DUI it yourself: Innovation and activities to promote learning by doing, using, and interacting within the firm

Silje Haus-Reve, Rune Dahl Fitjar and Andrés Rodríguez-Pose

Papers in Evolutionary Economic Geography

22.22

Utrecht University Human Geography and Planning

DUI it yourself: Innovation and activities to promote learning by doing, using, and interacting within the firm

Silje Haus-Reve,[a] Rune Dahl Fitjar [a] and Andrés Rodríguez-Pose [a,b]

[a] UiS Business School, University of Stavanger, Stavanger, Norway;

[b] Cañada Blanch Centre and Department of Geography and Environment, London School of Economics, UK.

ABSTRACT

Implicitly or explicitly, much innovation policy treats investments in research and development (R&D) as the main input to innovation. A large body of literature in innovation studies has challenged this, highlighting the role of external sources of innovation and of innovation based on learning by doing, using and interacting (DUI). Nonetheless, there has been limited empirical research on how firm-internal activities to promote DUI affect innovation, and on how important such activities are relative to internal R&D and to external sources of knowledge. We also know little about how internal DUI activities interact with internal R&D and with external knowledge sourcing. We address these gaps using Norwegian Community Innovation Survey data from 2010. We find that internal DUI is an important driver of new-to-market product innovation. Further, the results show partial substitution effects between internal DUI and internal R&D, as well as between internal DUI and external DUI.

KEYWORDS - *Innovation; Experience-based knowledge; STI; DUI; Firms*

Introduction

For decades, innovation scholars have sought to fathom the underlying processes of learning and knowledge accumulation with the aim of providing policy advice (e.g. Bush, 1945; Solow, 1957; Dosi, 1988; Romer, 1990). Among the many strands that have populated this literature, the linear approach to innovation, which emphasises investment in research and development (R&D), has been mostly dominant in shaping innovation policy until today. As a consequence, R&D subsidies or tax credits have been among the prevailing innovation instruments implemented in many countries, with the goal of attaining 3% of GDP in R&D expenditure a powerful symbolic aim. However, many researchers have remained profoundly sceptical about this narrow focus on R&D in much of past innovation policies (Kline and Rosenberg, 1986; Jensen et al. 2007; Ortega-Argilés, Vivarelli and Voigt, 2009; Hervás-Oliver et al. 2021). Research on how firms innovate has increasingly challenged the primacy of R&D on two main grounds.

First, firms are not limited to using internal sources of knowledge in the innovation process. Indeed, they frequently rely on networked or open innovation approaches, in which external sources of knowledge are as important as internal R&D in generating innovation (e.g. Powell, Koput and Smith-Doerr, 1996; Chesbrough, 2003). Second, firms often innovate without necessarily resorting to any R&D activities (e.g. Santamaría, Nieto and Barge-Gil, 2009; Thomä and Zimmermann, 2020; Alhusen et al. 2021; Hervás-Oliver et al. 2021). Instead, they depend on knowledge generated from practice and experience in the innovation process (Lundvall and Johnson, 1994; Thomä, 2017). This is the core idea in the literature on innovation modes, which highlights two main approaches to innovation: an R&D-based approach, labelled science, technology and innovation (STI), and an approach based on learning by doing, using and interacting (DUI).

However, research on innovation modes has so far shied away from examining the role of internal DUI activities – that is activities to discover, reproduce and share experience-based knowledge across different workers within the firm. It has studied DUI either by combining both internal and external activities into a single measure (Jensen et al. 2007; Parrilli and Elola, 2012; Nunes and Lopes, 2015; Alhusen et al., 2021; Alhusen and Bennat, 2021), or by focusing exclusively on external sources of DUI (e.g. Fitjar and Rodríguez-Pose, 2013; González-Pernía et al. 2015; Parrilli and Alcalde Heras, 2016; Apanasovich, Heras and Parrilli, 2016; Haus-Reve, Fitjar and Rodríguez-Pose, 2019). Accordingly, we still know relatively little about how internal activities to stimulate DUI affect firm-level innovation, beyond what can be derived from the broad literature on knowledge management or learning organisations (e.g. Nonaka and Takeuchi, 1995; Laursen and Foss, 2003). We also know little about the importance of internal DUI activities compared to traditional internal R&D investments, or compared to external knowledge sourcing, whether from science and technology organisations or from DUI-type partners.

Finally, while the literature on R&D-based innovation has frequently studied complementarities or substitution effects between internal R&D and external knowledge sourcing (e.g. Cassiman and Veugelers, 2006; Berchicci, 2013), there is no equivalent research to date which examines these issues for internal DUI activities. Hence, we simply do not know whether internal DUI activities substitute for or are complementary to external knowledge sourcing, or to internal R&D. In this paper, we address this gap by examining the relevance for firm innovation performance of firms' internal activities to promote DUI. We use a set of questions unique to the 2010 Norwegian Community Innovation Survey (CIS), which has data on 6076 Norwegian firms. This survey contained detailed information about the use of internal activities to foster innovation, such as brainstorming or interdisciplinary workgroups, which we use as proxies for internal DUI.[1] Like other CIS surveys, it also includes information on internal R&D and external knowledge sourcing activities, and on firm innovation outcomes. The results show that internal DUI is as important for firm innovation performance as external knowledge sourcing from DUI sources. Furthermore, we find that internal DUI substitutes, to some extent, for external knowledge sourcing from DUI sources and for internal R&D activities.

The paper starts with a discussion of the DUI approach to innovation and its interaction with other innovation activities. In the methodology section, we present the data and empirical strategy. The following section presents the empirical results, where we first examine the relationship between internal DUI and new-to-market product innovation and next its interaction with other innovation activities. The final section discusses the results and concludes.

Theoretical framework

The doing, using and interacting approach to innovation

Jensen et al. (2007) introduced what is now a popular distinction between two ideal types of firm-learning mechanisms to achieve innovation. One mode is based on the production and use of codified scientific and technical knowledge. It is referred to as 'Science, Technology and Innovation' (STI). The other is an experience-based mode based on learning by 'Doing, Using and Interacting' (DUI). In STI, research and development (R&D) is the main innovation driver. It relies mainly on know-what and know-why types of knowledge (Lundvall and Johnson, 1994). These types of knowledge can often be codified and transferred through universally accessible sources, such as books, scientific articles or internet sites. Within the firm, such knowledge is usually generated in R&D departments through targeted R&D activities conducted by highly trained specialists. Besides R&D activities within the firm, collaboration with organisations that produce scientific knowledge, such as universities and research centres, represent important external STI activities. Hence, in the STI mode, innovation builds on R&D, human capital, and research collaboration (Romer, 1990; Cohen and Levinthal, 1990; Griliches and Regev, 1995). However, scientific knowledge is not required for all types of innovation.

Furthermore, its relevance varies across different firms and industries (Pavitt, 1984; Cassiman and Veugelers, 2006; Ortega-Argilés et al. 2009; Hervás-Oliver et al. 2011). This motivated the proposal of the DUI mode, in which learning-by-doing and learning-by-using are fundamental for generating new knowledge (Lundvall et al. 1994). Innovation in this mode relies heavily on tacit knowledge in the form of 'know-how' and 'know-who' (Jensen et al. 2007).

Interacting and collaborating with customers and suppliers are essential sources of knowledge in the DUI mode. Indeed, due to the lack of widely accepted and available data on internal DUI activities – or on how firms work to support learning by doing and by using within their organisations – measures of DUI have mainly captured the interaction dimension of the concept (e.g. Jensen et al. 2007; Parrilli and Elola, 2012), and mostly only the external interaction (e.g. Fitjar and Rodríguez-Pose, 2013; González-Pernía et al. 2015; Parrilli and Alcalde-Heras, 2016; Apanasovich et al. 2016; Haus-Reve et al. 2019). This lack of information has until now prevented researchers from assessing how important internal DUI is to innovation. We simply do not know whether the benefits of DUI, as identified by previous scholarly research, are more generally simply the benefits of an open innovation approach.

According to the theory on innovation modes, learning by doing, using and interacting is something that takes place not just outside the firm. For DUI-based innovation, what happens within the walls of

[1] The definition of internal DUI builds on the description of internal activities that stimulate experience-based innovation and the use of practical knowledge within the firm by Lundvall (1988; 1994). Due to the lack of data on firms' internal activities to promote experience-based knowledge and learning, this has rarely been examined empirically in the innovation modes literature.

the firm is also important. As part of their daily activities, individual employees gain insights through experience which may lead to ideas for product and/or process improvements or new products. However, these insights will only lead to innovation if the firm is able to discover, reproduce and share the tacit knowledge held by individual employees (Kogut and Zander, 1992; Nonaka and Takeuchi, 1995; Gertler, 2003). To promote such learning, firms need to stimulate in- house interactions. Organisational practices such as project teams, problem-solving groups, and job and task rotation, which encourage learning and knowledge exchange, can contribute to developing and sharing experience-based knowledge within the organisation (Laursen and Foss, 2003; Lorenz and Valeyre, 2006). Good practices for collaboration and learning in the workplace are necessary to discover and exploit the experience-based knowledge held by individual workers (Kline and Rosenberg, 1986; Freeman, 1987; Lam, 2005; Arundel et al. 2007; Rammer et al. 2009), facilitating the 'learning organizations' at the base of innovation (see Levitt and March, 1988).

