systems. Each of these are denoted by binary variables, and then recoded as a single variable for overall operational investment.

3.4 Measure of innovative activities

For innovation output, commonly-used indicators are employed, such as whether the enterprise has improved or further developed a product or service (measure for incremental product innovation), whether the establishment has developed or implemented procedures that have improved production processes or services (measure for incremental process innovation) and whether the enterprise has offered a completely new product or service to the market (measure for radical innovativeness). Each of the three variables are indicated by binary (yes/no) values.

3.5 Measure of R&D cooperation

The measure for R&D collaboration, given by whether or not research and development is carried out in cooperation with others, is indicated by a binary variable (0/1). Furthermore, establishments who cooperate in R&D are asked to specify the kind of cooperation partners they have: other private establishments and competitors ('horizontal'), universities or research institutes ('institutional'), or consulting firms ('consulting'). Each of these three variables are given by dichotomous variables.

3.6 Control variables

A wide range of establishment-level, industry-level and market-level control variables are included in the analysis. Drawing on literature that finds a significant relationship between firm size and the probability of conducting R&D (Cohen et. al 1987, Cohen and Klepper 1996), establishment size is used to control for the level of R&D activities and is given by the natural logarithm of total workforce. Sector affiliation of establishments is given by 2-digit NACE industry classification and included in the analysis as dummies (for construction of aggregated sector dummies, see Table 7 in Appendix). Additional controls, such as whether establishment belongs to east/west Germany, whether establishment is part of a multi-establishment and whether the establishment is an individually-owned firm or a partnership are included. New hiring is given by a binary variable denoting whether the establishment has hired new staff in the previous year. Establishments are asked to assess the overall technical state of the plant in terms of technology, machinery, office equipment on a scale of 1-5 with 1 being state-of-the-art and 5 being obsolete. Finally, pressure from competition that the establishment has to deal with is added as a market-level control and is denoted by a categorical variable ranging from 1-4 with 1 being no competitive pressure and 4 being substantial pressure from external competition.

4 Methodology

In order to determine the relationship between firms' R&D cooperation strategies and human resource practices, the following equation is estimated:

$$Coop_{i,t} = \beta_1 + \beta_2 Empl. \text{ practices}_{i,t-2} + \beta_3 Compensation_{i,t-2} + \beta_4 R\&D_{i,t-2} + \beta_5 Z_{i,t} + \epsilon_{i,t} \quad (1)$$

where $Coop_{i,t}$ represents three binary equations, each represented by a dummy variable for each type of cooperation- with competitors and other private enterprises, with universities and research institutes and with consulting firms, respectively. $Empl. \text{ practices}_{i,t-2}$, $Compensation_{i,t-2}$ and $R\&D_{i,t-2}$ denote 2-years lagged variables on employment practices, compensation programs and R&D intensity respectively. $Z_{i,t}$ indicates the additional core and supplementary variables and $\epsilon_{i,t}$ is the unobserved error term. The main independent variables of interest are lagged by 2 years for two reasons. First, to reduce the potential simultaneity problem in the sense that while greater investment in human resource practices increases the likelihood of having a research collaboration, firms cooperating in R&D are also more likely to invest more in human resource practices. Second, R&D cooperation decisions requires past information on market and firm characteristics, which makes it necessary to use data from previous years to estimate collaboration strategy in the current year.

Earlier studies (Belderbos et al. 2004, Carboni 2010) find that the choice of a collaboration partner is not independent of another. In other words, the probability of having one type of cooperation partner is correlated with that of having the other type(s), therefore not accounting for such systematic correlations would produce biased results. Belderbos et al. (2004) employ a multivariate probit estimation in order to account for such systematic correlations among different cooperation partners. Kaiser (2002) uses a nested multinomial logit model in order to incorporate a sequential process, where firms decide whether to collaborate in R&D in the first stage and whom to collaborate with in the second. This specification implies that the second stage of the decision making process matters for the first stage, which might not be appropriate given that firms decide simultaneously upon research cooperation and the type of partners. Franco and Gussoni (2010) use a multinomial logit estimation assuming that the probability of choosing one type of collaboration partner is stochastically independent from the probability of choosing other types of partners. However, a potential problem with this approach is that in the presence of possible interdependencies between R&D cooperation strategies, estimates may turn out to be inefficient. This is indeed the case in this context, as it is highly likely that the three cooperation strategies are not independent of each other (see Table 9 in Appendix for correlation table). The multivariate limited dependent variable technique proposed by Belderbos et al. (2004) accounts for such pair-wise correlation and therefore has been employed in this analysis. Consequently, it takes the following form:

