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Implementing an R&D Strategy without Prior R&D-Experience

Recruitment as a Source of R&D-related Routines and Capabilities?

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ABSTRACT

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JEL codes: O31 J24 J63 O32 D22

Keywords: routines, capabilities, R&D strategy, micro-foundations, recruitment

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1. INTRODUCTION

Inter-firm heterogeneity in R&D efforts is a dominant characteristic in many, even narrowly defined, sectors. In most sectors we observe a small core of systematically R&D performing firms and a larger number of firms without R&D activities (Bottazzi et al. 2001, Cefis 2003, Malerba and Orsenigo 1996). Transition rates between the groups of R&D active and inactive firms are low, which imply persistent heterogeneity in R&D strategies across firms.

Evolutionary economics and the derived organizational routines and capability approaches explain the these phenomena by the presence or absence of firm-internal R&D-related routines and capabilities (Nelson and Winter 1982), which firms need to develop in order to engage in R&D activities (Dosi and Nelson 2010). Most authors agree that these development processes are based on experiential learning. Yet, as Nelson and Winter (2002) note, this view is of limited use to explain learning processes inside firms that start completely novel activities for which they lack internal experience. Therefore, experiential learning arguments are powerful in explaining why firms are good at doing things that they have always done. They might be less so in explaining why firms are good at something that they have not done before.

In this paper we focus on firms starting R&D activities without prior R&D experience. The experiential learning perspective suggests that these firms need to create their own organizational stock of experience to be successful, i.e. they simply have to start and learn from trial and error as well as repetition. However, relevant experience is not necessarily only bound within the organization, but may be stored otherwise (e.g. in individuals, machinery, blueprints). In view of this, we ask: can newly R&D active firms compensate their lack of internal organizational experience and, if yes, how? Are there ways to increase the chances of sustainable transitions to R&D?

These questions are inevitably linked to the more fundamental question of where organizational routines and capabilities come from. Building on a growing literature emphasizing the need for micro-foundations of organizational routines (Felin and Foss 2005, Rothaermel and Hess 2007, Teece et al. 2008, Abell et al. 2008), we argue that recruitment of experienced R&D personnel is a means by which firms can develop these routines and capabilities necessary to enforce and sustain a R&D strategy shift.

Using unique longitudinal matched employer-employee data for Sweden for the years 2004, 2006, and 2008, we focus on firms that switched from no to persistent R&D in 2006 and compare them to firms that remained R&D-inactive over the whole period. The sustainability of the R&D strategy shift is assessed by observing whether this transition was sustained in 2008.

We analyze whether the firms that undertake a transition from none to continuous R&D are more likely to recruit R&D workers than firms that remained R&D-inactive during the whole period. We also analyze whether higher rates of recruitment increase the likelihood of sustaining this strategy shift. The results support both hypotheses: While controlling for potential confounders, we find that firms undertaking an R&D strategy shift from none to persistent R&D activities are significantly more likely to recruit experienced R&D personnel from other R&D intensive firms. We also find that among the group of firms undertaking a strategy shift, firms with higher rates of recruitment of R&D personnel are more likely to sustain their strategy shift to R&D over time. We interpret this as evidence of the importance of recruitment as way to acquire individual skills and experiences as antecedents to the creation of internal R&D-related routines and capabilities, in particular when firms lack prior experience with R&D.

The question of how firms can build routines and capabilities for R&D is important for several reasons. First, it has bearings on theorizing about the micro-foundations of organizational routines, which several authors have identified as a gap in the literature (cf. Murmann et al. 2003). Also Zollo and Winter (2003) emphasize this by saying: "[...] the literature does not contain any attempt at a straightforward answer to the question of how routines – much less dynamic capabilities – are generated and evolve." While the literature on micro-foundations is now growing rapidly and most authors would agree that the micro-foundations should somehow relate to individuals, a commonly accepted theory framework has not yet emerged. In this paper we do not only empirically show that recruitment matters, but also propose theoretical mechanisms that explain how individual skills and organizational capabilities are linked. In particular, we argue that experiential learning is not the only way of learning. In fact, when firms lack experience with a task, such as R&D, our results suggest its implementation can be supported by intentional changes made to the skill-base of the individual employees.

Second, putting emphasis on recruitment and individual skills opens up perspectives for an increased interaction with other more individual-centered literatures inside management theory (e.g. HRM, team management, or managerial psychology) and outside (e.g. the evolutionary economic geography which has highlighted the importance of mobility to replicate routines). In the Discussion Section we explain why we believe that in particular the exchange with evolutionary economic geography could prove useful for strategic management.

Third, a large literature documents significant firm-level productivity, profitability, competiveness effects of R&D (Lööf et al 2012, Hall and Mairesse 2010, Andersson et al. 2012). Since we point at

the value of recruitment to prepare and sustain transitions towards R&D we provide practical advice for management on how to profit from R&D investments thereby creating competitive advantage.

The rest of the paper is organized as follows: In Section 2 we present our theoretical framework, developing arguments for hiring as a source of R&D related routines and capabilities. We also derive testable hypotheses about the role of recruitment of experienced R&D workers in implementing and sustaining an R&D strategy shift. Section 3 presents the data, defines variables and explains our identification strategy. Section 4 presents the results, whereas Section 5 concludes and discusses the implications of our findings.

2. THEORY

The literature has shown that the majority of R&D-related activities are conducted by only a minority of firms (Bottazzi et al. 2001, Cefis 2003, Malerba and Orsenigo 1996). Given that there are enormous financial benefits associated with R&D activities (Lööf et al. 2012, Hall et al 2010), this is somewhat surprising from a basic economic perspective, because under rational decision making, homogeneity in factor endowment, and equal access to investment opportunities all firms should behave identically.

The concept of organizational routines and capabilities has been introduced by Nelson and Winter (1982) to explain this empirically observable lack of convergence, where routines are understood as "recurrent patterns of interaction" (Becker 2004).[1] In this theoretical framework non-R&D active firms are unable to imitate the R&D behavior because the dominant source of routines and capabilities is R&D experience gathered in the past (cf. Zollo and Winter 2002).

While this explains quite well the rigidity and persistency of firm behavior, it does little to explain whether strategic management can contribute anything to support transitions towards R&D, which, given their profitability, should always be a topic on the agenda of strategic management. Before we explain alternative sources for the development of routines and capabilities we will now shortly review the some features of the experiential learning perspective.