Few studies, however, have used quantitative methods to explore these complex within-firm links. The exceptions (e.g. Laursen and Foss, 2003; Jensen et al. 2007; Thomä, 2017) have typically found a positive correlation between the frequency of product and process innovation and the use of 'high-involvement' work practices, such as autonomous teams, flexible demarcations in work tasks, and human resource manage-ment tools aiming to help employees accumulate and share person-embodied skills and know-how in the innovation process. Santamaría, Nieto and Barge-Gil (2009) found that non-R&D activities, such as design, the use of advanced machinery and training, are crucial to understanding the innovation process of Spanish manufacturing firms. McGuirk, Lenihan and Hart (2015) argued that intangible elements of human capital are relevant for small firms' innovation processes, while Lenihan, McGuirk and Murphy (2019) showed that firms' innovation activity benefits from human resource systems, such as proactive work practices, consultation, and bonus schemes.

These studies provide evidence of the impacts of specific internal DUI activities. Few studies, however, have adopted an integrated approach to the study of the relationship between internal DUI and innovation, covering a wider spectrum of the various activities firms use to promote internal DUI. The main reason for this is the absence of good and relevant measures capturing internal innovation-related organisational characteristics across a large number of firms. As a result, many of the findings remain piecemeal and the studies reach contradictory conclusions or focus exclusively on one aspect of internal organisation. Most research zooms into specific mechanisms of the firm and does not comprehensively address firm-level experience-based knowledge activities (with some recent exceptions, e.g. Alhusen et al. 2021). In this study, we address this gap in the literature, asking the following research question:

RQ1: Does the use of activities to promote internal DUI improve firms' likelihood of new-to -market product innovation?

Interactions between internal DUI and other innovation activities

Due to the lack of scholarly research on internal DUI, we also know little about the relationship between internal DUI and external knowledge sourcing, or between internal DUI and R&D investments. The second objective of this study is therefore to study this relationship in more detail. To this end, we address the following research question:

RQ2: Do internal DUI activities moderate the returns to other innovation activities?

For external knowledge sourcing, there has been limited research equivalent to that developed in the literature on R&D, which has examined the relationship between internal and external knowledge sourcing extensively (e.g. Cassiman and Veugelers, 2006; Berchicci, 2013). Hence, we do not know whether internal DUI activities are complementary to or substitute for external knowledge sourcing. Building on research on how internal R&D interacts with external knowledge sourcing, two contradictory perspectives emerge.

First, organisational practices mediate how firms search for and use knowledge from agents within and outside the value-chain (Foss, Laursen and Pedersen, 2011). This argument has been mostly developed in work on absorptive capacity, which sees internal and external knowledge production as complementary processes. The ability of firms to identify and use external knowledge depends on having sufficient absorptive capacity, for which internal investments in knowledge creation are important (Cohen and Levinthal, 1990). In particular, this literature considers internal investment in R&D to be crucial for firms to recognise the value of external knowledge and apply it in their own innovation process (Cohen and Levinthal, 1990). As such, firms conducting internal R&D are expected to benefit more from external collaboration.

Some approaches to absorptive capacity underscore the importance of factors beyond R&D in the ability of firms to exploit external knowledge (Schmidt, 2010). Zahra and George (2002) highlight the need for social integration within the firm and its role in information sharing. Organisational mechanisms, such as job rotation or inter-departmental connectedness, are key for developing absorptive capacity (Jansen et al. 2005; Vega-Jurado et al. 2008; Lewin et al. 2011). This suggests that internal DUI can also play a critical role in supporting the firm's absorptive capacity. It helps spread knowledge from external sources beyond the R&D department to the rest of the organisation, which provides additional opportunities for such knowledge to be recognised and exploited by other employees and departments involved in the innovation process. For instance, Moellers, Visini and Haldimann (2020) describe how multinational enterprises use various practices, including reward systems and integration mechanisms, for internal cross-departmental knowledge sharing to complement open innovation processes.

An alternative perspective is that there may be substitution effects between internal and external innovation activities. The question of whether to make or buy technology is central in the innovation strategy literature (e.g. Veugelers and Cassiman, 1999), building on the premise that internal and external innovation activities are at least partly overlapping. A firm investing heavily in internal knowledge creation may therefore have less to learn from external knowledge sources than a firm with few internal knowledge capacities (West and Bogers, 2014). The use of external knowledge may even have disadvantages. For example, firms need to protect their knowledge when they engage in formal external collaboration (Cassiman and Veugelers, 2006; Laursen and Salter, 2014). This is the 'paradox of openness': firms that open up to outside sources of knowledge may be jeopardising their capacity to capture rents derived from their own in-house innovation (Laursen and Salter, 2014; Arora, Athreye, Huang, 2016). Knowledge leakage has been described as 'the dark side of knowledge transfer' (Frishammar et al. 2015) and becomes a bigger problem the more firms invest in internal knowledge creation activities (Berchicci, 2013). When firms have more internal knowledge to protect, they also become more wary of who they collaborate with and tend to prune their collaboration networks (Hernández et al. 2015). Consequently, they may avoid external partners with valuable insights and develop second-best connections. The dynamics of the collaboration may also suffer, as firms become less forthcoming in sharing information with partners. This can undermine trust (Ritala et al. 2015).
A greater focus on internal R&D investments, which often generate intellectual property that needs protection, may also weaken collaboration with external partners. However, it may also apply to internal DUI. For instance, internal stakeholders may feel less involved in the innovation process when the focus shifts to external knowledge sources (Fu, 2012).

An important, but hitherto unaddressed, question in this regard is whether such substitution effects are particular to an innovation mode. For instance, does a focus on internal DUI mean that the firm has less to learn from external industrial partners with similar experiences, while its need for external scientific inputs in the innovation process is unaffected? A related discussion concerns the relationship between internal DUI and other innovation activities within the firm, such as R&D investments. The broader literature on innovation modes has developed the idea that there are benefits from combining both innovation modes (Jensen et al. 2007; Aslesen, Isaksen and Karlsen, 2012; Parrilli and Alcalde Heras, 2016). A core idea in Jensen et al.'s seminal paper is that 'what really improves innovation performance is using mixed strategies that combine strong versions of the two modes' (Jensen et al. 2007: 690), since both types of knowledge are needed in the innovation process. Within the firm, good ideas that emerge from the shop floor may require formal R&D processes to develop their full potential. Conversely, new technology developed through R&D activities can be put to use more effectively if the firm has good processes for learning by doing and using.

However, Haus-Reve et al. (2019) formally tested for complementarity between external knowledge sourcing in each mode, finding instead that there are substitution effects. While both R&D-based and DUI-type innovation activities are important, firms have limited capacity and need to prioritise which innovative ideas to pursue. Hence, there can be a trade-off between investing in one type of activity or the other. The relationship between R&D and DUI activities is also not necessarily harmonious or frictionless. Important tacit components of knowledge from DUI may be impossible to translate into formal R&D, and novel technological ideas may also be derailed by broad-based DUI processes. Although there are many open questions about the relationship between DUI and STI, no previous research has examined whether there are complementarity or substitution effects between the innovation modes when it comes to internal activities within the firm.

Methodology

Data

We address these research questions for the case of Norway, using data from the 2010 Community Innovation Survey (CIS). The CIS is based on the 2005 Oslo Manual and provides information on the innovation activities of firms, including detailed data about how and where firms source knowledge for innovation. One of the drawbacks of previous CIS surveys is that they did not capture non-R&D-related innovation activities within firms (Lorenz, 2005). The 2010 Norwegian CIS survey addressed this shortcoming by asking questions about the activities firms engage in to promote internal knowledge exchange for innovation. These questions make it possible to identify the internal organisational mechanisms implemented to foster innovation. Specifically, we examine internal DUI using indicators on the development of within-firm organisational practices to produce or share experience-based or tacit knowledge. This includes brainstorming, interdisciplinary workgroups, job rotation, creativity training, and non-financial incentives for employees to develop new ideas. The CIS survey from 2010 includes information on firms' use of each of these practices during the previous three years. We use this as a measure of internal DUI. On average, just above 41 percent of firms used at least one of these practices. As shown in Table A8 in the Appendix, brainstorming and interdisciplinary workgroups were the most widespread internal DUI practices.

We compare the association between internal DUI and innovation with that between internal STI and innovation. In contrast to Haus-Reve et al. (2019), who focus on the external dimensions of innovation activities and only include internal R&D investments as a control variable, we consider R&D investments here as an indicator of internal STI, as in the original conceptualisation of Jensen et al. (2007). We also compare the link between internal DUI and innovation with the association between external knowledge sourcing and innovation. Here, we follow previous literature (Jensen et al. 2007; Fitjar and Rodríguez-Pose, 2013; González-Pernía et al. 2015; Parrilli and Alcalde Heras, 2016; Apanasovich et al. 2016; Haus-Reve et al. 2019) and distinguish between DUI partners (suppliers, customers, competitors and other firms within the conglomerate) and STI partners (universities, research institutes, laboratories and consultants). In total, 11.0 percent of the sampled firms collaborate with DUI partners and 10.0 percent with STI partners. By classifying different types of external collaboration as indicators of different innovation activities, we do not intend to imply that firms cannot procure scientific knowledge from suppliers or customers, or indeed that universities or research partners cannot be sources of experience-based knowledge. However, the strategy and aims of a firm seeking external knowledge mainly from scientific communities will differ from those of a firm that sources external knowledge mainly from its supply chain. We therefore consider this a useful proxy for the innovation activities which typically characterise the firm's external knowledge sourcing strategy.