$$y_{i,k}^* = x_{i,k}\beta_k + \omega_{i,k} \quad (2)$$

$$y_{i,k} = \begin{cases} 1, & \text{if } y_{i,k}^* > 0 \\ 0, & \text{otherwise} \end{cases}$$

where $i = 1, \dots, N$ denotes the unit of analysis establishments and k stands for the number of cooperation strategies, which in this case corresponds to 3. $y_{i,k}^*$ is the set of unobserved latent variables. The assumption for multivariate probit model is that each observed variable $y_{i,k}$ will take the value 1 if and only if the underlying latent variable is positive. β_k is the vector of parameters to be estimated, $x_{i,k}$ is the set of explanatory variables, and $\omega_1\omega_2\omega_3 N(0, \Sigma)$ are the corresponding error terms, with Σ being the covariance matrix of error terms. Solving this system of equations requires a maximum likelihood estimation technique (Cappellari and Jenkins 2003) using the Geweke-Hajivassiliou-Keane (GHK) simulator that calculates the joint probabilities of all possible combinations. As robustness check, univariate logit models with exclusive cooperation categories are estimated, for private only, university only, consulting only and mixed type (see Table 5 in Appendix).

For the analysis on the effect of cooperative R&D on innovation performance, I follow the two-step estimation procedure proposed by Griffith et al. (2006). First, the linear predicted probabilities for R&D cooperation strategies determined by human resource practices are extracted from the multivariate probit estimation (eq.1). Next, these predicted probabilities are implemented in the final innovation equation instead of the raw values to estimate the probability of introducing an innovation. This method ensures that the predictions for cooperation-types are not systematically related to innovation output (simultaneity) and therefore accounts for unobserved heterogeneity that might determine R&D cooperation relationships. Additionally, it also allows for a better understanding of the mechanism through which firms' human resource practices stimulate research collaboration and subsequently, innovation. However, one disadvantage of using predicted values for interdependent R&D cooperation partners in a single equation framework is that it introduces multicollinearity into the system. In order to obtain unbiased estimated coefficients, therefore, individual estimations are conducted for each type of collaboration partner. Also, given the potential drawback associated with identification when considering highly significant variables from first-stage estimation in the second step, none of the main variables relating to human resource practices and R&D intensity are included in the innovation model.

An added concern with respect to unobserved heterogeneity may arise when analyzing data on time series cross-section or panel due to time-invariant individual effects. Two methods that are usually employed in order to address this issue are, fixed effect and random effect models. Fixed effect model assumes the individual-specific effect to be constant over time, while the random effect model treats this unobserved heterogeneity as randomly drawn from the underlying probabilistic distribution. For the current analysis, random effects model is employed, assuming that the individual effects are uncorrelated with the regressors. The reasons for such a model specification are as follows. First, estimates computed using a fixed-effect model for a panel can be biased over short periods (Heckman 1981a) which may not be a problem for random-effects. Since the analysis covers only three waves during 2007-2011, the random effect model is clearly the favored approach. Second, a fixed-effect model does not include estimation of the time-invariant components, which may be a serious limitation in this case. Finally, it can be assumed that the sampled cross-sectional units of the IAB establishment panel are drawn from a large population. Following these arguments, simple probit estimations using random effects, panel adjusted standard errors and time dummies are used, that compares the probability of firms coming up with product, process or radical innovation with that of

firms being non-innovative¹. Incorporating these econometric issues, equation 3 presents the final specification.

$$Innov_{i,t} = \beta_1 + \beta_2 Coop_{pred} + \beta_3 X_{i,t} + u_{i,t} \quad (3)$$

where $Innov_{i,t}$ represents the corresponding innovation variables: incremental product, incremental product and radical, and $Coop_{pred}$ denotes the predicted probabilities for cooperation. $X_{i,t}$ indicates the additional core and supplementary variables and $u_{i,t}$ is the unobserved error term.