2.1 Routines and capabilities as a result from past experience

Following the behavioral traditions organizational routines and capabilities are assumed to find their ultimate origins in past experience and repetition (Cyert and March, 1963, cf. also Felin and Foss 2011). As Zollo and Winter (2002) emphasize this holds also for dynamic capabilities changing

[1] We note that numerous slightly differing definitions exist as well.

operational routines (Teece et al. 1997, Eisenhardt and Martin 2000, Helfat et al. 2007), because eventually also these higher order capabilities must derive from an external source.[2]

The focus on past experience explains well high performance of organizations with an extant experience, but does not explain well why certain firms are good at tasks that they have never performed before. The reason for this is that this theory treats firms initiating new tasks without prior experience as 'empty buckets' (Popper 1972). These are gradually filled by accumulating experience allowing for the development of routines through trial and error and repetition. Firms starting new activities, under the assumption that the source of all capabilities is organizational experience, therefore cannot be high performers but at best fast experiential learners, maybe simply due to luck.

While this view explains well the rigidity of core strategies in general and R&D strategies in particular, it has been criticized as incomplete. First, it does little to explain the success factors in radical adaption of core processes (Nelson and Winter 2002), which are not necessarily the dominant source of novelty in a population of organizations (cf. Hannan and Freeman, 1984) but still are observable in practice (Oertel and Walgenbach, 2009). Second, the supposition that inexperienced organizations are 'empty buckets' is problematic, because the primary source of knowledge lies in the interaction at the level of individuals (Argote and Ingram, 2000). In that latter view no firm with a non-zero number of employees can be validly considered empty, not even if it hasn't accumulated internal experience.

In the next section we will therefore argue that individuals and their skills can be seen as important antecedents of organizational routines. This also raises a question about the possibilities of recruitment as an intentional measure to foster the creation of routines. Using the knowledge reservoir concept by Argote and Darr (2000) and Argote and Ingram (2000) we explore the theoretical potentials and subtleties of recruitment as a source of capability development in the next subsection. While the analysis of hiring and mobility as a source of knowledge and as a process of learning has a strong tradition in the management literature (cf. Song et al. 2003, Almeida and Kogut, 1999), our contribution is twofold. First, we explicitly develop the recruitment topic within the theoretical framework of the capabilities microfoundation approach. Second, we focus on a radical transition towards a strategy of continuous R&D. We thereby have a stronger focus on strategy, where we also explore the role of recruitment for the development of new capabilities, rather than conceiving them as the result of a smooth learning process relating to activities performed on an every-day-basis.

[2]It has been convincingly argued that explaining capabilities by higher order capabilities leads to infinite recursiveness and tautology in the concepts (Butler and Priem 1997, Williamson 1999).

2.2 Recruitment as a source of new routines?

Because all firm activities are eventually executed by individuals, it seems natural to assume that recruitment is a means to create new organizational capabilities. For example, Aldrich (1979) suggests that hiring allows firms to fulfill tasks they have not performed before. More broadly, Mansfield (1988) stated that, if capabilities are too costly to develop internally, firms may choose to acquire them on the market. Hardly surprising also the management literature has analyzed the role of recruitment in several respects: Almeida and Kogut (1999) and Rosenkopf and Almeida (2003) show that significant knowledge flows are associated with mobility. Song et al. (2003) and Maliranta et al. (2008) give evidence for "learning-by-hiring". The arguments are also supported by Rao and Drazin (2002), who show that younger or poorly connected firms from the US mutual fund industry are more likely to use hiring from experienced firms in order to compensate the absence age-dependent competences. Conceptually related to our question of new strategy implementation, Cockburn et al. (2000) analyze the role of recruitment in the development of new technological capabilities. They show that firms in the chemical industry intending to move from randomized drug development towards science driven techniques can do so by recruitment.

Despite these results it has been complicated to link up recruitment to the prevailing capabilities approach in strategic management because of the theoretical gap between individual skills and organizational routines and capabilities and a lack of knowledge of how they relate to each other. Particularly problematic is recruitment argument because it seems to suggest that organizational capabilities can be transferred between firms by hiring. Noting that capabilities are not simply the sum of individual skills (Nelson and Winter 1982), it is generally agreed that routines and capabilities are specific to their origin of creation in terms of history (Barney 1991, Reynaud 1996, Hodgson 2001), location (Simon 1976) and relation (Dyer and Singh 1998). Additionally, they incorporate tacit knowledge (Nonaka 1991). For these reasons capabilities are neither directly tradable on factor markets nor *completely* incorporated in any tradable factor (including labor).

While we agree with that, the skepticism about the idea that organizational capabilities are completely incorporated in tradable factors, does not preclude the possibility that the factors might still carry certain antecedents. Recruitment of R&D workers might therefore be a route to create capabilities because R&D workers might possess, amongst other, relevant individual experience that is integrated into the organizational experience. In order to fully develop this argument we now make use of the knowledge reservoir concept developed by Argote and Darr (2000) and Argote and Ingram (2000).

Building on approaches that see firms as inventories of knowledge (e.g. Levinthal and March, 1993, Feldman, 1989), Argote and Darr (2000) and Argote and Ingram (2000) propose suggest that (the

knowledge assets relating to) routines and capabilities are stored in members, tasks, and tools as well as the various sub-networks thereof, e.g. member-member, member-task networks, and so forth. The usefulness in this concept is that it is able to explain not only why capability transfer is difficult, but also why it still may be a promising venue for firms to hire personnel in order to create new routines and capabilities.

In the knowledge reservoir concept transferring a routine or capability from one firm to the next implies that all components together with their networks are transferred and adapted to local specificities. While the market is unlikely to contribute to adaptation, even the transfer will be incomplete. For instance, while we may buy the embodiment of a technology (e.g. machinery) we might not be able to make it work because we lack the members that know how to do it. If we recruit a member (e.g. hiring an R&D worker), this is not necessarily sufficient, because he might lack either the tools (lack of a member-tool network) or his colleagues (lack of a member-member network).

The acquisition of individual components of this full network may nonetheless support the creation of routines and capabilities, because either of the components is a reservoir of knowledge. Even if it might contain less of the knowledge that is contained in conjunction with the other components, transferring a component will also transfer parts of the knowledge that it initially related to in the original network.

Additionally and with respect to adaptation Allen (1977) highlights that members are able to reshape knowledge and adapt it to new contexts. According to this, recruitment can be a powerful way to create a specific capability. It transfers tacit and codified knowledge embodied in people (Galbraith 1990, Rothwell 1978), as well as skills to recreate the missing parts and to adapt them to the new contextual requirements. The direct implications for our question of recruitment and R&D strategy transitions will be outlaid in the next subsection.

2.3 Hypotheses

Doing something new requires the creation of new routines and capabilities. We have argued in the preceding section that recruitment is a means to support the implementation of new activities because it allows firms to substitute internal experience by recruitment of new employees. This argument clearly is generic in the sense that it could be applied to a multitude of situations in which firms do something that they have never done before, but we will focus in this paper on firms without prior R&D experience starting R&D.