One of the advantages of the Norwegian CIS is that participation is mandatory for sampled firms. Non-respondents are fined. This results in a response rate of almost 97 percent.[2] The sample includes the full population of Norwegian firms with 50 or more employees within the industries targeted,[3] as well as all firms with 10–49 employees that have reported significant R&D activities in the previous waves of the survey. Other firms with 5–49 employees are sampled through a procedure which stratifies firms by size and industry, with higher likelihood of inclusion for larger firms. This results in a sample of 6067 firms. These represent around a third of firms and two thirds of employees in the target population. In addition, we merge CIS data with linked employer-employee data (LEED) from Statistics Norway to add information on the location and human capital endowment of each firm.

The Norwegian innovation landscape is based on high levels of collaboration, especially between producers and consumers. R&D investments in the private sector as well as patenting output have, in contrast, been relatively low. The combination of this with high and growing productivity is known as the Norwegian paradox, largely explained by the country's sectoral composition with a high dependence on natural resource extraction (Fagerberg et al. 2009) and a predominance of the DUI rather than STI innovation modes (Cooke, 2016). Confirming this, previous studies using the CIS on Norwegian firms have shown that external collaboration – especially with DUI partners – positively impacts firm innovation output (Haus-Reve et al. 2019). In particular, global knowledge networks are important (Fitjar and Rodríguez-Pose, 2020). Both market-driven and more R&D intensive or science-based approaches are associated with innovation (Clausen, 2013). For the relationship between internal and external strategies, Ebersberger and Herstad (2011) find a substitution effect between internal R&D and external collaboration. Aarstad, Kvitastein and Jakobsen (2019) reach the same conclusion, but only for regional collaboration.

Empirical strategy

To address the research questions, we fit two main regression models [1] and [2] to the data. In both models, we use new-to-market product innovation as the main dependent variable. New-to-market product innovation is registered if the firm has introduced new or significantly improved goods or services, which were new to the market in the preceding three years. In 2010, 18.2 percent of the sample of Norwegian firms reported new-to-market product innovation (Table 1).

---

[2] The high response rate implies that non-response bias is not a problem in the Norwegian CIS. However, a downside might be that some respondents are less diligent in responding.

[3] The Norwegian CIS consists of manufacturing and services industries, as well as aquaculture and mining and quarrying. Specifically, firms in NACE codes 03, 05-33, 35-39, 41-44, 46, 49-53, 55-56, 58-66, 70-72, 74.9, 79, 82.9 and 93.3 are included.

Table 1
Description of the dependent variable.

Variable name	Description	Mean	Std.	Min	Max
New-to-market product innovation	1 if the firm has introduced new or significantly improved goods or services new to the market for the period 2008-2010, 0 if not	0.182	0.381	0	1

As the dependent variable is binary, a logit model is used as the base model. The analysis is based on the innovation production function, which relates firms' innovation outputs to the knowledge activities in the innovation process. The measure of innovation and the empirical approach have been widely used in similar analyses (see e.g. Laursen and Salter, 2006; Love et al. 2011; Fitjar and Rodríguez-Pose, 2013; Parrilli and Heras, 2016; Haus-Reve et al. 2019). First, we investigate the association between internal DUI and innovation to answer the first research question. To this end, we estimate the following logit model:

$$P(innovation_i) = \alpha + \beta_1\ DUI\ internal_i + \beta_2\ STI\ internal_i + \beta_3\ DUI\ external_i + \beta_4\ STI\ external_i + \beta_5\ \boldsymbol{Controls}_i + \varepsilon_i \qquad [1]$$

In this model, we compare the association between internal DUI and innovation with the equivalent associations for internal STI and external knowledge sourcing within both innovation modes. Second, we add interaction terms between internal DUI and each of the other innovation activities to answer the second research question:

$$P(innovation_i) = \alpha + \beta_1\ DUI\ internal_i + \beta_2\ STI\ internal_i + \beta_3\ DUI\ external_i + \beta_4\ STI\ external_i + \beta_5\ DUI\ external_i * DUI\ internal_i + \beta_6\ STI\ external_i * DUI\ internal_i + \beta_7\ STI\ internal_i * DUI\ internal_i + \beta_8\ \boldsymbol{Controls}_i + \varepsilon_i \qquad [2]$$

For comparability, we include all firms' innovation activities as dummy variables. Hence, in the analysis, we compare the likelihood of innovation between firms that do or do not use any activities to support internal DUI, do or do not invest internally in R&D, and do or not collaborate with external DUI or STI partners.[4] Table 2 shows the definitions of these independent variables and their descriptive statistics.

[4] For robustness, we have also run the analyses using various other operationalization of firms' innovation activities. We have used continuous measures of all activities in an alternative specification (number of different activities used for DUI internal, log internal R&D expenditures for STI internal, number of different types of partners for STI and DUI external). For STI internal, we have also used employment of S&T personnel as an alternative measure. For STI external, we have used knowledge sourcing from codified sources as an alternative measure. For DUI external, we have used collaboration with any type of partner as an alternative measure. The results for these alternative specifications are available upon request and are consistent with the results reported herein.

Table 2
Descriptive statistics and variable definitions of innovation activities.

Variable name	Description	Mean	Std.dev	Min	Max
DUI *internal*	1 if the firm used brainstorming, interdisciplinary workgroups, job rotation, non-financial incentives and/or creativity training during the period 2008-2010, 0 if not	0.41	0.49	0	1
STI *internal*	1 if the firm used internal expenditures on R&D during the period 2008 - 2010, 0 if not	0.24	0.43	0	1
DUI *external*	1 if the firm has collaborated or interacted with suppliers, customers, competitors, and/or partners within the conglomerate to promote innovation during the period 2008-2010, 0 if not	0.11	0.31	0	1
STI *external*	1 if the firm collaborated with laboratories, research institutes, universities, and/or consultants to promote innovation during the period 2008-2010, 0 if not	0.10	0.30	0	1

A number of firm-level controls are incorporated in $\boldsymbol{Controls_i}$ in the estimations to account for observable heterogeneity potentially affecting firm-level innovation performance and the use of different innovation activities. Innovation capabilities may be associated with the size and age of the firm. We include Firm size as the number of full-time employees in the firm. This variable is based on linked employer-employee data from tax registers, from which we count the number of people listed as employed in the firm in 2010. Larger firms have more resources to cope with the risks of innovation (Schumpeter, 1939), while smaller firms benefit from less rigidity in their innovation process (Cohen, 1995). Firm age is proxied by the number of years in which the firm is present in the register data between 2000 and 2010. Older firms may have drawbacks in the form of rigid organizational structure (Coad et al., 2016) but can benefit by building on their routine and capabilities. Share of educated employees is the percentage of the firm's workers who have completed a higher education degree. This variable is drawn from linked employer-employee data, using the Norwegian education database for details on each employee's educational background. The average share of workers with higher education is 26 percent. [5] One main plant is a dummy variable taking the value 1 if the firm has one plant which employs more than 50% of the staff. It distinguishes between firms with a distributed multilocational organisational structure and those where most employees are co-located. Export focus is a dummy variable taking the value 1 if the firm's most important market is outside Norway, using data from the CIS.

Different industrial sectors are characterized by different incentives and propensities of firms to engage in innovation activities. We control for industry by including dummy variables for industries at the NACE two-digit level. In total, 58 different NACE two-digit industries are present in the data. We further include dummy variables for economic regions. These are defined by Statistics Norway, corresponding to local administrative units at level 2 (LAU 2).[6] A lagged dependent variable is used as a control in all models. This lag accounts for firms' past innovation record, capturing some of the additional unobserved heterogeneity in firms' ability to innovate. Table A2 in the Appendix provides descriptive statistics for the control variables.

In order to formally test whether there is a complementary or substitutional relationship between internal DUI and other innovation activities we follow the approach of Antonioli, Marzucchi and Savona

---

[5] These variables are all log-transformed because of skewness in the distributions.
[6] Functionally integrated labour market regions are merged, building on a classification by Gundersen and Juvkam (2013). This leaves 78 labour market regions, matching a classification previously used in similar studies (e.g., Fitjar and Timmermans 2017; Haus-Reve et al., 2019).

(2017). The main focus is on the complementarity between internal DUI and other innovation activities (e.g., internal DUI and external DUI), while we control for the other types of innovation activities (e.g., internal STI and external STI). Specifically, we compare the sum of the marginal effects of using both (e.g., internal DUI = 1 and external DUI = 1) or none (e.g., internal DUI = 0 and external DUI = 0) of the activities to the sum of the marginal effects of using either one or the other (e.g., internal DUI = 1 and external DUI = 0, or internal DUI = 0 and external DUI = 1). After having retrieved the marginal effects using the logit estimates from Model (2), we implement a set of Wald tests of the linear restriction of the marginal effects: $\boldsymbol{b_1} + \boldsymbol{b_4} = \boldsymbol{b_2} + \boldsymbol{b_3}$ where b_1 is the associated marginal effect of (1,1); b_2 is the associated marginal effect of (1,0); b_3 is the associated marginal effect of (0,1); and b_4 is the associated marginal effect of (0,0).[7] A significant Wald test in combination with a positive sign of the linear combination of the estimated marginal effects provides evidence of complementarity, while a significant test in combination with a negative sign provides evidence of substitutability.[8]

Estimating the effect of firms' innovation activities on their innovation performance raises a number of conceptual and econometric difficulties. One important issue is simultaneity, as firms decide whether to invest in e.g., R&D activities or activities to stimulate internal DUI because of their expected returns in the form of innovation. In other words, the decision to undertake these practices is correlated with an underlying likelihood of innovation. There are various practices in the literature for addressing this — e.g., Heckman two-step (Haneda and Ito, 2018) or mixed-process model (Hewitt-Dundas, Gkypali and Roper, 2019) estimation approaches— which often rely on first estimating the likelihood that firms will engage in innovation processes and then modelling the likelihood that they will succeed. Since we have historical data on firms' innovation performance from the CIS surveys in 2004, 2006 and 2008, we can instead limit the sample to firms which have had a continuous strategy to innovate in past surveys and which are therefore known to actually engage in innovation processes. We can also exploit information from other questions in the CIS survey to identify firms which make active attempts to innovate. We therefore conduct an analysis on these sub-samples as a robustness check.