5 Results and Discussion

The pattern of R&D cooperation among the firms in the final pooled sample is presented in Table 1. Of the 1658 cases, about 89% are in R&D cooperation, as compared to 11% with no R&D cooperation. Among the R&D cooperation established, 8.81% are exclusively with other private enterprises or market competitors, 19.18% are with university or research institutes only and 4.70% are with consulting firms only. Evidently, most R&D cooperation are mixed (56.03%), implying that majority of the firms cooperating in R&D has more than one collaboration partners.

Table 1: Distribution of R&D cooperation types for the final sample

Cooperation type	Number of cases	% of total sample
No cooperation	187	11.28
Cooperation	1471	88.72
- Private only	146	8.81
- University/Institutional only	318	19.18
- Consulting only	78	4.70
- Mixed cooperation	929	56.03
Total Sample for 2007-2011	(N= 1658) (n= 1170)	

Following the empirical strategy previously mentioned, I start with estimating the relationship between human resource practices and R&D cooperation. Column 1 of Table 2 presents the marginal effects obtained from probit estimation with binary R&D cooperation variable, while column 2-4 present the estimated coefficients from the multivariate probit analysis with heterogeneous collaboration partners. With respect to binary R&D cooperation, R&D intensity is found to be a significant determinant, while weak significance is observed with regard to employment practices. However, none of the additional explanatory variables show any significance and the overall fit of the model indicates poor predictability. Subsequently, results from the multivariate probit estimation are presented in Table 2, that provide significantly improved model fit and confirm the drawback associated with aggregating varied cooperation strategies into a single indicator.

First, looking at the likelihood ratio test for the various combinations of R&D cooperation strategies, interdependency is confirmed. This finding reaffirms the choice of the estimation strategy, which assumes significant pair-wise correlation among different cooperation partners, rather than considering them as independent choices. Second, lagged

¹The Hausman test confirms the use of a random-effect model since the null hypothesis on the difference in coefficients not being systematic cannot be rejected

Table 2: Heterogeneity in R&D cooperation strategies

	Binary cooperation	Private cooperation	University cooperation	Consulting cooperation
Empl. practice _{st} -2	0.092* (0.052)	0.567*** (0.207)	0.891*** (0.221)	0.543*** (0.206)
Compensation _{st} -2	0.042 (0.028)	0.185* (0.112)	0.050 (0.128)	0.156 (0.112)
R&D intensity _{st} -2	0.140** (0.059)	0.758*** (0.219)	0.783*** (0.272)	0.111 (0.209)
Size	0.009 (0.008)	-0.041 (0.026)	0.175*** (0.033)	0.089*** (0.027)
University share	0.001 (0.001)	0.004* (0.002)	0.011*** (0.003)	0.001 (0.002)
Skilled share	0.001 (0.001)	0.002 (0.002)	0.005** (0.002)	-0.002 (0.002)
Operational investment	0.017 (0.027)	0.141 (0.109)	0.093 (0.123)	0.089 (0.116)
Constant		-0.512*** (0.194)	-1.595*** (0.225)	-0.974*** (0.195)
Sector dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes

Dummy DV(s). Cluster-adjusted standard errors in parentheses
 *p<0.10 **p<0.05 ***p<0.01. N= 1658, n= 1170

Univariate probit (column 1), Multivariate probit (column 2, SML draws = 100)
 Wald chi2 = 55.26* (243.09***), Log pseudolikelihood = -545.58 (-3071.86)
 Likelihood ratio test of rho21 = rho31 = rho32 = 0: chi2(3) = 70.41***

