



Paper to be presented at the DRUID 2011

on

INNOVATION, STRATEGY, and STRUCTURE -
Organizations, Institutions, Systems and Regions

at

Copenhagen Business School, Denmark, June 15-17, 2011

Paradigm shift? The contribution of intensive open innovation to the innovative performance of EU firms

Paul Windrum

University of Nottingham
Business School

paul.windrum@nottingham.ac.uk

Abstract

It is suggested that a paradigm shift is taking place, from the old innovation model based on internal R&D to a new innovation model based on the intensive use of external sources (search depth) for innovation. We test this using Eurostat SIC4 data for 40 sectors in 18 countries. The findings suggest a more nuanced understanding of the role of external search is required. Internal R&D and firm size rather than search depth are found to be the key factors affecting the performance of radical innovators. External search is identified as an important factor amongst incremental product innovators. These findings are consistent with the old innovation model. This cautions against suggestions that a paradigm shift has occurred.

Paradigm shift? The contribution of intensive open innovation to the innovative performance of EU firms

12th May 2011

Abstract

It is suggested that a paradigm shift is taking place, from the old innovation model based on internal R&D to a new innovation model based on the intensive use of external sources (search depth) for innovation. We test this using Eurostat CIS4 data for 40 sectors in 18 countries. The findings suggest a more nuanced understanding of the role of external search is required. Internal R&D and firm size rather than search depth are found to be the key factors affecting the performance of radical innovators. External search is identified as an important factor amongst incremental product innovators. These findings are consistent with the old innovation model. They caution against suggestions that a paradigm shift has occurred.

Keywords: Open innovation, search depth, innovation performance.

JEL codes: O32, C24.

1. INTRODUCTION

The open innovation literature proposes that search and interaction with external organizations are essential to firms to perform innovation, and to their ability to appropriate the benefits of that innovation (Chesbrough 2003). Open innovation is said to represent a new paradigm for the organisation, development, and execution of innovation. It is the “antithesis of the traditional vertical integration model where internal R&D activities lead to internally developed products that are then distributed by firms” (Chesbrough, 2006, p.1). The open innovation concept has attracted the attention of policy makers and academics over the last decade, and a body of research literature has grown rapidly.

Dahlander and Gann (2010) observe that a large gap exists in the empirical research on open innovation, with very few large-scale studies using datasets that cover a variety of different nations and industries. The handful of empirical papers that do exist analyse open innovation by manufacturing firms, and predominantly use data from the Third Community Innovation Survey data (CIS3) carried out in 2001 (see Laursen and Salter (2006), Grimpe and Sofka (2009), Grimpe and Kaiser (2010), and Sofka and Grimpe (2010)).

Our paper aims to shed greater light on the role of external knowledge acquisition and R&D investments, for incremental and radical innovation capability, and firms’ innovation performance (measured via share of turnover due to innovation). We consider whether global market exposure provides access to further external sources which can be used to generate and develop innovative ideas.

We argue that openness is related to whether a firm is a leader or a follower in the innovation race. Leaders generate and introduce innovations which are new to the market. By contrast, followers adopt innovations which are new to their firm but are not new to the market. The intensive use of external sources can be an effective mechanism by which followers gain information and knowledge. However, we propose that the capability to generate and introduce new market innovations tends to require the intensive exploitation of internal R&D capabilities rather than openness.

The paper contributes to the empirical literature by considering a dataset that contains a large number of countries and service sectors as well as manufacturing sectors. Our working dataset contains information on 40 services and manufacturing sectors in 18 countries. This is drawn from the micro-aggregated data of the Fourth Community

Innovation Survey (CIS4) conducted over the period 2002–2004 and coordinated by Eurostat.

We apply a measure of the ‘intensity of use’ of external sources for information and knowledge to test five hypotheses on external search depth and firms’ innovation performance. First, we test whether intensive external search is associated with radical product innovation, not incremental product innovation. Second, we test whether an inverse-u relationship exists between external search depth and innovative performance. Third, we test whether firms’ exposure to international markets positively affects innovation performance and, fourth, whether international market exposure is complementary to external search depth. Fifth, we test whether internal R&D and external search depth are complementary or substitutes.

Our research findings indicate the need for caution with regards to claims that a paradigm shift has occurred in innovation. There is evidence that those firms who intensively engage in many forms of external search are using these as a substitute for internal R&D. However, the key findings are, first, that external search is important for followers, not radical product innovators. This is consistent with the diffusion of innovations in the ‘old’ paradigm. The second key finding is that the explanatory variables for radical innovators are in-house R&D expenditure and firm size, which is again consistent with the old paradigm.

The paper is organised as follows. In the next section we briefly review the open innovation concept and the operationalization of search. Section three discusses the research hypotheses on external search depth, and section four discusses the Eurostat dataset and the variables that are used. Section five presents the estimated Tobit models, and section six concludes.

2. OPEN INNOVATION LITERATURE

Chesbrough (2003) was perhaps the first scholar to propose that a fundamental shift had occurred in how companies generate new ideas and bring them to market. He argued that firms can no longer rely solely on their own internal R&D capacities to successfully develop and commercialise innovations, but needed to engage with external organizations, consequently scaling down their in-house R&D resources, while expanding the scope of their innovation activities (Gianiodis et al., 2010).

Open innovation scholars have highlighted a number of factors for increasing openness in innovation (see the review of Dahlander and Gann, 2010). One factor is an

increase in the complexity of products and services that requires innovators to engage with, and draw upon, a wider range of external sources for relevant information and knowledge. It is argued that no single organization has sufficient human talent inside its boundaries and can cover all the scientific and engineering disciplines that contribute to its product offerings (Markman et al., 2008). Collins (2006) proposes that, today, the key to successful innovation lies as much in the ability to collaborate as it does the ability to perform applied science and engineering.

A second factor that is cited is globalization. An increasingly international division of labour and knowledge has increased the number, and geographical diversity, of relevant knowledge sites, forcing firms to access external knowledge to support their value chain activities (Rothaermel and Hess, 2007) and, thus, to create and manage connections with other organizations (Hess and Rothaermel, 2011). In a globally competitive environment, the generation and transfer of knowledge are key to sustainable competitive advantage (Mudambi and Tallman, 2010). Radical product innovators increasingly rely on their dynamic capabilities, shaping these through innovation and through collaboration with other enterprises, entities, and institutions (Teece, 2007), with wider international breadth (Smith, 2004; Chesbrough and Schwartz, 2007).