Nonetheless, endogeneity remains a concern in this type of analysis. There may be unobserved variables that determine both the use of innovation activities and innovation performance, as well as reverse causality. We cannot fully account for these. As the data for internal DUI are only available for 2010, we also cannot use a panel approach. Building a panel of three Norwegian CIS surveys, Haus-Reve et al. (2019) use a fixed-effects approach to show that the effects of external STI and DUI are not driven by time-invariant influences. For internal DUI, more data would be necessary to fully determine whether this is the case.

Pairwise correlations (Table A3) indicate that firms that invest in one type of activity to promote innovation are more likely to invest also in other activities. The other correlations tend to be low, indicating that severe multicollinearity is not a problem in the analysis. All models control for sector differences by including a dummy for industry. However, some innovation strategies are more important in low-technology industries than others (Heidenreich, 2009; Trott and Simms, 2017). Hence, we additionally run the models for different sub-samples of industries, distinguishing between high-technology/medium-high-technology (HMT) and low-technology/medium-low-technology manufacturing (LMT), and between knowledge-intensive (KIS) and less-knowledge-intensive (LKIS) services. Furthermore, innovation is a multidimensional phenomenon, and different activities can be important depending on the specific type of innovation outcome the firm aims to achieve. We therefore test the robustness of the findings across different outcomes by also estimating the model for new-to-firm product innovation and new-to-firm process innovation as dependent variables.

[7] The Wald tests are distributed as χ^2 with one degree of freedom since we are testing one single linear restriction at a time.

[8] These variables are all log-transformed because of skewness in the distributions.

Empirical results

Table 3 reports the results of the baseline logit model [1], addressing RQ1. We find that internal DUI has a significant and positive effect on new-to-market product innovation. Implementing organisational activities that aim to foster experience-based learning and knowledge exchange within the organisation improves the likelihood of succeeding with innovation. Moreover, this effect is independent of the effects of R&D investments and external knowledge sourcing, as internal DUI remains a positive and significant predictor of innovation even when controlling for these other innovation activities. Moreover, internal DUI does not absorb the positive effect from internal STI and external DUI. When including this variable in a stepwise approach, the coefficients for the other innovation activities are only slightly reduced (Table A4 in the Appendix) and remain significant and positive.

Furthermore, we find a significant and positive effect of internal STI and external DUI, as expected. However, external STI is not significant. The coefficient for external DUI is similar to the coefficient for internal DUI. Controlling for industry and regional fixed effects, firm size has a significant negative effect on innovation, while education, firm age and export focus are not significantly correlated with innovation.

Table 3
Regression results, model [1].

	New-to-market product innovation
New-to-market prod. inno. t-1	1.044***
	(0.136)
DUI *internal*	1.149***
	(0.102)
STI *external*	-0.111
	(0.197)
STI *internal*	1.887***
	(0.116)
DUI *external*	1.220***
	(0.173)
Firm size (log)	-0.282***
	(0.049)
Firm age (log)	-0.023
	(0.117)
Share of edu.emp. (log)	0.555
	(0.378)
One main plant	-0.151
	(0.175)
Export focus	-0.063
	(0.132)
Constant	-3.368***
	(0.817)
Observations	5,997
Pseudo R-squared	0.386

Note: Robust standard errors clustered over firms in parentheses. All models include industry and regional fixed effects. *** p<0.01, ** p<0.05, * p<0.1

In order to examine which of the components of internal DUI are most closely associated with successful innovation, Table A5 in the Appendix decomposes the indicator of internal DUI into its individual constituents. The results presented indicate that the use of brainstorming and job rotation have strong positive effects. Creativity training also has a positive and significant, albeit smaller, effect. The use of interdisciplinary workgroups or individual incentives do not significantly influence innovation.

Interactions and test for complementarity

Next, we turn to the second main contribution of this article and examine the relationship of interest for RQ2 on the interaction between internal DUI and other innovation activities. Table 4 presents the results for model [2] which includes the interactions between internal DUI and internal STI, external STI and external DUI, respectively. We first fit the interactions between internal DUI and each of the three other activities separately. Finally, we fit a model that includes the interactions between internal DUI and all three other activities simultaneously.

Table 4
Regression results, model [2]. Dependent variable: New-to-market product innovation.

	(1)	(2)	(3)	(4)
New-to-market product innov. t-1	1.051***	1.030***	1.041***	1.040***
	(0.136)	(0.134)	(0.136)	(0.134)
DUI *internal*	1.267***	1.507***	1.199***	1.534***
	(0.107)	(0.132)	(0.105)	(0.132)
STI *external*	-0.070	-0.071	0.294	-0.373
	(0.192)	(0.191)	(0.321)	(0.418)
STI *internal*	1.860***	2.421***	1.875***	2.357***
	(0.116)	(0.172)	(0.116)	(0.186)
DUI *external*	1.821***	1.210***	1.223***	1.759***
	(0.275)	(0.168)	(0.172)	(0.364)
DUI ext * DUI int	-0.795***			-0.713*
	(0.287)			(0.407)
STI int * DUI int		-0.807***		-0.726***
		(0.194)		(0.212)
STI ext * DUI int			-0.504	0.406
			(0.325)	(0.466)
Controls	Included	Included	Included	Included
Observations	5,997	5,997	5,997	5,997
Pseudo R-squared	0.387	0.389	0.386	0.389

Note: Robust standard errors clustered over firms in parentheses. All models include industry and regional fixed effects. Full models are included in Appendix, Table A6. *** p<0.01, ** p<0.05, * p<0.1

Starting with the interaction with external knowledge sourcing, we find a negative and significant interaction term between internal DUI and external DUI. Hence, internal DUI can to some extent substitute for external DUI. The interaction between internal DUI and external STI is also negative, but not significant. Moving on to the interaction with internal STI, we find the same pattern: There is a negative and significant interaction between internal DUI and internal STI. Hence, internal DUI can to some extent substitute for internal R&D investments (albeit imperfectly, as we still find significant positive coefficients for each activity when controlling for the other). While individually both internal DUI and internal STI, as well as external DUI, improve the likelihood of new-to-market product innovation, there is a negative interaction between them.

We move on to test formally for substitution or complementarity effects between the innovation activities. Table 5 reports the results of the Wald tests. The test shows evidence of substitutability between internal and external DUI, and between internal DUI and internal STI. For internal DUI and external STI, the result is not significant. This confirms the results from Model [2].

Table 5
Wald test for complementarity or substitution effects.

	Wald test Adj. P-value for H_0:	Sign of the linear combination
DUI ext * DUI_int	7.64***	<0
	0.005	
STI int * DUI int	17.25***	<0
	0.000	
STI ext * DUI int	2.40	<0
	0.121	

Note: Tests conducted on marginal effects. Adjusted p-value of inequality tests for Wald χ^2 statistics with 1 degree of freedom. [11] + [00] + [-01] + [01] >0 is index of substitution effect, while [11] + [00] + [-01] + [01] < 0 is index of complementary.

The presence of substitutability between internal and external DUI means that there is a trade-off between investing in each type of innovation activity. Internal and external knowledge sourcing activities partially substitute each other. This pattern is similar to what has previously been found for internal and external R&D in the innovation strategy literature (e.g., Veugelers and Cassiman, 1999). The law of declining returns also applies to investments in knowledge creation, and internal and external investments provides partly overlapping new knowledge. The same holds for the relationship between internal DUI and internal STI: Investing in one type of innovation activity can partially substitute for investing in the other type. This is also similar to what has previously been found for the relationship between external DUI and external STI (e.g., Haus-Reve et al., 2019). The law of declining returns is at work also here, with firms facing a trade-off between investing in DUI or in STI.

Internal DUI represents an important source of new knowledge for firm innovation activities. However, as with all innovation activities, there are declining returns. Firms that already engage in a lot of other innovation activities may have less to gain from also investing heavily in internal DUI. On the flipside, internal DUI can work as a substitute for external DUI and for internal STI, providing an alternative route to innovation for firms.

Robustness checks

The models above assume that all firms try to innovate, which may not necessarily be the case. If a firm is not actively pursuing innovation, they would be less likely both to conduct any innovation activities and to actually innovate. In order to address this issue, we do the analyses for two sub-samples: First, firms that report any type of innovation (including new-to-firm product and process innovation) in the CIS surveys in 2004, 2006 or 2008 are defined as ‘previous innovators’. Second, firms that demonstrate active attempts to innovate – by reporting any kind of innovation expenditure, collaboration or any kind of innovation outcome, aborted or ongoing innovation process – are defined as ‘innovation-active’, in line with previous research using the CIS (e.g. Herstad, Aslesen and Ebersberger, 2014). Table 6 shows the results of these analyses. These are consistent with those for the full sample across both sub-samples, albeit with smaller effect sizes for most variables.

Table 6
Regression results, consistent innovators and innovation-active firms.