employment practices are found to strongly explain R&D cooperation, regardless of the type of collaboration. This establishes the previous claim that, human resource practices are aimed at increasing employee productivity and capabilities, and therefore firms' overall knowledge stock and combinative capabilities. Hence, these should be significant for all types of R&D collaboration strategies, confirming hypothesis 1. Compensation and incentive programs on the other hand, are found to only explain R&D cooperation, albeit weakly, with private firms and competitors but not with any other type of collaboration partner. This result is also in line with the theoretical arguments, that oftentimes compensation and incentive payments are offered to employees when there is a higher risk of employee mobility and poaching between firms. Given that the risk of labor turnover and increased outgoing spillovers is greatest in case of horizontal R&D cooperation, it can be expected that firms having an effective appropriation mechanism for their employees are mostly associated with research collaboration with competing firms. The finding confirms hypothesis 2, while no such effect is found for institutional or consulting cooperation. With regard to R&D intensity measured in terms of R&D employees, it is found to have a significant and positive impact on horizontal cooperation with private establishments and cooperation with universities and research institutes, but none with respect to consulting firms. The results might stem from the fact that consulting firms are more often associated with marketing and advertising innovation, and not necessarily basic research unlike private firms or universities. When cooperating with other private firms or research institutes with similar basic knowledge spectrum, it is more likely that firms with higher degrees of R&D intensity are able to gain greater benefit from exploiting

complementary knowledge of their partners than firms with less R&D intensity. However when the cooperation partner is a consulting firm, cooperation agreements might be solely based on risk-sharing or marketing rather than exploitation of complementary assets relating to research and development.

With regard to other explanatory variables and controls, emphasis is first placed on the employment structure of the establishment. A greater share of employees having a university degree in total workforce is found to be significantly and positively associated with cooperation with private as well as research institutes, while no such effect is obtained with respect to consulting cooperation. Additionally, higher share of skilled workers in the workforce is found to significantly explain cooperation with research institutes and universities. Both these findings indicate the importance of human capital stock in firms' economic decisions and effective management of social capital. Next, size of the establishment measured in terms of workforce strength is found to be an important criterion for R&D cooperation, implying that larger establishments on average tend to cooperate more on R&D. However, significant differences are observed between private cooperation and institutional and consulting-based cooperation. This again relates to the literature on firm size, R&D activities and performance (Acs and Audretsch 1987, Pavitt et al. 1987, Cohen et al. 1987) which provides mixed evidence. Overall firm size is found to have a negligible impact on R&D intensity of business units when inter-industry differences are controlled for. Moreover, share of R&D employees, rather than aggregated employee stock, is more likely to be associated with research collaboration with private firms as is the case here. Finally, no significant effect of physical investment, investment in ICT, electronic data processing and production facilities is found on the probability of having an R&D cooperation.

Table 3 provides evidence on the heterogeneity in R&D cooperation strategies between manufacturing and service sector firms. Human resource practices, in the form of training and employment restructuring, are found to significantly explain research collaboration in R&D but only in case of manufacturing firms. While establishments belonging to the manufacturing sector and providing better employee compensation programs are more likely to be associated with horizontal cooperation, firms belonging to the service sector and providing better incentive-based payments are more often found to be associated with R&D cooperation with consulting-based firms. With regard to R&D intensity, share of R&D employees in total workforce in service sector firms better determines R&D cooperation than in manufacturing firms. Mixed evidence is found for establishment size, while education and skill structure of the workforce is found to have a significant impact on R&D cooperation strategies only in case of manufacturing. In a nutshell, firms in the manufacturing sector show better explanatory power in terms of human resource practices in determining collaboration strategies, than firms in the service sector. These findings provide novel evidence on significant sectoral differences in the choice of research collaboration partner with respect to absorptive capacity, R&D and human resource practices, and calls for a more in-depth analysis of industry characteristics in determining research activities in establishments (forthcoming).

For the final section, impact of cooperative R&D on innovation performance is reported in Table 4. Considering three measures of innovation- incremental product, incremental process and radical innovation, individual probit estimations are conducted, first with predicted binary cooperation without distinguishing between types of cooperation

