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Private and External Benefits from Investment in Intangible Assets

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1 Victoria Street

London SW1H 0ET

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Contact Information

Institute for International Management Practice
Lord Ashcroft International Business School
Anglia Ruskin University
East Road
Cambridge
CB1 1PT

Tel: 01223 695 686
Email: contact.iimp@anglia.ac.uk

Authors

Professor Emanuele Giovannetti, Institute for International Management Practice, Lord Ashcroft International Business School, Anglia Ruskin University; and Professor Claudio Piga, Keele Management School, University of Keele.

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Abstract

This report studies the micro-evidence on innovation activity at firm level in the UK. The main aim of this report is to assess the network effects generated by individual firms' decisions on intangible innovation activities, such as investing in internal and external R&D activities, training and advertising for the purpose of innovation. The network element of these decisions is provided by two dimensional coordinates: a firm's geographic location and sector of production. This analysis is based on four main categories of information collected at individual firm level: investment in intangibles and innovation activities; introduction of innovation outcomes; firm characteristics, behaviour, motivations and cooperation relations; and knowledge spillovers, based on proximity in both geographic and production spaces. This report focusses on the interrelations between the variables populating these four categories, with the objective of achieving a better understanding of the complex set of relations underlying firm's innovative activities.

Innovation activities play an essential role in determining a firm's innovation output and productivity. Our main research question is to assess whether, and how, these investments in innovation activities and intangibles not only affect the outcomes of the investing firm, the *internal* effects, but also generate knowledge spillovers affecting the innovation performance of other firms in the economic systems, the *external* effects. Our objective is to include the estimates of these external effects and to assess their direction and significance along with the other *direct* relations linking innovative activities to productivity. To this aim, we construct a set of new variables capturing the spillovers taking place along different dimensions of the innovation activities.

After the preliminary exploratory findings, our report introduces an econometric model to assess the role played by different innovative activities and their sector and spatial spillovers, in determining both innovation outcomes and productivity. The model is divided into a three-stage estimation procedure:

- In the first stage, we introduce four separate estimations, one for each of the intangible innovation activities – namely Research and Development (R&D), training and advertising (for the purposes of innovation).
- The second stage utilises the predicted values obtained from the first stage estimation, together with more covariates, for predicting the outcomes of a firm's three possible innovation outcomes: product, process and organisational innovations.
- Finally, in the last stage we use the estimated firm's joint probabilities of introducing process, product and organisational innovations to estimate their impact on productivity.

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Executive Summary

Introduction

Anglia Ruskin University was commissioned by the Department for Business Innovation and Skills to undertake research on the “External and Private Benefits from Investments in Skills and Training”. For this report we have constructed a merged dataset on innovation activities and introduced new spillovers variables, to distinguish between external and internal effects in intangible investments in training and skills.

The wealth of data obtained through the United Kingdom Innovation Surveys (CIS) matched with information from other relevant databases, such as the Annual Respondents Database (ARD) and the Business Expenditure on Research and Development (BERD) survey, allowed us to explore many interesting relations between firms’ characteristics and their innovative behaviour.

The main contribution provided by this report is in the assessment of the effects generated by individual firm’s innovation activities on productivity. These, overall positive, effects take place both directly, through the immediate impact that innovations have on productivity and indirectly, through the role the intangible innovation activities play in facilitating the introduction of product and process innovations that, in turn, positively affect productivity.

Motivation and Empirical Evidence

The report covers innovation data for the period 2002- 2010. The immediate evidence emerging from these data is the positive relation between firms’ innovation activities such as R&D and training and their turnover.

The data showed that the turnover of the firms investing in R&D peaks during the periods of innovation activity, compared to the turnover of the non-investing ones. A similar relation is observed for the turnovers of the firms engaging in training for innovative activities.

The Financial Crisis and Innovations

Innovation activities, R&D and training, declined across all the macro-regions and sectors between 2006 and 2008 and this decline further accelerated between 2008 and 2010, in the three year period overlapping with the financial crisis.

Organisational innovations increased during the financial crisis across almost all UK macro-regions. Both process and product innovations followed instead an almost symmetric declining pattern in the same period. This evidence indicates that alternative forms of innovation — process, product or organisational — may act as strategic substitutes depending on the macroeconomic conditions.

Moving to the role of public financial support, we found that turnover of the firms receiving public support for innovation increased with respect to that of the firms who did not. However, public funding towards innovation activity displays a predominantly decreasing trend over the period analysed and great variation across the regions.

Finally, R&D intensity showed persistent patterns of spatial agglomeration and the presence of clusters of *hot spots*, whereby higher levels of innovation activities in a given area positively affect those of its neighbouring locations. These effects pointing to the relevance of innovation knowledge spillovers were mainly concentrated around the *R&D hot spots clustered around*: Cambridge, Guildford & Alders and London.

Knowledge Spillovers

Innovation activities play an essential role in determining a firm's innovation output and productivity. This report's focus is on whether, and how, these innovation activities not only affect the outcomes of the investing firm, the *internal* effects, but also generate knowledge spillovers affecting the innovation performance of other firms in the economic systems, the *external* effects.

The economic analysis of the role played by knowledge spillovers in the firms' innovation activities faces many challenges. Spillovers are, in fact, flows of an intangible commodity, innovation knowledge that is difficult to define and quantify as the firms' exposure to these externalities is not mediated through market interaction and prices. Equally challenging is the analysis of the modalities of these intangibles' diffusion through the economy. Moreover, innovation spillovers not only change a firm's efficiency, but they also affect its direct competitors. Dealing with these challenges, this report provides estimates on the impact of these spillovers both on innovation and productivity.

We model the diffusion of the knowledge spillovers considering two different firms' dimensions:

- Their geographic location, used to calculate the spatial range of the spillovers a firm generates and benefits from, based on proximity, and

- The firms' locations in the production space, where the distance between them depends on the intensity of trade flows between the firms' specific sectors of production.

The Mechanism

Following an established tradition that models sequentially the impact of innovation activities (see, Hall, et al. (2012), and Crepon, et al. (1998)), this report analyses the drivers of productivity by introducing an econometric model composed by three sequential stages. In the first stage, we focus on a firm's intangible activities to predict its innovation efforts. The second stage uses these predicted efforts to estimate the probability that a firm introduced any combination of the three possible types of innovations: process, product or organisational. Finally, the third stage uses these predicted probabilities of innovation to estimate their impact on productivity.

The main benefit of concentrating on this sequential approach is that it allows a finer understanding of the channels and interactions used by innovative activity to percolate through the production system, before exerting its final effects on output and productivity.

Model Findings

The main findings of the research can be understood by tracing back the chain of relations analysed in the three stages of the model introduced in this report.

Direct Effects: Innovations Increasing Productivity

In the final stage of our model we show that a firm's productivity is positively and significantly related to the introduction of product, process and organisational innovations.

We also find that productivity is higher for larger firms, but these productivity benefits decrease with employment size.

The positive relation between productivity and process innovations has an immediate interpretation: improving production processes has the direct objective of raising productivity by reducing costs and increasing efficiencies. Our estimates show that an increase of 10% in the probability of introducing a process innovation is associated with a 0.27% increase in a firm's productivity, measured in terms of Gross Value Added (GVA) over turnover.

Similarly, we find a clear positive association between productivity and organisational innovation, captured when productivity is measured in terms of Gross Profits Margin (GPM) gains. Our results show that an increase of 10% in the probability of introducing an organisational innovation leads to a 0.24 % increase in GPM over turnover of the innovating firm.

The interpretation of the positive relation between product innovations and productivity is less immediate but equally relevant and interesting for both its policy and managerial implications. Instead of being related to increased static efficiency, product innovations are more likely to bring increments in GVA, as they enable a firm to extract more consumers' surplus due to the higher willingness to pay that consumers may have for the improved quality of the goods and services resulting from product innovations.

Once identified the direct effects of innovation on productivity, our sequential estimation strategy allows us to move one step back to look at the main determinants of these productivity enhancing factors: the indirect effects.

Indirect Effects: Intangibles Leading to Innovations

The analysis of the indirect effects focuses on the variables affecting process, product and organisational innovations. Clearly, all factors associated with these innovations will have indirect effects on productivity.

This executive summary discusses the indirect effects of the intangibles on productivity in terms of their sign and statistical significance. The specific numerical values of the different parameters are in the report, but the richness and complexity of the different indirect internal and external effects, linking different intangibles to productivity via their impacts on the three different types of innovations, is better summarised in terms of their resulting qualitative effects.

In more details, our findings show that process innovations are positively affected by R&D expenditure. Similarly, R&D spillovers, arising from proximity in production space, have positive indirect effects on productivity via their positive impact on process innovations. This finding confirms the positive role that percolation of production-specific knowledge through the system of business to business exchanges plays in the innovation stage, indirectly, on productivity.

A firm's training expenditure, as well as training spillovers, again due to proximity in production space, has a similar positive effect, showing the complementarities between training and the introduction of process innovations and pointing towards additional indirect positive effects of training on productivity. It is interesting to notice that these indirect effects of training on productivity, mediated via process innovations, are both internal, due to a firm's own investment in training, and external, due to the training taking place among the other firms with which a firm interacts along its supply chain.

Another key enabling element towards process innovation, indirectly and positively affecting productivity, is cooperation in innovation, with firms of the same group, suppliers and customers. This evidence suggests that there is an important dimension of positive feedbacks forming along the innovation value chain.

The drivers of product innovations are similar to those analysed above in the discussion of process innovation. An interesting difference emerging from our findings is that both R&D and training spillovers' impacts lose their statistical significance for product innovation, indicating the possibility that knowledge appropriability barriers are higher for new products than for new processes.

Most of the determinants of organisational innovations are similar to those discussed for process and product innovations. The main difference is only in the positive relation that organisational innovations show with the motivation for innovating *to meet regulatory requirements*.

Further Factors Affecting Intangibles

After the analysis of both direct and indirect effects of innovation activities on productivity our model explores another set of relevant relations, through the analysis of the factors affecting the intangibles investment decisions. While this first step was mainly introduced for technical reasons, it also allows us to capture additional effects that indirectly influence productivity.

In particular we found that R&D, which we have seen leads to increased innovations and, indirectly, higher productivity, is positively affected by a firm's export propensity and by its desire to introduce better products, improve profits and to expand its markets. Also, cooperation with firms of the same business group, consultants, customers, suppliers and universities are all positively associated with R&D while R&D is negatively affected by a firm's cooperation with its competitors. This last finding implies that reduced competition in the output market, captured both by a firm's inward orientation and by cooperation with its competitors, is detrimental to R&D and, consequently, to its propensity to innovate and productivity. This result is particularly interesting and highlights the benefits of competition, not only to increase allocative efficiency, but dynamic efficiency as well.

Policy Implications

Barnett et al 2014 discuss the steady British productivity decline throughout the financial crisis. The descriptive evidence in our report shows that expenditure in innovative intangible activities also has dramatically declined during this period, when introduced innovations were mainly organisational, and seen as a short term response to reduced demand conditions due to the recession.

Productivity is a key element to maintain sustainable growth in a framework of increased international competitiveness and can be improved through process innovations increasing a firm's cost efficiency. Similarly important are product innovations, as they allow quality differentiation of a firm's products on the international markets. Clearly, restarting the virtuous process of innovative activities is an essential step to improve processes and products to regain lost productivity and introduce product innovations, necessary to compete in increasingly globally integrated markets.

The survey data show that public subsidies to innovation have been steadily declining in the period covered by this report. While this reduction might have been driven by budgetary constraints, the estimated positive effect of subsidies on R&D shows the long term costs of such decline and the necessity to consider these costs into the cost-benefit analysis used to assess innovation policies.

The key driver for process innovations, and hence indirectly of productivity, is the firms' investment in R&D activities. While these are based on firms' decisions, we have also seen that process innovations are positively affected by R&D spillovers, arising from proximity in production space. The relevance of these external effects indicates a clear role for policy intervention in incentivising R&D whenever, due to the low appropriability of the benefits of R&D, private incentives would provide a level of investment below the desired one.

Our report also shows how knowledge spillovers percolate through the economy via business to business relations underlying the relevant supply chains. Hence, policy should identify the key sectors, the most central within the supply chain exchanges, whereby subsidies and incentives for R&D would maximise the wider spillover effects.

Finally, we show that cooperation along the innovation value chain contributes to the introduction of innovations and productivity. This type of cooperation may suffer from coordination failure, for example due to the presence of asymmetric information among innovating firms. A clear role for a successful innovation policy aiming at overcoming this problem would be to create a favourable institutional setting to facilitate the emergence of cooperation, to avoid the danger of free riding and increase trust along the innovation networks. Finally, cooperation among competitors in the output markets is not favourable to innovations showing that competition policy not only provides benefits in terms of allocative efficiency but that it also improves dynamic efficiency through positive effects on innovation.

Next Research Steps

The Community Innovation Survey contains many variables, among which we selected those that appeared to be the most relevant and promising for our research objectives. Clearly, many more relations can be tested and further variables and their interactions can be analysed in relation to their role in shaping the indirect effects between innovations and productivity.

Our methodology for considering R&D and training spillovers can be extended to many other variables of potential interest. A first extension could focus on the role of firms' ICT expenditure, and its potential spillovers on productivity. Also, the survey data allow the possibility of differentiating between innovations that are disruptive, being new to the markets, and the simply incremental ones. Future research extending our work should focus on the potentially different drivers for these types of innovations and analysing their potentially asymmetric impact on productivity.

Our estimates considered both macro-region and sector of production of each firm as covariates to focus on the effects of innovation intangibles. A more detailed analysis could be extended at sector and regional level, to test for potentially significant sector differences in the aggregate relations studied in this report.

The notion of distance utilised for the spillovers' estimation could be further analysed in terms of network of linkages and relations, whereby, for example, firms in sectors with low direct trade exchanges, appearing to be distant in the production knowledge space, might still influence each other's productivity by being both closely related to a third different sector. This type of network analysis could capture relevant modalities of the transmission of knowledge spillovers left unexplored in his report.

Equally relevant, would be to pursue further the analysis on the relation between market competitiveness and innovation. This was captured, in our report, through firms' export propensity and via the firms' declared degree of collaboration with their competitors. Additional market structure information on market shares, price elasticities and concentration could be explored to extend the research on the effects of market power on innovation and its implications on productivity.

Finally, by using similar multi country data from the Community Innovation Surveys we could capture UK specificities and explain similarities and differences with other European countries in the relations between innovation and productivity.

1 Introduction

Anglia Ruskin University was commissioned by the Department for Business, Innovation and Skills to undertake research into the "External and Private Benefits from Investments in Skills and Training".

In this report, jointly prepared by Professor Giovannetti and Professor Piga, we have constructed a merged dataset on innovation activities, as described in Chapter 3, based on Data accessed through the UK Secure Data Service, and constructed new spillovers variables to distinguish between external and internal effects in intangible investments in training and skills.

Chapter 4 analyses the descriptive associations between these spillovers variables, other covariates and innovation activities and output.

Chapter 5 provides a geographic analysis based on the mapping of the innovation activities.

Chapter 6 introduces a three-stage econometric model to address the chain of associations between innovation activities, innovation outcomes and productivity.

Finally, Chapter 7 provides the conclusions. The Appendix reports regressions data.

2 Data Sources

In this section, we provide information on the various datasets that were used to derive the evidence that supports the analysis. In all cases, the data was obtained through the Secure Access system of the UK Data Archive.

Community Innovation Survey

The Community Innovation Survey (CIS) provides the main source of information on business innovation in the UK. The survey data is a major resource for research into the nature and functioning of the innovation system and for policy formation. It is widely used across government, regions and by the research community.

It is a voluntary postal survey carried out by the Office of National Statistics (ONS) every two years. The survey covers both the production (manufacturing, mining, electricity, gas and water, construction) and the service sectors.

For this report, we used the last four releases of the CIS:

- CIS 4, which covers the period 2002-2004. It is the largest of the innovations surveys conducted so far, sent to some 28,000 UK enterprises. Of those, 16,445 enterprises provided valid responses, representing a response rate of 58%.

- CIS 5 (period 2004-2006) consists of 14,872 fully answered questionnaires;

- CIS 6, which covers the period 2006-2008, has a sample size of 14,281 enterprises;

- CIS 7 covers the period 2008-2010 and includes data from 14,342 enterprises.

The sample of enterprises is drawn from the ONS Inter-Departmental Business Register (IDBR) and is based upon those firms with more than 10 employees. The sample is designed to be statistically representative of 12 broad regions of the UK, most industrial sectors and all sizes of firms.

Each round of CIS contains information on firm characteristics, such as a firm's postcode, their number of employees and turnover for both, the beginning and the end of CIS period, sector of activity as defined by Standard Industry Classification (SIC) code, details of any innovation-related activities such as R&D, acquisition of equipment, the context for innovation (e.g. to increase the range of goods or services, entering new markets), the factors constraining innovation, main cooperation partners and a range of other firm level characteristics such as training expenditure for innovative activities.

Using the above-mentioned four waves of the CIS, it is possible to construct a panel where we use the code of the Reporting Unit (RU) as a panel identifier, whereas time is represented by the period of each wave. The use of the Reporting Unit deserves further clarification. Based on the definition of reporting unit from the UK Innovation Survey User

Guide, “The reporting unit holds the mailing address for the business and is the unit for which businesses report their survey data to ONS. In general, the reporting unit is the same as the enterprise. In some of the more complex cases, enterprises are subdivided into reporting units and are defined by specifying the appropriate local units from within an enterprise”. The code of the RU is the same across different types of surveys, which allows the merging of data from different sources.

Annual Respondents Database (ARD)

The ARD is one of the most comprehensive surveys undertaken of business organisations in the UK, covering over 100 key economic variables, and approximately two-thirds of the UK economy. The ARD samples UK businesses and other such establishments according to their employment size and industry sector. It is a census of large businesses, and a stratified sample of small and medium-sized enterprises. The stratified sampling framework means that smaller firms move in and out of the survey. The forms are customised for industry sectors and sub-sectors. Essentially, it records balance sheet data of the interviewed units. Detailed variables for turnover, employment, costs, capital expenditures and the derivation of sales and profits are included. A firm-level measure of Gross Value Added (GVA) is also generated so that the productivity of organisations can be evaluated. The receipt of subsidies and the investment in advertising are stored. Balance sheet data refer to the business year of each unit, generally from 1st January to 31st December or, if their business year is different from the calendar year, to any 12 month period ending within the financial year (from 6th April to 5th of April of the following year). Some sectors of the economy are not covered by the ARD; mainly agriculture, health and social work, public administration and defence as per SIC2007 classification.

Information in the ARD on employment and turnover may differ from information reported in the CIS, although we have verified that the correlation between the same values from the two datasets is normally very high, ranging from 0.8 to 0.9, although it may differ across waves of the CIS. For consistency, we use turnover data for the statistical analysis from the ARD, like the rest of the balance sheet data.

Business Expenditure on Research and Development (BERD)

The *Business Expenditure on Research and Development* is an annual survey whose main purpose is to supply data for policy purposes on Science and Technology, of which R&D is an important part. It uniquely provides information on total R&D expenditure in the UK by business enterprises, total R&D employment and sources of funds. In particular, it differentiates between internally funded, in-house R&D projects, and external R&D expenditures.

The use of these databases served two main purposes. First, we matched the BERD with the CIS, and then checked the extent to which the two datasets provided consistent figures regarding the R&D expenditures, both internal and external. As in the case of the ARD, CIS data are highly correlated with the BERD data, but since we use other information from the CIS questionnaires, we opted to use the R&D data reported in the CIS for the statistical analysis. Second, since the BERD data are collected annually and over slightly larger samples, we used the BERD data to construct total annual measures of R&D expenditure, aggregated either at the sectorial level or at geographical level defined by the *Travel to Work Area* (see Section 5). Such data was used to construct measures of infraand inter-sectorial spillovers, as well as infra- and inter-area spillovers for the R&D investment. Infra- and inter-sectorial spillovers were constructed by multiplying the above total values by a matrix of sectorial weights that are derived from the Input-Output matrix of the UK economy prepared by the ONS. The geographical spillovers used a similar method, where the matrix of weights is formed by using the inverse of the distance between two *Travel to Work areas*, measured by taking their centroids points. The matrix of these distances was self-produced by the authors of this report.

3 Knowledge Spillovers and Localised Externalities

Understanding Spillovers

In this section, we focus on the analysis of knowledge spillovers and their impact on the innovation and production activities of the UK firms. Spillovers are an essential factor in understanding the sources of productivity and, while their study has been central for many years both in macro and microeconomics, a satisfactory understanding of their role, for both the individual firms and the economy as a whole, has not yet been achieved.

This research report addresses this challenge and provides a first step towards the understanding of the role knowledge spillovers play in the innovative activities of the UK firms and the effects they may exert on their overall productivity.

Tacit Knowledge

The economic analysis of the role played by knowledge spillovers in the firms' innovation and production activities faces many challenges. The main one lies with the spillovers own nature. Spillovers are in fact flows of an *intangible* commodity, knowledge that is useful and necessary to different aspects of a firm's productive and/or innovative activity. This nature of the productive knowledge poses different hurdles to the researchers:

- The first problem concerns how to define the intangible knowledge's elements generating spillovers.
- The second, crucial, obstacle revolves around the choice of the metrics used to quantify them.
- The third necessary step requires to define the modalities, the routes taken, by these intangibles to diffuse through the economy.
- The fourth problem is provided by the economic analysis of the direct impact that these flows of intangible knowledge have on the firms, once they reach them. This is particularly challenging as the firms' exposure to these externalities is not mediated through market interaction and prices.
- The fifth issue involves the indirect, strategic impact that spillovers have on the profitability of a firm. Spillovers often improve the efficiency of a firm's competitors as well as the firm's own one. The resulting relative efficiency effects will have a different economic impact, depending on the interaction between these spillovers and other markets and firm's specific characteristics. These firms and market features may either act as complements or as barriers to the absorption of the knowledge transmitted through the spillovers.

This report deals with these challenges, focussing on the data emerging from the CIS surveys, where firms individually report on their innovation activities, matched with more firm-level information from the BERD and ARD datasets. In this chapter, we review some of the relevant contributions on knowledge spillovers, motivating our analysis of the available data, performed in the next chapters.

Agglomeration and Localised Spillovers

To better understand the notion of spillovers it is important to take one step back, by looking at the nature of what they transmit: knowledge that is useful for the economic activities of a firm.