	Previous innovators	Innovation active
	(1)	(2)
DUI *internal*	1.464***	0.451***
	(0.218)	(0.150)
STI *external*	0.074	-0.225
	(0.472)	(0.349)
STI *internal*	1.734***	0.856***
	(0.259)	(0.181)
DUI *external*	1.471***	1.146***
	(0.423)	(0.287)
DUI *ext.* * DUI *int.*	-0.205	0.312
	(0.524)	(0.394)
STI *int.* * DUI *int.*	-0.351	0.277
	(0.295)	(0.211)
STI *ext.* * DUI *int.*	-0.441	-0.279
	(0.471)	(0.330)
Observations	2,252	2,874
Pseudo R-squared	0.325	0.221

Note: Robust standard errors clustered over firms in parentheses. All models include controls, industry and regional fixed effects. *** p<0.01, ** p<0.05, * p<0.1.

Table 7:
Regression results, new-to-firm innovation.

	New-to-firm product innovation		New-to-firm process innovation	
	(1)	(2)	(3)	(4)
New-to-firm innov. t-1	1.105***	1.101***	0.891***	0.883***
	(0.113)	(0.112)	(0.107)	(0.105)
DUI *internal*	1.241***	1.490***	1.082***	1.430***
	(0.094)	(0.114)	(0.097)	(0.120)
STI *external*	-0.259	-0.575	-0.050	-0.125
	(0.215)	(0.427)	(0.174)	(0.384)
STI *internal*	1.918***	2.229***	1.228***	1.739***
	(0.111)	(0.175)	(0.114)	(0.196)
DUI *external*	1.378***	2.054***	1.172***	1.605***
	(0.187)	(0.346)	(0.156)	(0.324)
DUI ext.* DUI int.		-0.944**		-0.558
		(0.401)		(0.363)
STI int. * DUI int.		-0.499***		-0.754***
		(0.203)		(0.216)
STI ext.* DUI int.		0.524		0.161
		(0.488)		(0.425)
Controls	Included	Included	Included	Included
Observations	6,024	6,024	6,004	6,004
Pseudo R-squared	0.408	0.410	0.254	0.259

Note: Robust standard errors clustered over firms in parentheses. All models include industry and regional fixed effects. *** p<0.01, ** p<0.05, * p<0.1.

We also conduct the analysis separately for different sectors, considering that the importance of different innovation activities may be sector-dependent. We distinguish between high- and medium high-tech (HMT) and low- and medium low-tech (LMT) manufacturing and between knowledge-intensive services (KIS) and less-knowledge- intensive services (LKIS) industries.9 For RQ1, the results show that internal DUI has a positive effect on new-to-market product innovation in all industries (Table A7-A8). The coefficients are relatively stable across all sub-samples. For RQ2, the interaction between internal DUI and other innovation activities (Table A9) are still mostly negative. However, we only find significant substitution effects between internal DUI and internal STI for service industries and not for manufacturing industries. For the interaction between internal DUI and external DUI, we uncover significant substitution effects only in LKIS. There are no significant negative interactions between internal DUI and external STI. By contrast, we find a significant positive interaction between the two for HMT manufacturing.

Finally, we conduct the analysis for new-to-firm product innovation and new-to-firm process innovation in order to examine whether the results hold also for other innovation outcomes (Table 7). The results are consistent with the findings using new-to-market product innovation as the outcome. Internal DUI is significantly positively associated with both product and process innovation. The coefficient is similar to that of external DUI. For process innovation, it is also similar to that of internal STI. This implies that when it comes to new-to-firm process innovation, investing in activities that promote learning by doing, using and interacting within the firm can pay off to a similar extent as investing in R&D. For RQ2, negative interactions between internal DUI and external DUI, as well as internal STI, are identified also for new-to-firm product innovation. For new-to-firm process innovation, only the latter is significant.

Discussion and Conclusion

This paper examines the importance for innovation of activities to promote learning by doing, using and interacting (DUI) within the firm. The paper contributes to the innovation literature by empirically analysing whether firms' internal activities to promote DUI is associated with a higher likelihood of new-to-market product innovation. Furthermore, we ask whether internal DUI complements or substitutes for other innovation activities.

The ability of an organisation to prop up experience-based learning and knowledge exchange between employees is thought to be one of the most important sources of firm innovation, but has seldom been included in empirical models. This is partly due to a lack of large-scale data measuring this type of activity at the firm level. The attraction of the Open Innovation approach by Chesbrough (2003) has also put the external dimension of DUI in a privileged position, perhaps to the detriment of research on internal learning mechanisms and processes. However, research within other disciplines (e.g. human resources) has included the internal dimension of DUI in its frontier research. We show that internal DUI plays a major role for innovation. Internal DUI has a similar effect as external knowledge sourcing on the likelihood of innovation. Furthermore, internal DUI partly substitutes for other innovation activities. This includes both external DUI and internal R&D. We link this to the law of declining returns. The different types of innovation activities all yield important insights, but firms face trade-offs in deciding which activities to invest in.

These results have implications for research on firms' use of different innovation activities. We highlight the importance of incorporating internal experience-based knowledge, together with more

[9] We follow the OECD (2011) definition of high-tech, medium-high-tech, medium-low-tech and low-tech industries and the Eurostat (2016) definition of knowledge-intensive and less knowledge-intensive services. In order to get sufficient numbers of observations in each sub-sample, we group high-tech and medium high-tech industries into HMT and low-tech and medium low-tech manufacturing into LMT.

traditional innovation activities, to better understand firm innovation performance. Innovation researchers have long recognised the importance of tacit knowledge and of activities that support the ability of organisations to identify, appropriate and share this type of knowledge. However, the lack of good indicators and comprehensive data has led to a dearth of large-scale empirical evidence on the relationship between such internal DUI activities and actual innovation outcomes. It has also made it difficult to compare its importance to that of other innovation activities. As a result, policy-makers remain preoccupied with formal R&D activities for which the evidence base is more robust and indicators more readily available. By demonstrating the importance of internal DUI, both in itself and relative to other types of innovation activities, we hope to have contributed to putting it on the agenda.

Including internal DUI alongside other innovation activities in an empirical study also allows for the examination of interactions between different activities, which is the second main contribution of the paper. The empirical results do not support the idea that firms' internal DUI activities increase the benefits from other activities. On the contrary, firms that have internal DUI activities benefit less from the knowledge extracted from other innovation activities, as there are partial substitution effects between different innovation activities. This expands the understanding of the make-or-collaborate decision in innovation strategy from a narrow focus on R&D to also include innovation activities to promote DUI.

These findings have implications for future innovation policy and managerial practices. The findings underline the main message of the innovation systems approach that innovation is about more than R&D. Innovation policy and practice should also target the experience-based approach to innovation and support processes of learning by doing and using. Furthermore, firms and policies for supporting them need to go beyond facilitating external interaction and collaboration to also consider the importance of good conditions for internal exchange of experience-based knowledge.

These findings notwithstanding, some limitations remain. First, as the indicators for internal DUI are only available for 2010, we cannot study this phenomenon over time and have a limited capacity to address endogeneity. As a result, we rely on correlations, which do not allow to make strong causal claims about the relationships observed. In this context, the availability of panel data could lead to better analysis of the causal framework and feedback mechanisms between the innovation activities. Second, there are selection issues associated with innovation processes which cannot be completely dealt with. Ultimately, firms invest in different types of innovation activities with a view to increase the expected returns. However, we have little information on the extent to which different firms are trying to innovate. Third, the study is based on survey data, raising issues about self-reporting. While the high response rate reduces concerns about sampling bias, it may be a source of less diligent reporting. Finally, although we draw some of the control variables from register data, the main independent and dependent variables stem from the same survey, raising questions about common method bias. These limitations notwithstanding, the research conducted here offers new and important insights into the potential role of firms' activities to promote internal learning by doing, using and interacting in innovation processes, and of the interactions between this and other innovation activities.

References

Aarstad, J., O. A. Kvitastein, and S. E. Jakobsen. 2019. "What Drives Enterprise Product Innovation? Assessing How Regional, National, and International Inter-Firm Collaboration Complement or Substitute for R&D Investments." *International Journal of Innovation Management* 23 (5): 19500040. doi:10.1142/S1363919619500403.

Alhusen, H., and T. Bennat. 2021. "Combinatorial Innovation Modes in SMEs: Mechanisms Integrating STI Processes into DUI Mode Learning and the Role of Regional Innovation Policy." *European Planning Studies* 29 (4): 779–805. doi:10.1080/09654313.2020.1786009.

Alhusen, H., T. Bennat, K. Bizer, U. Cantner, E. Horstmann, M. Kalthaus, S. Töpfer, R. Sternberg, and S. Töpfer. 2021. "A New Measurement Conception for the 'Doing-Using-Interacting'mode of Innovation." *Research Policy* 50 (4): 104214. doi:10.1016/j.respol.2021.104214.

Antonioli, D., A. Marzucchi, and M. Savona. 2017. "Pain Shared, Pain Halved? Cooperation as a Coping Strategy for Innovation Barriers." *The Journal of Technology Transfer* 42 (4): 841–864. doi:10.1007/s10961-016-9545-9.

Apanasovich, N., H. A. Heras, and M. D. Parrilli. 2016. "The Impact of Business Innovation Modes on SME Innovation Performance in Post-Soviet Transition Economies: The Case of Belarus." *Technovation* 57: 30–40. doi:10.1016/j.technovation.2016.05.001.

Arora, A., S. Athreye, and C. Huang. 2016. "The Paradox of Openness Revisited: Collaborative Innovation and Patenting by UK Innovators." *Research Policy* 45 (7): 1352–1361. doi:10.1016/j.respol.2016.03.019.