H1*: Firms that change their R&D strategy from no R&D to persistent R&D significantly increase their recruitment of R&D-related personnel.*

R&D workers are not homogenous, neither in terms of skills nor in terms of function. Firms starting to perform R&D are likely to lack both technological as well as knowledge about how to organize R&D-activities. This distinction between the different types of knowledge is made by amongst others by Kogut and Zander (1992), who differentiate between declarative (under which technological knowledge would be subsumed) and procedural knowledge. It is straightforward to conjecture that the carriers of procedural knowledge should primarily be (R&D) managers and the carriers of declarative knowledge would be scientists or more general R&D workers. Both types of knowledge are essential to implement R&D activities. We therefore hypothesize:

H2: *Firms that change their R&D strategy from no to continuous R&D significantly increase their recruitment of both managers with R&D experience as well as R&D workers.*

The distinction between declarative and procedural knowledge has implications for the timing of recruitment decisions. Since routines are by definition recurrent patterns of interaction, and capabilities a collection thereof (Becker 2004), it is clear that routines are situated on the collective level – most directly on the level of the R&D team. As Abell et al. (2008) suggest collective production gives rise to externalities. Therefore, a major purpose of routines is to internalize these externalities, which is directly reflected by the procedures. But then the procedural knowledge about organization should be available before – at least not later than – the declarative knowledge. Thus we hypothesize the following structure about timing:

H3: *Firms that change their R&D strategy from no to continuous R&D recruit managers with R&D experience before they recruit R&D workers.*

As highlighted by empirical observations and the discussion above, changing R&D strategy is subject to frequent failure. We hypothesize therefore that most of the firms attempting to do so fail. Nonetheless, if recruitment can substitute lack of experience, we should expect that firms putting above average emphasis on recruitment initially are more likely to sustain the strategy shift also in later periods.

H4: *A significant share of all firms changing to an R&D strategy fails and return to a non R&D based strategies in later periods.*

H5: *Firms that hire more R&D workers and managers are (conditionally on the firm characteristics) more likely to remain R&D active in later periods.*

3. DATA, VARIABLES AND IDENTIFICATION STRATEGY

3.1. Data

We employ matched employer-employee panel data covering firms in three waves of the Swedish Community Innovation Survey (CIS), i.e. 2004, 2006 and 2008. The Swedish CIS is part of the CIS performed in all EU member states, being a harmonized survey of firms' innovation activities. The survey contains most sectors from services and manufacturing, i.e. from NACE 10 to 72.[3] While it is by construction a moving cross-section, many firms are surveyed in consecutive periods. This allows us to construct a panel data set including firms that are part of all three waves of the CIS.

The original Swedish data consists of 3,126 (response rate 66%), 3,247 (63%), and 4,624 (85%) firms of which 1,113 firms are in all three surveys. Statistics Sweden creates a stratified, random sample based on firms with 10-249 employees, whereas all firms with 250 or more employees are always included in the survey.[4] The survey is then sent to the top managers of the firms.

We add information from several other sources to the original CIS data through common firm identifiers in different sets of data. These other data sources include employment structure, balance-sheet data, ownership structure, international trade involvement and location. The final dataset comprises information from the following data sources:

- CIS (Community innovation survey 2004, 2006 and 2008, innovation information)
- LISA (Integrated database for labor market research 2002-2008, employees and regional variables)
- FEK (Business database 2004, 2006 and 2008, value added and business-related information)
- Database of business groups (2004, 2006 and 2008, states foreign vs. Swedish ownership)
- Export- and import-database (2002-2008, exporting experience)

[3] See *inter alia* Laursen and Salter (2005) for details of the CIS and its antecedents.

[4] Some potential sources of bias need to be addressed: the stratification Statistics Sweden employs in the CIS may work towards larger firms being included (as all Swedish firms with 250 or more employees are included as long as they are in CIS-relevant sectors). To circumvent problems of identifying firms, we have disregarded those firms that may have changed ownership structure, since that would also imply changing organizational identifier.

A main novelty of the data is that the firms included in all three waves of the CIS are identified in the LISA-database. This database include *all* individuals of age 16 and above in Sweden, which allows us to identify which employees are employed in each firm, and the longitudinal structure of LISA then enables us to trace these back in time, i.e. how long they have worked in the firm, other personal characteristics (age, education), the characteristics of their previous employer and their position there, etc. In our empirical context, the main benefit of these data is that it makes it possible to identify new hires of R&D-experienced workers and relate these hires to changes in firms' R&D strategies.

3.2. Defining changes in R&D strategy and recruitment of R&D experienced workers

The main variables of interest in our analysis are an indicator of change in R&D strategy and recruitment of R&D experienced personnel. Changes in R&D strategies are derived from firms switching from none to persistent R&D activities between waves one (2004) and two (2006) of the CIS. Recruitments are identified as new hires of highly qualified employees previously working at R&D-active firms. We provide a more detailed account of these variables below.

Identification of firms' changing R&D strategy

We define a strategy shift as firms that in the first wave of the CIS (2004) report no R&D but in the second wave (2006) reports persistent R&D. We interpret this as underlying shift in R&D strategy. In practice, this means that the firms satisfy the following criteria:

- Answer "no" to the question: *"During the three years 2002 to 2004, did your enterprise engage in the following innovation activities: Intramural R&D?"*, and
- Answer "yes" to the question: *"During the three years 2004 to 2006, did your enterprise engage in the following innovation activities: Intramural R&D?"*, and
- Answer "continuously" to the follow-up question in CIS (2006): *"If yes, did your firm perform R&D during 2004 to 2006 continuously or occasionally"*

Firms satisfying these criteria are considered as having enforced a R&D strategy shift between waves one and two as they have gone from undertaking none to continuously engage in R&D-activities. [5]

[5] It should be noted that this interpretation identifies such a shift in strategy instead of directly observing it. However, because Statistics Sweden sends these surveys only to top-level managers and, if possible, always to

We construct an implicit "control group" that consists of firms that answered the questions with no. We thus leave out firms that engage in continuous R&D in all waves or firms that have either in 2004 or 2006 been only temporary R&D performers. We regard this as a particular strength of our setting, because we compare firms that at least in 2004 did not differ in their R&D strategy. This design allows a cleaner identification, because it reduces the distorting potential of confounding factors.

Identification recruitments of R&D experienced personnel

We define three different types of experienced R&D workers:

1. R&D managers: *employees that worked as R&D managers at their previous employer. This corresponds to classification "1237" according to the four-digit level of the ISCO-88 in the LISA-database. Managers of this type are directly involved in R&D-related decisions*.

2. Other managers at R&D intensive firms: *employees that had a management position at their previous employer, according to the 1-digit ISCO-88. The employer was conducting R&D. These managers are generally the top- or middle-managers who are involved in decision-making and development of strategies and organization*.