Marshall (1890) first considered knowledge spillovers as one of the main drivers of economic agglomeration. Arrow (1962) developed Marshall's original notion of spillovers, emphasising the role of learning by doing associated with the process of production and Nordhaus (1969) focused on the relation between knowledge spillovers and a firm's innovation process[1]. Glaeser et al. (1992) emphasised the importance of geographic proximity for the knowledge spillovers to explain agglomeration, identified by Krugman (1991) as 'the most striking feature of the geography of economic activity'. Proximity matters as the tacit component of productive knowledge (Polanyi 1958) is usually shared through face-to-face interaction and transmitted through informal contacts, facilitated by the fact that workers of firms located in neighbouring areas are more likely to have this type of contact (Jaffe, 1989; Acs et al., 1992; and 1993; Audretsch and Feldman, 1995).

Fujita & Thisse (2002) saw the emergence of spatial economic agglomeration as the result of the interplay between two forces: localised positive externalities and transport costs. These authors excluded the possibility of transmitting tacit knowledge across distances as 'the transfer of information through modern transmission devices requires its organisation according to some pre-specified patterns, and only formal information can be codified in this way'.

Giovannetti et al. (2007) however, questioned whether this distinction between codified and tacit knowledge remains relevant across Internet based business relations when, for example, video conversations take place across large distances, through a codified protocol unknown to the users, but still successfully exchanging tacit knowledge between them. Indeed, an established tradition in geographic research emphasised that social interactions can develop in relational places, rather than in geographic spaces (Relph, 1976, 'Place and placeness', in Dodge & Kitchin, 2001). In this framework, social processes, more than proximity, are a necessary element for knowledge exchanges (Ancori et al., 2000).

However, the role of face-to-face contact remains relevant in the presence of fragmented production processes when the incompleteness of pervasive contracts leads to an increased need for mutual trust (Spagnolo, 1999; Leamer and Storper, 2001). In a similar framework, Arora, Fosfuri and Gambardella, (2001) showed that geographical proximity reduces the price of exchanging knowledge as it facilitates repeated interaction and the forming of mutual knowledge and trust relations. The tension between places and spaces as factors driving agglomeration was addressed by Giovannetti et al. (2007) and D'Ignazio and Giovannetti (2007) in an empirical analysis of the *virtual districts* composing the Internet.

[1] The literature on spillovers has since developed significantly, starting from the survey on US spillovers by Griliches (1973). For a recent study, focusing on UK evidence, see Goodridge, Haskel and Wallis (2012).

Intangibles

This report focuses on how different types of innovation activities influence both directly and through indirect localised spillovers, the innovation output and consequently the productivity of each firm in the system. The data analysed from the CIS surveys provide a detailed decomposition of these innovation activities, into different *intangible assets* (Corrado, et al (2006)) also used by Dal Borgo et al (2011), to assess their impact on total factor productivity. These authors considered among the intangible economic competencies:

- Advertising expenditure*,* capturing the firm investment in reputation*;*
- Firm-specific human capital, measuring training provided by firms;
- Investment in *organisational structure* based on purchased management consulting.

Since the late 1990s, the value of intangible investment overtook that of tangible ones, showing how intangibles are progressively becoming more relevant in explaining productivity dynamics. In this perspective, Van Reneen et. al. (2005) emphasised that "Britain needs to increase work-related training to improve long-term economic performance addressing the existing 'skills gap' *" (See also Green and Steedman, 1997*; Van Reenen et. al., 2005*;* Galindo-Rueda and Haskel 2005; Konings and Vanormelingen 2010; Adey et. al 2010; Jones et al. 2013).

Our analysis will focus on the quantification of the intangibles available from four CIS surveys integrated with BERD and ARD data, covering the years between 2002 and 2010. The intangibles we will include are: internal and external R&D, training for innovative activities and advertising, all reported at firm level.

Empirical Evidence on Spatial Spillovers

Crescenzi and Rodrıguez-Pose (2012) provide an extensive review of the literature assessing the empirical relevance of geographic spillovers, emphasising that this "suggests that the relationship between local innovative efforts and the localised generation of new knowledge is far from linear (and that) … the uneven impact of R&D investments in the EU regions is further reinforced by a highly differentiated exposure to extra-regional knowledge flows." In their comprehensive survey, they report the results by Greunz (2003), estimating that the maximum range of the impact of innovative efforts on regional patenting activity in Europe spans 306 km, with Bottazzi and Peri (2003) finding a spillovers' range of 200-300 km, Moreno et al. (2005) of 250 km, and Rodrıguez-Pose and Crescenzi (2008) estimating the limit of spatial spillovers at a 180 minute round trip – an equivalent of around 200 km). This European evidence contrasts with the typical maximum spillovers' distance estimated for the US at a shorter, 80-110 km, radius (Jaffe, 1989; Varga, 2000; Acs, 2002).

This rich set of empirical results indicates that in Europe "knowledge flows tend to be driven more by commuting patterns and temporary proximity than by the migration of 'knowledgeable' individuals." (Crescenzi and Rodrıguez-Pose, 2012). Dosi, et al. (2006) interpreted the shorter range in the US as resulting from the higher mobility of the US labour force, leading to commuting distances shorter than those observed in the less mobile, European markets. In this report, we will work with a definition of proximity and local areas, based on commuting patterns, using the Travel to Work Areas (TTWAs), rather than adopting other available administrative criteria, as we consider the commuting factors to be the driving force shaping the range of the externalities across space.

Absorptive Capacity

A typical example of localised externalities arises when a worker changes employment carrying embodied tacit knowledge. In this case, relevant features of their knowledge, those independent from the complementarities with the other colleagues in their original working place, may spill over into the new working environment. The worker's knowledge generates new complementarities through the new co-workers, who are themselves benefiting from the interaction with the tacit knowledge embodied in the new colleague.

However, as productive knowledge is embodied human capital, its transmission and codification are necessarily only partial. This imposes additional learning costs for the successful transfer of productive knowledge across workers. Cohen and Levinthal (1989) and Griffith et al. (2004) emphasised the relevance of also addressing this *demand side* of the skills diffusion process, focussing on a firm's capacity of absorbing the knowledge produced elsewhere, and linking this absorptive capacity to a firm's investment in R&D[2]. Antonelli (1999) also discussed the complementarity of both internal and external knowledge for successful absorption. Hence, the possibility that spillovers may enhance a firm's productivity crucially depends on the investment in R&D and in other intangibles made by the receiving firm. For these reasons, when modelling innovation output, we will consider the role played by both spillovers and a firm's intangibles.

When analysing the incentives for adopting an innovation, or engaging in innovative activity, one also needs to consider the potential negative side of being in proximity to innovators. These may, in fact, be direct competitors – both for customers in product markets or for suppliers in input markets. Innovators, while creating positive externalities, may also generate a process of creative destruction (Schumpeter 1942), of their closest competitors. Piga and Poyago-Theotoky (2004) and (2005) focussed on the local spillover effects on the competition between neighbouring firms and Giovannetti (2000) showed that integration, by strengthening the competitiveness effects of proximity in the output market, may increase the technological asymmetries among neighbouring firms and that often available innovations are adopted only if neighbouring competing firm do not adopt them (Giovannetti (2013)). This simultaneous presence of both negative and positive proximity effects, led Antonelli et al. (2011) to predict a nonlinear quadratic relation between agglomeration of innovation activities and productivity growth, whereby an initial net positive effect from agglomeration of innovative activities is followed by a negative one, after reaching a threshold, resulting from the negative effects of appropriability.

When modelling the production of innovations, we will estimate the potentially positive or negative associations between different innovation intangibles, their spillovers and a firm's innovation output resulting from these contrasting effects. Moreover, by considering three possible innovation outcomes: process, product and organisational innovation, we will disentangle the role of these spillovers effects for each one of them. In this way, we may

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[2] Griffith et al. (2006) also stressed the importance of geographic proximity to the leaders in the production of innovation.

capture specific effects, only affecting a subset of innovation outcomes that would otherwise be lost with a more aggregate approach.

Sectorial Spillovers

Tacit knowledge exchanges are non-marketable services. These types of exchanges take place through work, organisation, social and local interaction. Codified knowledge transfers, instead, involving: training, tuition, and consultancy work are all services provided through market interaction, exchanged at a market price. The non-excludable nature of tacit knowledge and the fact that it is a non-rival commodity implies that its use, as an input in a production process, does not prevent other firms from using it in alternative ones. Hence, the tacit dimension of productive knowledge also implies lower barriers in the process of knowledge diffusion and percolation through the system, as appropriability, and property rights, of tacit knowledge are negatively affected by its un-codifiable nature.

As these spillovers are not transferred through market transaction we need to focus on a more general approach that allows technology spillovers to flow both across regions or industries. We follow the approach used by Medda and Piga (2014) and separate between intra-industry spillovers, measured by the innovation activity performed by all other firms in the sector a firm belongs to, and the inter-industry ones. These last ones are calculated based on weights derived from the Input Output tables reflecting the intensity of the trade links each sector has with the other sectors, where innovative activity is taking place.

Other studies focussed on manufacturing sectors to explore intra-industry spillovers (Nadiri 1993; Bernstein and Nadiri 1989; Los and Verspagen, 2000). Relying on the idea that only trade proximity matters in the interaction across firms, these studies have used trade flows statistics at sector level to construct an inverse distance matrix, thus assuming that technology spills over with a trade proximity transport cost (Anselin, 2007). This method relies on the assumption that the more an industry buys from, and sells to, another industry, the more it can benefit from its technological spillovers.

Wolff and Nadiri (1993) and Keller (2002) assume that the benefit a firm can derive from other firms is inversely related to their distance from the firm emanating the externality. Similarly, we focus both on trade relations whereby a firm benefits both from its suppliers' innovative efforts and from the reverse flows whereby a supplier benefits from its customers' innovations. In this framework, the distinction between supplier- and customer-driven innovation externalities (Bartelsman et al., 1994) refers to the difference between the spillovers originating either from downstream or from upstream linkages in the innovation supply chain. These authors found that suppliers' originated spillovers tend to affect long run growth more than those generated by the R&D performed by the firm's customers.

Morrison, Paul and Siegel (1999) obtained similar results, confirming the relevance of supply-driven spillovers. In this report we study the association between innovative efforts and innovation outcomes, also focussing on the specific firms' survey responses about the source of cooperation, whether this is customer, supplier- or competitor-driven.

Taxonomies

Pavitt (1984) characterised similarities and differences among different sectors, by producing a taxonomy based on the sectors' innovative spillovers. He identified innovations that are used in the same sector where they are produced as *process innovations* and those used in different sectors as *product innovations*. The main objective was to show inter-sectorial and interregional patterns of skills transfers. The resulting taxonomy consists of four categories of firms:

1. Supplier-Dominated: firms from mostly traditional manufacturing such as textiles and agriculture, which innovate by acquiring machinery equipment, produced externally to the firm.

2. Specialised Suppliers: smaller, more specialised firms producing technology to be sold to other firms, (specialised machinery production and high-tech instruments), innovating in a symbiotic way with their customers.

3. Science-based: high-tech firms that rely on R&D from both in-house sources and university research, including industries such as pharmaceuticals and electronics. Firms in this sector develop new products or processes and have a high degree of appropriability from patents, secrecy, and tacit know-how.

4. Scale-Intensive: firms characterised by mainly large firms producing basic materials and consumer durables, e.g. automotive sector. Sources of innovation may be both internal and external to the firm with a medium-level of appropriability.

The debate on Pavitt's initial contributions has produced a large body of literature, aimed at classifying different innovation behaviours. For example, Peneder (2001) proposed a taxonomy based on the innovations' factor intensity while O'Mahony and Vecchi (2009) based their taxonomy on the labour force skills. While it is not the objective of this report to suggest an additional innovation taxonomy, we follow Archibugi's (2001) approach to base the classification of innovative behaviour at the firm, rather than at the industry level. Hence, while modelling the factors associated with alternative innovative outcomes, we do consider both the firm's own sector influence and that coming from other sectors as well, maintaining, however, the respondent firms as the main unit of analysis. In this way firms in the same sector may display very different innovation behaviours due to their geographic locations, their proximities, and/or any other relevant differentiation characteristics, such as age, size, and modalities of collaboration with suppliers, customers, competitors or institutions.

Spillovers and Economic Growth

The pioneering work of Romer (1986) and Grossmann and Helpman (1990) linked the previously separated areas of research in economic growth and innovation, into the now well established field of *endogenous economic growth*. The unifying factor in the many different approaches to endogenous economic growth is that internal innovative activities, at firm level, generate industry-wide spillovers, contributing to long-run economic growth. Durlauf (1993) introduced localised knowledge spillovers, within an endogenous growth model. His main assumption was that depending on the spillovers intensity the model could show multiple equilibria. Interestingly, Durlauf proved that the higher the degree of integration among industries (the number of industries that directly affect each other via technological complementarities), the greater the spillovers intensity and the more likely is the possibility of having multiple equilibria.

Galor (1996) showed that only economic growth models predicting multiple equilibria can explain the empirical evidence of club convergence, a situation where groups of countries or regions converge towards different local growth rates. Hence, localised knowledge spillovers within endogenous growth models are sufficient to generate different growth rates between geographically separated locations. In the last part of this report, we link the results of the estimation of innovation outcomes, also based on inter-sector trade-weighted localised spillovers, to productivity, with the final aim of assessing the potential for different types of spillovers to affect economic growth.

The intuition behind the localised interaction and multiplicity of equilibria is brilliantly recounted in David (1992) through his '*snowplough metaphor'*, described in the textbox below.

Text Box 1	**The snowplough metaphor: for local externalities**
The Metaphor	David (1992) considers a city with shops distributed along the main road at regular intervals. After a snowfall, every shopkeeper can make his own shop accessible, only by sweeping away the snow from his doorstep. However, 'to make a customer visit a shop from the pavement, at least another shop, adjacent to the first, must have its pavement free'. The shopkeeper's results from sweeping are affected by the actions of his next door neighbours: the best he can do is 'to sweep away snow if his two neighbours have swept their threshold in their turn, not to clean if they haven't, and to sweep with one half probability in case only one neighbour has cleaned its own threshold'. In this setting, the results of a strategy depend on the shopkeeper neighbours' actions, due to the local externalities.
Results	The snowplough model is characterised by two possible equilibrium configurations: 1. Everyone sweeps or 2. Nobody sweeps; Given any initial mixed state, the system will converge towards one of these two possible equilibria, depending on the random realisation of the decision processes. This metaphor clearly illustrates how localised externalities can generate multiple equilibria. When this model is applied to different cities, depending on the initial

Text Box 1	The snowplough metaphor: for local externalities
	sequence of local decisions, one city may end up, with accessible shops while another will have all them covered in snow. Durlauf (1993) formalises this metaphor in terms of endogenous economic growth models, explaining different growth rates depending on the intensity of the localised inter-industry spillovers.

4 Descriptive Evidence on Innovation Activities

Our first task was to construct a coherent database and to start an explorative analysis focussing on the relevant associations between innovative activity indicators and behavioural and environmental features of the sampled firms. This chapter discusses these descriptive results emerging from the analysis of merged databases, introduced in chapter 3.

The CIS Questionnaire defines as innovation "New or significantly improved goods or services and/or processes used to produce or supply all goods or services that the business has introduced, regardless of their origin. These may be new to the business or new to the market. Investments for future innovation and changes that the business has introduced at a strategic level (in organisation and practices) are also covered." (CIS Questionnaire 2008-2010).

Innovation and International Market Participation

The first factor we explore relates the innovative activities of the firms sampled in the four CIS survey waves, to their participation to international markets. The data presented, refers to the specific questions asking: "In which geographic markets did the enterprise sell goods and/or services during the three year relevant period?" The possible choices were UK regional (up to 100 miles of business), UK national, European countries, and all other countries.

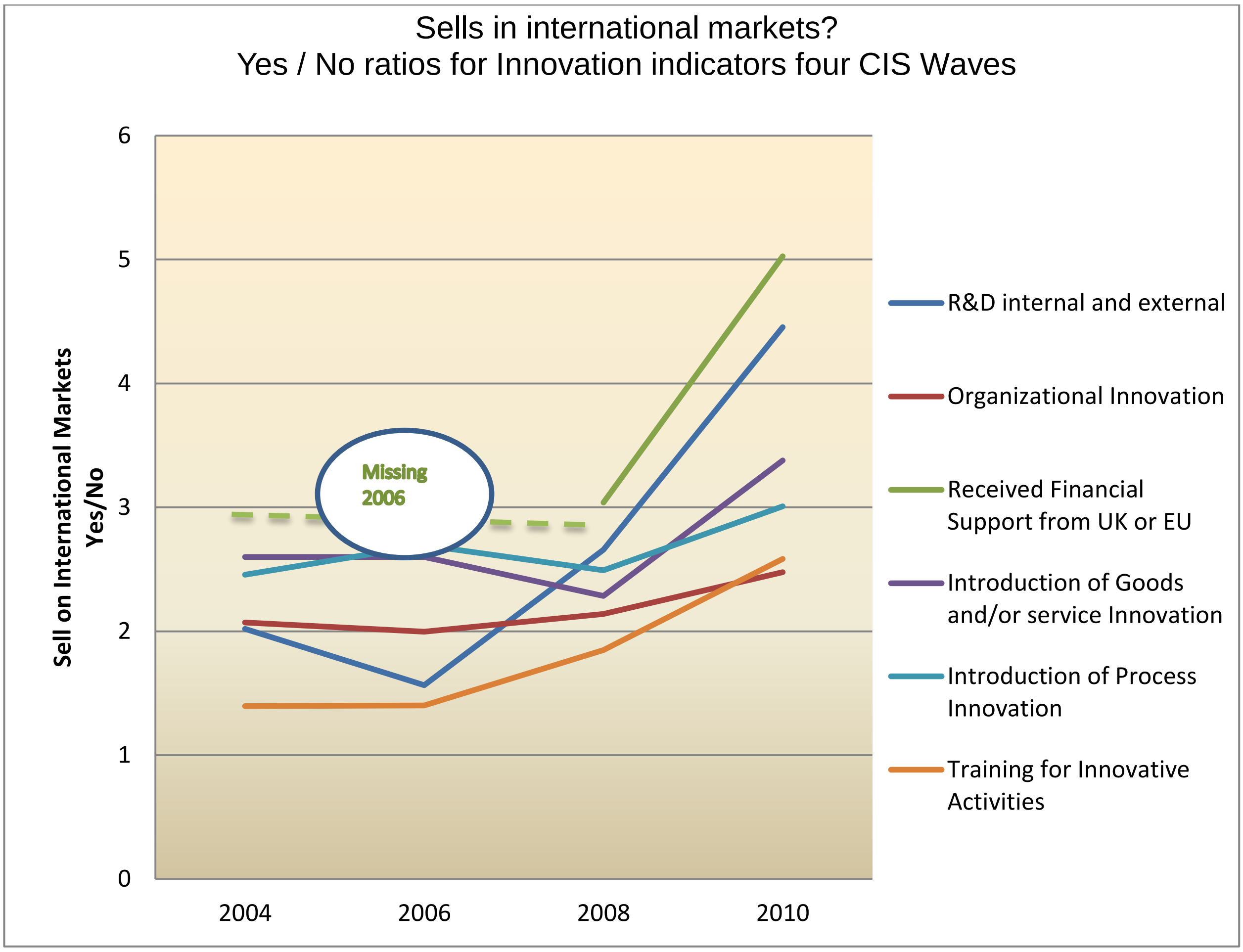
In the following descriptive analysis, the international market participation is associated with six metrics of innovative activity, based on the questionnaire's replies on whether the firm:

1. Invested in either Internal & External R&D,
2. Made major Organisational Innovations,
3. Received Financial Support from the UK or European Union,
4. Introduced new Products and/or services Innovation,
5. Introduced new Process Innovation and
6. Invested in Training for Innovative Activities.

Selling in International Markets and Innovative Activity

Graph 1 below, plots the ratio of the firms that sell their products on international markets over those who do not. We show how this ratio varies according to different indicators of innovative activities and through the four CIS waves of 2004, 2006, 2008, and 2010.

Graph 1: Sells in international markets? Yes/no ratios for innovation indicators



<u>Source</u>: Our elaboration on the CIS Data

A positive slope in this graph means that, with time, an increasing proportion of innovative firms have been exporting. Of course, the relation could either be spurious or going in any of the two directions, as more innovative products and services may well be more successfully exported or, vice-versa, the internationalisation of the market where a firm operates may provide the incentives to increase the innovative activity of a firm.

This evidence[3] provides an indication that all these variables have, individually, a significantly positive association with a firm's export activities. Hence, internationalisation and innovation are closely associated dimensions of a firm's activity.

[3] Based on the observations reported in graph 1, we tested the null hypotheses that each different variable, indicating innovation activities, is not significantly associated with the reply of whether a firm is selling in

Innovative Activity and Financial Support

Next, we consider the role of institutional financial support towards innovation as a valuable proxy measure for innovation policies.

Institutional Support for Innovation Activities

In graph 2 below we follow the association between innovation policies and firms' turnover.

In particular, we plot for three CIS waves[4] (2004, 2008 2010), a separate graph displaying the ratio between the turnover of the firms receiving public financial support for innovation activities and the turnover of those not receiving it. Financial support includes tax credits or deductions, grants, subsidised loans and equity investments, excluding research and other innovation activities conducted entirely for the public sector under contract.