Arundel, A., E. Lorenz, B. Å. Lundvall, and A. Valeyre. 2007. "How Europe's Economies Learn: A Comparison of Work Organization and Innovation Mode for the EU-15." *Industrial and Corporate Change* 16 (6): 1175–1210. doi:10.1093/icc/dtm035.

Aslesen, H. W., A. Isaksen, and J. Karlsen. 2012. "Modes of Innovation and Differentiated Responses to Globalisation—a Case Study of Innovation Modes in the Agder Region, Norway." *Journal of the Knowledge Economy* 3 (4): 389–405. doi:10.1007/s13132-011-0060-9.

Berchicci, L. 2013. "Towards an open R&D system: Internal R&D investment, external knowledge acquisition and innovative performance." *Research Policy* 42 (1): 117–127. doi:https://doi.org/10.1016/j.respol.2012.04.017.

Bush, V. 1945. *Science: The Endless Frontier*. Washington, USA: Ayer, North Stanford.

Cassiman, B., and R. Veugelers. 2006. "In Search of Complementarity in Innovation Strategy: Internal R&D and External Knowledge Acquisition." *Management Science* 52 (1): 68–82. doi:10.1287/mnsc.1050.0470.

Chesbrough, H. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston, MA: Harvard Business School Press.

Clausen, T. H. 2013. “External Knowledge Sourcing from Innovation Cooperation and the Role of Absorptive Capacity: Empirical Evidence from Norway and Sweden.” *Technology Analysis & Strategic Management* 25 (1): 57–70. doi:10.1080/09537325.2012.75100.

Coad, A., A. Segarra, and M. Teruel. 2016. “Innovation and Firm Growth: Does Firm Age Play a Role?” *Research Policy* 45 (2): 387–400. doi:10.1016/j.respol.2015.10.015.

Cohen, W. M. 1995. “Empirical Studies of Innovative Activity.” In *Handbook of the Economics of Innovation and Technological Change*, edited by P. Stoneman, 182–264. London: Blackwell, Oxford.Cohen, W. M., and D. A. Levinthal. 1990. ”Absorptive Capacity: A New Perspective on Learning and Innovation.” *Administrative Science Quarterly* 35 (1): 128–152. Stable URL. doi:10.2307/2393553.

Cooke, P. 2016. “Nordic Innovation Models: Why is Norway Different?” *Norwegian Journal of Geography* 70 (3): 190–201. doi:10.1080/00291951.2016.1167120.Dosi, G. 1988. “Sources, Procedures, and Microeconomic Effects of Innovation.” *Journal of Economic Literature* 26 3 1120–1171.

Ebersberger, B., and S. J. Herstad. 2011. “Product Innovation and the Complementarities of External Interfaces.” *European Management Review* 8 (3): 117–135. doi:10.1111/j.1740-4762.2011.01014.x.Eurostat (2016). Aggregation of Knowledge-Intensive Activities Based on NACE Rev. 2.

Fagerberg, J., D.C. Mowery, and B. Verspagen (2009). “The evolution of Norway’s national innovation system.” Science and Public Policy. 36 (6): 431–444http://www.ingentaconnect. com/content/beech/spp

Fitjar, R. D., and A. Rodríguez-Pose. 2013. “Firm Collaboration and Modes of Innovation in Norway.” *Research Policy* 42 (1): 128–138. doi:10.1016/j.respol.2012.05.009.

Fitjar, R. D., and A. Rodríguez-Pose. 2020. “Where Cities Fail to Triumph: The Impact of Urban Location and Local Collaboration on Innovation in Norway.” *Journal of Regional Science* 60 (1): 5–32. doi:10.1111/jors.12461.

Fitjar, R. D., and B. Timmermans. 2017. “Regional Skill Relatedness: Towards a New Measure of Regional Related Diversification.” *European Planning Studies* 25 (3): 516–538. doi:10.1080/09654313.2016.1244515.

Foss, N. J., K. Laursen, and T. Pedersen. 2011. “Linking Customer Interaction and Innovation: The Mediating Role of New Organizational Practices.” *Organization Science* 22 (4): 980–999.

Freeman, C. (1987). “Technical innovation, diffusion, and long cycles of economic development” In The long-wave debate Springer Berlin, Heidelberg 295–309

Frishammar, J., K. Ericsson, and P.C. Patel. (2015). “The dark side of knowledge transfer: Exploring knowledge leakages in joint R&D projects.” Technovation. 41 : 75–88. doi: https://doi.org/10.1016/j.technovation.2015.01.001

Fu, X. 2012. “How Does Openness Affect the Importance of Incentives for Innovation?” *Research Policy* 41 (3): 512–523. doi:10.1016/j.respol.2011.12.011.

Gertler, M. S. 2003. ”Tacit Knowledge and the Economic Geography of Context, Or: The Undefinable Tacitness of Being (There).” *Journal of Economic Geography* 3 (1): 75–99. Stable URL.

González-Pernía, J. L., M. D. Parrilli, and I. Peña-Legazkue. 2015. “STI-DUI Learning Modes, Firm-University Collaboration and Innovation.” *The Journal of Technology Transfer* 40 (3): 475–492.

Griliches, Z., and H. Regev. 1995. “Firm Productivity in Israeli Industry 1979–1988.” *Journal of Econometrics* 65 (1): 175–203. doi:10.1016/0304-4076(94)01601-U.

Gundersen, F., and D. Juvkam. 2013. “Inndelinger I Senterstruktur, Sentralitet Og BA.” *Regioner NIBR-Rapport* 1: 15.

Haneda, S., and K. Ito. 2018. “Organizational and Human Resource Management and Innovation: Which Management Practices are Linked to Product And/Or Process Innovation?” *Research Policy* 47 (1): 194–208. doi:10.1016/j.respol.2017.10.008.

Haus-Reve, S., R. D. Fitjar, and A. Rodríguez-Pose. 2019. “Does Combining Different Types of Collaboration Always Benefit Firms? Collaboration, Complementarity and Product Innovation in Norway.” *Research Policy* 48 (6): 1476–1486. doi:10.1016/j.respol.2019.02.008.

Heidenreich, M. 2009. “Innovation Patterns and Location of European Low- and Medium-Technology Industries.” *Research Policy* 38 (3): 483–494. doi:10.1016/j.respol.2008. 10.005.

Hernández, E., W. G. Sanders, and A. Tuschke. 2015. “Network Defense: Pruning, Grafting, and Closing to Prevent Leakage of Strategic Knowledge to Rivals.” *Academy of Management Journal* 58 (4): 1233–1260. doi:10.5465/amj.2012.0773.

Herstad, S. J., H. W. Aslesen, and B. Ebersberger. 2014. “On Industrial Knowledge Bases, Commercial Opportunities and Global Innovation Network Linkages.” *Research Policy* 43 (3): 495–504. doi:10.1016/j.respol.2013.08.003.

Hervás-Oliver, J. L., J. A. Garrigós, and I. Gil-Pechuán. 2011. “Making Sense of Innovation by R&D and Non-R&D Innovators in Low Technology Contexts: A Forgotten Lesson for Policymakers.” *Technovation* 31 (9): 427–446. doi:10.1016/j.technovation.2011.06.006.

Hervás-Oliver, J. L., M. D. Parrilli, A. Rodríguez-Pose, and F. Sempere-Ripoll. 2021. “The Drivers of SME Innovation in the Regions of the EU.” *Research Policy* 50 (9): 104316.

Hewitt-Dundas, N., A. Gkypali, and S. Roper. 2019. “Does Learning from Prior Collaboration Help Firms to Overcome the ‘Two-Worlds’ Paradox in University-Business Collaboration?” *Research Policy* 48 (5): 1310–1322. doi:10.1016/j.respol.2021.104316.

Jansen, J. J. P., F. A. J. van den Bosch, and H. W. Volberda. 2005. ”Managing Potential and Realized Absorptive Capacity: How Do Organizational Antecedent Matter?” *Academy of Management Journal* 48 (6): 999–1015. Stable URL.

Jensen, M. B., B. Johnson, E. Lorenz, and B. Å. Lundvall. 2007. "Forms of Knowledge and Modes of Innovation." *Research Policy* 36 (5): 680–693. doi:10.1016/j.respol.2007.01.006.

Kline, S. J., and N. Rosenberg. 1986. *An Overview of Innovation. The Positive Sum Strategy: Harnessing Technology for Economic Growth*. USA: The National Academy of Science.

Kogut, B., and U. Zander. 1992. "Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology." *Organization Science* 3 (3): 383–397. Stable URL. doi:10.1287/ orsc.3.3.383.

Lam, A., J. Fagerberg, D. C. Mowery, R. R. Nelson 2005. "Organizational Innovation." In *The Oxford Handbook of Innovation*, edited by J. Fagerberg, D. C. Mowery and R. R. Nelson Oxford: Oxford University Press, 115–147.

Laursen, K., and N. Foss. 2003. "New Human Resource Management Practices, Complementarities and Impact on Innovation Performance." *Cambridge Journal of Economics* 27 (2): 243–263. doi:10.1093/cje/27.2.243.

Laursen, K., and A. Salter. 2006. "Open for Innovation: The Role of Openness in Explaining Innovation Performance Among UK Manufacturing Firms." *Strategic Management Journal* 27 (2): 131–150. doi:10.1002/smj.507.

Laursen, K., and A. J. Salter. 2014. "The Paradox of Openness: Appropriability, External Search and Collaboration." *Research Policy* 43 (5): 867–878. doi:10.1016/j.respol.2013.10.004.

Lenihan, H., H. McGuirk, and K. R. Murphy. 2019. "Driving Innovation: Public Policy and Human Capital." *Research Policy* 10 (3): 791. doi:10.1016/j.respol.2019.04.015.