3. Knowledge workers: *employees having a qualified (but not management) position at their previous employer according to the 1-digit ISCO-88. The employer was conducting R&D. A further requirement is that these employees have at least a university bachelor's degree.*

In the empirical analysis that follows, we aggregate R&D workers of type 1 and 2 into one single group. This leaves us with two categories of experienced R&D workers which we define for the sake of easier labeling as (i) R&D managers and (ii) Knowledge workers. These two differ in the sense that the managers should possess R&D-related knowledge of organization and processes, in the wording of Kogut and Zander (1992) procedural knowledge, while the knowledge workers can be considered as holders of declarative knowledge.

The CIS is conducted every two years. Therefore, we create annually available variables not coming from CIS as an average over the two years in question. Thus, in characterizing firms' employees, we

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the same contact person, a switch from not-R&D-active to persistent R&D should reflect some degree of strategic decision making.

merge individual data for two consecutive years and then create employee and other characteristics based on averages across *t* and *t*-1.[6] We construct inflow, outflow and common workers for each respective group of R&D workers.

3.3. Identification strategy

Our ability to infer a role played by recruitment of experienced R&D workers in implementing and sustaining an R&D strategy shift hinges crucially on our identification strategy. Below we describe our main strategy to identify the role played recruitment of R&D workers, as well as the main confounding factors for which we control.

Testing recruitment as means to implement a shift of R&D strategy

Based on the methods explained in the previous sections, we define two sets of firms: one with firms undertaking an R&D strategy shift and one with firms that do not. For both sets of firms, we identify recruitment of experienced R&D workers. There are 401 firms that do not report any R&D spending in all consecutive periods, and 41 firms undertaking an R&D strategy shift between waves one and two. This leaves us with 442 firms in total. In order reduce issues of unobserved heterogeneity with drop all other firms, where we not that this is a selection on an exogenous variable (see Model (1)) and therefore will not induce selection bias.

If recruitment of experienced R&D personnel is a means by which firms acquire routines and capabilities for R&D, we should observe that those firms that do undertake an R&D strategy shift, all else equal, are more likely to recruit than firms with no observed change in R&D strategy.[7] Our baseline empirical model for testing this proposition is as follows:

$$(1) \quad R_{it}^{g} = \alpha + \gamma IS_{it} + \mathbf{X}'_{\mathbf{it}}\boldsymbol{\lambda} + \sum_{s=1}^{S}\theta_s D_s + \sum_{t=1}^{T}\delta_t D_t + \varepsilon_{it}$$

where R_{it}^{g} denotes recruitment of experienced R&D workers of type *g* (managers or knowledge worker*)* by firm *i* in year *t*. The matrix $\mathbf{X_{it}}$ contains the confounding factors and control variables

[6]To measure newly recruited R&D managers in each firm in a year, say 2004, this means that we first create an interaction variable of "new R&D managers" and "inflow" for both 2003 and 2004. We then sum this, by year, for each firm and merge the datasets on the firm level. Assume that for firm *j*, it recruits 1 in 2003 and 2 in 2004, respectively. For firm *j*, this value would be 1.5 (since (1+2)/2=1.5).

[7]Note that the fact that we have longitudinal data on firms that do undertake an R&D strategy shift as well as those that do not allows for a cleaner identification than e.g. exploitation of pure cross-sectional variance. An alternative identification strategy would be to simply compare R&D-active with non R&D active firms, and then study the experiences of their stock of workers. This would however entail significant simultaneity and endogeneity problems. Here we exploit variance over time in the R&D strategy of each firms and its recruitment of R&D personnel.

discussed below.[8] D_s and D_t are sector and time dummies, respectively. IS_{it} is a dummy variable which is 1 for firms that shift from none to persistent R&D in CIS (2006), and 0 otherwise.

For each firm and time period, R_{it}^{g} is defined as recruitment of R&D workers of group g as a fraction of all recruitments to the firm. It is thus expressed as a recruitment rate bounded between 0 and 1, and we employ a Panel-Tobit estimator with corresponding left- and right-censoring limits. The parameter of main interest is γ. This parameter informs whether switching to persistent R&D influence recruitment of experienced R&D workers of different types *g*. It is identified from systematic variation in recruitment rates between firms that do shift strategy and those that do not.

To test H1 and H2, then, we estimate the model in (1) for the total recruitment rate of experienced R&D workers, as well as separately for R&D managers and knowledge workers (see Section 3.2). This allows us to test the relationship between R&D strategy shifts and total recruitment of R&D workers (H1), as well as hires of different kinds of experienced R&D workers (H2).

With regard to the timing of hires, our theoretical framework suggests that recruitment of R&D workers is the result of a preceding (unobserved) decision to engage in persistent R&D; hence our focus on recruitment as a means to *implement* a shift of R&D strategy.[9] By this argument, we expect that the hires of experienced R&D managers should primarily occur before we observe a firm's R&D strategy shift in the data. Routines and capabilities need to be developed in order to enforce a strategy shift. H3 indeed states that firms that change their R&D strategy from none to persistent R&D recruit managers with R&D experience before they recruit R&D workers, the argument being that procedural knowledge should precede declarative knowledge.

We test this proposition by introducing a lag structure in the model in (1).[10] We then test, for R&D managers and knowledge workers respectively, whether R&D strategy change primarily influence recruitment before, after or in the same period as the R&D strategy change takes place. A verification of H3 would imply that the recruitment of R&D managers primarily takes place before the R&D strategy change is implemented, and that this is followed by recruitment of more general knowledge workers with R&D experience.

[8] Basic descriptives for all variables in the analyses are reported in Appendix A.

[9] To be clear, the theoretical arguments developed in the paper suggests that a realized R&D strategy shift of a firm in the data is the outcome of a preceding management decision to undertake such a shift, followed by a successful strategy to build routines and capabilities to enforce the new R&D strategy. Firms with no observed change in R&D strategy may still have decided to try to shift strategy, but failed even before anything was observable.

[10] We implement this using forward and backward lags of the IS_{it} variable.

Testing whether recruitment helps to sustain a shift of R&D strategy

We also test whether recruitment of R&D workers has an influence on the probability that a firm sustains its R&D strategy shift into as indicated in CIS 2008, i.e. two years after the observed strategy shift. Among the set of firms shifting R&D strategy between waves one and two, only a subset continues with a persistent R&D strategy throughout wave three. We argue that those firms that sustain their R&D strategy should have been more successful in establishing R&D routines and capabilities. We assume that firms conditional on their characteristics have recruited more R&D workers in 2006 (we use the error term in Model (1) as a measure) has a positive effect on the likelihood to stay R&D active in 2008. Using a Probit model, the estimating equation is:

$$\Pr\left(Sustain_i = 1 \middle| \mathbf{Z_i}\right) = \Phi\left(\mathbf{Z_i'\Gamma}\right)$$

(2)

$$\mathbf{Z_i'\Gamma} = \alpha + \sigma\varepsilon_{i2006} + \mathbf{X_i'\lambda} + \sum_{s=1}^{S}\theta_s D_s + u_i$$

Firm fixed effects?