Table 3: R&D cooperation partner-type: Manufacturing versus Services

	Manufacturing			Services		
	Private	University	Consulting	Private	University	Consulting
Empl. practice _{st-2}	0.716*** (0.271)	0.920*** (0.289)	0.515* (0.274)	0.570 (0.465)	0.684 (0.576)	0.886* (0.479)
Compensation _{t-2}	0.303** (0.143)	0.108 (0.164)	-0.027 (0.145)	0.446 (0.345)	-0.371 (0.402)	0.868*** (0.326)
R&D intensity _{t-2}	0.078 (0.363)	0.508 (0.457)	0.544 (0.369)	1.019*** (0.260)	1.124*** (0.324)	0.180 (0.254)
Size	-0.060 (0.038)	0.201*** (0.046)	0.145*** (0.041)	0.042 (0.047)	0.167** (0.076)	0.046 (0.050)
University share	0.010*** (0.003)	0.012*** (0.004)	0.002 (0.003)	-0.005 (0.004)	0.007 (0.005)	0.001 (0.004)
Skilled share	0.004 (0.002)	0.007** (0.003)	0.002 (0.003)	-0.001 (0.005)	0.002 (0.005)	-0.006 (0.005)
Operational investment	0.095 (0.146)	-0.020 (0.164)	0.081 (0.156)	0.017 (0.223)	0.293 (0.243)	-0.175 (0.235)
Constant	-0.631** (0.292)	-1.657*** (0.342)	-1.437*** (0.308)	-0.483 (0.370)	-0.985** (0.434)	-0.782** (0.378)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Multivariate probit model with dummy dependent variable(s)						
N= 936 (342), n= 647 (250)						
Cluster-adjusted s.e. in parentheses, *p<0.10 **p<0.05 ***p<0.01						
Wald chi2 = 122.26*** (79.61***), Log pseudolikelihood = -1743.71 (-561.44)						
Likelihood ratio test of rho21 = rho31 = rho32 = 0: chi2(3) = 62.81*** (6.47*)						
Corresponding values for services in brackets, primary sector excluded						

partner (Model 1), and second with predicted probabilities for each of type of collaboration partner (Model 2- Model 4). Starting with the binary cooperation variable, evidence suggests that variation in R&D cooperation predicted by human resource practices and R&D intensity significantly explain all types of innovation performance of establishments. However, the marginal effects obtained from individual probit estimations indicate that the conditional probabilities of incremental process and radical innovation increases by more than 70% as compared to incremental product innovation, in response to a one unit change in R&D cooperation.

Looking next at the different types of R&D cooperation, significant differences in innovation performance are obtained for private, institutional and consulting cooperation. With respect to product innovation, cooperative R&D with research institutes and consulting firms are found to significantly impact the likelihood of coming up with incremental product innovation; while no such effect is found with regard to horizontal cooperation. This finding could either indicate that variation in private R&D cooperation predicted by human resource practices have no significant effect on product innovation, or that such cooperation in general have a positive effect on product innovation but not through human resource practices. However, in the case of incremental process and radical innovation, all three types of cooperation are found to have strong and positive impacts, confirming hypothesis 4b and 4c. With regard to the control variables, hiring of new staff in the previous year increases firms' human capital stock and R&D activities and accordingly are found to significantly affect incremental product innovation. Regional geography is

found to determine innovation performance, in the sense that establishments belonging to West Germany are found to innovate more than East German firms. However, the effect is most pronounced for product and process innovation while no such east-west differences are obtained for radical innovation performance. Overall technical state of the plant in terms of technology, machinery, office equipment is considered to be a strong determinant of innovation, and the negative significant relationship suggests that establishments with obsolete technologies innovate less than establishments that are on par with latest technological requirements. Finally, firms with multiple business units are found to innovate more than single establishment firms, while substantial pressure from external competition motivates firms to continuously innovate and improve upon already existing products and processes in the market.