Levitt, B., and J. G. March. 1988. "Organizational Learning." *Annual Review of Sociology* 14: 319–340.

Lewin, A. Y., S. Massini, and C. Peeters. 2011. "Microfoundations of Internal and External Absorptive Capacity Routines." *Organization Science* 22 (1): 81–98. doi:10.1287/orsc.1100.0525.

Lorenz, E., J. Fagerberg, B. R. Martin, E. S. Andersen 2005. "Innovation, Work Organization, and Social Protection." In *Innovation Studies: Evolution and Future Challenges*, edited by J. Fagerberg, B. R. Martin, & E. S. Andersen Oxford: Oxford University Press, 71- 82.

Lorenz, E., and A. Valeyre. 2006. *Organizational Forms and Innovative Performance: A Comparison of the EU-15*. Vol. 226. Oxford: Oxford University Press.

Love, J. H., S. Roper, and J. R. Bryson. 2011. "Openness, Knowledge, Innovation and Growth in UK Business Services." *Research Policy* 40 (10): 1438–1452. doi:10.1016/j.respol.2011.05.016.

Lundvall, B. Å. 1988. "Innovation as an Interactive Process – from User– Producer Interaction to the National System of Innovation." In *Technical Change and Economic Theory*, edited by G. Dosi, London: Pinter, 349–369.

Lundvall, B. Å., and B. Johnson. 1994. “The Learning Economy.” *Journal of Industry Studies* 1 (2): 23–42. doi:10.1080/13662719400000002.

McGuirk, H., H. Lenihan, and M. Hart. 2015. “Measuring the Impact of Innovative Human Capital on Small Firms’ Propensity to Innovate.” *Research Policy* 44 (4): 965–976. doi:10.1016/j.respol.2014.11.008.

Moellers, T., C. Visini, and M. Haldimann. 2020. “Complementing Open Innovation in Multi-Business Firms: Practices for Promoting Knowledge Flows Across Internal Units.” *R&D Management* 50 (1): 96–115. doi:10.1111/radm.12343.

Nonaka, I., and H. Takeuchi. 1995. *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*. Oxford: Oxford University Press.

Nunes, S., and R. Lopes. 2015. “Firm Performance, Innovation Modes and Territorial Embeddedness.” *European Planning Studies* 23 (9): 1796–1826. doi:10.1080/09654313.2015. 1021666.OECD. 2011. *ISIC Rev. 3 Technology Intensity Definition*. OECD Directorate for Science, Technology and Industry.

Ortega-Argilés, R., M. Vivarelli, and P. Voigt. 2009. “R&D in SMEs: A Paradox?” *Small Business Economics* 33 (1): 3–11. doi:10.1007/s11187-009-9187-5.

Parrilli, M. D., and H. Alcalde Heras. 2016. “STI and DUI Innovation Modes: Scientific- Technological and Context-Specific Nuances.” *Research Policy* 45 (4): 747–756. doi:10.1016/j. respol.2016.01.001.

Parrilli, M. D., and A. Elola. 2012. “The Strength of Science and Technology Drivers for SME Innovation.” *Small Business Economics* 39 (4): 897–907. doi:10.1007/s11187-011-9319-6.

Pavitt, K. 1984. “Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory.” *Research Policy* 13 (6): 343–373. doi:10.1016/0048-7333(84)90018-0.

Powell, W. W., K. W. Koput, and L. Smith-Doerr. 1996. “Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology.” *Administrative Science Quarterly* 41 (1): 116–145. doi:10.2307/2393988.

Rammer, C., D. Czarnitzki, and A. Spielkamp. 2009. “Innovation Success of Non-R&D– Performers. Substituting Technology by Management in SMEs.” *Small Business Economics*. 33 (1): 35–58 doi: 10.1007/s11187-009-9185-7

Ritala, P., H. Olander, S. Michailova, and K. Husted. 2015. “Knowledge Sharing, Knowledge Leaking and Relative Innovation Performance: An Empirical Study.” *Technovation* 35: 22–31. doi:10.1016/j.technovation.2014.07.011.

Romer, P. M. 1990. “Endogenous Technological Change.” *The Journal of Political Economy* 98 (5): S71–102.

Santamaría, L., M. J. Nieto, and A. Barge-Gil. 2009. “Beyond Formal R&D: Taking Advantage of Other Sources of Innovation in Low-And Medium-Technology Industries.” *Research* 38 (3): 507–517- 0048-7333. doi:10.1016/j.respol.2008.10.004

Schmidt, T. 2010. “Absorptive Capacity – One Size Fits All? A Firm-Level Analysis of Absorptive Capacity for Different Kinds of Knowledge.” *Managerial and Decision Economics* 31 (1): 1–18. doi:10.1002/mde.1423.

Schumpeter, J. A. 1939. *Business Cycles*. Vol. 1. New York: McGraw-Hill.

Solow, R. M. 1957. “Technical Change and the Aggregate Production Function.” *The Review of Economics and Statistics* 39 (3): 312–320.

Thomä, J. 2017. “DUI Mode Learning and Barriers to Innovation—a Case from Germany.” *Research Policy* 46 (7): 1327–1339. doi:10.1016/j.respol.2017.06.004.

Thomä, J., and V. Zimmermann. 2020. “Interactive Learning—the Key to Innovation in Non- R&D-Intensive SMEs? A Cluster Analysis Approach.” *Journal of Small Business Management* 58 (4): 747–776. doi:10.1080/00472778.2019.1671702.

Trott, P., and C. Simms. 2017. “An Examination of Product Innovation in Low- and Medium-Technology Industries: Cases from the UK Packaged Food Sector.” *Research Policy* 46 (3): 605–623. doi:10.1016/j.respol.2017.01.007.

Vega-Jurado, J., A. Gutiérrez-Gracia, and I. Fernández-de-Lucio. 2008. “Analyzing the Determinants of Firm’s Absorptive Capacity: Beyond R&D.” *R&D Management* 38 (4): 392–405. doi:10.1111/j.1467-9310.2008.00525.x.

Veugelers, R., and B. Cassiman. 1999. “Make and Buy in Innovation Strategies: Evidence from Belgian Manufacturing Firms.” *Research Policy* 28 (1): 63–80. doi:10.1016/S0048-7333(98) 00106-1.

West, J., and M. Bogers. 2014. “Leveraging External Sources of Innovation: A Review of Research on Open Innovation.” *Journal of Product Innovation Management* 31 (4): 814–831. doi:10.1111/jpim.12125.

Zahra, S. A., and G. George. 2002. “Absorptive Capacity: A Review, Reconceptualization, and Extension.” *Academy of Management Review* 27 (2): 185–203. doi:10.5465/amr.2002.6587995.

APPENDIX
DUI it yourself:

Table A1 Descriptive statistics of **DUI** *internal*.

Variable name	Description	Mean	Std.dev.	Min	Max
Brainstorming	1 if the firm has used brainstorming to promote new ideas or creativity in the period 2008-2010, 0 if not	0.31	0.46	0	1
Interdisciplinary workgroups	1 if the firm has used interdisciplinary workgroups to promote new ideas or creativity in the period 2008-2010, 0 if not	0.30	0.46	0	1
Job rotation	1 if the firm has used in job rotation of employees to other departments or plants to promote new ideas or creativity in the period 2008-2010, 0 if not	0.08	0.27	0	1
Non-financial incentives	1 if the firm has used non-financial incentives for employees to develop new ideas in the period 2008-2010, 0 if not	0.09	0.28	0	1
Creativity training	1 if the firm has educated or trained employees specifically to develop creativity or new ideas in the period 2008 - 2010, 0 if not	0.09	0.24	0	1

Table A2. Descriptive statistics and variable definitions of control variables.

Variable name	Description	Mean	Std.dev	Min	Max
Firm size	The number of full-time employees in the firm.	95.1	402.1	6	18249
Firm age	Proxy by the number of years for which we observe the firm in the register data between 2000 and 2010	9	2.86	1	11
Share of educated employees	Percentage of the firm's workers who have completed a higher education degree	0.26	0.25	0	1
One plant	1 if the firms where one plant employs more than half of employees, 0 if not	0.89	0.31	0	1
Export	1 if the firm's main market is outside Norway, 0 if not	0.14	0.35	0	1
New to market product innovation t-1	1 if the firm has introduced new or significantly improved goods or services new for the market for the period 2006-2008, 0 if not	0.09	0.28	0	1

Table A3. Correlation matrix.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Product innovation	1	1.0000														
Product innovation t-1	2	0.4289	1.0000													
Process innovation	3	0.4718	0.2582	1.0000												
Process innovation t-1	4	0.2749	0.5459	0.2831	1.0000											
New-to-market Prod. Innov	5	0.8691	0.4062	0.4184	0.2497	1.0000										
New-to-market Prod. I. t-1	6	0.3589	0.7293	0.2307	0.4413	0.3644	1.0000									
STI *external*	7	0.3129	0.2678	0.2799	0.2281	0.3131	0.2316	1.0000								
STI *internal*	8	0.5695	0.4732	0.4012	0.3507	0.5415	0.4061	0.4539	1.0000							
DUI *external*	9	0.4101	0.3166	0.3591	0.2458	0.4054	0.2815	0.7199	0.5032	1.0000						
DUI *internal*	10	0.3744	0.2773	0.3047	0.2369	0.3387	0.2354	0.2593	0.3954	0.3043	1.0000					
Log_emp	11	0.0732	0.1292	0.0713	0.1136	0.0472	0.1110	0.1094	0.0995	0.0938	0.0970	1.0000				
Firm age	12	0.0492	0.1154	0.0261	0.0884	0.0380	0.0922	0.0102	0.0410	0.0207	0.0409	0.0403	1.0000			
Log edu	13	0.2322	0.1951	0.1322	0.1186	0.2276	0.1642	0.1789	0.3061	0.1847	0.1959	0.0199	-0.0493	1.0000		
One main plant	14	-0.0124	-0.0458	-0.0322	-0.0649	-0.0105	-0.0246	-0.0641	-0.0514	-0.0540	-0.0869	-0.2471	-0.0700	0.0270	1.0000	
Export focus	15	0.1772	0.1949	0.1089	0.1299	0.1713	0.1633	0.2221	0.2919	0.2079	0.1301	0.0273	-0.0225	0.1892	0.0238	1.0000

Table A4 Estimated results, Model [1]. Estimated coefficients. Stepwise approach. Dependent variable: New-to-market product innovation.