To estimate Model (1), we employ a panel-robust pooled Tobit estimator. This estimator has the same consistency characteristics as Random Effects. While in particular the economics literature has a preference for fixed effects regression because of its ability to control for endogenous unobserved heterogeneity, there are some arguments in favor of a random-effects-like model in our empirical context.

From a capabilities perspective Cockburn et al. (2000) argue that while economists justify fixed effects by "measurement problems, ranging from the difficulty of computing appropriately depreciated capital stocks and […] of controlling for difficult-to-observe factors such as worker effort or worker quality", strategy researchers must *estimate and analyze* the fixed effects (instead of only controlling for them) because they are the very resemblance of the capabilities and routines they theorize about. In that respect, using fixed effects would imply cancelling out the very objects of interest. This means to means that we try to explain phenomena defined in terms of *inter*-firm variation by the use of *intra*-firm variation, which is theoretically meaningless.

As a consequence from a technical point of view, any associations found in fixed-effect regression operating on roughly time-constant variables (the recruitment rates are example of such a variable) are either likely to lead to insignificant results and to the degree that they remain significant there is a serious risk that the results are due to outliers. This is because fixed effects regression cancels out all inter-firm variation. If intra-firm variation is low, outliers or measurement error may be the dominant drivers of identification.

Furthermore, our sample is constructed so that issues of unobserved heterogeneity are reduced already from the beginning: Because we focus on firms that start with similar outsets (no R&D activity in 2004), we believe that the initially the sample is more homogenous compared to a situation where we had used all observations. We thus limit the need for fixed effects estimation.

Because of these reasons we believe that the random effects assumption leads to the better model choice. Nonetheless, as a control of robustness we also used Mundlak correction terms (Mundlak 1978) which parameterize the fixed effects as linear functions of yearly averages of the explaining variables. Despite their strong assumptions Mundlak corrections have the advantage that they do not cancel out cross-section variation directly making the estimation more efficient than full fixed effects. Furthermore, under some additional distributional assumptions it is easy implementing a fixed effects model in the Panel-Tobit case. Due restrictions in space and since we do not observe qualitative changes to the panel-robust pooled Tobit estimators presented in Section 4, we do not present the Mundlak regressions.[11]

Confounding factors

There are several reasons why a firm may hire R&D experienced workers. Additional to some other factors (listed below), we account for the four main confounding factors: (i) exports, (ii) sales growth, (iii) location characteristics and (iv) product innovation.

A large literature shows that there are significant costs of entering foreign markets. Exports are associated with entry costs, which imply productivity thresholds that only more productive firms can overcome (Wagner 2007). Foreign markets may also be more competitive, requiring refinements of product lines and production processes as well as reductions of X-inefficiencies (Andersson and Lööf 2009, Schubert and Simar 2011). This implies that firms active on international markets may be more inclined to recruit highly qualified workers with experience from R&D-active (and presumable more productive) firms. If exports or initiation of exports coincide with a shift of R&D strategy, then there is a risk of spurious identification of the effect of R&D strategy shift on recruitment.[12] We thus include two dummy variables reflecting firms' export strategy in the empirical model.

Firms' recruitment patterns are linked to their growth (Faberman and Nagypal 2008). Stronger recruitment can thus simply be the result of growth in sales. Firms shifting from no to persistent R&D may also be more likely to experience sales growth, precisely because of the same arguments as above

[11] These are yet available from the authors upon request.

[12] In fact, the incentives for R&D may increase with expanding markets, the reason being that the fixed costs of R&D may be spread over larger sales (cf. Aw et al 2008).

for exports – incentives for R&D become larger as sales increase. This suggests that sales growth may be an important confounding factor and we include a control for growth in sales in the empirical model. While we also have controlled in some regression for absolute firm size, this variable did neither contribute to explanatory power given that growth was included nor did it change the results. Because of this and because size is in the evolutionary innovation literature as a highly endogenous variable, we exclude it from the regressions.

The third confounding factor is location. The reason why location matters are the following: First, labor market mobility is subject to significant spatial transaction costs and is therefore highly localized (Andersson and Thulin 2013). Second, different regions offer different access to R&D experienced workers.[13] Firms located in regions with density of R&D workers in incumbents are thus in a better position to hire R&D workers because there are more potential recruits. To verify that our estimated relationship between recruitments of R&D workers and change in R&D strategy is not caused by an underlying location pattern of firms, we control for location. We do this by including the size of the region in which they have their main activity as well as the pool of each respective group of R&D workers. The former account for general agglomeration phenomena and the latter measures the directly observable pool of R&D workers.

The fourth confounding factor is product innovation. Product innovation in the form of the development of improved or new products in the firm does not necessarily require persistent R&D activity. Such innovation activity may yet trigger recruitment of experienced R&D workers. Based on these arguments, we control for product innovation activity in each firm. We measure this as the fraction of sales due to new or improved products, which is a standard measure of product innovation employed in studies using CIS data (Kleinknecht et al 2002, Robin and Schubert 2012).

We also control for a number of other factors. First, we include measures of the existing stock as well as outflow of R&D workers. Both these variables may explain recruitment of new experienced R&D workers. Second, we also control for firm-level productivity, as proxied by value-added per employee. Last, we account for sector heterogeneity and time effects using industry and year dummies.

[13]Inter-firm job-switching is significantly less frequent between firms located in different regions as between firms located in the same region. Andersson and Thulin (2013) show that about 80% of all inter-firm job-switching takes place between firms located in the same local labor market region.

4. RESULTS

Recruitment rate of R&D workers and shift of R&D strategy

We will see that the timing of recruitment (before, during, after the strategy shift) differs by R&D worker group. We begin with our baseline specification in equation (1) with no lag structure, where Table 1 presents the estimated parameters. These results inform whether an R&D strategy shift influence the recruitment frequency of R&D workers in the same period as the R&D strategy shift is realized. The first model refers to recruitment of all types of R&D workers, whereas the second and third model present results for R&D managers and knowledge workers with R&D experience, respectively. We have argued that managers will mainly possess procedural knowledge while knowledge workers will embody declarative knowledge. This should be kept in mind because we hypothesized that managers are likely to be hired before the strategy shift (the results to be presented in Table 2).

Firms changing R&D strategy have indeed a higher recruitment rate of knowledge workers with experience that possess the task-related declarative knowledge. Consistent with our theory that managers are hired before the shift, the rate of recruitment of managers is not higher during the period of the strategy shift. This suggests that the periods during which a strategy shift from none to persistent R&D is realized are primarily associated with higher recruitment rates of knowledge workers.