Improved market institutions are a third cited factor. Intellectual property right (IPR) protection, venture capital (VC), and technology standards have facilitated the increased use of inter-organizational network relationships and alliances in innovation, to share knowledge and the risk associated with innovation (Rothaermel and Deeds, 2006; Perkmann, and Walsh, 2007; Neyens et al., 2010). Networks can include all types of partners: specialist start-ups and other businesses, universities and public research bodies, and third sector organizations (Veugelers, 1997; Fritsch and Lukas, 2001).

Openness can thus be understood as the increased flow of information and knowledge across firms' boundaries, with innovation migrating beyond the confines of central R&D labs in large corporations to small start-ups, universities, research consortia, and other organisations. Within this more fluid innovation environment, it makes sense for firms to externalise their technological options and innovation opportunities – through licensing to other businesses or by forming alliances and engage in cooperative agreements - rather than keeping options in stock and running the risk of never exploiting them (Chesbrough, 2003). Open innovation is a business model that is designed to purposefully allow and facilitate knowledge and technology transfers across organizational boundaries, enabling organisations to appropriate value (Gianiodis et al., 2010).

The open innovation thesis chimes with research on strategic cooperation between private sector organisations (Piller and Walcher, 2006; van der Meer, 2007; Chiaroni et al., 2008; Belussi et al., 2008), and the increased prominence of university-industry links in biotech and a number of other fields (Harwing, 2004; Blau, 2007; Perkmann and Walsh, 2007; Link et al., 2008). In addition to greater knowledge sharing, there has been an increase in the licensing of intellectual property, higher rates of new spin off companies, and increased mergers and acquisitions (Hagedoorn, 1993; Fritsch and Lukas, 2001; Parhankangas et al., 2003). By pooling their complementary assets, organizations seek to generate synergies and cross-fertilization effects (Becker and Dietz, 2004). An ‘open’ approach to innovation allows firms to discover combinations of product features that would be hard to envision with internal integration, and increases the likelihood of finding innovative solutions (Almirall and Casadesus-Masanell, 2010).

It is an empirical question whether or not a paradigm shift has occurred. Laursen and Salter (2006) were the first to operationalize the concept of external search depth as the intensity with which an external information or knowledge source is accessed. They use a question which asks respondents to state the importance (on 4-point Likert scale) of a set of external sources of information to the enterprise’s product innovation during the previous three-year period. Laursen and Salter’s dataset comprised 2707 manufacturing firms, a sub-sample drawn from the 8172 respondents (operating in manufacturing and service sectors) who took part in the Third UK Community Innovation Survey (CIS3) carried out in 2001, and covers the period 1998-2000. Their paper contains three important findings with regards to search depth. The impact of search depth upon firm performance is higher for firms engaged in product radical innovation than for firms engaged in incremental product innovation. The second finding is an inverse-u relationship between innovative performance and depth of external search, suggesting decreasing returns for firms which intensively use more than a few external sources. The third finding is a negative relationship between internal R&D and search depth amongst firms who introduce innovations that are new to the world. This suggests a substitution effect exists between the intensive use of external sources for innovation and the use of internal R&D for innovation, at least amongst this subset of firms.¹

Grimpe and Sofka have extended the research agenda by considering, in different ways, the link between search and absorptive capacity underpinned by R&D capabilities.

¹ They do not report results for firms who introduce product innovations that are new to the firm but not new to the world.

They use the micro-aggregated Eurostat CIS3 data base which provides information on manufacturing in 13 EU countries: Belgium, the Czech Republic, Estonia, Germany, Greece, Hungary, Iceland, Latvia, Lithuania, Norway, Portugal, Slovakia, and Spain. Micro-aggregated data provides information on the proportions of firms in each sector who use external sources in their innovation process. With this type of data one can consider relationship between search depth and innovation performance for a larger number of countries and sectors.

Grimpe and Sofka (2009) consider differences in search depth strategies of firms in high- or medium-high-technology (HMT) industries and in medium-low-technology and low-technology industries (LMT). Latent class analysis combined with Tobit regression analysis is used to identify these classes and to test their explanatory power on the contribution to firm turnover of products that are new to the world. Their findings indicate that investments in R&D and consequent absorptive capacity in LMT industries provide superior innovation success if these are combined with a search pattern that targets market knowledge (customers and competitors). By contrast, they find that R&D investments in HMT industries provide superior innovation success if these are combined with a search pattern that targets technological knowledge (universities and suppliers).

Restricting the analysis to data on five European countries (Germany, Belgium, Greece, Portugal and Spain), Sofka and Grimpe (2010) consider clusters within search depth strategies. Applying principal components analysis, they identify three clusters. One is 'science driven' (universities and public research centres), another is 'market driven' (customers and competitors), and the third is suppliers. These factors are then used as regressors in Tobit estimations on contribution to firm turnover. In contrast to Laursen and Salter, their findings indicate (for this different subset of firms) a positive and statistically significant interaction between R&D and market driven search on product innovation. This suggests that R&D and close interaction with customers and competitors enhances the absorptive capacity for incremental innovations. Interactions between R&D and the other two clusters were not found to be statistically significant.

3. RESEARCH HYPOTHESES ON EXTERNAL SEARCH DEPTH

External search depth is defined as the intensive use of an external source of information or knowledge within the firm's internal innovation process. This source can be a public or private sector organization. It is widely acknowledged that radical, disruptive technological change frequently requires firms to develop new competences and knowledge bases that are different to those required to produce older technology products (Abernathy and Utterback, 1975; Tushman and Anderson, 1986; Song et al., 2005). According to the open innovation thesis, the open innovation paradigm is characterised by the extensive use of external sources for radical product innovation, and the associated development of new firm competences and knowledge. External sources are not important for product innovation, as this activity involves the development and exploitation of established technological competences and knowledge.

As discussed, Chesbrough contrasts the open innovation paradigm with a 'traditional' innovation paradigm in which radical innovation is based on the exploitation of internal R&D activity. We would add that incremental innovation is associated with imitation in this 'traditional' model. The ability to emulate the success of more radically innovative rivals is essential to firms' survival. Follower firms move rapidly and include in their own products any features which rivals have demonstrated to be popular amongst customers². To survive in dynamic markets, followers must have sufficient technological knowledge to understand technological developments developed by radical product innovators, and in the last resort be able to reverse engineer their rivals' products (Dosi, 1982; Nelson and Winter, 1982; Cohen and Levinthal, 1990; Klepper, 1996; Geroski, 2000).

Strategic management and innovation scholars have identified advantages to being a follower. Followers are second movers who learn from the successes and failures of first mover firms without incurring the initial R&D set-up costs or the financial and technological risks associated with product failures (Mansfield, 1998). Indeed, second movers can become the dominant industry firms if they are able to release products that contain those features which customers demand at lower prices (Wernerfelt and Karnani, 1987; Schnaars, 1994; Geroski and Markides, 2005).