	(1)	(2)
New to market product innovation t-1	1.074***	1.044***
	(0.134)	(0.136)
STI *internal*	2.127***	1.887***
	(0.113)	(0.116)
STI *external*	-0.094	-0.146
	(0.193)	(0.196)
DUI *external*	1.366***	1.220***
	(0.170)	(0.173)
DUI *internal*		1.149***
		(0.102)
Firm size (log)	-0.152***	-0.282***
	(0.044)	(0.049)
Firm age (log)	0.001	-0.023
	(0.115)	(0.117)
Share of edu.emp (log)	0.652*	0.555
	(0.365)	(0.378)
One main plant	-0.067	-0.151
	(0.168)	(0.175)
Export focus	-0.068	-0.063
	(0.130)	(0.132)
Constant	-3.363***	-3.368***
	(0.819)	(0.817)
Observations	5,997	5,997
Pseudo R-squared	0.362	0.386

Note: Robust standard errors clustered over firms in parentheses. All models include industry and regional fixed effects.
*** p<0.01, ** p<0.05, * p<0.1.

Table A5 Regression results, model [1] with internal DUI decomposed into its individual constituents. Dependent variable: New-to-market product innovation.

	(1)	(2)
New to market product innovation t-1	1.074***	1.025***
	(0.134)	(0.138)
STI *internal*	2.127***	1.918***
	(0.113)	(0.116)
STI *external*	-0.094	-0.146
	(0.193)	(0.196)
DUI *external*	1.366***	1.221***
	(0.170)	(0.172)
DUI *internal:*		
Brainstorming		0.413***
		(0.122)
Job rotation		0.617***
		(0.125)
Interdisciplinary		-0.035
		(0.158)
Creat. training		0.296**
		(0.141)
Individual incentives		0.244*
		(0.143)
Observations		5,997
Pseudo R-squared		0.383

Note: Robust standard errors clustered over firms in parentheses. All models include controls, industry and regional fixed effects. *** p<0.01, ** p<0.05, * p<0.1

Table A6:
Regression results, model [2]. Dependent variable: New-to-market product innovation. Full model.

	(1)	(2)	(3)	(4)
New-to-market product inno. t-1	1.051***	1.030***	1.041***	1.040***
	(0.136)	(0.134)	(0.136)	(0.134)
DUI *internal*	1.267***	1.507***	1.199***	1.534***
	(0.107)	(0.132)	(0.105)	(0.132)
STI *external*	-0.070	-0.071	0.294	-0.373
	(0.192)	(0.191)	(0.321)	(0.418)
STI *internal*	1.860***	2.421***	1.875***	2.357***
	(0.116)	(0.172)	(0.116)	(0.186)
DUI *external*	1.821***	1.210***	1.223***	1.759***
	(0.275)	(0.168)	(0.172)	(0.364)
DUI *external** DUI *internal*	-0.795***			-0.713*
	(0.287)			(0.407)
STI *internal** DUI *internal*		-0.807***		-0.726***
		(0.194)		(0.212)
STI *external** DUI *internal*			-0.504	0.406
			(0.325)	(0.466)
Firm size (log)	0.534	0.489	0.549	0.483
	(0.379)	(0.379)	(0.379)	(0.379)
Firm age (log)	-0.274***	-0.281***	-0.277***	-0.278***
	(0.049)	(0.049)	(0.049)	(0.049)
Share of edu.emp (log)	-0.025	-0.014	-0.025	-0.015
	(0.117)	(0.117)	(0.117)	(0.117)
One main plant	-0.158	-0.153	-0.153	-0.158
	(0.173)	(0.171)	(0.174)	(0.170)
Export focus	-0.041	-0.055	-0.050	-0.047
	(0.132)	(0.130)	(0.132)	(0.130)
Constant	-3.467***	-3.618***	-3.428***	-3.633***
	(0.811)	(0.806)	(0.811)	(0.806)
Observations	5,997	5,997	5,997	5,997
Pseudo R-squared	0.387	0.389	0.386	0.389

Note: Robust standard errors clustered over firms in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All models include regional and industry fixed effects

Table A7: Regression results by type of industry, High-tech/medium high-tech manufacturing, HMT vs. low-tech/medium low-tech manufacturing, LMT, model [1]. Dependent variable: New-to-market Product Innovation.

	HMT	LMT
	(1)	(2)
DUI *internal*	1.667***	1.311***
	(0.304)	(0.221)
STI *external*	0.244***	0.245***
	(0.044)	(0.031)
STI *internal*	-0.751*	-0.410
	(0.443)	(0.410)
DUI *external*	1.141***	1.508***
	(0.430)	(0.357)
Observations	496	1,266
Pseudo R-squared	0.350	0.382

Note: Robust standard errors clustered over firms in parentheses. All models include controls, industry and regional fixed effects. *** p<0.01, ** p<0.05, * p<0.1. High technology and Medium-high technology industries include: 24.4 manufacture of pharmaceuticals, medicinal chemicals and botanical products; 30 manufacture of office machinery and computers; 32 manufactures of radio, television and communication equipment and apparatus; 33 manufactures of medical, precision and optical instruments, watches and clocks; 35.3 manufacture of aircraft and spacecraft. manufacture of chemicals and chemical product, excluding 24.4; 29 manufactures of machinery and equipment, 31 manufacture of electrical machinery and apparatus,34 manufacture of motor vehicles, trailers and semi-trailers; 35 manufacture of other transport equipment, excluding 35.1 and 35.3. Medium-low technology and Low technology includes 23 manufacture of coke, refined petroleum products and nuclear fuel; 25–28 manufacture of rubber and plastic products; basic metals and fabricated metal products; other non-metallic mineral products; 35.1 building and repairing of ships and boats, 15–22 manufacture of food products, beverages and tobacco; textiles and textile products; leather and leather products; wood and wood products; pulp, paper and paper products, publishing and printing; 36–37 manufacturing.

Table A8: Regression results by Knowledge Intensive services (KIS) vs. Less-Knowledge Intensive Services (LKIS), model [1] Dependent variable: New-to-market Product Innovation.

	Knowledge Intensive Services	Less Knowledge Intensive Services
	(1)	(2)
DUI *internal*	1.041***	1.325***
	(0.178)	(0.222)
STI *external*	0.258***	0.240***
	(0.023)	(0.047)
STI *internal*	0.239	-0.643
	(0.316)	(0.843)
DUI *external*	0.897***	1.553***
	(0.277)	(0.599)
Observations	1,046	1,262
Pseudo R-squared	0.338	0.285

Note: Robust standard errors clustered over firms in parentheses. All models include controls, industry and regional fixed effects. *** p<0.01, ** p<0.05, * p<0.1. Eurostat (2016) definition of knowledge-intensive and less knowledge-intensive services.

Table A9

Regression results by type of industry, High-tech/medium high-tech industries HMT vs. low-tech/medium low-tech industries, LMT, and Knowledge Intensive services and Less-Knowledge Intensive Services. Model [1]. Dependent variable: New-to-market Product Innovation.

	HMT	LMT	Knowledge Intensive services	Less Knowledge Intensive Services
	(1)	(2)	(3)	(4)
DUI *internal*	1.793***	1.610***	1.648***	1.598***
	(0.465)	(0.271)	(0.268)	(0.216)
STI *external*	-2.896**	-0.058	0.322	-2.902***
	(1.237)	(1.072)	(0.620)	(1.751)
STI *internal*	2.130***	1.963***	2.811***	2.483***
	(0.508)	(0.428)	(0.342)	(0.558)
DUI *external*	1.861**	2.351***	1.396**	26.911***
	(0.862)	(0.853)	(0.688)	(1.187)
DUI *external** DUI *internal*	-0.955	-1.118	-0.648	-2.777***
	(0.954)	(0.925)	(0.746)	(1.384)
STI *internal** DUI *internal*	-0.517	-0.296	-0.978***	-0.821
	(0.613)	(0.482)	(0.380)	(0.680)
STI *external** DUI *internal*	2.721**	-0.184	-0.007	2.594***
	(1.316)	(1.126)	(0.711)	(2.043)
Observations	496	1,268	1,046	1,288
Pseudo R-squared	0.355	0.386	0.348	0.335

Note: Robust standard errors clustered over firms in parentheses. All models include controls, industry and regional fixed effects. *** p<0.01, ** p<0.05, * p<0.1. OECD (2011) definition of high-tech, medium-high-tech, medium-low-tech and low-tech industries and Eurostat (2016) definition of knowledge-intensive and less knowledge-intensive services. High-tech and medium high-tech industries grouped into HMT and low-tech and medium low-tech manufacturing into LMT.