The institutional levels providing support are:

1. UK local or regional authorities,

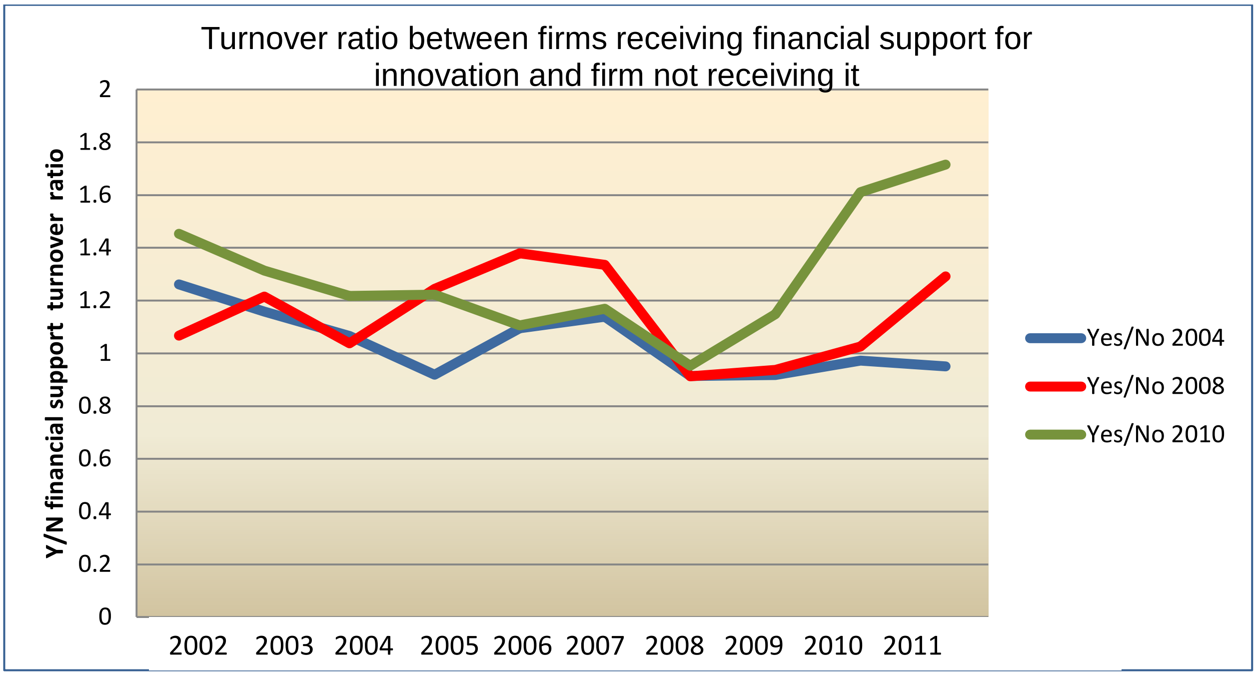
2. UK Central Government or

3. European Union institutions or programmes.

international markets. The t-tests show, that we can reject this null Hypotheses at 99% confidence for all the different survey periods of 2004, 2006, 2008 and 2010, and for all innovation activities indicators: Internal & External Research & Development, Organisational Innovation, Financial Support from the UK or European Union (missing observation for 2006), introduction of Product and/or service Innovation, and Introduction of Process Innovation and Training for Innovative Activities.

[4] Data on Financial Support for the UKIS 2006 are missing.

Graph 2: Turnover ratio between firms receiving financial support for innovation and firms not receiving it.



Source: responses to Question 20 of the CIS survey and on the firm's turnover data from the ARD Database

From graph 2 we can see that the average turnover of firms that received public financial support towards innovation is generally higher than that of the firms who did not receive any public financial support.

The matching of the two databases, CIS and ARD, allows the use of firms' turnover data, prior, during, and after the survey to see whether the funding is shifting future turnover, or if previous turnover could be a predictor for funding. Our first evidence shows that the average turnover ratios are at their maximum level over the time periods covered by the survey. Hence, the three relevant surveys are showing a shift of the maximum of this ratio, suggesting the potential impact of public funding on turnover.

Innovation Intangibles and Turnover

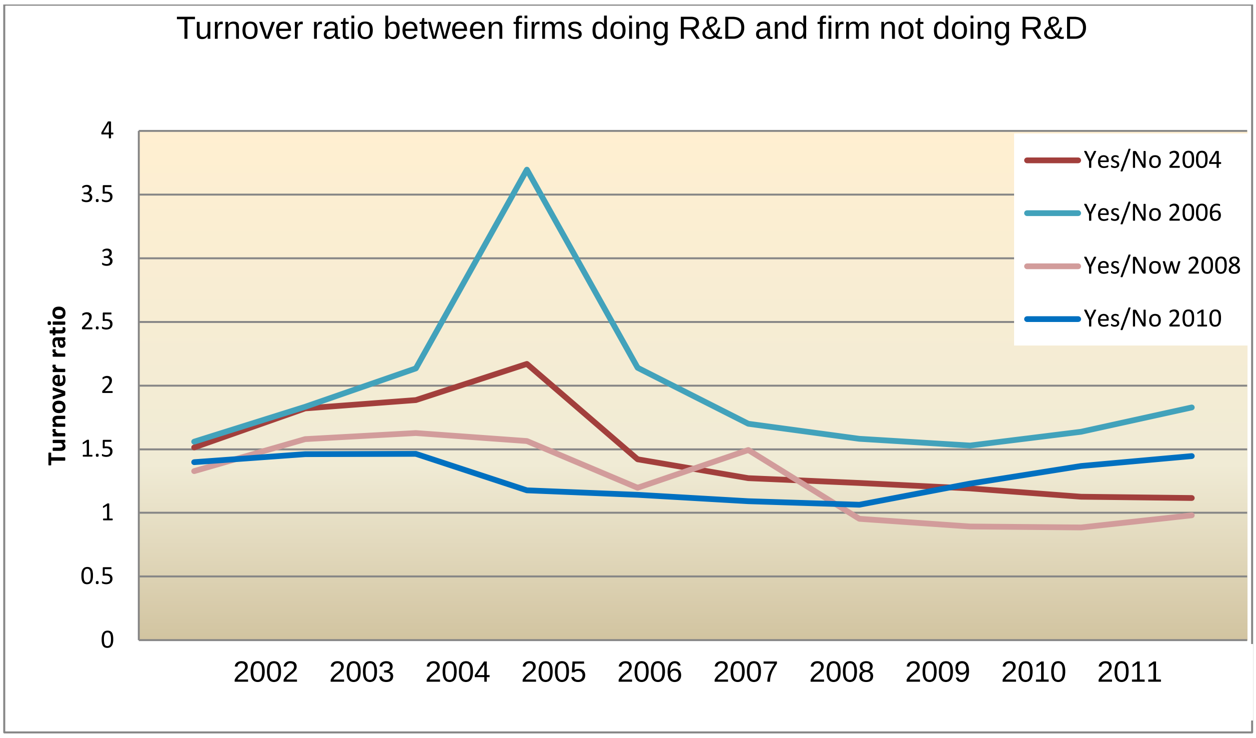
Question 4 of the CIS survey asked firms whether, during the relevant three years period preceding the survey, they had invested for the purposes of current or future innovation in:

1. Internal R&D: defined as creative work undertaken within your business that increases knowledge for developing new and improved goods or services and processes or in the
2. Acquisition of external R&D: same activities as above but performed by companies, including other businesses within your group, or by public or private research organisations and purchased by your business.

Graph 3 below shows the relation between the turnovers of the firms who had responded that they performed one or both of these intangible activities, internal or external innovation activities, over the turnover of those who did not. The graph displays this ratio over the ten year period 2002 to 2011.

Again, by merging turnover data from the ARD database with the R&D activities, as described in the CIS survey, we study the directions and the relevant temporal lags of this association. Interestingly, we can see that the turnover ratio peaks often during the periods of internal/ external innovation activity. Of particular interest is also the negative effect of innovation activities during the financial crisis, as shown after the CIS survey from 2008, with this turnover ratio taking values below one.

Graph 3: Turnover ratio between firms reporting internal or external R&D and those not doing R&D

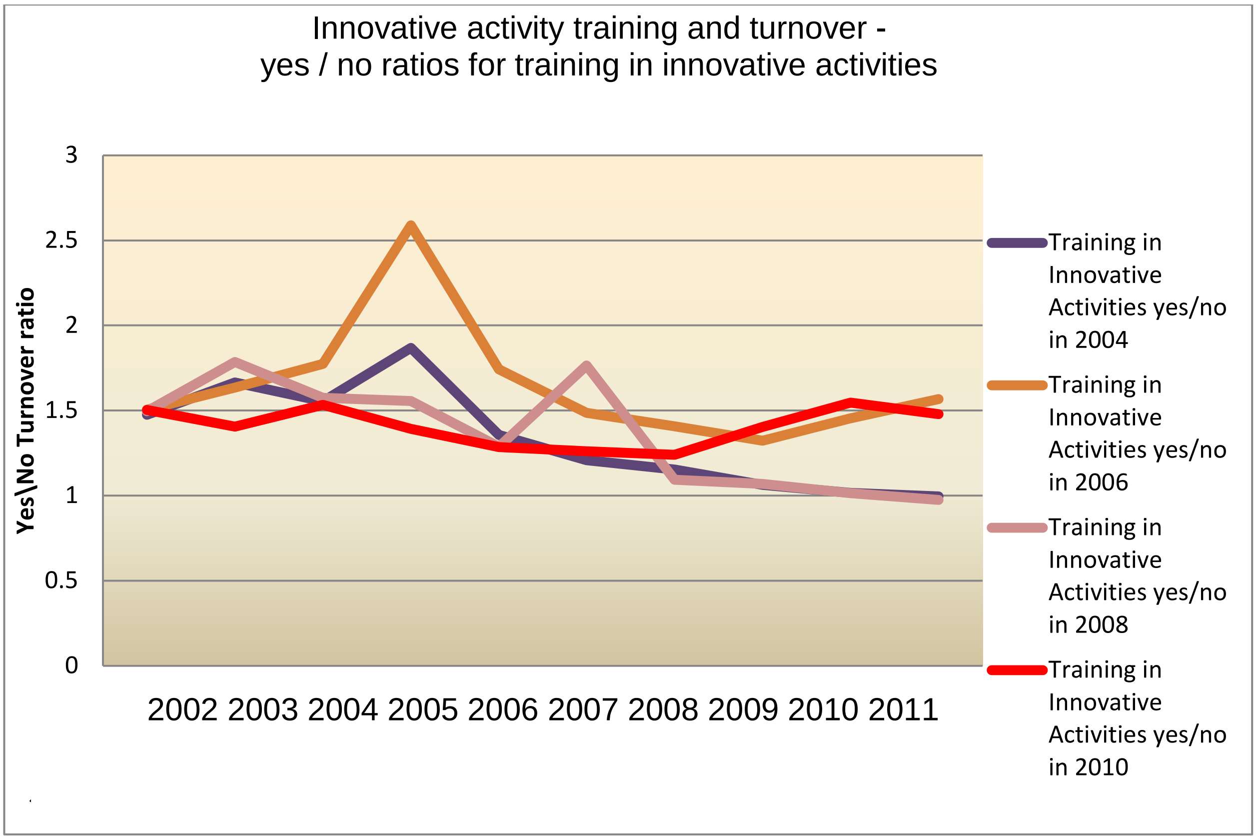


Source: CIS survey and the firm's turnover data from the ARD Database

Question 4 of the CIS surveys also asked the firms whether, during the relevant three years period preceding the survey, they had invested for the purposes of current or future innovation in training for innovative activities, i.e. internal or external training for personnel, specifically for the development and/or introduction of innovations.

Graph 4 explores the associations between the participants' responses on training activities and the total turnover for the 2002-2010 periods.

Graph 4: Innovative activity training and turnover



Source: CIS survey and on the firm's turnover data from the ARD Database

Graph 4 shows the presence of a shifting peak whereby turnover ratio between the firms who engaged in innovation training activities and those who did not, is highest for the three relevant years covered by the CIS surveys. This evidence shows not only an association between turnover and a positive answer to innovation training activities, but also that there is a marked difference between the turnover for the years of the survey`s reporting periods and both previous and future ones.

Again, when looking at the 2008 plot in graph 4, we can see that the firms who performed training activities during the period covered by the 2008 survey, showed a negative post-survey turnover performance. The negative post-survey performance could possibly indicate that the sign of the association between innovation training activities and turnover is crucially linked to the macroeconomic and financial conditions, which prevailed during the relevant training periods.

Regional Analysis of Innovation Activity

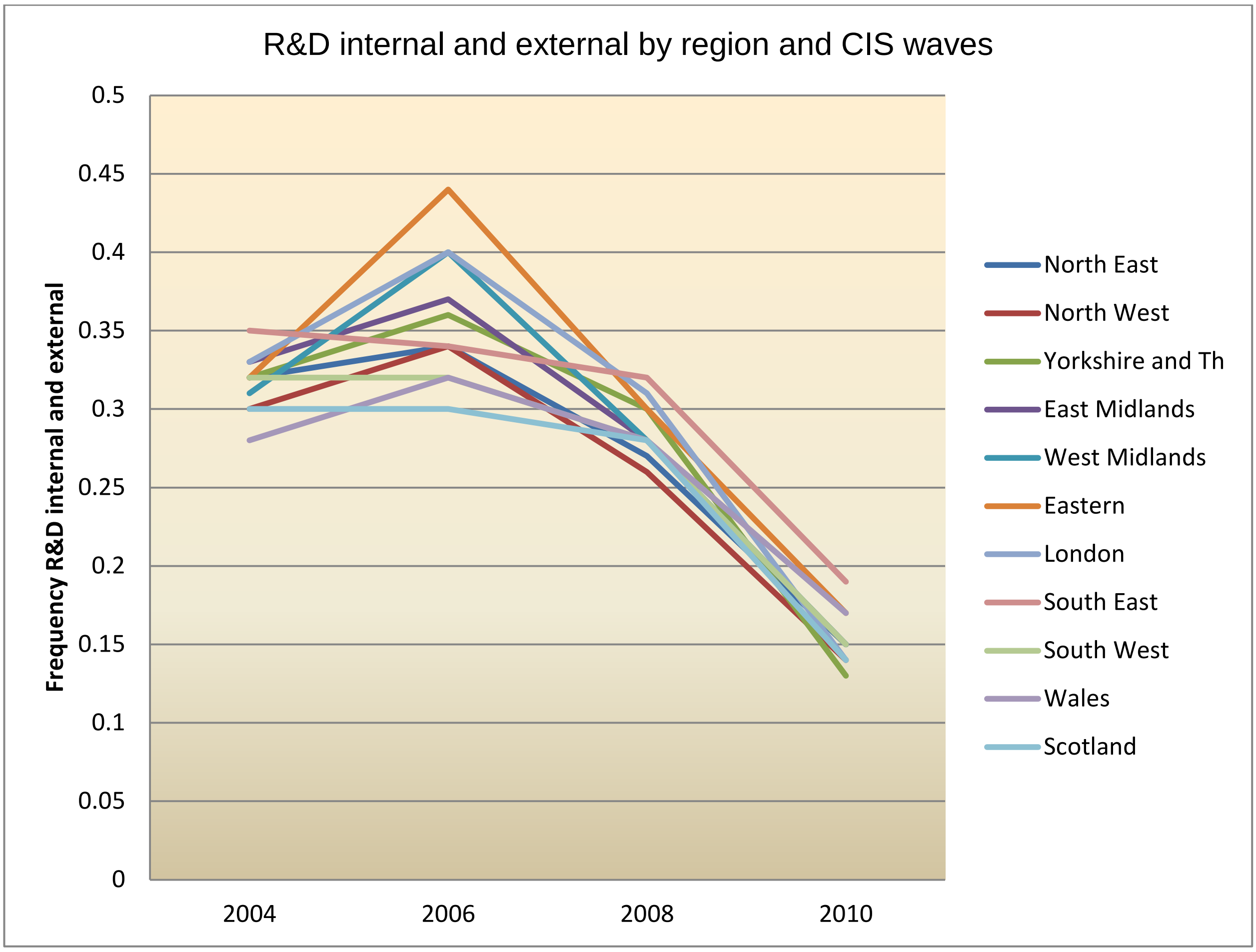
Next, we explore some of the emerging features of the regional dimensions of innovation.

Regional Dimensions of R&D

As an introductory step, we analyse the time profile of different metrics for intangible innovative activity for the eleven UK Macro regions.

In graph 5, we consider the frequency of firms that responded positively on the questions whether they invested in either internal or external R&D activities, classified according to their Macro-region, through the four CIS waves: 2004, 2006, 2008 and 2010.

Graph 5: Internal and external R&D by region and CIS waves



Source: CIS survey

These frequencies show that the percentage of firms declaring to have performed either internal or external R&D increased across most macro-regions (apart from Scotland, South East and South West) between the periods of 2004 and 2006. The Eastern region is the most innovative area, with circa 44% (followed by London with 40%) of sampled firms responding that they have engaged in either internal or external innovative activity. The innovation activity, however, declined across all the macro-regions between 2006 and 2008 and this decline accelerated even further between 2008 and 2010.

Regional Patterns of Organisational Innovation

Question 3 of the CIS survey asked firms whether, during the 3 year period preceding the survey, they had made major changes in the following areas:

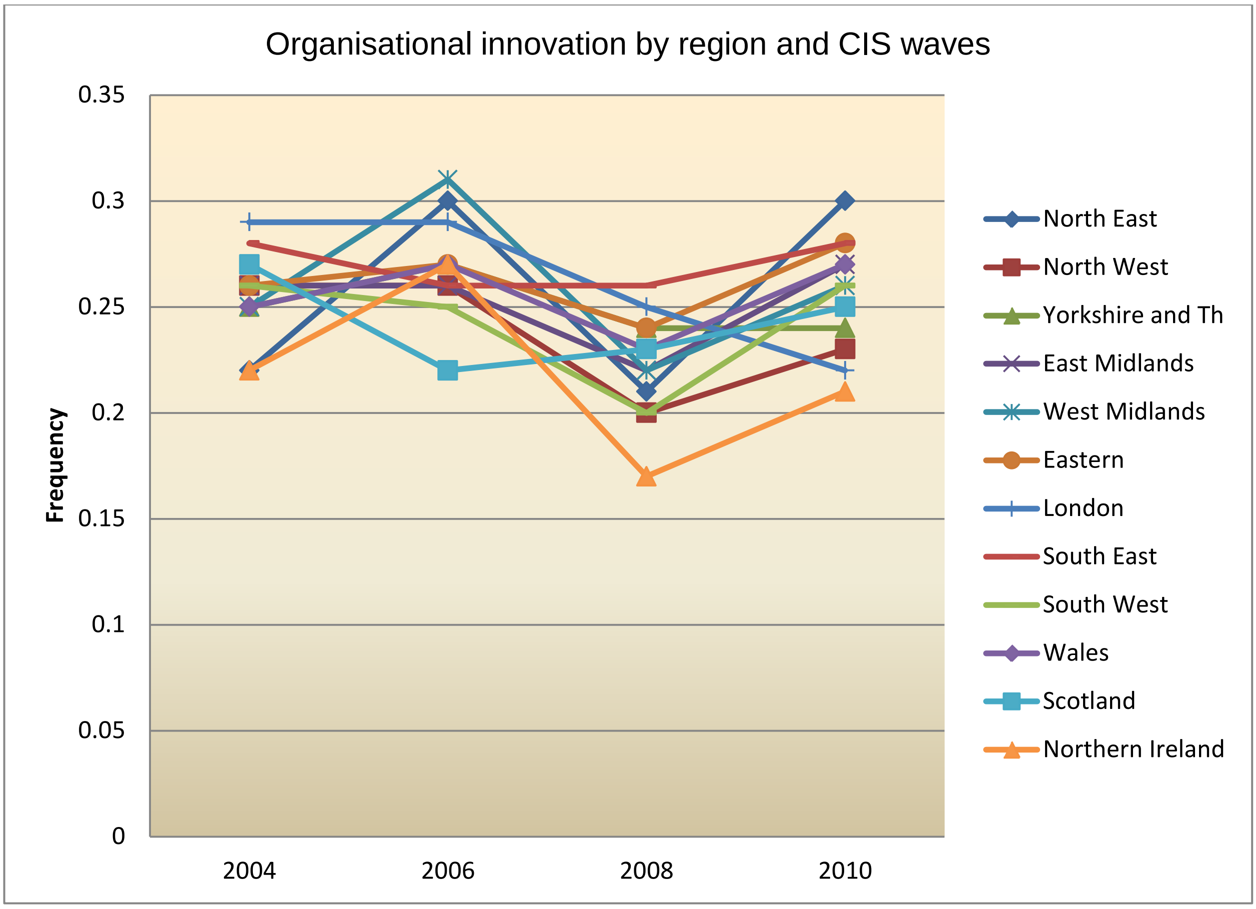
1. New business practices for organising procedures (i.e. supply chain management, business re-engineering, knowledge management, lean production, quality management etc.).

2. New methods of organising work responsibilities and decision-making (i.e. first use of a new system of employee responsibilities, team work, decentralisation, integration, or integration of departments, education / training systems etc.).

3. New methods of organising external relationships with other firms or public institutions (i.e. first use of alliances, partnerships, outsourcing or sub-contracting etc.).

4. Acquisition of external R&D: same activities, as above, performed by companies, including other businesses within your group, or by public or private research organisations and purchased by your business.

Graph 6: Organisational innovation by region and survey waves



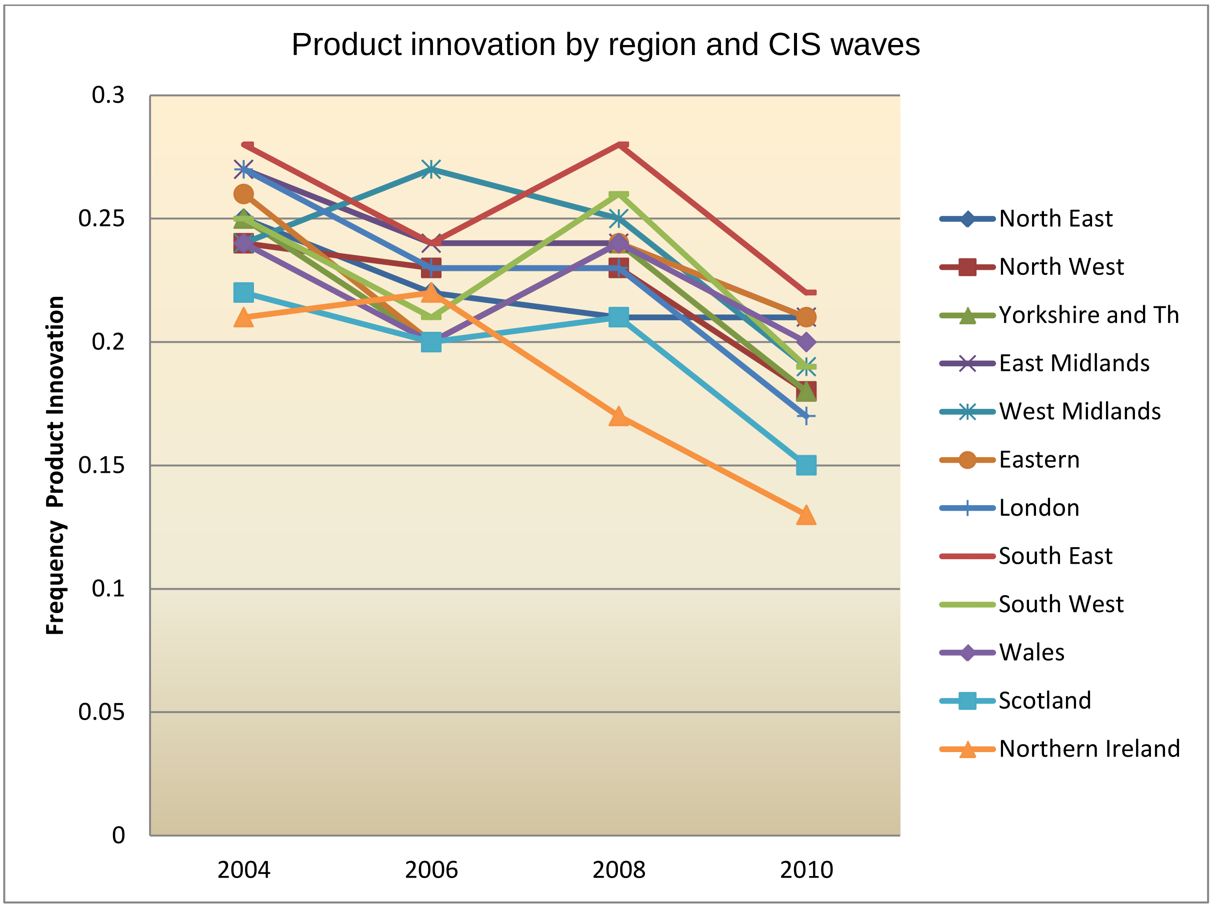
Source: CIS survey

The plots in graph 6 show the results obtained from the aggregated answers to these categories of organisational innovation. A striking result is that, across almost all UK macro-regions, organisational innovations have increased during the period of the financial crisis up to the 2010 survey. This leads us to consider whether adverse macroeconomic conditions are one of the main drivers for the organisational restructuring of UK firms, and whether organisational innovations can be seen as a preferred form of innovative activity during periods of macroeconomic and financial instability.