6 Concluding remarks and policy implications

"As competition becomes more knowledge-based, a firm must develop a thorough understanding of its own knowledge, the processes by which it converts knowledge to capabilities, and the capacity of those capabilities to meet the demands of its environment" (Lane and Lubatkin 1998, p. 474). Accordingly, the paper claims that a major drawback in the working definition of absorptive capacity is its uni-dimensionality, given which one needs to account for organizational settings and employment relations in determining the process of knowledge creation and utilization. A refined definition of absorptive capacity is provided, taking into account human resource practices in the form of employment restructuring and compensation programs, and their role in R&D cooperation, type of collaboration partner and innovation. The analysis uses IAB Establishment Panel on around 1200 German private-sector establishments for a period of 2007-2011. Distinction is drawn between horizontal, institutional and consulting cooperation partners and a multivariate probit model is estimated assuming interdependency of collaboration strategies. Finally, impact of such cooperative R&D on product, process and radical innovation performance of firms is examined. Confirming theoretical expectations, firms' human resource practices are found to play a major role in determining R&D cooperation and partner selection. Specifically, adoption of employment practices is found to positively affect R&D cooperation, irrespective of the type of partner, while compensation programs are found to positively affect R&D cooperation only with private firms. Next, differences in appropriability conditions, human capital structure and the risks involved in the process of collaboration across manufacturing and service sectors underlie the effects of human resource practices on R&D cooperation. Finally, cooperative R&D with research institutes and consulting firms are found to have significant and positive impact on the likelihood of coming up with incremental product, process and radical innovation, whereas the effect is relatively weaker in case of horizontal R&D cooperation.

Findings from this paper not only contribute to the theoretical understanding of human resource practices as major determinants of absorptive capacity and innovation in cooperation relationships, but also provide implications for policy intervention. First, by defining absorptive capacity as employment practices and compensation programs, the main practical implication derived is that investment solely in R&D and capital resources is not sufficient for innovation in inter-firm linkages. It is also essential to know when, how and to what extent to adopt strategies that improve employee competencies and capabilities as well as build social capital and innovative capabilities. Looking at statis-

Table 4: Marginal effects for Innovation performance

	Product				Process				Radical			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Pred. binary coop.	0.417** (0.212)				1.339*** (0.311)				1.031*** (0.309)			
Pred. private coop.		0.029 (0.040)				0.150** (0.063)				0.221*** (0.058)		
Pred. university coop.			0.040* (0.021)				0.180*** (0.032)				0.126*** (0.031)	
Pred. consulting coop.				0.092** (0.043)				0.389*** (0.063)				0.228*** (0.062)
Hiring	0.030* (0.018)	0.037** (0.017)	0.026 (0.018)	0.024 (0.018)	0.012 (0.028)	0.034 (0.028)	-0.010 (0.029)	-0.015 (0.028)	0.044 (0.027)	0.059** (0.027)	0.030 (0.028)	0.031 (0.028)
East/West	0.055*** (0.016)	0.055*** (0.017)	0.052*** (0.016)	0.045*** (0.017)	0.090*** (0.027)	0.097*** (0.028)	0.078*** (0.027)	0.047* (0.028)	0.004 (0.026)	0.019 (0.026)	-0.005 (0.026)	-0.022 (0.026)
Techstate	-0.033*** (0.012)	-0.035*** (0.012)	-0.033*** (0.012)	-0.032*** (0.011)	-0.119*** (0.017)	-0.124*** (0.017)	-0.115*** (0.017)	-0.113*** (0.017)	-0.062*** (0.016)	-0.064*** (0.016)	-0.061*** (0.017)	-0.061*** (0.017)
Legalform	-0.009 (0.010)	-0.007 (0.010)	-0.014 (0.010)	-0.012 (0.010)	-0.007 (0.017)	-0.001 (0.018)	-0.031* (0.018)	-0.023 (0.018)	0.020 (0.017)	-0.019 (0.017)	-0.036** (0.018)	-0.028 (0.018)
Status	0.039** (0.017)	0.043** (0.017)	0.038** (0.018)	0.037** (0.018)	0.071*** (0.026)	0.087*** (0.026)	0.060*** (0.026)	0.054** (0.027)	-0.014 (0.025)	-0.002 (0.025)	-0.021 (0.025)	-0.021 (0.025)
Competition	0.030*** (0.009)	0.032*** (0.009)	0.030*** (0.009)	0.028*** (0.009)	0.052*** (0.016)	0.058*** (0.016)	0.049*** (0.016)	0.044*** (0.016)	0.015 (0.015)	0.019 (0.015)	0.013 (0.015)	0.011 (0.015)
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald chi2	110.25***	109.39***	115.13***	117.96***	116.07***	105.76***	123.82***	131.63***	42.38***	46.57***	47.60***	45.29***
Pseudo R2	0.12	0.11	0.11	0.12	0.06	0.06	0.07	0.07	0.02	0.03	0.03	0.03