² Adoption of is also a key aspect of the diffusion of technological or process innovations. However, their diffusion across potential users can take substantially longer than product innovations (see Battisti and Stoneman, 2003).

Thus, the role of external sources in radical and incremental innovation performance is stated to be diametrically different in the open and traditional innovation paradigms. This enables us to empirically test the existence of the open innovation paradigm using the research hypothesis;

Hypothesis 1. The more radical the innovation, the more effective is external search depth on innovative performance.

Laursen and Salter (2006) find an inverted U-shaped relationship between innovative performance and external search depth, indicating the existence of diminishing returns to the intensive exploitation of external sources. Past a certain point, further reliance on external sources may actually reduce firms' innovation performance (Grimpe and Kaiser, 2010). Diminishing returns, we propose, can arise for external sources that are intensively used for either radical or incremental innovation. This is our second research hypothesis:

Hypothesis 2. An inverted U-shaped relationship exists between innovative performance and external search depth.

Chesbrough (2003) observes that open innovation can compensate for a firm's more limited internal R&D resources. If this is the case, then firms can substitute external search depth for internal R&D. However, Cassiman and Veugelers (2006), and Lokshin et al. (2008) have suggested that R&D intensity and search capabilities are complementary. Firms with superior internal research knowledge are expected to benefit more from connections to external knowledge sources (Fabrizio, 2009). To test the validity of these arguments, we test the following research hypothesis;

Hypothesis 3. External search depth is a substitute for R&D intensity.

As discussed, previous studies have found different estimated signs for the interaction between search depth and in-house R&D. If, as the open innovation literature suggest, external search and in-house R&D are substitute strategies for radical innovation, then the expected sign of the interaction term will be negative.

Hypothesis 4. Firms' exposure to international markets positively affects innovation performance.

Firms with a significant export profile not only have access to larger markets and potential revenues than businesses that only operate domestically, they also have access to a wider set of suppliers, clients, universities and public R&D labs from whom to can gain information and knowledge. Opportunities to access foreign markets and upgrade technological capabilities, products, and services have increased due to falling transport costs and trade barriers, and greater international intellectual property protection afforded by WTO accords (Narula and Dunning, 2000).

Hypothesis 5. International market exposure is complementary to external search depth.

Finally, we test for complementarities between international exposure and search depth. This has not been considered in previous studies. If a complementary relationship exists then the estimated coefficient will be positive.

4. DATA AND METHODOLOGY

The Eurostat reference database provides a micro-aggregated dataset of the Fourth Community Innovation Survey (CIS4). The observation period is the beginning of 2002 to the end of 2004. CIS4 data was collected by national statistical offices in the 27 Member States of the EU, plus Iceland and Norway. Eurostat CIS4 was released in 2005 (for further details see http://europa.eu/estatref/info/sdds/en/inn/inn_cis4_sm.htm). The micro-aggregated Eurostat CIS4 addresses sample bias issues across the national data, to provide a comparable and consistent dataset on innovation-related variables for the 29 countries. The micro-aggregation procedures used by Eurostat enable researchers to applying a full set of micro-econometric techniques to this mirco-aggregated data (Mohen and Röller, 2005).

In our research we use data on 40 service and manufacturing sectors across 18 countries: Belgium (BE), Bulgaria (BG), Cyprus (CY), Czech Republic (CZ), Germany (DE), Estonia (EE), Spain (ES), France (FR), Greece (GR), Hungary (HU), Italy (IT), Lithuania (LT), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), and Slovakia (SK). Austria, Iceland, Ireland, and Malta are excluded due to the very small number of observations in many sectors. Demark, Finland, Latvia, Luxembourg,

Slovenia, Sweden and the UK, are excluded due to missing data on our key variables, or data not made available by national statistical offices.

The target sample population of CIS4 was private sector enterprises in mining and quarrying, manufacturing, electricity, gas and water supply, wholesale trade, transport, storage and communication, financial intermediation, computer and related activities, architectural and engineering activities, and technical testing and analysis. We consider the data collected for 40 manufacturing and service sectors. A complete list of these sectors is provided in the Appendix.

Dependent variable

We construct proxy variables to capture firms' performance in radical and in incremental product innovation. CIS data offers 'a direct measure of success in commercializing innovations for a broad range of industries . . . that more traditional measures may not capture' (Leiponen and Helfat, 2003). The questionnaire asks firms to indicate whether the firm has been able to achieve a product innovation. The CIS4 definition of product (good or service) innovation is:

'A product innovation is the market introduction of a **new** good or service or a **significantly** improved good or service with respect to its capabilities, such as quality, user friendliness, software or subsystems. The innovation must be new to your enterprise, but it does not need to be new to your market. It does not matter if the innovation was originally developed by your enterprise or by other enterprises' (Bold in original text).

The definition is based on the Oslo Manual (second edition, 1997) which, in turn, draws on established definitions used by product innovation scholars. Radical innovation leads to the introduction of new features in existing product groups, or the introduction to the market of entirely new products that contain novel bundles of new product features. Incremental innovation involves improvements in the quality of existing product features (Baldwin and Clark 2000, Swann 2009). Classic empirical studies of product innovation include Saviotti 1985, Saviotti & Trickett 1993, Trajtenberg 1989, Swann 1993, and Grupp 1998.

The OSLO Manual defines innovation and product innovators in the following way;

Innovation: an innovation is a new or significantly improved *product* (good or service) introduced to the market (or the introduction within an

enterprise of a new or significantly improved *process*). Innovations are based on the results of new technological developments, new combinations of existing technology or the utilisation of other knowledge acquired by the enterprise. Innovations may be developed by the innovating enterprise or by another enterprise. However, purely selling innovations wholly produced and developed by other enterprises is not included as an innovation activity. Innovations should be new to the enterprise concerned. For *product* innovations they do not necessarily have to be new to the market (and for process innovations the enterprise does not necessarily have to be the first one to have introduced the *process*).

Product innovators: introduced *new* good or service or a *significantly* improved good or service with respect to its capabilities, such as improved software, user friendliness, components or sub-systems. Changes of a solely aesthetic nature and the pure sale of product innovations wholly produced and developed by other enterprises are not included.

An important distinction is made here between the wholesale copying of existing products and emulation leading to re-combinatorial innovation. The CIS-Oslo definition explicitly excludes wholesale copying as a form of innovative activity. However, it does include as innovative firms who emulate certain product features which are initially developed by rivals, and recombine these with new/altered features within their own existing products. This recombinatorial activity can lead to new experimentation with (previously) unthought of combinations of product features, and may even lead to the development of new product classes (Baldwin and Clark 2000). Emulation when combined with recombination is therefore an important aspect of product innovation.