Regional Patterns of Product Innovation

Question 6 of the CIS surveys asked the firms to include all **new** or **significantly improved** goods or services. The data, in graph 7 below, shows that the macro-regions time trends for the introduction of product innovations are almost opposite and symmetric to those representing the organisational innovations, seen in graph 6. In particular, apart from the North East, the West Midlands and Northern Ireland, product innovation was increasing up to 2008, and started to decrease during the financial crisis between 2008 and 2010.

Graph 7: Product innovation by region and CIS waves



Source: CIS survey

The contrasting time profiles of product and organisational innovations indicate that different forms of innovation can be substitutes, and that a firm's choice of introducing one or the other form of innovation, might depend on their different suitability in alternative aggregate economic conditions.

Regional Patterns of Process Innovation

Question 9 of the CIS explored the effect of introducing process innovations, our third category of innovation output. The survey asked respondents to include all **new** or **significantly improved** methods for the production or supply of goods or services.

The data seems to confirm the behaviour of the introduction of product innovations across the UK macro regions as previously shown in graph 7 and its symmetry with organisational innovation patterns across regions, as seen in graph 6. Hence, product and process innovations seem to be complementary in nature and jointly substitute to organisational innovation.

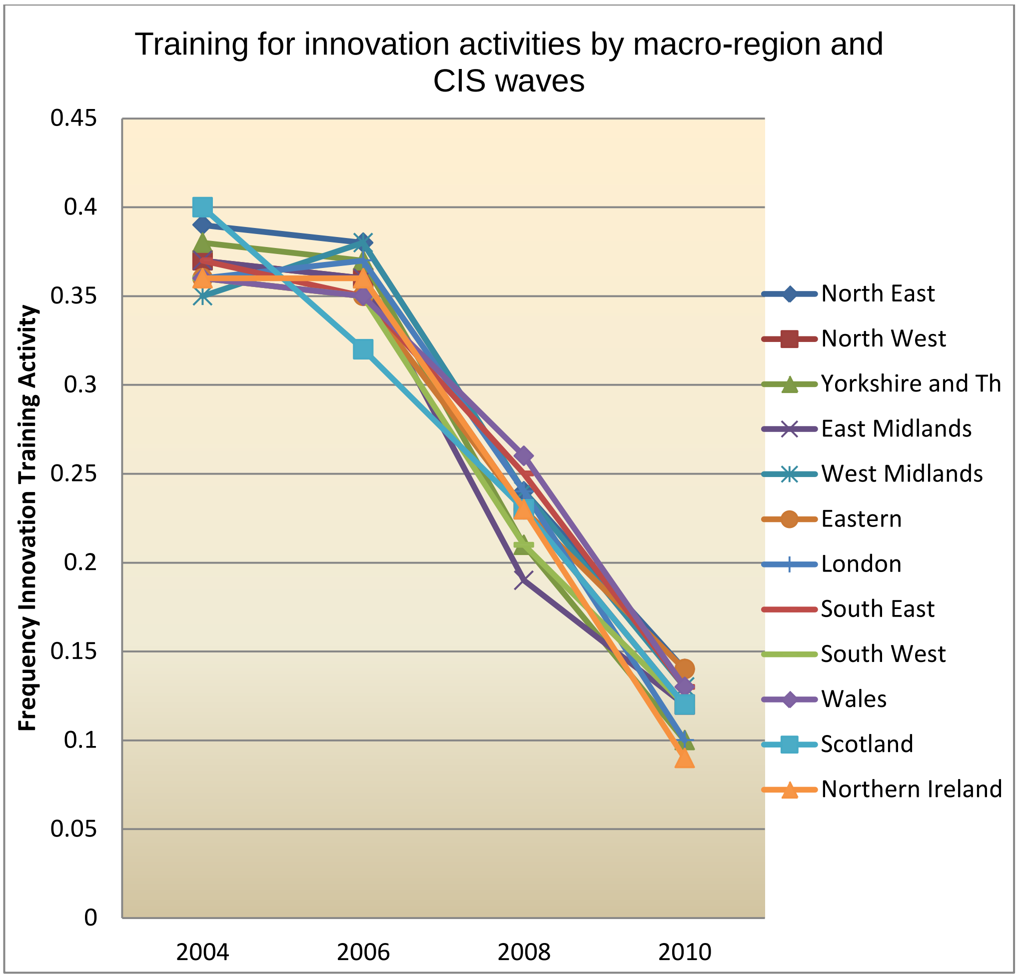
Training Activities and Public Funding for Innovation across the UK Macro Regions

We have already seen that question 4 of the CIS survey asked firms whether during the relevant three year period preceding the survey they had invested in training for innovative activities, for the purposes of current or future innovation.

Graph 8 below is showing that training for innovative activities has been steadily declining since 2006 across all regions, in a fairly uniform way.

It is interesting, and somehow surprising to notice that, while innovation activity was still increasing in the years preceding the financial crisis, the training activities started their decline well before the worsening of the macroeconomic conditions.

Graph 8: Innovation training activities by macro-region and CIS waves



Source: CIS survey

The time profile of public funding towards innovation activity, by UK macro-regions also showed a predominantly decreasing trend across the regions, and large regional variations, as for example, circa 8% of the firms in Wales reported public financing of innovative activity against only 2% in London.

Sector Analysis of Innovation Activity

Next, we explore the sector dimension of innovation, again, based on the merged CIS and ARD datasets.

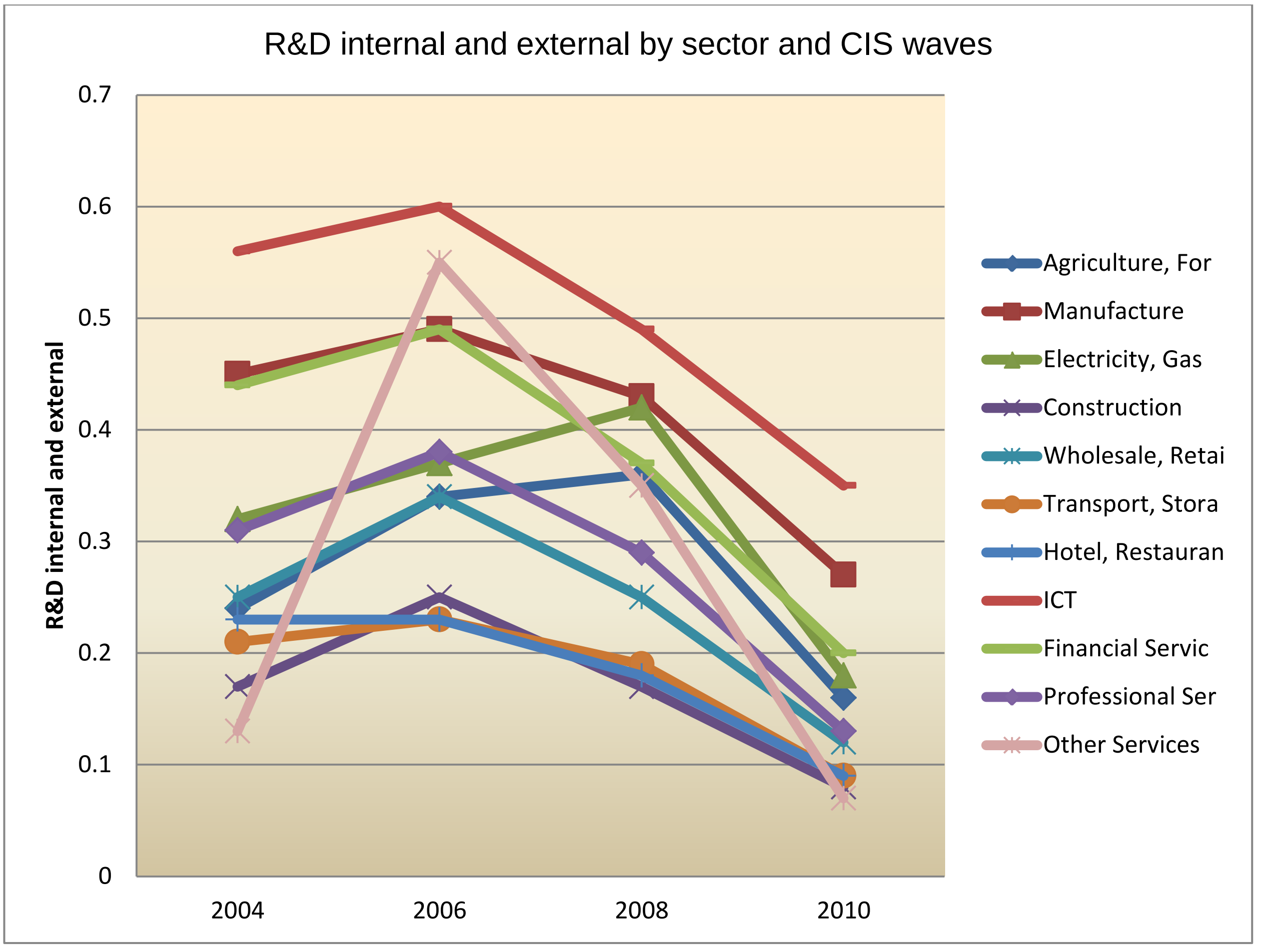
One important component in the analysis of skills spillovers will focus on the inter-sectorial flows of trade. These are very important to capture both supply and demand driven relations between different firms, and one of our research questions is whether and to what extent these inter-sectorial trade flows affect the innovative activity at firm level.

As an introductory step, we analyse the time profile of the different metrics for innovation activity for the UK Macro-sectors.

Macro-Sector Dimensions of Innovation Intangibles

The plots in graph 9 below show again that, innovation activities declined across all macro-sectors for both internal and external R&D activities in the three year period, overlapping with the financial crisis. These activities increased, instead, in all sectors in the three years prior to the 2006 CIS survey, and showed different sector dynamics between 2006 and 2008.

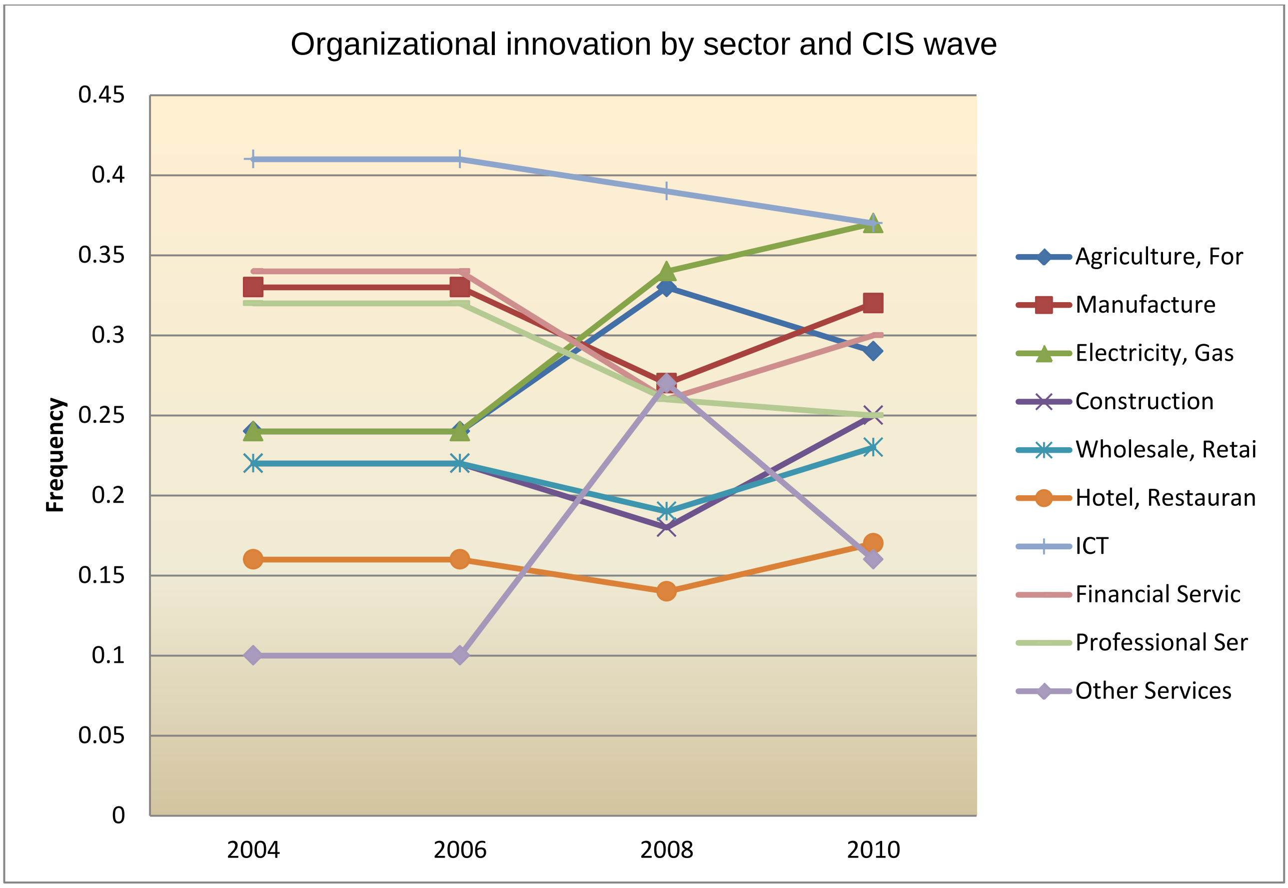
Graph 9: R&D internal and external by sector and CIS waves.



Source: CIS survey

The plots in graph 10, below, show that organisational innovations declined across most macro-sectors prior to 2008, while for many sectors investment in organisational innovations increased during the financial crisis.

Graph 10: Organisational innovation by sectors



Source: CIS survey

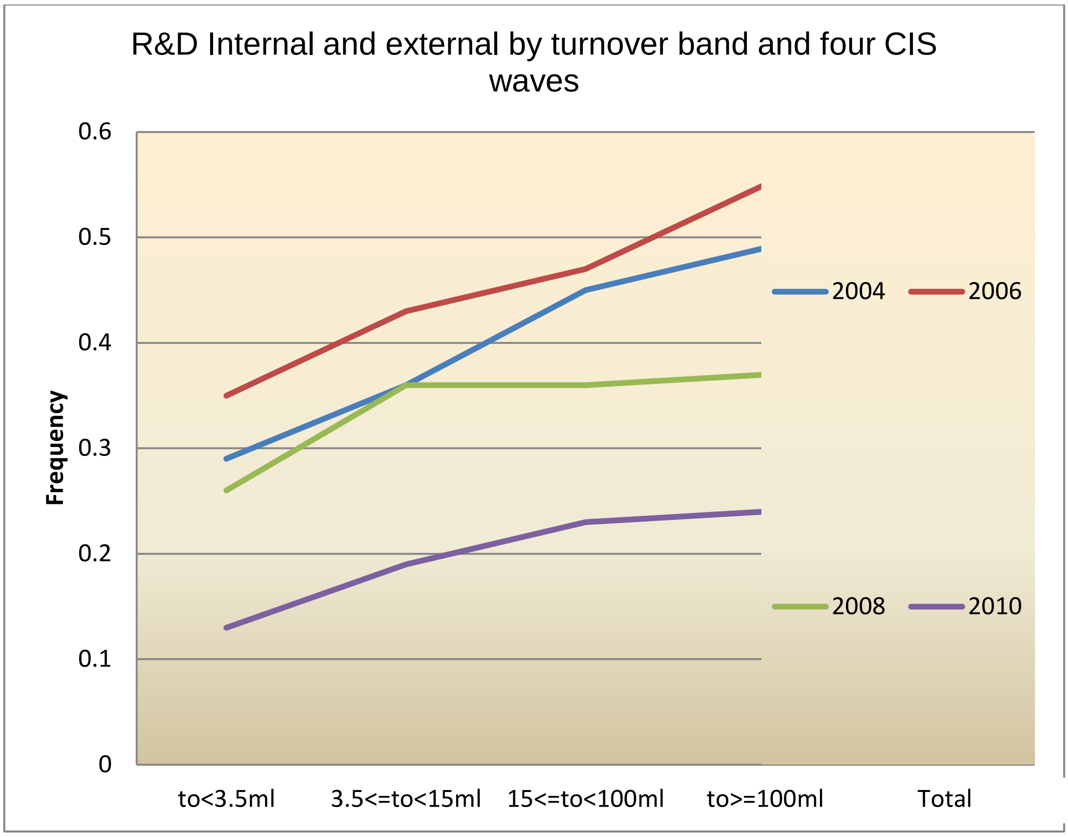
By comparing graph 9 with graph 10, we can see that, in many sectors, during the financial crisis organisational innovations moved counter-cyclically with respect to R&D activities. This inverse relation, during the three year period 2008-2010, is clear for the Manufacturing, Financial services, Wholesale and Retail, Electricity and Gas, Construction, Hotel and Restaurants sectors. Organizational innovations and R&D activities moved instead in the same direction during the same three year period for the Agriculture and Forestry, ICT, Other services and the Professional services sectors.

Associations between Innovation Indicators and Firms' Turnovers

We now look at the relation between the different innovation indicators and turnover classes, for 2004, 2006, 2008, and 2010. This exploratory step is done to analyse whether there are potential associations between innovative activities and firm size, in terms of turnover and, if so, whether these potential associations have changed through the different survey periods.

In the graphs below we consider four turnover bands against the frequencies for different types of innovation activities. The first class includes respondent firms that report a turnover below £3.5 million, the second class includes the firms reporting a turnover between £3.5 and £15 million, the third class spans between £15 and £100 million and the fourth group is made by firms with turnover above £100 million.

Graph 11: Internal & external R&D by turnover bands

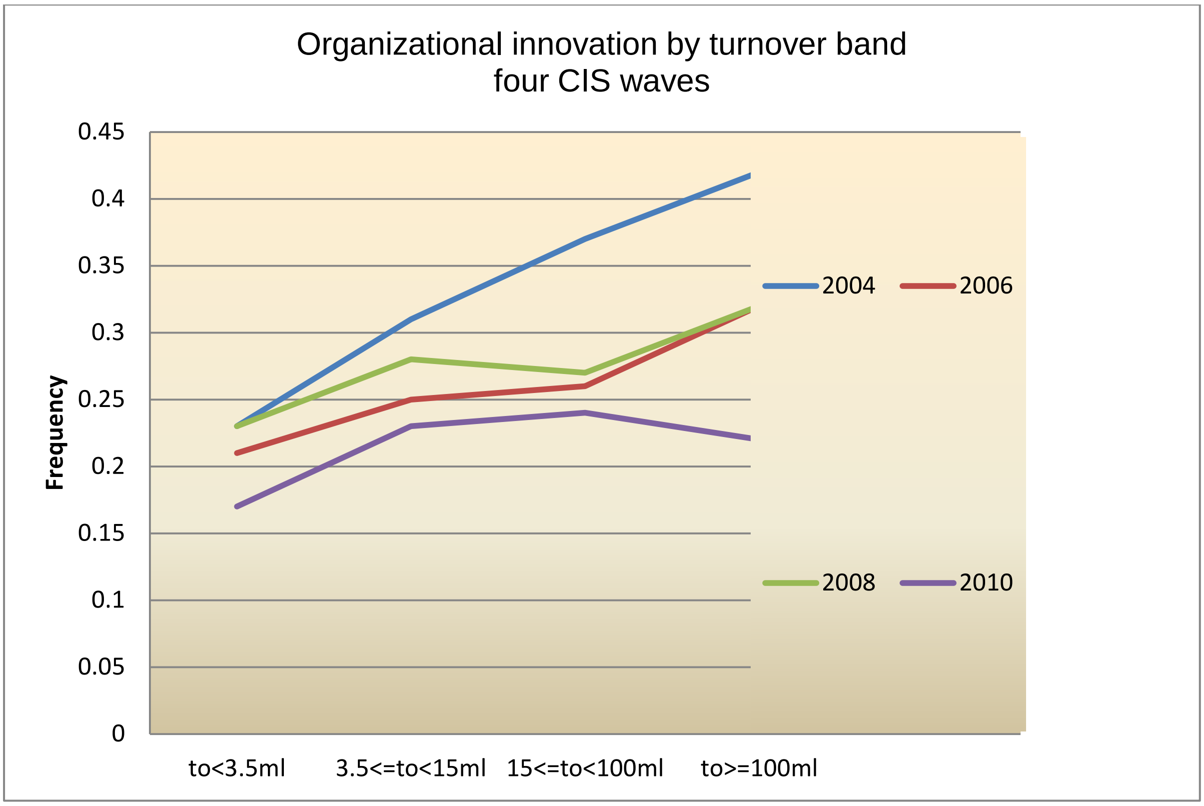


Source: CIS survey

Graph 11 shows how the investment in external and internal R&D activities rose up to the 2006 CIS survey and then started to decline across all turnover bands in the years covered by the 2008 and 2010 surveys. The decline in the three year prior to 2010 is very dramatic, showing a large gap in the firms investing in either internal or external innovations between 2008-2010, compared to the peak reached in the period 2004-2006. Graph 11 also shows that the proportion of investors in internal and/or external R&D is increasing with the firms' turnover and that this relation remains stable across the different survey periods between the years 2002- 2010.