Looking at the confounding factors, we see that outflow and relative stock of employee category, labor productivity as well as regional size are statistically significant in most specifications. That firms experiencing an outflow of R&D workers tend to have higher recruitment of R&D workers is in line with our expectations. Outflow of workers, either caused by exits or retirement, should induce hires to replace those leaving the firm. But this result primarily applies to R&D managers.[14] This may be appreciated as R&D managers being more central for the organization and therefore more important to replace. For knowledge workers, it is instead the relative stock of workers inducing higher rates of recruitment of knowledge workers, reflecting that larger stocks are associated with generally higher churning. In line with expectations, firms with higher labor productivity are in general more inclined to hire R&D managers. Moreover, the size of the region in which a firm is located induces a higher rate of recruitment of all types of R&D workers. This is consistent with the general finding that availability of skilled workers as well as the overall rate of inter-firm job switching is higher in larger regions (cf. Andersson and Thulin 2012).

[14]For knowledge workers with R&D experience, the estimated coefficient is positive but not statistically significant.

Table 1. The influence of R&D strategy change on recruitment of R&D workers, no lag structure.

	All R&D workers	R&D managers	Knowledge workers with R&D experience
R&D strategy shift (2006)	0.0477	0.0268	0.0873**
	-0.037	-0.0298	-0.0377
Outflow of employee category	0.311***	0.343***	0.0625
	-0.11	-0.11	-0.3
Relative stock of worker category	0.819***	0.421	1.776***
	-0.194	-0.273	-0.321
Labor productivity (log)	0.0487***	0.0713***	0.0293
	-0.018	-0.0156	-0.0207
Presence on foreign markets (CIS)	0.0223	0.023	0.00843
	-0.0199	-0.0184	-0.0234
Export strategy shift (2006)	-0.00504	0.0215	-0.103*
	-0.0366	-0.0315	-0.0589
Change in sales (2004-2006)	0.21	0.373*	80.124
	-0.232	-0.212	8-0.221
Product innovation	0.14	0.0985	0.104
	-0.136	-0.138	-0.174
Region size (log)	0.0211***	0.0185***	0.0240***
	-0.00639	-0.00597	-0.00783
Pool of employee category in region	0.0475	0.0793	0.0792
	-0.0334	-0.0937	-0.0493
Sector dummies?	YES	YES	YES
Year dummies`?	YES	YES	YES

Note: The dependent variable is recruitment of the respective employee categories (column) as a fraction of all recruits (see Equation 1 in the main text). The estimator is a panel-robust Tobit, using left- and right-censoring limits of 0 and 1, respectively. Relative stock of worker category refers to the number of employees of the worker category as a fraction of the total number of employees in the prior year. Pool of employee category in region refers to the number of workers of respective category (column) in the region in which the firm is located. Robust standard errors are presented below each parameter estimate. *** p<0.01, ** p<0.05, * p<0.1

The fact that a shift in R&D strategy from none to persistent R&D has no statistically significant influence on recruitment of R&D managers may appear to partly contradict the general idea of hiring as a source of routine transfer. After all, R&D managers are more likely to embody procedural knowledge of R&D, pertaining to organizational routines and practices in R&D. But our hypothesis in this regard, H3, is that such kind of procedural knowledge should primarily be acquired before the declarative knowledge. Firms are expected to first recruit experienced R&D managers that bring procedural knowledge with them and then build an R&D team by recruiting knowledge workers.

To test if recruitment of R&D managers occurs before hiring of knowledge workers, we lag the indicator of R&D strategy shift forward and re-estimate the model in Table 1.[15] A significant estimate of the parameter associated with R&D strategy shift indicator will in this case imply that firms shifting to persistent R&D have a higher recruitment rate of R&D workers in the period *before* the R&D

[15] Naturally, we also lag the confounding factors reflecting changes in the firm.

strategy shift is realized. This would correspond to the idea that firms 'prepare' an R&D strategy shift by recruiting experienced R&D managers. The results of this undertaking are presented in Table 2.

The results support our hypothesis. Firms initiating a strategy of persistent R&D do show higher recruitment rates of R&D workers than the reference group of firms in the period *before* the strategy shift is realized, and this result is driven by a higher recruitment rate of R&D managers. In contrast, we find no statistically significant effect on recruitment of knowledge workers. These patterns are supportive for the idea that firms first hire R&D managers to build procedural knowledge associated with R&D, and then build up declarative knowledge as captured by knowledge workers with R&D experience.

Table 2. The influence of R&D strategy change on recruitment of R&D workers, forward lag structure.

	All R&D workers	R&D managers	Knowledge workers with R&D experience
R&D strategy shift (2006), *F-lag*	0.106**	0.0937*	0.0612
	-0.05	-0.0489	-0.051
Outflow of employee category	0.483*	0.273	0.856**
	-0.249	-0.252	-0.353
Relative stock of worker category	0.715***	0.257	1.812***
	-0.244	-0.384	-0.433
Labor productivity (log)	0.0833***	0.0654**	0.0850***
	-0.0248	-0.0291	-0.0211
Presence on foreign markets (CIS)	0.0438	0.0284	0.0494
	-0.0287	-0.0254	-0.0369
Export strategy shift (2006), *F-lag*	0.0286	0.0462	-0.0133
	-0.0439	-0.041	-0.0521
Change in sales (2004-2006), *F-lag*	0.369**	0.410**	0.258
	-0.171	-0.192	-0.16
Product innovation, *F-lag*	-0.123	0.00176	-0.0698
	-0.208	-0.215	-0.145
Region size (log)	0.0279***	0.0215**	0.0384***
	-0.00906	-0.0087	-0.00947
Pool of employee category in region	0.120***	0.275*	0.223***
	-0.0453	-0.141	-0.0804
Sector dummies?	YES	YES	YES
Year dummies`?	YES	YES	YES

Note: The dependent variable is recruitment of the respective employee categories (column) as a fraction of all recruits (see Equation 1 in the main text). The estimator is a panel-robust Tobit, using left- and right-censoring limits of 0 and 1, respectively. *F-lag* refers to that the variable is lagged forwards in time. Relative stock of worker category refers to the number of employees of the worker category as a fraction of the total number of employees in the prior year. Pool of employee category in region refers to the number of workers of respective category (column) in the region in which the firm is located. Robust standard errors are presented below each parameter estimate. *** p<0.01, ** p<0.05, * p<0.1

The estimates of the influence of the confounding factors are similar to Table 1. One difference is that change in sales is now significant for R&D workers in general and R&D managers. This suggests that

a rise in firms' sales induce recruitment of R&D managers, which is in line with the argument in the preceding section. For knowledge workers the estimated coefficient is positive but not statistically significant. The results in Table 2 further emphasize the relevance of firms' local environment in that the size as well as the pool of the pertinent workers in the region firms are located in has a positive impact on recruitment rates.

We also test if a change in R&D strategy from none to persistent R&D influences the recruitment rate of R&D workers in the periods *after* the R&D strategy shift is realized. These results are reported in Table C1 in Appendix C, and show that firms indeed continue to show higher recruitment rate of R&D workers of both types in the periods after the strategy shift is undertaken. This is broadly in line with our expectations, and may be appreciated as the strategy shift is intended as a long-term commitment.