CIS4 gathers information on radical product innovation performance (i.e. the development of innovations which are new to the world) by asking respondents to record the percentage of total firm turnover in 2004 that is due to 'Products introduced during 2002-2004 that were new to your market'. This provides the data for the variable *INNWORLD*. The Eurostat CIS4 database provides information on the average percentage for each sector, by country.

CIS4 gathers information on incremental innovation performance by asking respondents to record the percentage of total firm turnover in 2004 that is due to 'Products introduced during 2002-2004 that were new to your enterprise'. This provides the data for

the incremental innovation variable *INNFIRM*. Once again, the Eurostat CIS4 database provides information on the average percentage in each sector, by country, in Euros.

Independent variables

We follow previous researchers by constructing the measure of search depth *DEPTH* which captures the intensity of use of external sources of information and knowledge for innovation. This is appropriate for the micro-aggregated data provided by Eurostat. This is collected by the CIS4 through a question which asks firms to indicate the significance of the following six categories of external sources to the enterprise's innovation activities during the three-year period 2002-2004:

- Suppliers of equipment, materials, services, or software
- Clients or customers
- Competitors or others enterprises in the same industry
- Consultants, commercial labs, or private R&D institutes
- Universities or other higher education institutions
- Government or public research institutes

The question asks respondents to indicate the significance of each category on a four-point Likert scale of 'high significance', 'medium significance', 'low significance', or 'not used'.

Our variable *DEPTH* addresses country specific response bias by transforming the data into a binary indicator that indicates whether the proportion in each sector is above the average country response. For each of the 6 categories, a value of 1 is coded if the proportion is above the national average. A value of 0 is coded if the proportion is below (or equal to) the national average. Using these scores, *DEPTH* takes a value of 6 if all six categories are used intensively in the sector of that particular country (i.e. all 6 categories have individual scores of 1). Cronbach's alpha coefficient is 0.8, indicating a high degree of internal consistency for this variable.

Using this variable, we create the interaction variable *DEPTH*R&D_INT*. *R&D_INT* is the average level of intramural R&D expenditure in each sector.

We construct the variable *INTSELL* using data on the proportion of firms, in each sector, whose main sales markets are local (regional or national) or international. This variable is calculated as

$$INTSELL=1-((1-\text{proportion of export sales to other EU, EFTA and/or EU-CC countries})*(1-\text{export sales to any other country}))$$

Using this variable, we create the interaction variable *INTSELL*DEPTH*.

Control variables

LOGEMP is the number of employees (expressed in logarithms). For each sector in each country we have information on the average number of employees divided by the number of enterprises in that sector. This provides a control variable for the impact of firm size on innovative performance.

We control for sector heterogeneity in two ways. First, we control for R&D intensity of sectors by creating a set of dummy variables, using data on the level of intramural R&D expenditure as a share of total turnover. We calculate the average value of intramural R&D expenditure each of the 40 sectors used in our analysis. Then, we calculate the five quintiles ($QU_5, QU_4, QU_3, QU_2, QU_1$) of the 40 new values, in order to sort data into different equal-sized groups, with equal number of sectors per quintile. The complete list of quintiles is provided in Table A1 in the appendix. Using this information, a set of five dummy variables is constructed: *R&D_5* (which is the highest quintile), *R&D_4*, *R&D_3*, *R&D_2*, and *R&D_1* (the lowest quintile). For example, *R&D_5* takes the value of 1 when the observation refers to any sector within the fifth-quintile (QU_5) and 0 otherwise. The other four dummies are similarly constructed.

In order to control for additional sector variation between service and manufacturing sectors we construct the dummy variable *SERVICES*.

To control for national effects which may affect the propensity to innovate in different countries, we construct 18 country dummies.

The effect of formal collaboration agreements is controlled using data provided in the CIS4 questionnaire. Respondents are asked to indicate whether firms have formal cooperation agreements with organizations in each of the external source categories discussed above. We use the Eurostat data on sector proportions to construct the variable *DEPTH_COLLAB* in the same manner as that used to construct the variable *DEPTH*.

Estimators

The dependent variables *INNWORLD* and *INNFIRM* are censored from above and below since proportion data takes values that lie between zero and one. We follow previous researchers in estimating a set of Tobit censored regression models. However, the Tobit model has a number of well know limitations (see Long 1997), e.g. the range of predicted values falling outside the range zero and one. Also the Tobit model is not appropriate in the presence of non-normal or highly skewed residuals. A traditional solution to this problem is to perform a lognormal transformation of the model (see Filippucci et al. 1996) or a logit transformation of the data and use OLS or weighted least squares. The former approach has been taken by prior scholars (see above). For consistency with prior research, we report a set of regressions that use this transformation.

A better approach is to specify a Generalized Linear Model for fractional response variables. For our proportion data with predicted values that fall between zero and one, we estimate models with a logit canonical link function and assume the dependent variable is generated from a binomial exponential family (for further details see Papke and Wooldridge, 1996). We estimate robust standard errors for all models (Tobit and GLM).

5. RESULTS

5.1 Descriptive results

Table 1 provides information on the aggregate proportion of firms who state that a particular category of external organization is highly relevant to their innovation practices and processes. The table also provides information on the aggregate proportion of firms who established formal cooperation arrangements in these categories.

Table 1.

External sources of information and knowledge for innovation activities

<i>Source</i>	<i>Highly relevant source of information (%)</i>	<i>Formal cooperation arrangements (%)</i>
Suppliers of equipment, materials, services, or software	26.04	26.29
Clients or customers	29.05	29.95
Competitors or others enterprises in your industry	15.16	13.54
Consultants, commercial labs, or private R&D institutes	8.48	14.93
Universities or other higher education institutions	5.65	12.58
Government or public research institutes	4.60	8.25
<i>Average</i>	<i>14.83</i>	<i>16.09</i>

Respondents state that organizations which are closely located along the value chain are of greatest significance. In the 40 manufacturing and service sectors of our 18 country sample, 29% of firms state that clients / customers are a highly relevant source of information. This supports von Hippel's (1988) arguments regarding the importance to innovation of demand side sources of information and knowledge.

Organizations on the supply side of the value chain, i.e. suppliers of equipment, materials, services, or software, are the second highest category with 26% of firms stating these are a highly relevant external source. Competitors are the third highest information source (15%), followed by the category 'consultants, commercial labs, or private R&D institutes'.