Graph 12, displayed below, explores the relation between organisational innovation and turnover band, again across the four innovation surveys. As before, we find that also organisational innovations are increasing in the respondents' turnover. The temporal profile shows a sharp decline in the frequency of the investors between 2004 and 2006, and again up to 2008. However, the total number of investors in organisational innovation was higher in the three years of the financial crises, 2008 to 2010, than in the preceding period: 2006-2008.

Graph 12: Organisational innovation by turnover bands



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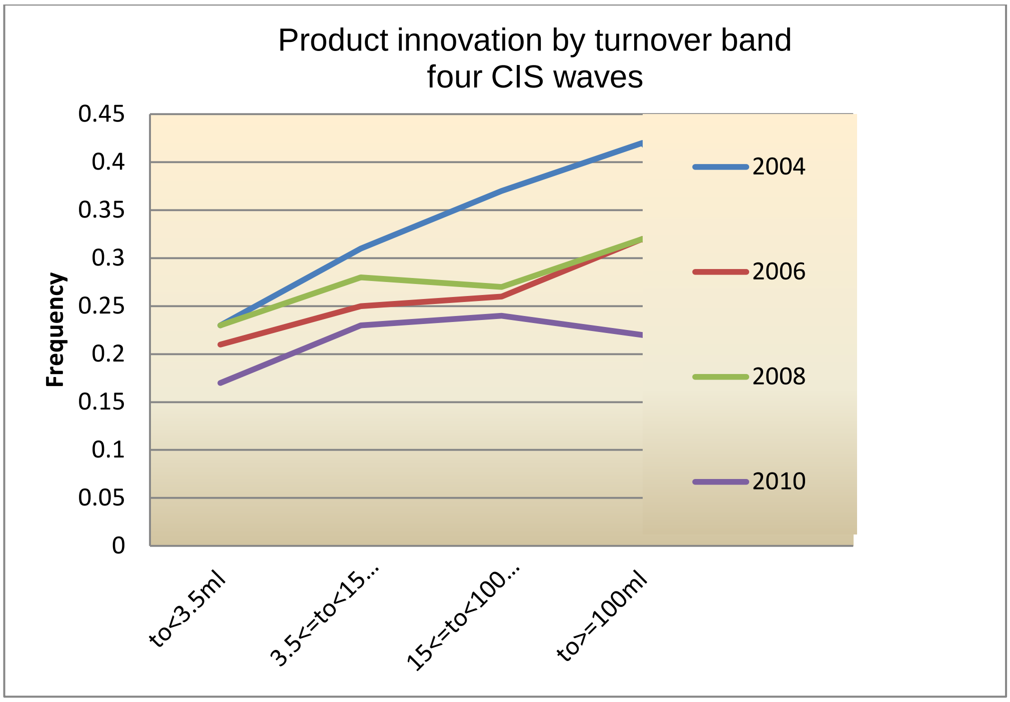
Source: CIS survey

The distribution of public funding towards innovation also showed a sharp decline in the frequency of respondents receiving financial support, between the 2004 and 2008 surveys, and interestingly, a shifting of support towards higher turnover bands in the 2010 survey.

Graph 13 shows the distribution of the frequency of firms that introduced a product innovation, as a function of the turnover band and survey wave. Again, we can see that the frequency of product innovators decreased rapidly between the 2004 and 2010 surveys, across all turnovers bands. Clearly, the financial crisis has not incentivised the introduction of innovative products. This might reflect market expectations, or the increasingly tightened access to the credit market that was not accompanied by a policy of increasing financial support towards innovation.

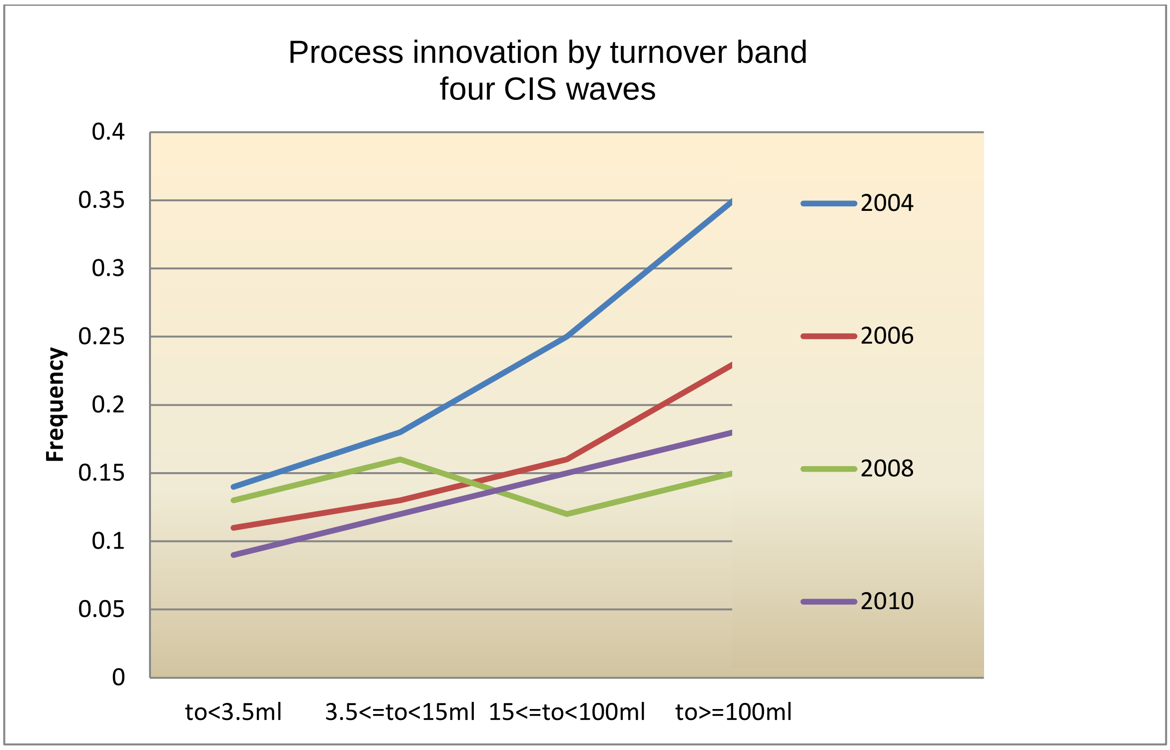
Graph 13: Product innovation by turnover bands



Source: CIS survey

Graph 14 describes the relation between process innovation and turnover band, across the four survey waves. While it is possible to see, again, the sharp decline in the introduction of process innovation between 2004 and 2010, as in the previous case of product innovation, we also observe an interesting criss-crossing element: the frequency of the firms with turnover above £15 million, investing in process innovation, during the three years prior to 2010, was higher than in the three years preceding the 2008 survey. This observation shows a main difference between process and product innovation dynamics during periods of macroeconomic instability: investment in process innovations was more resilient than investment in product innovation, as process innovation can be used to introduce cost reducing processes, while product innovation is necessarily linked to positive expectations about the market demand for new products.

Graph 14: Process innovation by turnover bands



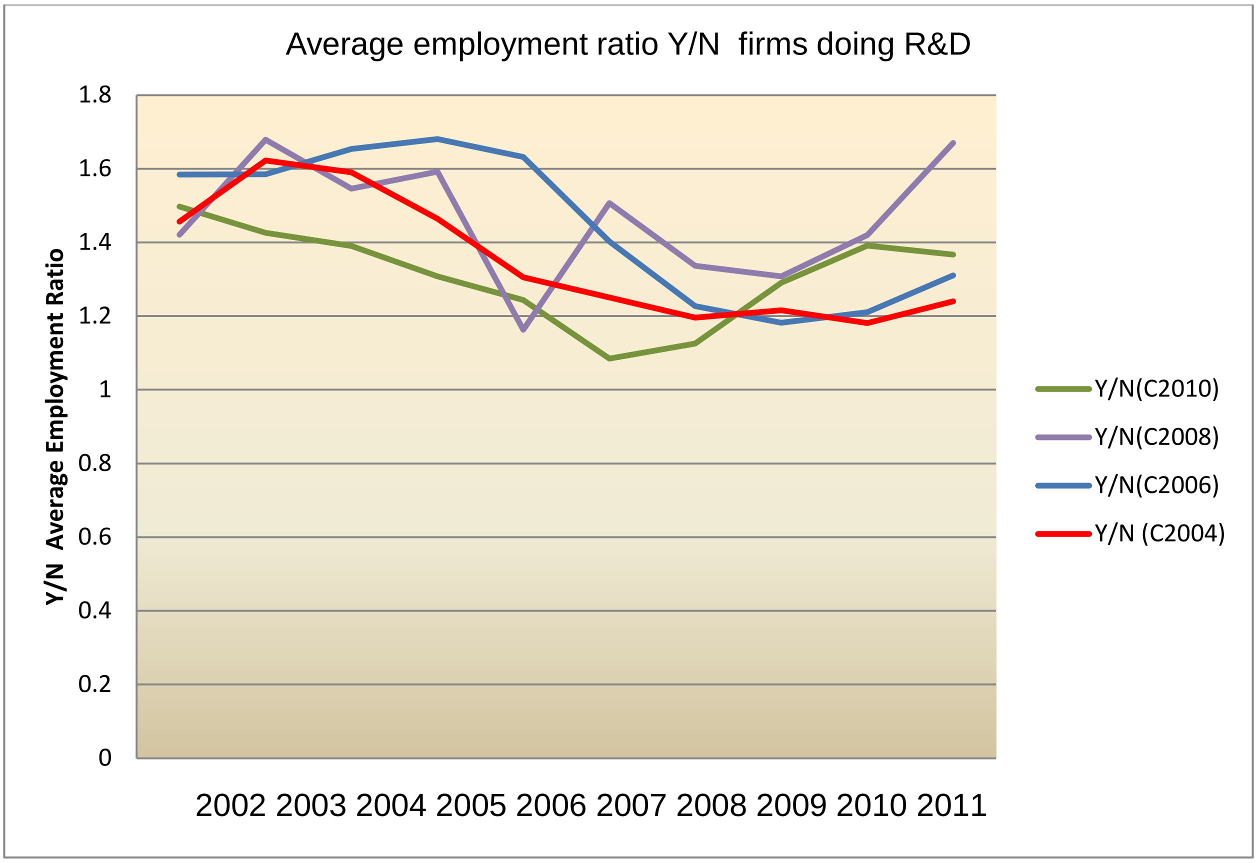
Source: CIS survey

R&D Activity and Ten Years of Employment Data

Below we consider more in detail the relation between employment and intangible innovation activity. The following analysis is based on matching different datasets, so that we can use the employment data from the ARD Database collected on a yearly basis for the entire period between 2002 and 2011.

In this way, we are able to follow the relation between innovation indicators and employment data that both predate and then follow each CIS survey wave. These data are particularly useful in exploring the existence of temporal lags and potential directions of causality in the relation between innovation activities and employment.

Graph 15: Average employment ratio for firms having R&D activities



Source CIS and ARD.

Graph 15 shows the temporal evolution of the average employment ratio between the firms who engaged in innovation activities and those who did not, at each innovation survey. We have four different curves:

- The first curve: Y/N (C2004) indicates how the employment ratio between the firms who performed innovation in the three years 2002-2004, has evolved year by year from 2002 until 2011. Interestingly, we can see that this curve peaks in 2003, during the survey period, and then it declines until 2010. This shows that, by considering the temporal evolution of the employment ratios of the respondents of the 2004 survey, the share of the employment of the innovators have been reduced throughout the years. This evidence can be interpreted as indicating a negative forward association between innovative activity and employment, as it shows the "future levels" of the employment ratio, for the firms who had innovated in 2004.
- The second curve: Y/N (C2006) seems to confirm the same story. The employment ratio between innovators and non-innovators, in the 2006 survey, peaks during the survey periods just before 2006 and falls thereafter, confirming a post innovation lowering of the ratio.
- The third curve: Y/N (C2008) indicates a local peak of the employment ratio at 2007, during the survey period, followed by a sharp two year decline and an increase in the 2010-2011 periods.
- The fourth curve: Y/N (C2010) is interesting to see employment as the preconditions, rather than the implication of the innovative investment. The curve

shows that the employment ratios between innovators and non-innovators in the fourth survey had been constantly decreasing since 2002, but displays a clear trend change during the innovation survey period 2008-2010.

Similarly, by focussing on training for innovative activities the data shows that the employment ratios between the respondents who invested in training activities over those who did not invest in training, peaked during the survey period, followed by a steady decline. This evidence is possibly indicating a negative lagged association between training and employment.

5 Geographic Analysis of Innovative and Training Activities

This section describes how the R&D and Training activities are distributed across Great Britain. To this purpose, the country is divided into 243 Travel to Work Areas (TWWAs), as defined by ONS (2007).

Text Box 2	**Travel to work areas**
Definition	The current criteria for defining TTWAs is, that generally at least 75% of an area's resident workforce works in the area and at least 75% of the people who work in the area also live in the area. Essentially, TTWAs correspond to non-overlapping and contiguous areas inside which a large proportion of the resident working population commutes to work. That is, TTWAs' boundaries are not defined from an administrative point of view but to capture the relevant commuting patterns of the working population.
Relevance of the Selection	TTWAs are ideal to model how the research and training activity in one area can generate a spatial spillover externality. This is because they capture the area boundaries where commuters interact on a daily basis and where the transmission of generic ideas, Marshallian externalities take place. When analysing geographic spillovers we will start from activities performed in each TTWA. In this way, the total level of investments in R&D and/or training within a given area has the property of a pure public good. Inter-Area spillovers indicate the level of the externality that the investment activity in R&D and training in area *j* generates for area *w.* The intensity of the Inter-Area spillover is assumed to be inversely proportional to the distance between the two areas.

In this section, we will use the TTWA classification to provide an immediately recognisable visual mapping of the most active areas in terms of investment in R&D and training.

We aim to evaluate:

1) **which areas exhibit a greater intensity in R&D and training investment;**

2) **whether each activity tends to be clustered or geographically diffused;**

3) **whether the two activities tend to be correlated over space and time**

While point 1) and 2) are not generally novel, the evidence we produce should validate our choice of both the databases we employ and the geographical categories we apply.

Geographical Analysis of R&D Activities

Using the BERD database, the total annual investment in R&D in each TTWA was calculated for each year during the period 2002-2011. For each TTWA, we then calculated the percentage contribution of each area to the total level of investment in the country.

We then averaged these values for the two sub-periods 2002-2006 and 2007-2011 and clustered areas into broader categories whenever this was needed to maintain data confidentiality.

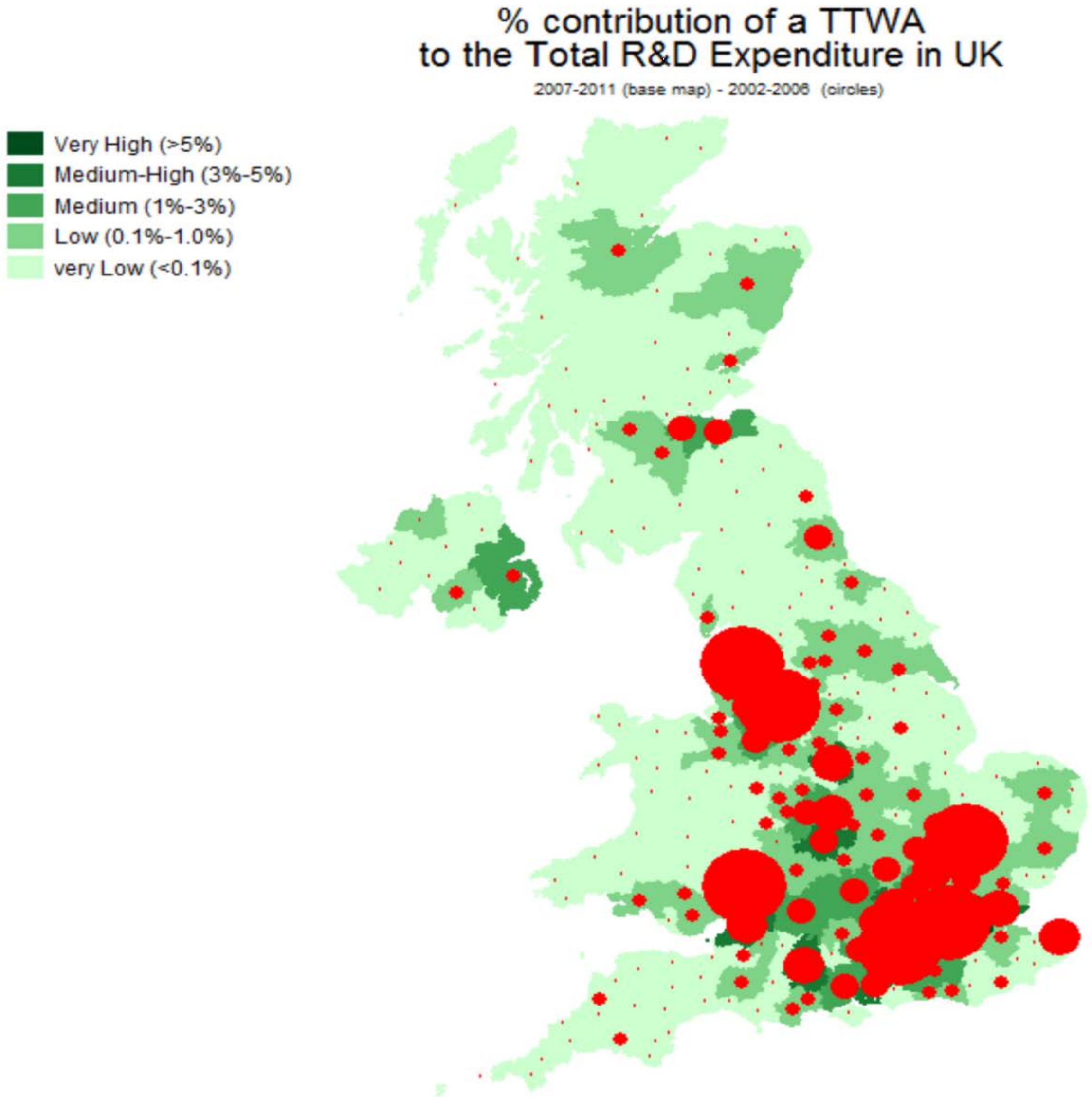
Map 1 refers to the entire Great Britain and illustrates the percentage contribution of Research & Development expenditure of each Travel to Work Area (TTWA), over the UK total for these two time intervals.

To represent the geographic distribution of each TTWA's Research & Development expenditure contribution over two different periods in the same map, we adopted two different distributional keys:

- The size of the diameter of the circles, centred on the TTWA map, measures the area's contribution in the first period, 2002-2006.

- The intensity of the base colour in each TTWA corresponds to the second period, 2007-2011, spatial distribution of the variable: with darker colours indicating higher percentages.

Map 1: Comparison of the total R&D expenditure per TTWA across time



Map 1 clearly reveals that R&D activity is a spatially concentrated activity with a large proportion of R&D investment located in the South, especially in the areas that include London, Cambridge and Oxford. Outside this large cluster, it appears evident that R&D activity gravitates around medium-large urban areas where, amongst other things, universities are present. Indeed, TTWAs that include large cities also are very active investors: the areas of Bristol, Cardiff, Birmingham, Nottingham, Manchester, Liverpool, and Newcastle. A similar scenario applies to the case of Scotland and Northern Ireland, where the areas of Belfast, Edinburgh and Glasgow account for about 1-3% each of the total R&D investment in the nation.

By focussing on the TTWAs in England and Wales, the map reveals that, in addition to being largely clustered, the R&D activity is also quite persistent over time: the same areas that were responsible for the greater proportion of total R&D in the period 2002-2006 were also investing more heavily than other areas in the nation in 2007-2011. The map indeed shows that underneath the large circles the darker colour reveals more intense investments values.

A similar persistence effect is shown also in Scotland and Northern Ireland, where the same areas are involved in both periods. The greater intensity is found around Edinburgh and Glasgow, while a possible increase in intensity for the period 2007-2011 is recorded for the area around Belfast. Finally, the TTWAs centred at Inverness and Aberdeen also appear to be important players in terms of their contribution to R&D.

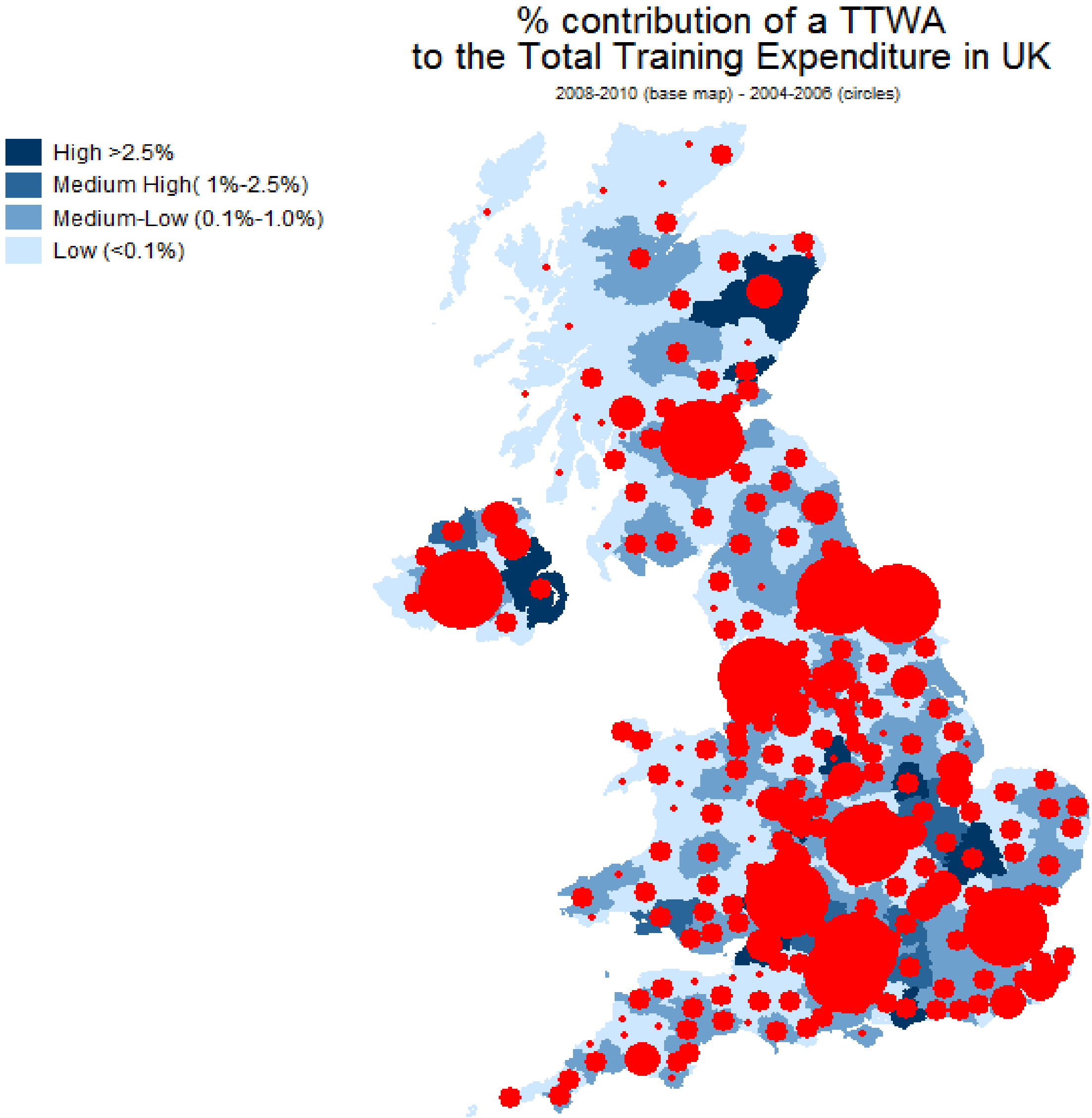
To sum up, the geographical descriptive analysis of R&D investment suggests that 1) R&D activity is largely clustered around large urban areas: whether R&D spillovers actually disseminate over space is suggested by the fact that the areas bordering high-intensity areas also report some noticeable R&D investment; 2) the same areas that were top contributors to the total national activity in R&D in 2002-2006 confirmed their role in the subsequent period. Note that, however, the analysis is carried out in relative terms, and does not take into account possible decreases in R&D investment due, for instance, to the financial crisis.