The effect of recruitment of R&D workers on the probability of sustaining an R&D strategy shift.
As explained in the preceding section, we also assess whether firms with higher recruitment rates are more likely to sustain the R&D strategy shift throughout the third wave. The basic idea is that firms sustaining their new R&D strategy should have been more successful in establishing new R&D routines and capabilities and we test whether this could be explained by their recruitment rate of R&D workers.

Our fourth hypothesis (H4) stated that a large fraction of firms lacking experience of R&D activity should fail in their endeavor to shift R&D strategy due to the difficulty in building up new routines and capabilities. Without going into details, simple descriptive statistics support this. Out of the 41 firms shifting from none to persistent R&D between waves one and two, only about 22% sustain their strategy of persistent R&D throughout wave three. Do the firms sustaining their R&D show higher rates of recruitment of R&D workers?

We estimate two models. In both of them the dependent variable is a dummy variable taking the value 1 for firms sustaining their new R&D strategy in period three and 0 otherwise. The first model includes all 441 firms. The independent variable of main interest is here a dummy variable which is 1 if the firm recruited at a rate higher than predicted by the model in Table 1 and 0 otherwise.[16] In this way we can estimate the influence on recruitment on the probability of sustaining an R&D strategy shift while keeping all firms in the sample. We also include R&D investments as a fraction of sales to control for the fact that not all firms in the sample did undertake R&D in period 2, where those that did report positive R&D expenditures.

[16] We identify such firms by re-estimating the model in equation (1) with no lag structure and then save the predicted recruitment rate of these firms. Those firms whose actual recruitment rate is above the predicted one are then assigned the value 1 and 0 otherwise.

The results are reported in Table 3. There are two main messages from the table. First, we do find that firms with a higher recruitment rate of both R&D managers and knowledge workers are more likely to keep their strategy of persistent R&D throughout the third wave. The estimated parameters are positive and significant at the 10%.[17] Second, we find that firms with larger R&D spending as a fraction of sales are consistently more likely to sustain their R&D strategy.

These patterns support our fifth hypothesis (H5). A higher rate of recruitment of R&D workers has a positive influence on the probability that firms continue with persistent R&D activity. Firms continuing with their new R&D strategy are expected to have been more successful in establishing routines and capabilities for R&D, and our results are consistent with a higher rate of recruitment of R&D workers being one reason for this.

Table 3. The influence on recruitment of R&D workers on the probability of sustaining an R&D strategy shift.

	All R&D workers	R&D managers	Knowledge workers with R&D experience
Recruitment rate of R&D workers (*more than predicted)*	-0.328	1.285*	1.333*
	-1.351	-0.668	-0.757
R&D investments (fraction of sales)	0.00663***	0.00703***	0.00688***
	-0.0022	-0.00228	-0.0023
Product innovation	3.186	3.28	1.786
	-2.637	-2.635	-3.167
Region size (log)	0.00469	0.0513	0.00784
	-0.134	-0.141	-0.137
Pool of employee category in region	0.116	-0.00017	0.398
	-1.516	-6.685	-2.25
Sector dummies?	YES	YES	YES

Note: The dependent variable is a dummy variable which is 1 if the firm continues with a strategy of persistent R&D throughout the third wave, and 0 otherwise. The sample consists of all firms observed in wave two. The estimator is a Probit model. The variable "Recruitment of category of experienced R&D workers" is a dummy taking the value 1 if the firm has a higher recruitment rate than predicted by the model in equation (1), and 0 otherwise. Pool of employee category in region refers to the number of workers of respective category (column) in the region in which the firm is located. Robust standard errors are presented below each parameter estimate. *** p<0.01, ** p<0.05, * p<0.1

To further probe our assessment of the influence of recruitment of R&D workers on the likelihood of sustaining a shift of R&D strategy we estimated a second model with a restricted sample of firms, where the sample is only the 41 firms that did undertake a strategy shift in between waves one and

[17]Note there are few firms sustaining their R&D strategy in the third wave. Only about 22% of the 41 firms initiating a strategy of persistent R&D do so. A statistically weak significance may thus be explained by the few numbers of observations following this pattern.

two. The dependent variable was the same as before. We thus asked the following question: among the group of firms shifting from none to persistent R&D, do the firms continuing with persistent R&D throughout wave three show higher recruitment rates of R&D workers? The results gave evidence of an increased probability to remain R&D performer also in 2008 when the recruitment rate in 2006 was higher. Because the results basically corroborate the findings in Table 3, we do not report the regression table, which is, however, available upon request.

5. DISCUSSION AND CONCLUSIONS

Investments in R&D and innovation activity are typically considered key for sustained long-term competitiveness of firms. Analyses of the private returns to R&D show that they are significant and positive (Hall et al 2010), and R&D is also essential for firms' absorptive capacity, i.e. their capacity to recognize and assimilate new information and knowledge (Cohen and Levinthal 1990). Despite this, surprisingly few firms undertake R&D activity. In most sectors there are a small number of systematically innovating firms and a larger number of firms without any observable R&D and innovation activity. The rigidity in this pattern over time is often explained by R&D requiring routines and capabilities that firms without R&D experience lack (Dosi and Nelson 2010). This explanation is static in the sense that it explains 'lack of change' in the heterogeneity in firms' R&D activity, and devotes less attention to the question from where routines and capabilities for R&D come as well as how (if at all) they can be consciously developed to sustain firms' transition towards R&D activity. To deepen our understanding of these issues, this paper has focused on one specific source of routines and capabilities for R&D activity: recruitment of experienced R&D workers. We show that recruitment of experienced R&D managers and knowledge workers is a way in which firms can create new routines and capabilities to enforce and sustain a strategy shift from none to persistent R&D spending despite a lack of internal experience with this task.

These analyses and results link up to the general discussion of the micro-foundations of routines and capabilities (Murmann et al. 2003, Zollo and Winter 2003). By suggesting an explicit source of new routines and capabilities in firms that lies outside the routines and capabilities themselves, our results take into account the critique of tautology and infinite recursiveness of routines (Mosakowski and McKelvey 1997, Priem and Butler 2000, Williamson 1999). The issue whether routines and capabilities reside at the individual or the organization level is indeed embedded in the overall critique of the lack of micro-foundations for routines in the organization and management sciences (Abell et al 2008, Felin and Foss 2004). We do not go as far as Felin and Foss (2004, p. 22) who argue that "… capabilities can [...] be brought in as a function of certain, key individuals, which implies that capabilities in the first place may reside in individuals vs. the organization". This would essentially imply that the organizational capabilities are fictitious in the sense that the differences in them are just

reflections of differences on the individual level. But we argue that the origins of the collective lie in the individual level. These are fundamental issues for management, because practical advice for management requires us to understand where routines, capabilities, and dynamic capabilities come from and the extent to which management can influence or "orchestrate" the process of their creation (Teece 2007).