It is notable that formal cooperation agreements continue to play an important role in formal relationships with external organizations. Firms are careful to specify and draw up agreements in order to protect their knowledge. The highest percentage of cooperation agreements are with clients and customers (30%), followed by suppliers (26%), and consultants (15%).

With organizations who are not in the immediate value chain, the percentage of formal agreements recorded is around twice as large as the percentage of respondents who rate these external sources as highly significant to their innovation. This suggests that firms are particularly careful to formalize intellectual property rights with external organizations that are R&D-intensive, i.e. with private R&D institutes, universities, and public R&D institutes, in order to prevent diffusion of new knowledge to competitors.

Table 2 provides descriptive statistics for the dependent and independent variables. On average, 7.1% of firm turnover is attributable to the introduction of radical products which are new to the world (*INNWORLD*), while 7.7% of turnover is attributable to incremental product innovation (*INNFIRM*). Firms use 2 to 3 sources of knowledge intensively, with around the same average number of formal collaborations being set up. Simple Pearson correlations amongst the dependent and independent variables are provided in the Appendix.

Table 2.
Descriptive statistics on dependent and independent variables

	N	Minimum	Maximum	Mean	Std. Deviation
INNWORLD	502	0	0.99	0.071	0.095
INNFIRM	506	0	0.54	0.077	0.072
DEPTH	514	0	6	2.52	1.409
DEPTH_COLLAB	514	0	6	2.44	2.119
PANYSOURCE	514	0.09	1	0.599	0.171
PANYCOLLAB	514	0.05	1	0.542	0.261
RDINT	514	0	0.85	0.018	0.070
LOGEMP	514	0.93	7.12	3.761	1.097
INTSELL	514	0	1	0.336	0.227
MANUF	514	0	1	0.660	0.474

Table 3 provides aggregate information, by country, on the mean depth of search on the six external source categories. The average mean depth across all 18 countries is 2 sources. This is also the mode and median values as 11 of the 18 countries have a mean depth of 2. Countries which lie below this average are Cyprus (CY), Greece (GR), and The Netherlands (NL). Countries which lie above this average are the Czech Republic (CZ), France (FR), Lithuania (LT), and Norway (NO).

Table 3 also provides information on the relative contributions to turnover of radical product innovations (*INNWORLD*), incremental product innovations (*INNFIRM*), and intramural R&D expenditure as a share of turnover. There are just 8 countries for which the contribution of radically new product innovation to turnover (*INNWORLD*) is greater than the contribution of incremental product innovation (*INNFIRM*). These are Belgium (BE), Bulgaria (BG), France (FR), Germany (DE), Greece (GR), Hungary (HU), Lithuania (LT), and Poland (PL). Levels of intramural R&D expenditure (as a share of total turnover) do not appear to be a discriminating factor as just 4 of these 8 countries

have levels of R&D spend that are above average. These are Belgium (BE), France (FR), Germany (DE), and Greece (GR).

Table 3.

Mean search depth, contribution of radical and incremental product innovation to turnover, and intramural R&D expenditure by country

	Mean search depth	Turnover of new products to the market as a share of total turnover (<i>INNWORLD</i>)	Turnover of new products to the firm as a share of total turnover (<i>INN FIRM</i>)	Intramural R&D expenditure as a share of total turnover
Belgium (BE)	2	0.0817	0.0783	0.0355
Bulgaria (BG)	2	0.0835	0.0465	0.0047
Cyprus (CY)	1	0.0168	0.0212	0.0034
Czech Rep. (CZ)	3	0.0714	0.0855	0.0164
Estonia (EE)	2	0.0449	0.1406	0.0067
France (FR)	3	0.0702	0.0670	0.0365
Germany (DE)	2	0.1051	0.0960	0.0184
Greece (GR)	1	0.1032	0.1023	0.0153
Hungary (HU)	2	0.0662	0.0323	0.0146
Italy (IT)	2	0.0706	0.0722	0.0230
Lithuania (LT)	3	0.0679	0.0651	0.0065
Netherlands (NL)	1	0.0366	0.0505	0.0072
Norway (NO)	3	0.0415	0.0997	0.0456
Poland (PL)	2	0.1128	0.0638	0.0247
Portugal (PT)	2	0.0727	0.0743	0.0069
Romania (RO)	2	0.0546	0.1096	0.0170
Slovakia (SK)	2	0.1009	0.0512	0.0123
Spain (ES)	2	0.0448	0.0927	0.0315
<i>Average</i>	2	0.0691	0.0749	0.0181

5.2 Statistical results

Table 4 reports the results of the Tobit and GLM models that are estimated. There is a high degree of consistency in the estimated Tobit and GLM models. The most notable finding is the persistence of the conventional (old paradigm) explanatory variables of R&D expenditure and firm size for firms engaged in radical product innovation (Models I and II). *R&D_5* is statistically significant for radical innovation (at the $p < 0.05$ level) and *LOGEMP* is statistically significant at the 1% level for radical innovators. Importantly, none of the R&D dummies are statistically significant (at the $p < 0.10$ level) for incremental innovators (models III and IV). It is amongst incremental innovators that that we find

evidence for the importance of external information sources to innovation. This is consistent with the traditional innovation paradigm rather than the open innovation paradigm.

Table 4.

Tobit and GLM regression estimates on innovation performance with *DEPTH*.

Model	I Tobit INNWORLD		II GLM INNWORLD		III Tobit INNFIRM		IV GLM INNFIRM	
	Coeff.	SE	Coeff.	Robust SE	Coeff.	SE	Coeff.	Robust SE
DEPTH	0.001	0.010	-0.042	0.199	0.016**	0.007	0.205**	0.092
DEPTH_2	0.002	0.002	0.005	0.316	-0.003**	0.001	-0.036**	0.016
DEPTH*R&D_INT	-0.127**	0.050	-0.583	0.569	-0.018	0.037	-0.064	0.363
INTSELL	0.131***	0.028	1.742***	0.492	0.060***	0.020	0.837***	0.336
INTSELL*DEPTH	0.257***	0.085	1.192	1.019	0.043	0.062	0.223	0.613
LOGEMP	0.012***	0.004	0.185***	0.060	0.019***	0.003	0.186***	0.045
R&D_5	0.027**	0.014	0.420**	0.175	0.015	0.010	0.198	0.125
R&D_4	0.005	0.006	0.113	0.080	0.004	0.005	0.074	0.042
R&D_3	0.009	0.013	0.136	0.178	-0.007	0.009	-0.091	0.123
R&D_2	-0.006	0.014	-0.125	0.312	-0.009	0.009	-0.215	0.146
SERVICES	0.022*	0.010	0.330*	0.194	-0.009	0.008	-0.103	0.125
DEPTH_COLLAB	-0.004	0.007	-0.027	0.100	1.56E-4	4.91E-3	0.028	0.067
DEPTH_COLLAB_2	8.587E-4	1.12E-3	9.918E-4	0.016	-1.36E-4	8.270E-4	-0.003	0.011
COUNTRY DUMMIES	YES		YES		YES		YES	
Joint Significance	68.06 (.000)		68.06 (.000)		147.29 (.000)		147.29 (.000)	
No. observations	502		502		506		506	
Log likelihood	443.8				635.3			
Chi-square	178.5				185.5			
Pseudo R2	0.1				0.2			
Log pseudolikelihood			91.4				98.7	
Scaled deviance			29.2				20.0	
Pearson chi-square			34.6				21.9	