Geographical Analysis of Training Activities

A similar approach was followed to calculate the propensity of each area towards investment in training for innovation activity. A notable difference, in this case, is that the data was taken from the various waves of the Community Innovation Survey. We divided the data into the same sub-periods: the first includes the data from the CIS4 and CIS5, respectively covering the periods 2002-2004 and 2004-2006, while the second is based on the CIS6 (2006-2008) and CIS7 (2008-2010) datasets.

The geographical analysis of the investment in training activities is organised in the same way and is based on the same indicators as in the case of the R&D investment. It is worth stressing that the training investment reported in the various cohorts of the Community Innovation Survey refers mainly to training outlays that are related to the innovative activity of the interviewed firms. The CIS uses a broad definition for innovation that includes, in addition to process and product innovation, new and significantly improved forms of organisation, business structures or practices aimed at raising internal efficiency or the effectiveness of approaching markets and customers. Therefore, training activity indicates outlays specifically aimed for the development and/or introduction of a broad range of innovations, and is likely to show patterns that differ from those shown by the R&D activity.

Map 2: Comparison of the total training expenditure per TTWA across time



Map 2 covers the entire UK territory; it is immediately apparent that training investment is more widely dispersed across the areas than R&D. The predominant role of the South-East area of the nation, which characterised the R&D in Map 1, is less prominent now. The map reveals that some positive training investment is carried out in most areas, unlike the case of R&D where the majority of areas had a rather negligible contribution. Areas close to or within large urban entities, however, continue to play an important role, although to a lesser extent than the R&D case.

Again, based on map 2, we can infer that training intensity is less persistent over time. Some areas report small circles (i.e., less intensive activity in 2002-2006) but a dark colour for the subsequent period. While this may be partly induced by changes in the way the CIS samples are formed over time, it is also a reflection of the fact that the training activity is more flexible than the R&D activity, since it does not involve large sunk cost investment; that is, training activity is more likely to address short- and medium-term goals that a company pursues.

Measures of Spatial Autocorrelation: the Moran Index

The maps displaying the spatial distributions of R&D and training across TTWAs, seen above, provided a preliminary explorative spatial data analysis for these variables. In the following, we explore the hypotheses of whether these variables show spatial autocorrelation, so that two or more TTWAs that are spatially close tend to have more similar values for these variables than TTWAs that are more distant in space.

To test for the presence of spatial autocorrelation we use the Moran Index, (see Text Box 3) this allows us to discover the possibility of spatial clustering for our variables of interest.

Text Box 3	**The Moran Index**
Agglomeration	Global indices of spatial autocorrelation summarise the spatial correlation for a variable with a single value, hence they are not used for identifying individual spatial clusters, but they are useful in detecting the presence of a general tendency to clustering within the entire set of areas considered. The Moran's I index (Moran, 1948) is often used to test the hypothesis of no clustering for spatially distributed variables. This index, actually measuring spatial autocorrelation, is calculated by taking into account the value assumed by the variable under analysis at different locations, in our case the TTWAs. In particular, let N be the total number of observations, x_i the value that the relevant variable takes at location i, μ its average and let $w_{i,j}$ be elements of a spatial weights matrix. These weights are based on distance decay between the two TTWAs i and j. Then, Moran's index is given by $$I = \left(\frac{N}{S_0} \sum_i \sum_j \frac{w_{i,j}(x_i - \mu)(x_j - \mu)}{\sum_j (x_j - \mu)^2} \right)$$ Where S_0 is a normalising factor $S_0 = \sum_i \sum_j w_{i,j}$
Inference from the Index	The inference, to test the hypothesis of no spatial autocorrelation, is based upon the analysis of the standardised value of Moran's index, z: this is obtained by subtracting its expected value E(i) under the hypothesis of no spatial autocorrelation and dividing the result by the observed standard deviation, sd(I). Moreover, the z test also indicates the sign of the geographical clustering, if any: a positive value for the z statistic suggests positive spatial autocorrelation clustered outcome, while a negative value for the z statistic suggests a dispersed one.

Table 1, below reports the Moran index, for both the R&D and training distributions across Travel to Work Areas over the two time periods 2004-06 and 2008-2010.

Table 1 Indexes of global spatial autocorrelation

Variables	I	E(I)	sd(I)	z	p-value*
TTWA R&D over total 2004-06	0.019	-0.004	0.006	4.194	0
TTWA R&D over total 2008-10	0.027	-0.004	0.006	5.586	0
TWA Training over total 2004-06	-0.002	-0.004	0.006	0.453	0.325
TTWA Training over total 2008-10	-0.007	-0.004	0.006	-0.56	0.288

The values of the Moran index, I, confirm the initial exploratory spatial analysis based on the maps: while we can reject the hypothesis of no clustering for the spatial distribution of R&D across TTWAs, for both periods analysed, the spatial distribution of training does not show clustering.

In the next set of tables we move from the calculation of the global index of agglomeration to a local index of agglomeration expressing, for each TTWA, the degree of similarity between that region and its neighbouring regions. We calculate local spatial autocorrelation, again, with respect to R&D. Below, we report the results for the specific TTWAs that display a significant degree of spatial autocorrelation. The negative values of their localised Moran Index Ii, indicate *outliers* while positive values show the presence of *local clusters*.

Table 2 shows that, for the period 2002-2206, Preston appears to be the only *outlier*, a TTWA with a significantly different (higher) level of R&D compared to its neighbouring TTWAs.

The other locations reported on the table below are instead clusters, with an increasingly significant level of neighbourhood similarity starting from Margate up to London, appearing to be the most important *cluster* for R&D in the country.

Table 2 Local spatial agglomeration index for the contribution of a TTWA's to total R&D for the period 2002-2006

Moran's I_i (2002-2006 TTWA R&D Value) TTWA Name	I	E(I)	sd(I)	z	p-value*
Preston	-0.167	-0.004	0.068	-2.396	0.008
Margate, Ramsgate	0.103	-0.004	0.084	1.273	0.101
Basingstoke	0.088	-0.004	0.066	1.402	0.08
Oxford	0.071	-0.004	0.053	1.422	0.078
Milton Keynes & Aylesbury	0.077	-0.004	0.056	1.441	0.075
Huntingdon	0.08	-0.004	0.057	1.468	0.071
Bedford	0.082	-0.004	0.059	1.472	0.071
Coventry	0.099	-0.004	0.059	1.751	0.04
Salisbury	0.11	-0.004	0.064	1.787	0.037
Bristol	0.11	-0.004	0.062	1.848	0.032
Luton & Watford	0.11	-0.004	0.061	1.863	0.031
Harlow & Bishop's	0.11	-0.004	0.059	1.933	0.027
Southend & Brentwood	0.245	-0.004	0.066	3.788	0
Stevenage	0.324	-0.004	0.062	5.3	0
Wycombe & Slough	0.356	-0.004	0.061	5.886	0
Reading & Bracknell	0.368	-0.004	0.062	5.992	0
Cambridge	0.591	-0.004	0.058	10.313	0
Guildford & Aldershot	1.042	-0.004	0.06	17.471	0
London	1.105	-0.004	0.056	19.782	0

The next table 3 describes the same levels of spatial auto-correlation over the period 2007-2011. Interestingly, we observe a change in the significant *outliers*, but persistence in the top *clusters* still led by Cambridge, Guildford & Alders and London.

Table 3 Local spatial agglomeration index for the contribution of a TTWA's to total R&D for the period 2007-2011

Moran's I_i (2007-2011 TTWA R&D Value) TTWA Name	I	E(I)	sd(I)	z	p-value*
Manchester	-0.24	-0.004	0.064	-3.69	0
Chichester & Bognor	-0.103	-0.004	0.069	-1.434	0.076
Margate, Ramsgate	0.183	-0.004	0.084	2.235	0.013
Monmouth & Cinderford	0.149	-0.004	0.06	2.54	0.006
Luton & Watford	0.153	-0.004	0.061	2.565	0.005
Reading & Bracknell	0.169	-0.004	0.062	2.783	0.003
Bristol	0.203	-0.004	0.062	3.355	0
Warwick & Stratford	0.191	-0.004	0.056	3.465	0
Salisbury	0.221	-0.004	0.064	3.525	0
Portsmouth	0.416	-0.004	0.069	6.117	0
Southend & Brentwood	0.407	-0.004	0.066	6.264	0
Stevenage	0.491	-0.004	0.062	8.018	0
Wycombe & Slough	0.555	-0.004	0.061	9.143	0
Cambridge	0.614	-0.004	0.058	10.709	0
Guildford & Alders	1.358	-0.004	0.06	22.759	0
London	1.361	-0.004	0.056	24.366	0

If we consider the values of local spatial agglomeration for gross added value, as a measure of productivity, we find that in the period 2004-2006 only Cardiff showed a significant and negative spatial autocorrelation in productivity, while in the period covered by the two CIS 2008-2010 only Leeds had negative spatial autocorrelation.

Hence, while R&D showed significant signs of localised autocorrelations this was not, in general mirrored in the spatial distribution of productivity across all 253 UK TTWAs.

6 Innovation and Productivity: the Econometric Model

A Three-stage Approach

This chapter builds on the exploratory analysis performed in the previous chapters to develop an econometric model based on three sequential stages:

- In the first stage we focus on the drivers of innovation, using the evidence on a firm's engagement with the innovation intangible activities to predict innovation efforts.
- The second stage uses the predicted efforts, obtained as the outcome of the first stage, to estimate the probability that a firm introduced any combination of the three possible types of innovations: process, product or organisational innovation.
- Finally, the third stage will use the predicted levels of innovation outcomes, from the second stage, to estimate a firm's productivity. The focus will be on the specific impact that innovation activities have on final productivity, through these three stages.

Crepon, Duguet and Mairesse (1998), following the sequential nature of an innovation supply chain, divided the relation between innovation and final output into three separate processes. The first stage sees a firm facing the binary decision whether to engage in R&D. If the firm decides to invest, then they model the decision on how much to invest in R&D. The resulting resources invested in R&D become then an input for the next stage: estimating the relation between a firm's R&D expenditure, together with other inputs, into knowledge, in a process defined as knowledge production function (Griliches, 1979; Pakes and Griliches 1984).

Hall, Lotti and Mairesse (2012), building on the work of Crepon, Duguet and Mairesse (1998), also followed a multistage estimation approach to address the relevant issue of whether investment in ICT and R&D are complements or substitutes in explaining innovation and productivity. They decomposed the typical aggregate production function into different sequential steps, feeding one into each other, to capture complementarities between existing inputs such as innovation intangibles and ICT. The main benefit of concentrating on this sequential approach is, that it allows a finer understanding of the channels, and interactions, both positive and negative, used by innovative activity to percolate through the production system, and achieving its macroeconomic effect on output and productivity.

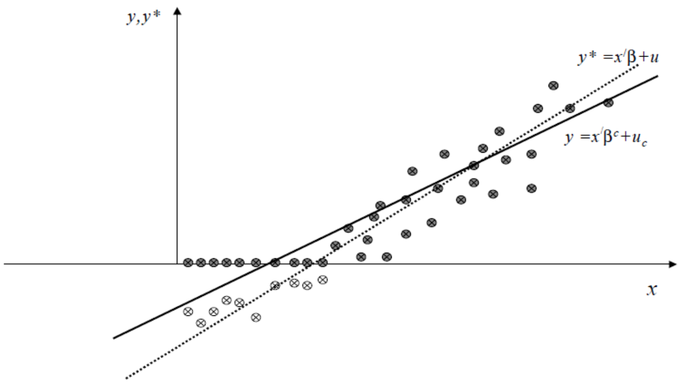
First Stage of Estimation of the Intangibles

As discussed in the previous section we introduce three different stages to estimate the effects of innovative activity on output and productivity. This section focuses on the first stage: understanding the drivers for innovation. This is clearly interesting in itself but it is also an essential step in the following analysis on the effects of innovation on productivity and growth.

Step One, Estimating Innovation Activities

The initial decision concerning the amount of R&D performed by each firm cannot be satisfactorily modelled through a simple regression model. The main problem is given by the censored nature of the observations from the CIS sample as the minimum value of R&D expenditure equals zero. For this reason, we will model this first stage using a Tobit approach (see Text Box 4).

Text Box 4	**Addressing the sample selection bias**
Type of Data: Censored	R&D expenditure is censored at zero, i.e. all firms that do not invest in R&D activities are assumed to have the same value of the dependent variable, equal to zero. To deal with this problem we will use a censored regression model or Tobit model. Consider a latent relationship of the form $$y*_{i1} = x'_i\beta_1 + u_1$$ With $u_i \sim N(0, \sigma 2)$, where the observed dependent variable is linked to the latent, unobserved one, via a function assuming positive values when the latent variable is positive and zero otherwise. $$y_{i1} = 1(y*_{i1} > 0)$$ In this case, it would be inappropriate to estimate this model on the entire sample using the observed information on y, since for censored observations, we cannot consider the censoring rule as a true realisation of the underlying relationship, as depicted in the diagram below.
Problems Arising from Traditional Estimation Techniques	The figure below shows the typical problems that would arise from using a regression approach.The true regression line would be biased because of the censoring of the observations. The Tobit model presents a solution to address these problems for censored data.

Text Box 4	**Addressing the sample selection bias**
	 Source Duncan (2013)

In this first stage of our global estimation strategy, we develop four different Tobit models to predict, separately the value of four intangibles linked to a firm innovative activity. These are: 1) Internal R&D, 2) External R&D, 3) Training expenses, and 4) Advertising.

Internal R&D Intensity

Below we report our results from the Tobit model with the dependent variable internal R&D expenditure over turnover. We are looking at the determinants of this variable at firm level as an intermediate step for our productivity estimation strategy. We consider the model over the four community innovation surveys: reported in the regression tables from columns (1) to (4) and, in column (5), we report the estimates for the pooled regressions over all the periods. For ease of readability, we decompose the regression tables into sub-tables with the relevant variables discussed separately. For some of the estimates discussed in the main text, the tables of which are not included in the chapter, the reader should refer to the full set of estimates in the Appendix.

We first considered the role played by the market for output of on a firm's internal R&D expenditure. We found that exporting on the international markets has the strongest significant and positive association with internal R&D. Employment, estimated in logs, instead has a significant negative impact on internal R&D expenditure while the firm's age does not seem to exert interesting results on this dependent variable.

The next set of covariates focuses on the motivation for performing R&D. We report these estimates, in Table 1 below, as they reflect the crucial link between intangibles and incentives, which is of great interest for a deeper understanding of the drivers for innovative activities.

The values reported below show that the dependent variable – internal R&D expenditure intensity – is positively and significantly associated with the incentives to have better products, to improve profits and to expansion.

Table 4: Motivation for innovating and internal R&D

Dependent Variable: internal R&D / over Turnover Tobit Model I	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Independent Variables					
Motive: Better products	1.240***	0.531	-0.682	2.687**	0.578**
	(3.35)	(0.70)	(-1.01)	(2.20)	(2.07)
Motive: Better production	-0.0524	-0.379	0.664	-1.461	-0.0298
	(-0.18)	(-0.83)	(0.83)	(-1.52)	(-0.14)
Motive: Improve Profit	1.429***	0.713	0.543	-0.351	1.052***
	(3.86)	(1.21)	(0.53)	(-0.28)	(2.98)
Motive: Meet Regulation	-0.281	0.747	0.0986	4.312***	-0.0504
	(-1.09)	(1.48)	(0.23)	(3.12)	(-0.22)
Motive: Expansion	0.857***	0.834*	1.667***	-0.735	0.836***
	(4.32)	(1.75)	(3.41)	(-0.93)	(4.78)

* p<0.1 ** p<0.05 *** p<0.01

The next set of independent variables focuses on the identification of the sources of cooperation relevant for the innovative activity. In particular, we focus on the answers to the question whether a business co-operated for innovation activities with any of the relevant private and public actors forming a firm's innovation environment. Our results show that:

- Cooperation within the same enterprise group (variable Coop – Group) has a significant and positive association with internal R&D intensity that can be interpreted as an indication of the presence of group level internalised positive externalities.
- Cooperation with "Suppliers of equipment, materials, services or software" (variable Coop – Suppliers) is even more significant and positive for internal R&D indicating the presence of positive externalities along the innovation vertical supply chain.
- Cooperation with "Clients, customers or end users" (variable Coop – Customers) also exerts a positive externality on internal R&D intensity, with increased significance in the last two surveys (2008 and 2010), and is globally significant at pooled level. This indicates an innovation value chain that receives reinforced positive feedbacks both from the downstream customers and the upstream suppliers.
- Cooperation with "Consultants, commercial labs, or private R&D institutes" (variable Coop – Consultants) captures the role of complementary private actors in the

collaboration on innovative activities. Our results show a significant, clear and positive association between this variable and internal R&D intensity. It is important to note, however, that this type of relationship, is more likely to be a price-mediated form of collaboration rather than an externality.

- The last positive association we found was in cooperation with "Universities or other higher education institutions" (variable Coop – Universities).
- An opposite effect is derived from the cooperation with "Competitors or other businesses in your industry" (variable Coop - Other firms) as its association with internal R&D intensity is significant and negative.
- Cooperation with "Government or public research institutes" (variable Coop – Government) does not show any significant association with internal R&D intensity.

Table 5: Cooperation and internal R&D

Dependent Variable: Internal R&D / over Turnover Tobit Model I	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Independent Variables					
Coop - Group	-0.0480	0.603*	0.202	0.709*	0.381**
	(-0.15)	(1.68)	(0.66)	(1.74)	(2.08)
Coop - Suppliers	0.928**	-0.0183	0.507**	0.308	0.476***
	(2.46)	(-0.06)	(2.18)	(0.97)	(2.85)
Coop - Customers	0.227	0.581	0.611**	0.613**	0.556***
	(0.52)	(1.55)	(2.26)	(2.38)	(3.44)
Coop - Other firms	-1.047*	-0.574*	-1.050***	-0.285	-0.854***
	(-1.89)	(-1.69)	(-2.82)	(-0.66)	(-3.09)
Coop - Consultants	0.614*	0.712*	0.880***	0.881	0.756***
	(1.89)	(1.79)	(2.70)	(1.64)	(3.54)
Coop - Universities	1.653***	0.728*	0.557	1.126**	1.151***
	(2.75)	(1.78)	(1.13)	(2.49)	(3.69)
Coop - Government	0.622	-0.0946	-0.633	-0.138	-0.156
	(1.28)	(-0.23)	(-1.51)	(-0.23)	(-0.56)

* p<0.1 ** p<0.05 *** p<0.01

Geographic spillovers in R&D and training were used to capture the presence of *Marshallian externalities* related to the spread of generic ideas and productive knowledge due to geographic proximity. We considered geographic externalities in the first stage of our three stage estimation procedure, while we will focus on the different sector spillovers, capturing the *Jacobian externalities*, in the second stage when studying the specific contribution of productive knowledge on innovation and productivity[5]. Our estimates show that neither geographic spillovers of R&D nor training have a significant association with the dependent variable internal R&D intensity.

We also considered the covariate “Subsidies over turnover” to capture the intensity of subsidies received, but we did not find any significant association with the internal R&D intensity. Similarly we considered also covariates with dummies for the macro-sector ad for the regions. While some of these have significant sign, they were mainly introduced as control variables.

External R&D Intensity

Next, we consider the second intangible dependent variable: external R&D expenditure over turnover. Concerning the role-played by the market for output of the firms on this variable, we found that the strongest and most significant positive association is with the participation on the international output markets. The impact of employment, estimated in logs, has again constantly a significant negative association with the external R&D intensity as it was for the internal one. Hence, total R&D expenditure per pound of turnover, is higher for firms with fewer employees. The firm’s age, again, does not seem to exert interesting results on external R&D expenditure intensity. External R&D intensity is positively and significantly associated with the incentives to improve profits. The incentive for better production only appears to be significant in the 2010 CIS and the motive to improve products in the 2004 CIS.

[5] In the second stage we will consider the sector spillovers whereby the notion of proximity is interpreted in terms of intensity of trade relations between two sectors, as derived from the Input-Output tables.