This offers new perspectives not only for the capabilities approaches in strategic management but also for evolutionary theorizing itself, which has sometimes quite explicitly expressed its agnosticism about the abilities to manage organizational change because of inertia (Hanna and Freeman, 1977). The organizational ecology approach explicitly emphasized the importance of new firm entry rather than incumbent adaptation as a source of novelty in the relevant population (Hannan and Freeman, 1984). While being more Lamarckian than Darwinistic, also the routine-focused evolutionary approaches regard change as incremental and path dependent, implying that firms will find it hard to adapt in the light of environmental turbulence and to start new activities. Our results show that successful adaptation is possible and therefore deserves more attention in evolutionary models. This is particularly true, if they are used in the context of strategic management, whose very *raison d'être* is the analysis of strategic organizational adaption.

The findings in the paper also associate to the broader literature on inter-firm labor mobility and knowledge transfer emphasizing labor markets as conduits for knowledge flows (Almeida and Kogut 1999, Agrawal et al 2006). Almeida and Phene (2012, p27) argue that "… most research does no more than simply suggest a connection between mobility and knowledge flows, offering at best indirect evidence". The analyses in the paper take a further step by empirically verifying a direct link between changes in firms' R&D strategies and recruitment of R&D workers.

Furthermore, the analyses highlight the importance of interactions between firms and their external local environment. Location has long been a rather neglected factor in strategy and management research (Porter 1990, 1994). Yet, in the advent of globally distributed production activities, it has gained increased interest in the last years. In the context of our research, location is implicit in any research linking mobility of labor to inter-firms transfers of knowledge and routines, because labor market mobility is subject to significant spatial transaction costs and is therefore highly localized (Andersson and Thulin 2013, Almeida and Kogut 1999). As a consequence, local conditions matter: For example firms in locations with a high density of R&D performing firms have a greater pool of experienced R&D labor to recruit. Our analyses controlled for the local pool of R&D workers as well as the size of the region in which a firm is located, and we found that recruitment was indeed higher for firms located in larger regions with a larger pool of R&D workers. Our findings point in this sense to a potential synergy between the management literature on inter-firm capability transfer and the

emerging literature on evolutionary economic geography which puts the spatial dimension of routine replication and creation at center stage (Boschma and Frenken 2006, Frenken and Boschma 2007). In accordance with our paper, EEG highlights the importance of labor mobility as a prime mechanism of routine replication and diffusion in space. Yet, this literature seldom studies strategy and management consequences despite the obvious implications: since locational decisions are very long-lasting, they are certainly among the most strategic choices a firm can make, even more so, if recruitment is locally bound and an important means to create new capabilities. Because of this we believe that there is considerable room for cross-fertilization between EEG and various literatures in strategic management (e.g. outsourcing and off-shoring). The shared theoretical basis should facilitate a fruitful exchange.

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APPENDIX A– basic descriptives

Variable	Firms changing to persistent R&D in 2004		Firms remaining with no R&D through all periods	
	Mean	*Std. Dev.*	*Mean*	*Std. Dev.*
Inflow managers	3.05	10.82	0.28	0.81
Outflow managers	0.28	0.89	0.13	0.60
Common employees managers	3.34	4.82	2.03	6.29
Additional recruits managers	2.44	10.57	0.11	0.41
Relative inflow of R&D related personnel	0.07	0.15	0.06	0.14
Relative inflow of knowledge workers	0.02	0.05	0.02	0.08
Relative inflow of managers	0.05	0.15	0.04	0.11
Relative outflow of R&D related personnel	0.05	0.16	0.02	0.10
Relative outflow of knowledge workers	0.02	0.09	0.01	0.06
Relative outflow of managers	0.03	0.11	0.01	0.07
Relative number of common employees: R&D related personnel	0.78	0.40	0.77	0.41
Relative number of common employees: knowledge workers	0.45	0.49	0.19	0.38
Relative number of common employees: managers	0.71	0.44	0.72	0.43
Labor productivity	2827679.00	2886246.00	2002008.00	2685820.00
Relative number of R&D related personnel	0.05	0.05	0.05	0.05
Relative number of knowledge workers	0.02	0.03	0.01	0.04
Relative number of managers	0.03	0.03	0.04	0.04
Export strategy	0.39	0.49	0.26	0.44
Relative wage costs	0.51	0.31	0.47	0.76
Present on world market	0.37	0.49	0.18	0.39
Sales	860000000.00	1920000000.00	212000000.00	943000000.00
% of turnover in new or improved products introduced during the period that were new to the market	0.05	0.14	0.01	0.04
R&D-intensity	156309.40	698235.10	10331.98	58727.08
Wage costs	67800000.00	93300000.00	22200000.00	67000000.00
Personnel costs	106000000.00	146000000.00	34500000.00	105000000.00

APPENDIX B– recruitment of R&D workers after the R&D strategy shift

Table C1. The influence of R&D strategy change on recruitment of R&D workers, backward lag structure.

	All R&D workers	R&D managers	Knowledge workers with R&D experience
R&D strategy shift (2006), *B-lag*	0.162***	0.122***	0.117***
	-0.0366	-0.0321	-0.0396
Outflow of employee category	0.286**	0.311**	0.0527
	-0.125	-0.127	-0.348
Relative stock of worker category	0.630**	0.215	1.468***
	-0.263	-0.298	-0.512
Labor productivity (log)	0.0406*	0.0302	0.0603**
	-0.0214	-0.0219	-0.0238
Presence on foreign markets (CIS)	0.0125	0.027	-0.0055
	-0.0297	-0.0257	-0.0356
Export strategy shift (2006) , *B-lag*	-0.0362	-0.00433	-0.132
	-0.0567	-0.0473	-0.0911
Change in sales (2004-2006) , *B-lag*	0.215	0.155	0.352
	-0.26	-0.214	-0.301
Product innovation, *B-lag*	-0.316	-0.19	-0.301
	-0.214	-0.176	-0.242
Region size (log)	0.0123	0.0119	0.0189*
	-0.0091	-0.00808	-0.0109
Pool of employee category in region	0.0214	0.0588	-0.156
	-0.0433	-0.11	-0.151
Sector dummies?	YES	YES	YES
Year dummies`?	YES	YES	YES

Note: The dependent variable is recruitment of the respective employee categories (column) as a fraction of all recruits (see Equation 1 in the main text). The estimator is a panel-robust Tobit, using left- and right-censoring limits of 0 and 1, respectively. *B-lag* refers to that the variable is lagged backwards in time. Relative stock of worker category refers to the number of employees of the worker category as a fraction of the total number of employees in the prior year. Pool of employee category in region refers to the number of workers of respective category (column) in the region in which the firm is located. Robust standard errors are presented below each parameter estimate. *** p<0.01, ** p<0.05, * p<0.1

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