Univariate probit model with dummy dependent variable(s)
Delta-method standard errors in parentheses, *p<0.10 **p<0.05 ***p<0.01
Number of observations = 1658, Number of firms= 1170

-tics for Germany, the Federal Institute for Vocational Education and Training reports that the dual system of vocational education has made an important contribution in keeping the youth unemployment rates across the country low. However, the overall picture is significantly different when considering investment in human capital in private sector firms, with the rate of company-sponsored training decreasing by 0.8% in 2012 as compared to the previous year thus reporting the lowest level of in-company training since 1999. Given the necessity of human capital and employee resources in building and upgrading absorptive capacity, managing external knowledge linkages and building innovative capabilities in firms, policy should therefore focus on providing greater access to training, employment restructuring, better employability conditions and incentive-compensation schemes for employees to improve innovation performance especially in research collaborations. Second, significant differences are obtained with respect to composition of absorptive capacity and appropriability mechanism between manufacturing and service sector establishments. Thus, attention should be given to sectoral characteristics when devising policies for innovation in R&D cooperation relationships. Finally, results from the empirical analysis indicate that cooperation with private firms, universities and consultation-based firms are important for process and radical innovation and less so for product innovation. Consequently, policy should aim at greater investment in absorptive capacity of employees that increase their motivation, interpersonal skills and dynamic creativity to be able to derive substantial benefits from R&D collaboration relationships, especially in terms of explorative innovation performance.

While the study provides interesting insight into the black box of firms' human resource practices in determining social capital and innovation, it also advances scope for further analysis. First, even though human resource practices and compensation programs are found to positively influence R&D cooperation across different partner-types and between manufacturing and service sector firms, it can be expected that there exist further sectoral differences depending on how technologically advanced a sector is. For example, firms in high-tech sector might be associated with greater horizontal cooperation than firms in the low-tech sector. This is because high-tech firms might find it essential to better exploit complementary knowledge and R&D resources of the rivals in order to extend their network structure. Similar differences are also expected with respect knowledge-based, ICT-based firms and supply-dominated firms. Second, the sample presented here consists of innovation firms. This might be a reason to expect that the sample suffers from a "sample-selection" bias. Given the nature of the dependent variables used in the analysis, a Heckman correction (Heckman 1979) is not possible. However, one can think of using Generalized Linear Latent and Mixed Model (GLLAMM, Rabe-Hesketh et al. 2002) in order to account for the potential limitation. Finally, given that both are somewhat different proxies of firm-level absorptive capacity, it can be expected that there exists a strong complementarity between employment practices and compensation programs. Following this line of thought, a complementarity analysis between different measures of human resource practices is being conducted in a succeeding study using the adoption-productivity approach suggested by Cassiman and Veugelers (2002).

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Appendix

Table 5: Univariate probit model with exclusive R&D cooperation categories

	Only private	Only university	Only consulting	Mixed cooperation
Empl. practice ² -2	-0.850*** (0.298)	-0.545** (0.235)	-0.668** (0.336)	1.199*** (0.216)
Compensation ² -2	0.013 (0.164)	-0.095 (0.131)	0.077 (0.193)	0.166 (0.114)
R&D intensity ² -2	-0.349 (0.328)	-0.326 (0.262)	-1.146*** (0.414)	0.753*** (0.215)
Size	-0.160*** (0.041)	0.023 (0.029)	-0.088** (0.043)	0.064** (0.028)
University share	-0.009*** (0.003)	-0.001 (0.003)	-0.003 (0.003)	0.007*** (0.002)
Skilled share	-0.001 (0.002)	0.001 (0.002)	-0.006** (0.002)	0.003 (0.002)
Operational investment	-0.017 (0.142)	-0.070 (0.123)	-0.021 (0.194)	0.149 (0.111)
Constant	0.179 (0.267)	-0.773*** (0.221)	-0.461 (0.282)	-1.401*** (0.206)
Sector dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Wald chi ²	74.75***	27.89***	32.84***	111.50***
Pseudo R ²	0.08	0.02	0.05	0.06

Cluster-adjusted standard errors in parentheses
 *p<0.10 **p<0.05 ***p<0.01. N= 1658, n= 1170