Table 6: Motivation and external R&D

Dependent Variable: External R&D / over Turnover Tobit Model II	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Independent Variables					
Motive: Better products	0.720**	0.986	-1.409	-0.602	0.356
	(2.01)	(1.64)	(-1.04)	(-0.58)	(1.25)
Motive: Better production	0.112	-0.147	-0.216	2.466**	0.0218
	(0.38)	(-0.37)	(-0.47)	(2.08)	(0.10)
Motive: Improve Profit	0.915**	0.278	2.042*	0.442	0.790**
	(2.26)	(0.52)	(1.82)	(0.39)	(2.25)
Motive: Meet Regulation	-0.0762	0.767*	-0.654	-0.713	-0.0887
	(-0.34)	(1.90)	(-1.53)	(-0.64)	(-0.51)
Motive: Expansion	0.0600	-0.288	1.107	0.683	0.114
	(0.25)	(-0.53)	(1.45)	(0.78)	(0.51)

* p<0.1 ** p<0.05 *** p<0.01

Moving to the sources of cooperation relevant for the innovative activity we found that cooperation within the same enterprise group shows a significant and positive association with external R&D intensity. The interpretation of this sign indicates that, cooperating within the enterprise group is linked with increased expenditure on external R&D intensity expressing a form of positive complementarity between internal cooperation and the purchasing of external R&D. Even more significant and also positive is the association between external R&D intensity and the cooperation with the suppliers. This is indicating the presence of positive network externalities along the innovation chain, as more cooperation with suppliers is associated with higher levels of external R&D intensity that might be purchased from other suppliers, or from other sources, highlighting the network nature of potential positive associations along the innovations chain. Cooperation with customers does not show any significant association with external R&D intensity. This result is interesting as it indicates that external R&D might be more supplier-driven while internal R&D was found to be also customer-driven.

Our results also show a significant, clear and positive association between cooperation with consultants, commercial labs, or private R&D institutes and external R&D intensity, as it was positively associated with internal R&D. A significant and positive association between cooperation with universities and external R&D intensity is also captured by the estimates. These results, considered together with the positive association with internal R&D shows a clear association between university cooperation and total R&D intensity

The association between cooperation with actual or potential competitors and external R&D intensity is significant and negative. This result, considered together with the negative association found before with internal R&D, tends to show that collaboration with competitors takes place among firms characterised by a lower level of total R&D intensity.

Geographic spillovers of R&D expenditure and training activities did not show any significant association with the external R&D intensity of a firm, apart from a negative relation only in the 2010 CIS for the training expenditure spillovers that however, does not remain significant in the pooled results.

Finally, our estimates do not show a significant association between Government/public research institutes and external R&D intensity. Hence, given the similar results found on the association of this covariate with internal R&D, we can say that cooperation with public institutions is not associated with total R&D intensity. Moreover, we found that subsidies have a significant negative association with external R&D intensity, but only in the pooled model.

Table 7: Cooperation and external R&D

Dependent Variable: External R&D / over Turnover Tobit Model II	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Independent Variables					
Coop - Group	0.330	0.166	0.594**	0.0870	0.373**
	(1.12)	(0.55)	(2.53)	(0.39)	(2.43)
Coop - Suppliers	0.648***	0.308	0.443**	0.625***	0.533***
	(2.61)	(0.78)	(2.28)	(2.67)	(3.70)
Coop - Customers	0.121	-0.0160	0.00116	-0.0541	-0.00339
	(0.51)	(-0.03)	(0.00)	(-0.36)	(-0.02)
Coop - Other firms	-0.796	0.0670	-0.538**	-0.372	-0.435**
	(-1.54)	(0.18)	(-2.15)	(-1.38)	(-2.05)
Coop - Consultants	1.319***	0.879**	1.091***	0.897***	1.063***
	(4.17)	(2.25)	(4.78)	(3.32)	(7.32)
Coop - Universities	1.204***	0.364	0.00606	0.395*	0.630***
	(3.16)	(0.99)	(0.03)	(1.70)	(3.96)
Coop - Government	-0.113	0.695	-0.150	0.318	0.0872
	(-0.29)	(1.64)	(-0.58)	(1.39)	(0.39)
Subsidies over turnover	-0.0703	-0.0552	-0.0198	-0.0575	-0.0650**
	(-0.78)	(-0.85)	(-0.86)	(-0.78)	(-2.04)

* p<0.1 ** p<0.05 *** p<0.01

Training Expenditure

Next, we consider as dependent variable the third intangible: training expenditure normalised over turnover.

Concerning the role-played by the market for output on the dependent variable, we found that the strongest and most significant positive association is provided by the participation in the regional and national output markets. This results is particularly interesting if compared with the results, seen above, for R&D expenditure, as it indicates that training and total R&D expenditures are associated with different typology of firms depending on their main output markets, so that training seems to be related to local/national oriented firms, while R&D expenditure to international ones.

Employment, estimated in logs, has, again, a significant negative association with training intensity. The firm's age, as for the previous intangibles, does not seem to exert interesting results on training intensity.

Training intensity is positively and significantly associated with the incentives to have better products, apart from a negative association observed in the CIS 2008, it is also positively associated with the incentive to improve profits and with the motivation of improving production. Finally, the motive to meet regulation appears as positively and significantly associated with the training expenditure.

Table 8: Motivation and training

Dependent Variable: Training expenditure / over Turnover Tobit Model III Independent Variables	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Motive: Better products	0.447***	0.0694	-0.392**	0.973***	0.259***
	(3.81)	(0.44)	(-1.97)	(3.36)	(3.02)
Motive: Better production	0.195**	0.106	0.210	0.129	0.181***
	(2.16)	(0.83)	(1.55)	(0.37)	(2.66)
Motive: Improve Profit	0.319***	0.242	0.319	0.614	0.249***
	(3.35)	(1.24)	(1.46)	(0.72)	(3.18)
Motive: Meet Regulation	0.203**	0.162	0.0880	-0.800	0.122**
	(2.47)	(1.28)	(0.78)	(-0.73)	(2.22)
Motive: Expansion	0.0463	0.185	0.115	-0.0907	-0.0200
	(0.67)	(1.42)	(1.17)	(-0.27)	(-0.32)

* p<0.1 ** p<0.05 *** p<0.01

Considering the role-played by geographic spillovers, our estimates show that R&D expenditure spillovers are significantly and negatively associated with the training intensity of a firm but only in the pooled model. Spillovers from training expenditure of other firms, again weighted inversely to the geographic distance between originating and receiving firms, are positively associated with the dependent variable indicating the presence of a pure positive spatial spillover effect.

Table 9: Geographic Spillovers and Training

Dependent Variable: Training expenditure / over Turnover Tobit Model III Independent Variables	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
R&D Geog. Spillover	0.0170	-0.00784	-0.0239	0.0315	-0.0506***
	(0.60)	(-0.24)	(-1.05)	(1.22)	(-3.24)
Training Geog. Spillover	-0.0199	-0.0187	0.00255	-0.0477*	0.0472***
	(-0.68)	(-0.41)	(0.11)	(-1.75)	(2.89)

* p<0.1 ** p<0.05 *** p<0.01

Next, we consider the association between the different sources of cooperation and a firm's training intensity. Cooperation with suppliers of equipment, materials, services or software shows a significant and positive association with a firm's training intensity. This relation could provide a possible interpretation for training expenses as enabling cooperation with the upstream suppliers of a firm. Also cooperation with consultants, commercial labs, or private R&D institutes shows a significant and positive association with a firm's training intensity, but only in the pooled model. None of the other cooperation shows a significant association with a firm's training intensity.

Table 10: Cooperation and training

Dependent Variable: Training expenditure / over Turnover Tobit Model III	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Independent Variables					
Coop - Group	-0.101	0.116	-0.00710	0.0870	-0.00666
	(-0.93)	(1.22)	(-0.12)	(1.61)	(-0.12)
Coop - Suppliers	0.356***	0.0707	0.183***	0.145*	0.178***
	(3.27)	(0.52)	(2.74)	(1.90)	(3.34)
Coop - Customers	0.0535	0.0379	0.105	0.117*	-0.0208
	(0.64)	(0.34)	(1.58)	(1.71)	(-0.41)
Coop - Other firms	0.109	0.163	-0.0902	0.138	0.115*
	(0.93)	(1.43)	(-1.29)	(1.35)	(1.78)
Coop - Consultants	0.0780	0.154	0.111	0.161	0.105*
	(0.60)	(1.16)	(1.38)	(1.22)	(1.70)
Coop - Universities	0.0401	0.0562	0.0587	0.0220	0.109
	(0.39)	(0.32)	(0.65)	(0.24)	(1.63)
Coop - Government	0.0480	-0.0792	0.00886	0.113	0.0465
	(0.34)	(-0.47)	(0.08)	(0.87)	(0.59)
Subsidies over turnover	-0.0361**	-0.00161	0.00690	0.0129	-0.00275
	(-2.42)	(-0.18)	(1.32)	(1.05)	(-0.35)

* p<0.1 ** p<0.05 *** p<0.01

Advertising Expenditure

Finally, we consider as dependent variable the fourth and last intangible: a firm's advertising expenditure normalised over turnover.

Concerning the role played by the market for output on a firm's advertising expenditure, our estimates show that a focus on regional markets has a negative association with advertising intensity, while participation in national and international markets has a positive association with it. Clearly, these associations could go in different ways, as participation in international markets might well require a higher advertising intensity.

The impact of employment, estimated in logs, has a predominately positive association with this intangible. This association is noticeably different from the negative one that employment had with the other intangibles. The firm's age, as for the previous intangibles, does not seem to exert interesting results on internal advertising intensity.

Advertising intensity is positively and significantly associated with the incentives for expansion and improved profits. These associations confirm the intuition that advertising is a necessary investment required to reach new markets.

Regulation has a negative relation with advertising. As one would expect, the targets of advertising are not the regulators but the final consumers.

Table 11: Motivation and Advertising

Dependent Variable: Advertising expenditure / over Turnover Tobit Model IV	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Independent Variables					
Motive: Better products	-0.186*	0.182	0.155	-0.239	-0.108
	(-1.82)	(0.69)	(0.45)	(-0.84)	(-1.12)
Motive: Better production	0.00401	-0.220	0.212	-0.308	-0.00488
	(0.04)	(-1.44)	(1.17)	(-0.48)	(-0.05)
Motive: Improve Profit	0.273**	-0.356	0.0239	0.474	0.221**
	(2.22)	(-1.62)	(0.13)	(0.95)	(2.25)
Motive: Meet Regulation	-0.187**	0.0909	-0.121	0.0162	-0.176**
	(-2.23)	(0.69)	(-0.92)	(0.04)	(-2.15)
Motive: Expansion	0.255***	0.433**	0.0808	0.225	0.280***
	(2.89)	(2.57)	(0.33)	(0.60)	(3.73)

* p<0.1 ** p<0.05 *** p<0.01

Our estimates also show that geographic R&D and training spillovers play almost no role in relation with advertising.

We finally consider the possible associations between different sources of cooperation and a firm's advertising intensity. Cooperation with suppliers of equipment, materials, services or software shows a positive association with a firm's advertising intensity only in the CIS (2010). The cooperation with competitors only shows a positive and significant association win the pooled model. Cooperation with consultants, commercial labs, or private R&D institutes shows a significant and positive association between these actors and advertising intensity. Cooperation with universities only showed a negative and significant association with advertising intensity in the CIS (2008) while the association with government or public agencies is negative and significant, but only for the pooled model.

Finally, subsidies have a significant positive association with advertising intensity, but only in the first CIS (2004).

Table 12: Cooperation and advertising

Dependent Variable: Advertising expenditure / over Turnover Tobit Model IV	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Independent Variables					
Coop – Group	-0.148	0.0149	0.132	-0.688	-0.165
	(-0.83)	(0.10)	(0.88)	(-1.38)	(-1.25)
Coop - Suppliers	0.112	0.234	-0.220	0.244*	0.0828
	(0.76)	(1.36)	(-1.27)	(1.82)	(1.02)
Coop - Customers	-0.270	-0.260	-0.173	0.391	-0.108
	(-1.64)	(-1.54)	(-0.72)	(0.66)	(-0.66)
Coop - Other firms	0.241	0.00253	0.0454	0.487	0.192**
	(1.34)	(0.01)	(0.26)	(1.63)	(1.98)
Coop - Consultants	0.256	0.120	0.345*	0.117	0.254**
	(1.30)	(0.47)	(1.75)	(0.68)	(2.22)
Coop - Universities	-0.00413	0.163	-0.340**	-0.170	-0.129
	(-0.02)	(0.82)	(-2.51)	(-0.86)	(-1.16)
Coop - Government	-0.148	-0.322	-0.0346	-0.405	-0.214**
	(-0.69)	(-1.46)	(-0.19)	(-1.55)	(-2.01)
Subsidies over turnover	0.0512***	0.00829	-0.00296	0.00719	0.0155
	(2.75)	(0.78)	(-0.26)	(0.69)	(1.34)

* p<0.1   ** p<0.05   *** p<0.01

Step Two: From Innovation Activities to Innovation Outputs

In the second step of our estimation strategy, we focus on the relation between innovation intangibles, as estimated in the first stage, and innovation outcomes. The work we are developing at this stage is in line with the tradition of estimating an innovation production function. In this process we explore the effects that sector spillovers in R&D and training activities have on the probabilities of introducing innovations.

Categorising the Innovation Outcome

In this second stage, we decompose the outcomes of the knowledge production function into three, not mutually exclusive, types of innovations: product, process and organisational innovations. This is an essential step as the innovation questionnaires allow the respondents to choose any combination of answers about the types of innovation introduced.

Our focus is on the effects of the intangible innovation activities, the determinants of which have been estimated in the first stage of our econometric model. In particular, we consider the predicted values of R&D, training and advertising intensities as the relevant inputs for this innovation function.

$$Innovation\ output = y_{i,j} \in \{0,1\}\ and\ j = \{New\ Product; New\ Process, Organizational\ Inovation\}\ and$$

$$y_{i,j} = \beta_1 RX^* + \beta_2 TX^* + \beta_3 AX^* + \beta' X + u_{i,j}$$

Where the latent variables for the R&D, Training and Advertising efforts: RX^*, TX^*, AX^*, are proxied by the predicted values calculated in the Tobit regression estimates obtained in the first stage. By using these predicted values we followed the work by Hall, Lotti and Mairesse (2012). Their justification of this multistep approach was based on the idea that estimated values will reduce problems due to simultaneity and also will take into account innovative efforts from the firms who did not declare innovation activities in the survey.

Text Box 5	Multivariate Probit model
Structure	As commonly done in the multivariate discrete choice model, we assume that these discrete choices are expression of an underlying system of latent propensities: $$y*_{i0} = x'_i\beta_0 + u_{i0}$$ $$y*_{i1} = x'_i\beta_1 + u_1$$ $$y*_{i2} = x'_i\beta_2 + u_{i2}$$ We also assume that we are only able to observe an indicator function taking a value one when the latent variable is greater than zero, and zero otherwise. $$y_{i0} = 1(y*_{i0} > 0)$$ $$y_{i1} = 1(y*_{i1} > 0)$$ $$y_{i2} = 1(y*_{i2} > 0)$$ Also, we allow for these three decisions, whether or not to introduce, any combination of these three forms of innovation, to be correlated so that we assume that the random error terms: u_{i0}, u_{i1}, u_{i2} are jointly trivariate normal with a symmetric Variance-Covariance matrix given by: $$\Sigma = \begin{bmatrix} 1 & \rho_{01} & \rho_{02} \\ & 1 & \rho_{12} \\ & & 1 \end{bmatrix}$$
Probabilities	Thus, the joint probability of a triplet of firm's choices: {*Y_i* = *y_i*, *i* = 1, 2, 3} is conditioned on the coefficients β , the covariances Σ and the set of explanatory variables, X. The estimation of the probabilities of introducing process, product and organisational innovations is a joint estimation that exploits the correlations between these binary variables. $$Pr[Y_i = y_i, i = 0,1,2/\beta, \Sigma] = \iiint_{A0,A1,A2} \phi(z_0, z_1, z_2, \rho_{01}, \rho_{02,}\rho_{12})\, dz_0 dz_1 dz_{12}$$ where ϕ is the density function of a multivariate normal distribution with mean (0,0,0) and variance-covariance matrix Σ and A_i for *i=0,1,2*, is the interval: $(-\infty, \beta'_i X'_i)$ if $y_i = 1$ and $(\beta'_i X'_i, \infty)$ if $y_i = 0$ The parameters and the correlations terms are estimated with the mvprobit command from Stata.

Second Stage Results

A discussed in the introduction of this section, our dependent variable in this second stage has three possible, non- exclusive discrete outcomes, the introduction of:

- a process innovation, $y_{i,0}$,
- a product innovation, $y_{i,1}$,and
- an organisational innovation, $y_{i,2}$.

Below, we discuss the estimates of this second stage by looking at the most significant associations based on the pooled observations across the different innovation surveys. Our estimates report the results of two models: both using as independent variables the predicted levels of training, advertising and R&D intensities (this last variable obtained by merging predicted internal and external R&D intensities) resulting from the first stage of the estimation and further considering, in one of these models, a covariate for sectorial training spillovers and in the other model one capturing sectorial R&D spillovers.

The first clear result emerging from our estimates is about the role played by the predicted total R&D expenditure intensity. This variable shows a positive and significant association with the probability of introducing all three forms of innovations. This finding confirms the expectation that the sum of the predicted internal and external R&D intensities, as estimated from the intangible innovation activities in the first stage of our model, increases the probability of a firm introducing any one of the three types of innovations.

Moreover, by comparing the effect of this intangible with those of the other predicted ones we can see that predicted R&D is more significant towards the introduction of product and process innovations, while predicted training is more significant for the introduction of organisational innovations. Predicted advertising expenditure has mainly significant negative associations, both with process and product innovations.

The role of subsidies is positive, for both process and product innovations, but this policy instrument loses its statistical significance in relation to organisational innovations. The positive and significant role played by the (Log of) employment shows that a firm's size is positively related to the probability of introducing all different types of innovations. These findings are interesting when read in conjunction with the estimates obtained in the first stage, as we saw that employment had a negative relation with them.

Moving to the role of sectorial spillovers, our estimates show that the total amount of R&D expenditure, performed by other firms in the economy produces significant positive spillover effects on the probability that a firm introduces a process innovation. These spillovers were weighted according to the *proximity in production* of the different economic sectors, measured through their input-output relations and capturing the circulation of *production-specific* knowledge along the value chains, based on the trade relations each sector has with the others. The highest weight is therefore given to the R&D performed by firms belonging to the same sector while weights were progressively reduced for R&D

performed in sectors with less intense trade exchanges with the sector of the innovating firm.

It is important to recall that at this second stage of the estimation procedure we do not consider the geographic spillovers, the impact of which was instead included in the first stage when estimating the predicted intangibles.

Training expenditure performed in the economy, again weighted in relation to input/output trade intensities with the sector a firm belongs to, also generates positive sectorial spillovers that are positively associated with the introduction of process innovations, but these appear to be less significant than the spillovers associated with R&D expenses.

Table 13: Intangibles, sector spillovers and the introduction of product and organisational innovations

Second Stage Pooled estimation CIS (2004-2010) Predicted Innovation Outcomes	Process innovation Model with Training Spillovers	Process innovation Model with R&D Spillovers	Product innovation Model with Training Spillovers	Product innovation Model with R&D Spillovers	Organizational ınovation lodel with raining pillovers	Organizational innovation Model with R&D Spillovers
Predicted Total R&D expenditure /Sales	0.0421***	0.0377***	0.0757***	0.0735***	0.0133*	0.0124*
	(-3.08)	(-2.95)	(-6.01)	(-6.09)	(-1.85)	(-1.75)
Predicted Training expenditure /Sales	0.110*	0.117**	0.147**	0.102	0.249***	0.223***
	(-1.72)	(-1.98)	(-2.31)	(-1.63)	(-5.17)	(-4.63)
Predicted advertising expenditure /Sales	-0.0783**	-0.059	-0.0625*	-0.0411	0.0164	0.0273
	(-2.02)	(-1.53)	(-1.77)	(-1.17)	(-0.54)	(-0.89)
Subsidies over turnover	0.0177*	0.0209**	0.0287***	0.0320***	0.00187	0.00137
	(-1.91)	(-2.19)	(-4.52)	(-4.93)	(-0.24)	(-0.16)
Log Total Employment	0.160***	0.154***	0.151***	0.137***	0.227***	0.216***
	(-7.62)	(-7.63)	(-8.05)	(-7.36)	(-16.33)	(-15.48)
R&D Sector Spillover		0.0187***		0.00673		0.00749*
		(-3.32)		(-1.34)		(-1.65)
Training Sector Spillover	0.0151**		-0.00234		0.00596	
	(-2.11)		(-0.36)		(-1.01)	

* p<0.1 ** p<0.05 *** p<0.01

Moving to the motivations for introducing innovations, our estimates show that these are among the most relevant drivers in predicting the introduction of different types of innovations.

Our estimates show that the incentives to improve products and to increase profits both provide a significant and positive contribution to the introduction of both process and product innovations, while the motivation to improve the production process is a significant predictor for process and organisational innovations.

The regulatory environment also has a significant impact on innovations, our estimates show very clearly, that the motive to meet regulatory requirements reduces both process and product innovations while increasing organisational ones. This factor captures some aspects of the potentially reactive nature of organisational innovations, whose probability of being introduced seems to be closely linked to the need of meeting regulatory requirements. These innovations however, also have a significant relation with the expansion motivations of a firm. This should not be surprising as expansion often necessitates introducing organisational changes in the structure of a firm. To expand, firms also introduce product innovation as these are often pivotal in penetrating into a new market.

Table 14: Motivation and the introduction of product and organisational innovations

Second Stage Pooled estimation CIS (2004-2010) Predicted Innovation Outcomes	Process innovation Model with Training Spillovers	Process innovation Model with R&D Spillovers	Product innovation Model with Training Spillovers	Product innovation Model with R&D Spillovers	Organizational innovation Model with Training Spillovers	Organizational innovation Model with R&D Spillovers
Motive: Better products	0.513***	0.530***	0.680***	0.698***	-0.149*	-0.133
	-4.27	-4.43	-8.3	-8.58	(-1.72)	(-1.55)
Motive: Better production	0.676***	0.671***	0.0194	0.0182	0.200***	0.208***
	-7.22	-7.17	-0.27	-0.26	-2.7	-2.8
Motive: Improve Profit	0.305***	0.297**	0.302***	0.309***	0.0611	0.058
	-2.6	-2.55	-3.37	-3.51	-0.67	-0.64
Motive: Meet Regulation	-0.330***	-0.320***	-0.365***	-0.356***	0.230***	0.233***
	(-4.54)	(-4.44)	(-5.38)	(-5.39)	-3.84	-3.92
Motive: Expansion	0.0346	0.0354	0.377***	0.379***	0.284***	0.281***
	-0.48	-0.49	-5.56	-5.66	-4.65	-4.63

* p<0.1 ** p<0.05 *** p<0.01

The last set of relevant covariates relates to the role the partners with whom a firm cooperates in introducing innovations.