*** p<0.01; ** p<0.05; * p<0.10

Base: R&D_1

Turning to our individual research hypotheses, intensive search *DEPTH* over all types of external sources is statistically significant for incremental innovation (at the $p < 0.05$ level) (models III and IV) but not statistically significant in the performance of firms engaged in radical product innovation (models I and II). The estimated coefficient for *DEPTH* in *INN FIRM* GLM Model IV is 0.205 (significant at $p < 0.05$) and -0.042 (not statistically different from 0) in *INN WORLD* GLM Model II.

These results lead us to reject Hypothesis 1 that external search depth has a larger impact on innovative performance the more radical is the innovation activity. Indeed, the results indicate that the importance of intensive external search lies in incremental innovation performance. For radical product innovators, the most effective strategy is to develop and exploit in-house R&D expertise. For incremental innovators (second movers), an effective strategy is targeted emulation of more radical first movers.

Hypothesis 2, that an inverse-u relationship exists between search depth and innovative performance, is supported in the estimated models III and IV of incremental innovation. *DEPTH_2* takes the expected negative sign, and is significant at the $p < 0.05$ level, in both models. The relevant coefficients are not statistically significant in the other models.

Hypothesis 3 that a substitution effect exists between R&D intensity and external search is not supported by the empirical findings. Only in Tobit model I is the estimated coefficient of *DEPTH*R&D_INT* statistically significant. The estimated coefficient is not significant (at $p < 0.10$) in the comparable GLM Model II, nor in models III or IV.

Hypothesis 4, that international market exposure is positively correlated with innovation performance is supported in the estimated models. *INTSELL* takes the expected positive sign and is significant at the $p < 0.01$ level in models I, II, III and IV. This suggests that firms who are internationally orientated, through export markets sales, have a higher probability of successfully engaging in both radical and incremental innovation.

Finally, there is insufficient evidence to support Hypothesis 5 of an interaction between international exposure and intensive search depth. Only in Tobit model I is the estimated coefficient for *INTSELL*DEPTH* statistically significant.

6. DISCUSSION AND CONCLUSIONS

Innovation is far more open today than it was twenty or thirty years ago. Many sectors have seen a significant increase in the use of formal strategic R&D alliances, and firms make greater use of external sources for information and knowledge acquisition as part of the innovation process. Certainly the academic and policy literature on ‘open innovation’ has increased enormously since the publication of Chesbrough’s book in 2003. Yet much empirical work needs to be carried out using large scale datasets to understand the key drivers of open innovation, its contribution to firm performance, and the relationship between open innovation factors and the traditional explanatory factors of innovation of internal R&D capabilities, and economies of scale and scope. Using the Eurostat CIS4 database, we have sought to contribute to this large and important empirical agenda.

In our estimated models we distinguish between radical and incremental product innovators. The picture that emerges is different to that suggested by the current literature on open innovation. The findings indicate that the key factors which contribute to the innovation performance of firms engaged in radical product innovation are internal R&D and firm size. These are consistent with the traditional innovation paradigm; not the open innovation paradigm. This cautions one against the proposition that a paradigm shift having taken place. It may be that open innovation is important for radical innovators in some sectors, in some countries, but our extensive dataset indicates that this is not the general case.

Where external search is found to be an important factor is amongst firms who intensively use many external sources in order to conduct incremental product innovation. For these firms, internal R&D is not a statistically significant factor affecting their performance. But, once again, this is consistent with the traditional innovation paradigm. External sources – rivals, clients and suppliers – are important for firms who need to emulate in order to survive. Second movers with the requisite absorptive capacity can understand and absorb the lessons provided by radical product innovators, without incurring the costs and risks associated with conducting radical R&D. The diffusion of innovation literature suggests that information acquisition is very effective for diffusion in that it lowers the technological and financial risk of adoption.

Our findings indicate the need for further research using large scale international datasets. The open innovation paradigm may be significant in some sectors in some countries, but there are clearly many sectors in which firms gain innovation performance

advantages by operating with the old innovation model. There are likely to be good reasons for why this is the case. In future research we will explore regional effects in greater detail. National institutional factors and the different post-war histories of western and eastern European countries may continue to influence openness and the way in which external sources and internal R&D can be explored and exploited. Another issue requiring further analysis is sector specificity for firms operating in service and manufacturing sectors. Our research findings suggest that, when also controlling for sector R&D intensity, private sector service firms engage more in radical product innovation than firms in manufacturing sectors. This may reflect lower asset specificity of service providers or the need to engage in higher rates of product innovation due to the ability of rivals to understand and emulate radical service product innovation. This runs counter to the oft-made claim that service firms are innovative laggards compared to manufacturing firms. Clearly, there is much research still to be conducted on this issue.