Table 6: Rotated factor loadings generated from Tetrachoric correlation on 11 binary human resource practices

Variable	Factor1	Factor2
Profit share	0.1170	0.6591
Staff share	0.0867	0.7810
External training	0.4286	0.0265
In-company training	0.6466	0.0017
On-the-job	0.7507	0.1296
Lectures	0.6571	-0.0054
Job rotation	0.6382	0.2301
Self study	0.5799	0.1747
Quality workshop	0.5819	0.1688
Other	0.4643	-0.1380
Hired personnel	0.4422	0.0316

Table 7: Industrial classification and subsequent generation of sector dummies

Current sector affiliation	Dummies generated
Agriculture/forestry	Primary sector (base group)
Mining/energy	Manufacturing
Food/luxury	Construction and engineering
Textiles/clothing	Trade, repair and transport
Paper/printing	Financial and insurance services, ICT, real estate
Wood sector	Other services, organizational and public administration
Chemical sector	
Plastics industry	
Glass/stones/ore extraction	
Metal production	
Recycling	
Metal goods/steel production	
Engineering	
Vehicle engineering	
Other vehicle production	
Electrical engineering	
Precision engineering/optics	
Furniture/jewelry/toys	
Main building sector	
Building/installation	
Car-rent/-reparation/gas-station	
Wholesale trade	
Retailing/reparation	
Traffic	
Financial sector	
Insurance	
Data processing	
Research/development	
Judiciary/advertising	
Realities/flats	
Renting	
Educational institutions	
Health/social	
Waste-management	
Culture/sports/entertaining	
Other services	
Organizations	
Civil service/social insurance	
Other civil services	
Others	

Table 8: Variable Description

Variables	Definition
Employment practices	Index of employment practices. Average of the scores for all items calculated and recoded on a scale of 0-1, 1 being highly provided and 0 otherwise
Compensation	Index of compensation schemes. Average of the scores for all items calculated and recoded on a scale of 0-1, 1 being highly provided and 0 otherwise
R&D intensity	Fraction of full-time and part-time R&D employees in total workforce
Skilled share	Share of skilled blue-collar and white-collar workers requiring vocational education in total workforce
University share	Share of qualified white-collar employees requiring university degree in total workforce
Operational investment	Operational investment made in one or several of the areas such as real estate, ICT, electronic data processing, production facilities and transportation system.
Incremental product innovation	Average of the scores for all items calculated and recoded on a scale of 0-1, 1 being highly provided and 0 otherwise
Incremental process innovation	1 if establishment has improved or further developed a product or service, 0 otherwise
Radical innovation	1 if establishment has developed or implemented procedures that have improved production processes or services, 0 otherwise
Cooperation	1 if establishment has offered a completely new product or service to the market, 0 otherwise
Private cooperation	1 if research and development is carried out by the establishment in cooperation with others, 0 otherwise
University cooperation	1 if research and development is carried out by the establishment in cooperation with other private establishments and competitors, 0 otherwise
Consulting cooperation	1 if research and development is carried out by the establishment in cooperation with universities or research institutes, 0 otherwise
Establishment size	1 if research and development is carried out by the establishment in cooperation with consulting firms, 0 otherwise
Sector affiliation	Natural logarithm of total workforce
New hiring	Dummies corresponding to NACE2-digit industry classification
East/west Germany	1 if establishment has hired new staff in the previous year, 0 otherwise
Technical state	1 if establishment belongs to West Germany, 0 otherwise
Legal form	Overall technical state of plant (technology used, machineries, office equipments), on a scale of 1-5 with 1 being state-of-the-art and 5 being obsolete
Establishment status	Legal form of organization of enterprise, 1 if individually-owned, 2 if partnership, 3 if limited partnership, 4 if capital corporation, 5 if public corporation, 6 if others
Competition	1 if multiplant establishment, 0 otherwise
	Pressure from market/external competition, categorical variable ranging from 1-4 with 1 being no competitive pressure and 4 being substantial pressure

Table 9: Correlation Table

[illegible]

Correlation matrix: Correlations greater than or equal to 0.05 (in absolute terms) are significant ($p < 0.05$)