REFERENCES

- Abernathy, W.J. and Utterback, J.M. (1975) A dynamic model of process and product innovation, *Omega*, 3(6): 639–656.
- Almirall, E. and Casadesus-Masanell, R. (2010) Open versus closed innovation: A model of discovery and divergence, *Academy of Management Review*, 35(1): 27–47.
- Baldwin C.Y. and Clark K. 2000, *Design Rules, Vol. 1: The Power of Modularity*, Boston, MA: MIT Press.
- Battisti, G. and Stoneman, P. (2003) Inter firm and intra firm effects in the diffusion of new process technologies, *Research Policy*, 32 (8): 1641-1655.
- Becker, W. and Dietz, J.R. (2004) R&D cooperation and innovation activities of firms: Evidence for the German manufacturing industry, *Research Policy*, 33(2): 209-223.
- Belussi, F., Sammarra, A. and Sedita, S.R. (2008) Managing long distance and localized learning in the Emilia Romagna life science cluster, *European Planning Studies*, 16(5): 665 – 692.
- Blau, J. (2007) Philips tears down Eindhoven R&D fence, *Research Technology Management*, 50(6): 9-10.
- Cassiman, B. and Veugelers, R. (2006) In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition, *Management Science*, 52(1): 68–82.
- Chesbrough, H., (2003) *Open Innovation: The New Imperative for Creating and Profiting from Technology*, Harvard Business School Press, Boston, MA.
- Chesbrough, H. (2006) ‘Open Innovation: A new paradigm for understanding industrial innovation’, In H. Chesbrough, W. Vanhaverbeke and J. West (eds.), *Open Innovation: Researching a New Paradigm*, Oxford: Oxford University Press.
- Chesbrough, H. and Schwartz K. (2007) Innovating business models with co-development partnerships, *Industrial Research Institute*, 50: 55-59.
- Chiaroni, D., Vottorio C. and Frattini, F. (2008) Research section: Patterns of collaboration along the bio-pharmaceutical innovation process, *Journal of Business Chemistry* 5(1): 7-22.
- Cohen, W.M. and Levinthal D.A. (1990) Absorptive capacity: a new perspective of learning and innovation, *Administrative Science Quarterly*, 35: 128–152.
- Collins, L. (2006) Opening up the innovation process. *Engineering Management Journal*, 16(1): 14-17.
- Dahlander, L. and Gann, D.M. (2010) How open is innovation?, *Research Policy*, 39(6): 699-709.

- Dosi, G. (1982) Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change, *Research Policy*, 11(3): 147-162.
- Fabrizio, K.R. (2009) Absorptive capacity and the search for innovation, *Research Policy*, 38: 255–267.
- Filippucci C, Drudi I, Papalia RB. (1996) Testing the relevance of Tobin’s approach for modelling consumption, *Economic Notes*, 25(2): 225–247.
- Fritsch M. and Lukas R. (2001) Who cooperates on R&D?, *Research Policy*, 30(2): 297-312.
- Geroski, P. (2000) Models of technology diffusion, *Research Policy*, 29: 603-625.
- Geroski, P. and Markides, C.C. (2005) *Fast Second: How Smart Companies Bypass Radical Innovation To Enter and Conquer New Markets*. San Francisco: Jossey-Bass.
- Gianiodis, P.T., Ellisy, S.C. and Secchi, E. (2010) Advancing a typology of open innovation, *International Journal of Innovation Management*, 14(4): 531–572.
- Grimpe, C. and Kaiser, U. (2010) Balancing internal and external knowledge acquisition: The gains and pains from R&D outsourcing, *Journal of Management Studies*, 47(8): 1483-1509.
- Grimpe, C. and Sofka, W. (2009) Search patterns and absorptive capacity: Low- and high-technology sectors in European countries, *Research Policy*, 38: 495–506.
- Grupp, H. (Ed.). (1998) *Foundation of the Economics of Innovation: Theory, Measurement and Practice*, Cheltenham: Edward Elgar.
- Harwing, R. (2004) Open innovation, *Philips Research Passport*, 19: 1-13.
- Hagedoorn, J. (1993) Understanding the rationale of strategic technology partnering: Inter-organizational modes of cooperation and sectoral differences, *Strategic Management Journal*, 14: 371-385.
- Hess, A.M. and Rothaermel, F.T. (2011) When are assets complementary? Star scientists, strategic alliances, and innovation in the pharmaceutical industry, *Strategic Management Journal*, Forthcoming: DOI: 10.1002/smj.916.
- Klepper, S. (1996) Entry, exit, growth, and innovation over the product life cycle, *American Economic Review*, 86(3): 562-583.
- Laursen K. and Salter, A. (2006) Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms, *Strategic Management Journal*, 27: 131–150.

- Leiponen A and Helfat CE. (2003) Innovation objectives, knowledge sources and the benefit of breadth. Paper presented at *What Do We Know About Innovation?: A Conference in Honour of Keith Pavitt*, Freeman Centre, University of Sussex, Brighton, U.K.
- Link, A., Rothaermel, F. and Siegel, D. (2008) University technology transfer: An introduction to the special issue. *Transactions on Engineering Management*, 55(1): 5-8.
- Lokshin, B., Belderbos, R. and Carree, M. (2008) The productivity effects of internal and external R&D: Evidence from a dynamic panel data model, *Oxford Bulletin of Economics and Statistics*, 70(3): 399–413.
- Long, J. S. (1997) *Regression Models for Categorical and Limited Dependent Variables*, Thousand Oaks, CA: Sage.
- Markman, G.D., Siegel, D.S. and Wright, M. (2008) Research and technology commercialization, *Journal of Management Studies*, 45(8): 1401-1423.
- Mansfield, E. (1998) Academic research and industrial innovation: An update of empirical findings, *Research Policy*, 26 (7-8): 773-776.
- Mohen, P., and Roller L. (2005) Complementarities in innovation policy, *European Economic Review*, 49: 1431-1450.
- Mudambi, S.M. and Tallman, S. (2010) Make, buy or ally? Theoretical perspectives on knowledge process outsourcing through alliances, *Journal of Management Studies*, 47(8): 1434-1456.
- Narula, R. and Dunning, J.H. (2000) Industrial development, globalization and multinational enterprises: New realities for developing countries, *Oxford Development Studies*, 28(2): 141-167.
- Nelson, R R. and Winter, S.G. (1982) *An Evolutionary Theory of Economic Change*, Cambridge, Mass.: Belknap Press of Harvard University Press.
- Neyens, I., Faems, D., and Sels, L. (2010) The impact of continuous and discontinuous alliance strategies on startup innovation performance, *International Journal of Technology Management*, 52(3/4): 392 – 410.
- Papke, L. E. and J. Wooldridge (1996) Econometric methods for fractional response variables with an application to 401(k) plan participation rates, *Journal of Applied Econometrics*, 11: 619–632.
- Parhankangas, A., Holmlund, P. and Kuusisto, T. (2003) Managing non-core technologies experiences from Finnish, Swedish and US Corporations, *Technology Review*, 149: 1-81.
- Perkmann, M. and Walsh, K. (2007) University-industry relationships and open innovation: Towards a research agenda, *International Journal of Management Reviews*, 9: 259-280.

- Piller, F.T. and Walcher, D. (2006) Toolkits for idea competitions: A novel method to integrate users in new product development. *R&D Management*, 36(3): 307 – 318.
- Rothaermel, F.T. and Deeds, D.L. (2006) Alliance type, alliance experience and alliance management capability in high-technology ventures, *Journal of Business Venturing*, 21(4): 429–460.
- Rothaermel F.T. and Hess A.M. (2007) Building dynamic capabilities: Innovation driven by individual, firm, and network level effects, *Organization Science*, 18(6): 898–921.
- Saviotti, P.P. (1985) An approach to the measurement of technology based on the hedonic price method and related methods, *Technological Forecasting and Change*, 29: 309-334.
- Saviotti P.P. and Tricket A. (1993) The evolution of helicopter technology: 1940 – 1986, *Economics of Innovation and New Technology*, 2: 111-130.
- Schnaars, S. P. (1994) *Managing Imitation Strategies: How Later Entrants Seize Markets from Pioneers*, New York: Free Press
- Smith, P. (2004) Book review. Open innovation: The new imperative for creating and profiting from technology, *Journal of Product Innovation Management*, 21: 221-224.
- Sofka, W. and Grimpe, C. (2010) Specialized search and innovation performance – evidence across Europe, *R&D Management*, 40(3): 310-323.
- Song, M., Droge, C., Hanvanich, S., and Calantone, R. (2005) Marketing and technology resource complementarity: An analysis of their interaction effect in two environmental contexts, *Strategic Management Journal*, 26: 259-276.
- Swann, G.M.P. (1993) Identifying asymmetric competitor networks from characteristics data: application to the spreadsheet software market, *Economic Journal*, 103(147): 468-473.
- Swann, G.M.P. (2009) *The Economics of Innovation: An Introduction*. Cheltenham: Edward Elgar.
- Trajtenberg, M. (1989) The welfare analysis of product innovations with an application to CAT scanners, *Journal of Political Economy*, 97(2): 444-479.
- Tushman, M.L. and Anderson, P. (1986) Technological discontinuities and organizational environments, *Administrative Science Quarterly*, 31: 439-465.
- Teece, D.J. (2007) Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance, *Strategic Management Journal*, 28: 1319–1350.
- van der Meer, H. (2007) Open innovation- the Dutch treat: Challenges in thinking in business models, *Creativity and Innovation Management*, 16(2): 192-202.
- Veugelers, R. (1997) Internal R&D expenditure and external technology sourcing, *Research Policy*, 26: 303-315.

von Hippel, E. (1988) *The Sources of Innovation*. Oxford University Press: New York.

Wernerfelt, B. and Karnani. A. (1987) Competitive strategy under uncertainty, *Strategic Management Journal*, 8: 187-194.

APPENDIX

Table A1.

Quintiles of R&D sector intensity for manufacturing and service sectors across 18 EU countries

VERY HIGH R&D INTENSITY (QU ₅)	NACE codes	Activity
Research and development	K73	Service
Computer and related activities	K72	Service
Manufacture of radio, television and communication equipment and apparatus	DL32	Manuf
Manufacture of office machinery and computers	DL30	Manuf
Manufacture of medical, precision and optical instruments, watches and clocks	DL33	Manuf
Manufacture of other transport equipment	DM35	Manuf
Other business activities	K74	Service
Manufacture of chemicals and chemical products	DG24	Manuf
HIGH R&D INTENSITY (QU₄)		
Manufacture of electrical machinery and apparatus n.e.c.	DL31	Manuf
Manufacture of machinery and equipment n.e.c.	DK29	Manuf
Manufacture of motor vehicles, trailers and semi-trailers	DM34	Manuf
Manufacture of food products and beverages	DA15	Manuf
Manufacture of rubber and plastic products	DH25	Manuf
Tanning and dressing of leather; manufacture of luggage, handbags and footwear	DC19	Manuf
Manufacture of textiles	DB17	Manuf
Financial intermediation, except insurance and pension funding	J65	Service
MEDIUM R&D INTENSITY (QU₃)		
Recycling	DN37	Manuf
Manufacture of wearing apparel; dressing; dyeing of fur	DB18	Manuf
Manufacture of furniture; manufacturing n.e.c.	DN36	Manuf
Activities auxiliary to financial intermediation	J67	Service
Post and telecommunications	I64	Service
Manufacture of fabricated metal products, except machinery and equipment	DJ28	Manuf
Manufacture of other non-metallic mineral products	DI26	Manuf
Manufacture of pulp, paper and paper products	DE21	Manuf
LOW R&D INTENSITY (QU₂)		
Real estate activities	K70	Service
Publishing, printing and reproduction of recorded media	DE22	Manuf
Manufacture of wood and of products of wood and cork, except furniture	DD20	Manuf
Land transport; transport via pipelines	I60	Service
Hotels and restaurants	H55	Service
Manufacture of basic metals	DJ27	Manuf
Water transport	I61	Service
Wholesale trade and commission trade, except of motor vehicles and motorcycles	G51	Service
VERY LOW R&D INTENSITY (QU₁)		
Insurance and pension funding, except compulsory social security	J66	Service
Supporting and auxiliary transport activities; activities of travel agencies	I63	Service
Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	G52	Service
Renting of machinery and equipment without operator	K71	Service
Manufacture of tobacco products	DA16	Manuf
Sale, maintenance and repair of motor vehicles; retail sale of automotive fuel	G50	Service
Manufacture of coke, refined petroleum products and nuclear fuel	DF23	Manuf
Air transport	I62	Service

Table A2.

Pearson correlations amongst the dependent and independent variables

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	INNWORLD	1									
2.	INNFIRM (p-value)	0.292 (0.000)	1								
3.	DEPTH (p-value)	0.138 (0.002)	0.120 (0.007)	1							
4.	DEPTH_COLLAB (p-value)	0.271 (0.000)	0.243 (0.000)	0.308 (0.000)	1						
5.	PANYSOURCE (p-value)	0.156 (0.000)	0.180 (0.000)	0.604 (0.000)	0.198 (0.000)	1					
6.	PANYCOLLAB (p-value)	0.195 (0.000)	0.151 (0.001)	0.229 (0.000)	0.717 (0.000)	0.130 (0.003)	1				
7.	RDINT (p-value)	0.252 (0.000)	0.145 (0.001)	0.204 (0.000)	0.279 (0.000)	0.164 (0.000)	0.251 (0.000)	1			
8.	LOGEMP (p-value)	0.297 (0.000)	0.305 (0.000)	0.177 (0.000)	0.413 (0.000)	0.180 (0.000)	0.331 (0.000)	0.062 (0.159)	1		
9.	INTSELL (p-value)	0.326 (0.000)	0.326 (0.000)	0.170 (0.000)	0.358 (0.000)	0.193 (0.000)	0.316 (0.000)	0.258 (0.000)	0.372 (0.000)	1	
10.	SERVICES (p-value)	-0.014 (0.749)	-0.124** (0.005)	0.010 (0.822)	-0.054 (0.226)	0.018 (0.687)	0.031 (0.484)	0.150 (0.001)	0.008 (0.857)	-0.315 (0.000)	1