Our estimates show that, in the pooled data, cooperation with both customers and suppliers is significant in its positive relation with the introduction of all types of innovations. This implies that all these three different types of innovation are not just the results of the individual intangible efforts of individual firms, but they are an essential component of an integrated value chain whereby cooperation with customers and suppliers plays a significant and positive role. Internal cooperation within the firm's group plays instead a marginal role and mainly for the introduction of organisational innovations, for which a positive and significant role is also played by cooperation with consultants.

Table 15: Cooperation and the introduction of product and organisational innovations

Second Stage Pooled estimation CIS (2004-2010) Predicted Innovation Outcomes	Process innovation Model with Training Spillovers	Process innovation Model with R&D Spillovers	Product innovation Model with Training Spillovers	Product innovation Model with R&D Spillovers	Organizational innovation Model with Training Spillovers	Organizational innovation Model with R&D Spillovers
Coop - Group	0.113*	0.119*	0.0896	0.0927	0.233***	0.234***
	-1.71	-1.84	-1.31	-1.39	-3.42	-3.45
Coop - Suppliers	0.290***	0.289***	0.241***	0.246***	0.134**	0.141**
	-4.32	-4.36	-3.62	-3.75	-2.01	-2.13
Coop - Customers	0.159**	0.160**	0.272***	0.291***	0.244***	0.243***
	-2.44	-2.51	-4.29	-4.71	-3.87	-3.87
Coop - Other firms	0.0316	0.00571	0.0377	0.0345	-0.063	-0.0408
	-0.38	-0.07	-0.47	-0.43	(-0.78)	(-0.50)
Coop - Consultants	-0.0183	-0.0157	-0.0401	-0.0301	0.204**	0.192**
	(-0.23)	(-0.20)	(-0.50)	(-0.38)	-2.53	-2.4
Coop - Universities	0.0491	0.0574	-0.126	-0.124	-0.0123	-0.00423
	-0.51	-0.6	(-1.34)	(-1.33)	(-0.13)	(-0.05)
Coop - Government	-0.0883	-0.0721	-0.147	-0.131	-0.0664	-0.0656
	(-0.86)	(-0.72)	(-1.48)	(-1.32)	(-0.68)	(-0.67)

* p<0.1 ** p<0.05 *** p<0.01

Third Stage Productivity Analysis

Based on the predicted values from the second stage we are now able to address the main research question of assessing the significance of the relation between innovative activities and productivity. More specifically, we consider two accounting measures of productivity: gross value added (GVA), obtained as the difference between total revenues and the cost of materials and labour, and the gross profit margin (GPM), which is equal to the GVA minus capital expenditures. In the remainder of this report, both GVA and GPM refer to the annual values of these variables normalised by the firm's total turnover. Both measures identify a proxy for a firm's profitability and are often used in productivity analysis, as shown in the list of studies surveyed in Medda and Piga (2014).

The third stage of our econometric model builds on the approach pioneered in Crepon, Duguet and Mairesse (1998) where productivity is assumed to depend on the innovation activity which is the focus of the second stage. That is, the first set of regressors consists of the predicted probability that a firm engages in any of the three forms of innovation estimated in the second stage: *process, product and organisational*. Using the predicted probability, as opposed to the actual values of the three innovation variables, is a sensible way to purge the analysis of the simultaneity effects linking innovation and productivity. In this sense, the variables included in the second stage, but excluded from the third, operate as instruments for the (possibly endogenous) innovation variables in the productivity equation. As controls, each model includes the firm size, expressed as the log of the number of employees, and the firm age (also squared to capture possible non-linear effects).

Some specifications of the productivity equation expand the analysis to consider other possible effects of the intangible assets studied in the first stage on productivity. Our estimation strategy evaluates separately the impact of each set of regressors added to the productivity equation to avoid multi-collinearity.

Given the panel structure that the various cohorts of the Community Innovation Survey allow, we estimate the productivity equation using the observations from the CIS for which we could match annual balance sheet data from the Annual Respondents Database. The full sample includes 23,845 observations, which amounts to about 40% of the total observations in the four waves of the CIS that we have considered in the analysis.

Finally, each equation was estimated using two different panel estimation techniques: Fixed Effects (FE) and Random Effects (RE), which provide different angles from which we can look at the resulting evidence. First, the FE estimator concentrates on differences that, over time, characterise a single firm. This is why the FE estimator is also referred to as the 'within' estimator. That is, it explains to what extent a given firm's change in a variable of interest affects its own productivity. Thus, the FE estimator does not account for possible differences that exist across firms at a given point in time and thus does not identify the factors capturing why, for instance, the productivity of firm *i* is different from that of firm *j.* This is not the case of the RE estimator, whose estimates are obtained by weighing the 'within' effect with the 'between' effect, which allows us to identify the factors that explain the differences between the firms in the panel.

Thus, at a first glance, looking at the RE estimates should provide a more exhaustive scenario of the drivers of productivity in our sample. However, the possibility of a simultaneity bias induced by unobservable factors often suggests that the FE estimates may be preferred. To understand why, consider the following example. Assume that firm *i* can rely on superior managerial ability than firm *j* throughout the panel temporal period. Further assume that managerial ability is positively correlated with higher investment in R&D, and thus with higher innovation outcomes. Loosely speaking, the FE estimator treats the managerial ability as a given and can directly identify the impact of variation in R&D and innovation on productivity. On the contrary, the RE estimator cannot control for differences in unobserved characteristics between firms: the coefficients for the R&D investment and for innovation are biased because they include the effect that the unobserved managerial ability has on productivity. A poorly managed firm is likely to be less productive even if it innovates and/or invests in R&D. In particular, in similar situations simultaneity implies that the poor performance may induce a firm, even if poorly managed, to invest in R&D and training and to try to innovate with its organisation, its processes and products. With this in mind, the following sub-section reports the estimates from the FE estimators.

Estimating the Impact of Innovation on Productivity

In this section, the dependent variable is a direct accounting annual measure of productivity, either the Gross Value Added (GVA) or the Gross Profit Margin (GPM). Both measures are normalised, divided by a firm's turnover and then multiplying this proportion by 100. Thus, the estimates reported in all the tables can be interpreted as the percentage change in the dependent variable induced by a unit change (percentage change if the variable is expressed in log) in the regressor of interest.

The table below reports twelve different estimates, a set of six each for GVA and GPM as dependent variables. In the first three model specifications, for each dependent variable, GVA and GPM, we include a covariate representing the geometric average of the intangibles, while the last three do not include it. Otherwise each one of three specifications with intangibles covariate contains only one of the three main independent variables, the predicted probabilities of each of the three possible types of innovation. These are treated separately to avoid multi-collinearity due to their high correlations. Similarly, there will be three different specifications per dependent variables each containing one of the predicted values of the probability of introducing an innovation: process, product or organisational, without considering the intangibles covariate.

Our results show that the predicted probability of introducing a process innovation has a relevant and positive impact on both measures of productivity, GVA and GPM and that this impact is statistically significant when we include the covariate intangibles.

This positive association between productivity and the predicted probability of introducing a process innovation has an immediate interpretation: firms decide to introduce and adopt innovations that improve production processes to reduce costs and increase efficiencies, leading to a direct increase in productivity. Our estimates show that an increase of 10% in the probability of introducing a process innovation is associated with a 0.27% increase in Gross Value Added over turnover.

Our results also show a clear positive association with the predicted probability of introducing an organisational innovation. This relation is stronger when productivity is measured in terms of Gross Profits Margin gains. We have seen in this report that organizational innovations increased during periods of adverse macroeconomic conditions. In light of this evidence we interpret this positive association as an indication that organizational innovations can be seen as a defensive strategy adopted by firms to reduce costs and to maintain profit margins when revenues are threatened by adverse macroeconomic conditions. Hence, restructuring the organisation of an enterprise improves productivity. Our estimates show that an increase of 10% in the probability of introducing an organisational innovation may be associated with an increase of 0.24% in the GPM over turnover of the innovating firm.

Finally, our results show that the predicted probability of introducing a product innovation is always positive and significant for both measures of productivity, with and without considering the intangibles. However, instead of leading to increased static efficiency, product innovations are more likely to increase dynamic efficiency, by improving the Gross Value Added of a firm's products and allowing them to extract more surplus from the buyers, due to their higher willingness to pay for the improved goods and services resulting from product innovations.

This result captures the role that product innovations play in improving the dynamic efficiency of the UK productive system. Our estimates show that an increase of 10% in the probability of introducing a product innovation is associated with an increase between 0.13% and 0.19 % in Gross Value Added over turnover in the two different model specifications with and without considering the intangibles as covariate.

In summary, the final stage of our estimation shows that *productivity* is positively and significantly related to four variables: the three probabilities of introducing an innovation, product, process and organisational, and also employment. Our next step, in the conclusions, is to move backwards along the different estimation steps developed in this report, exploring the main insights to be gained about the nature of the different paths and sequences of relations, linking intangible innovation activities and spillovers to productivity. We will do this first, by assessing the role played by both intangibles and spillovers on the innovations and then by, assessing their indirect effects on productivity.

Step 3 Fixed Effect Panel Estimates.												
	GVA	GVA	GVA	GVA	GVA	GVA	GPM	GPM	GPM	GPM	GPM	GPM
Pred. Prob. Process Innovation	2.714**			1.930***			2.371**			1.130		
Pred. Prob. Product Innovation		1.913**			1.330***			2.187**			0.939*	
Pred. Prob. Organizational Innovation			1.558			1.204**			2.422**			0.921
Intangibles	-0.153	-0.148	-0.0775				-0.242	-0.317	-0.328			
Log Total Employment	1.204**	1.240**	1.244**	1.299**	1.324***	1.298**	0.682	0.664	0.594	0.834	0.844	0.822
Net Capital Exp./Sales	0.0322	0.0331	0.0334	0.0319	0.0326	0.0331						
Observations	23828	23828	23828	23828	23828	23828	23828	23828	23828	23828	23828	23828

* p<0,1   ** p<0.05   *** p<0.01 Note: GVA=(gross valued added)*100 / (total turnover); GPM =100*(gross valued added – net capital expenditures)/(total turnover)

Table 16: Productivity and innovations

7 Conclusions from Innovation Intangibles to Productivity

In these conclusions we trace back the chain of relations analysed in the three stages of the model discussed in this report to explore the possible multiple links of relations between innovative activities and their final impact on productivity. We do this by backward induction, remembering however that the significant relations emerged in our analysis, are not necessarily causal relations, given the non-experimental nature of the data.

The Last Stage: From Innovations to Productivity

In the final stage of our estimation we have seen that *productivity* is positively and significantly related to four variables: the three probabilities of introducing an innovation, product, process and organisational, and employment.

- The positive association with employment relation indicates that productivity is higher for larger firms, but that these productivity benefits decrease with size. Hence, higher productivity gains are achieved by smaller firms increasing their workforce than those achieved by already larger firms. This relation can be interpreted as indicating the presence of a critical threshold in firm size that is particularly beneficial towards productivity.

- The positive association between productivity and the predicted probability of introducing a process innovation has an immediate interpretation: improving production processes has often the direct objective of increasing productivity, by reducing costs and increasing efficiencies. Our estimates show that an increase of 10% in the probability of introducing a process innovation is associated with a 0.27% increase in Gross Value Added over turnover.

- Similarly, the positive association with the predicted probability of introducing an organisational innovation is very clear, but stronger in terms of Gross Profits Margin gains. Restructuring the organisation of an enterprise, often during periods of adverse macroeconomic conditions, as we have seen in the descriptive chapters, is meant to improve productivity. Our estimates show that an increase of 10% in the probability of introducing an organisational innovation may be associated with an increase of 0.24% in the GPM over turnover of the innovating firm.

- The interpretation of the positive relation between the probability of introducing a product innovation and productivity is less immediate. Instead of being related to increased static efficiency, it is likely to bring increments in GVA, by the extra consumer surplus a firm is able to extract, due to the higher willingness to pay that consumers may have for the improved goods and services resulting from the product innovation.

Having identified the direct associations with productivity, our hierarchical estimation strategy allows us to move one step back to look at the main determinants of these productivity enhancing factors.

The Second Stage: From Predicted Intangibles to Innovations

The second stage of our estimation process focuses on the factors affecting the joint probability of introducing process, product and organisational innovations.

We start from the determinant of process innovation: remembering that all the factors positively associated with the probability of process innovation in this second stage of the estimation process will then affect the subsequent positive association of this variable with productivity.

- The predicted total R&D expenditure intensity of a firm has a positive impact on the probability that the firm will introduce a process innovation. This is an intuitive relation linking R&D effort to process innovation output.

- Similarly, R&D spillovers have positive effects on the probability of introducing a process innovation. At this second stage, we have considered only spillovers arising from sector proximity, not from spatial contiguity. This choice was dictated by the role that production-specific knowledge plays in the innovation stage, rather than the role that area-specific knowledge plays instead in the first stage of R&D intangible activities.

- The level of predicted training expenditure intensity has a similar positive effect, showing the complementarities between training and the introduction of process innovations.

- For the same reason, training spillovers, again relating to proximity in the sectors of production, increase the probability of introducing a process innovation.

- The presence of a positive relation between subsidies and the probability of introducing process innovation shows that there is an impact between policies and innovation outcomes, while the positive association with employment confirms the presence of the obstacles faced by smaller firms to introducing process innovations.

- Motivations towards innovation play a relevant, mainly positive, role. We observe that the desire to achieve better products, better production and to improve profits, are all motives linked to an increased probability of introducing a process innovation.

- Cooperation with firms of the same group, suppliers and customers affects positively the probability of introducing a process innovation, confirming the set of positive feedbacks arising along the innovation value chain.

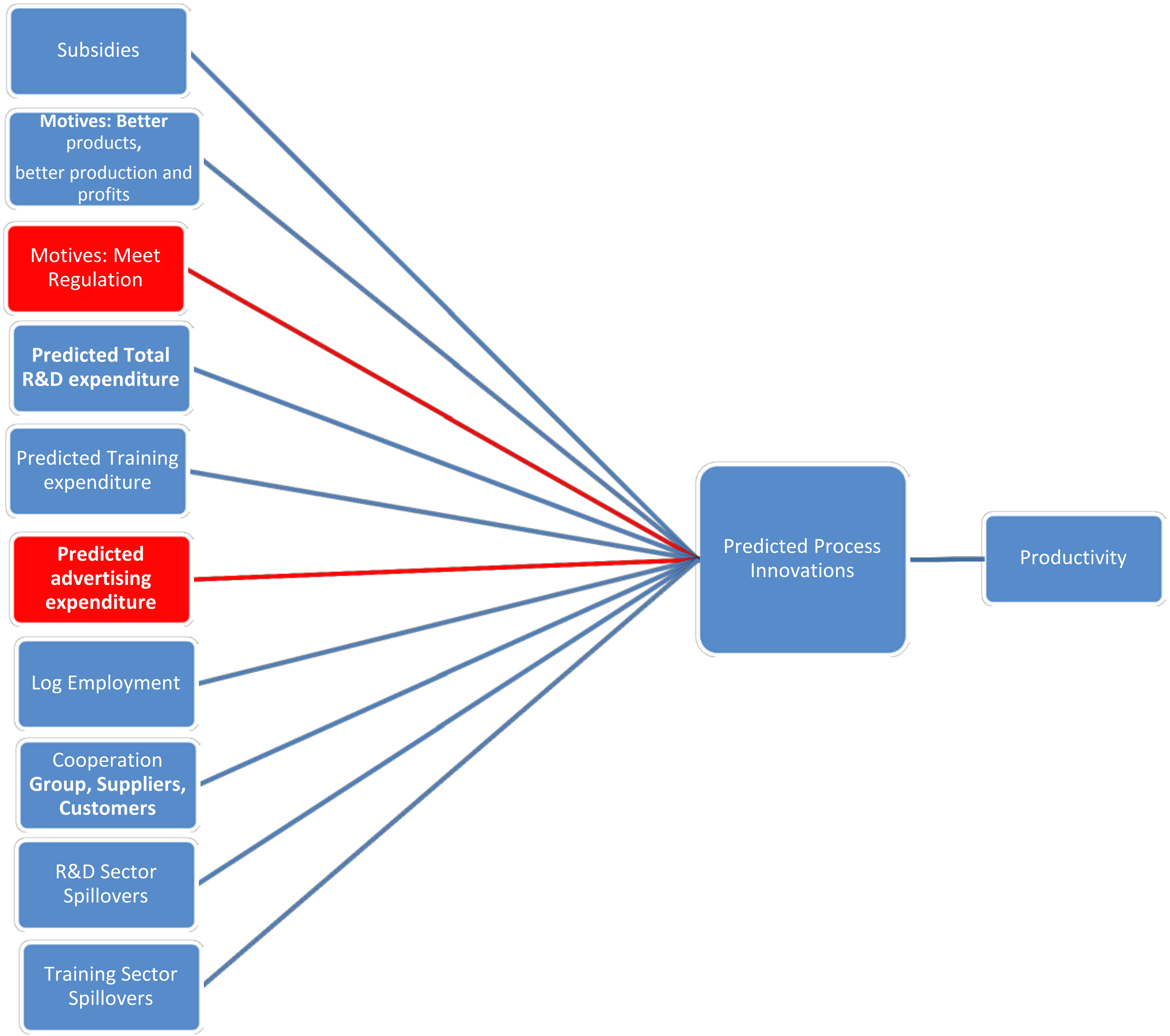
On the other hand, we found out that factors having a negative effect on the introduction of the probability of introducing a process innovation include:

- Predicted advertising expenditure, however this relation is not very significant and

- The motivation to meet regulations. This negative relation with process innovation is not surprising, as these are not usually targeted by regulation.

The diagram below captures these relations, which emerged in the second stage of estimation between the different covariates and the probability of introducing a process innovation. Red boxes represent negative associations and blue boxes show the positive ones.

Flowchart 1: Determinants of predicted process innovations

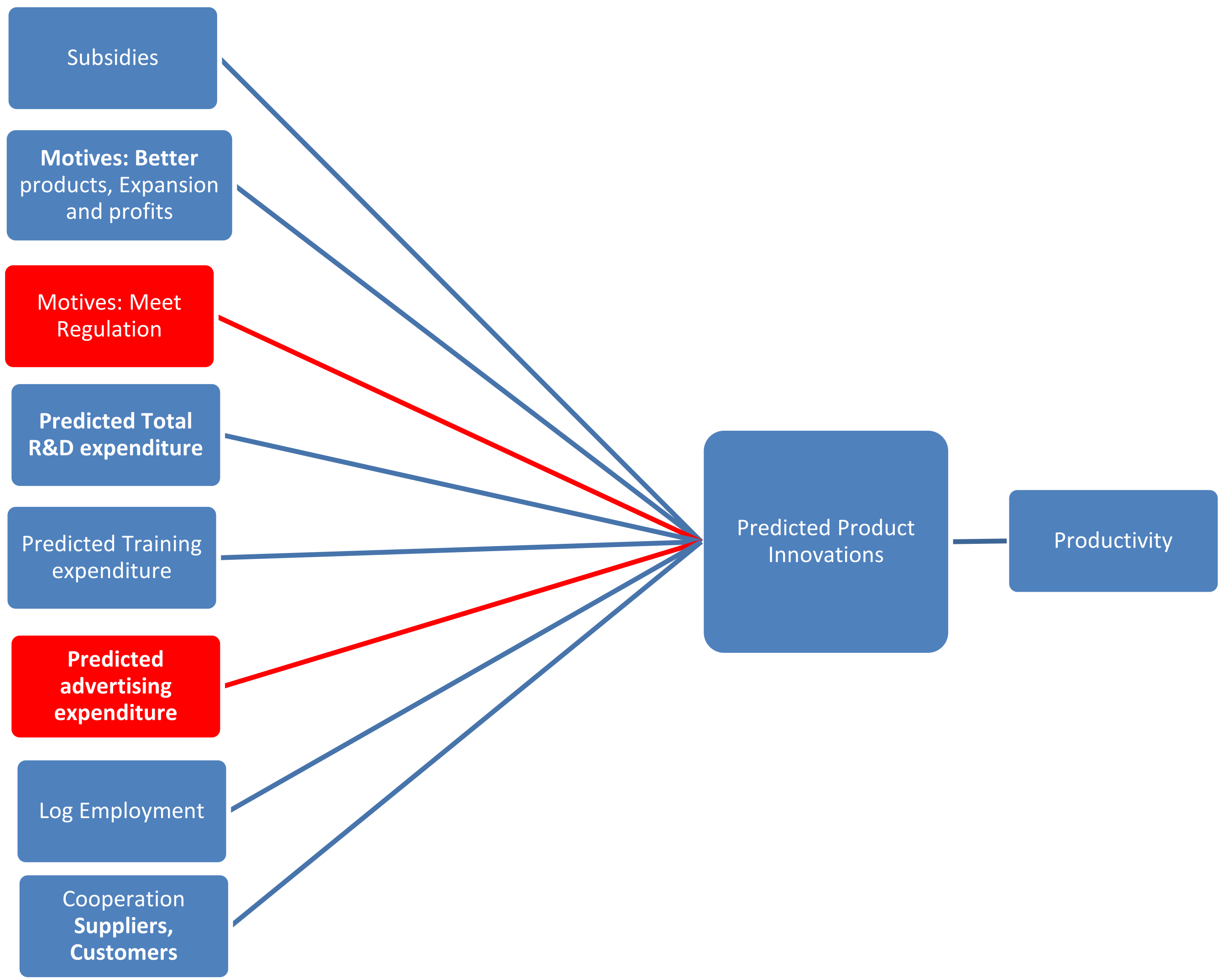

Subsidies
Motives: Better products, better production and profits
Motives: Meet Regulation
Predicted Total R&D expenditure
Predicted Training expenditure
Predicted advertising expenditure
Log Employment
Cooperation Group, Suppliers, Customers
R&D Sector Spillovers
Training Sector Spillovers
Predicted Process Innovations
Productivity

The factors affecting product innovations are similar to those analysed above in the discussion of the probability of process innovation.

Interestingly, our estimates show that both R&D and training spillovers lose their statistical significance in the association with the probability of introducing a product innovation, indicating that spillovers of productive knowledge seem to be more relevant in improving production processes rather than products. This could be because the appropriability barriers are higher for new products than for new processes, hence the different impact of knowledge spillovers on the two types of innovations.

Finally, some of the motivation and cooperation variables change their level of significance, from what was previously discussed. In particular, our estimates show that the motive of improving production, while relevant for introducing process innovations, loses its significance for product innovation. The motive of expansion instead gains prominence as this is probably better achieved through product innovations. Also cooperation within the business group, while relevant for process innovations, loses its significance in its relation to product innovation.

The diagram below summarises the main associations with the probability of introducing a product innovation discussed above.



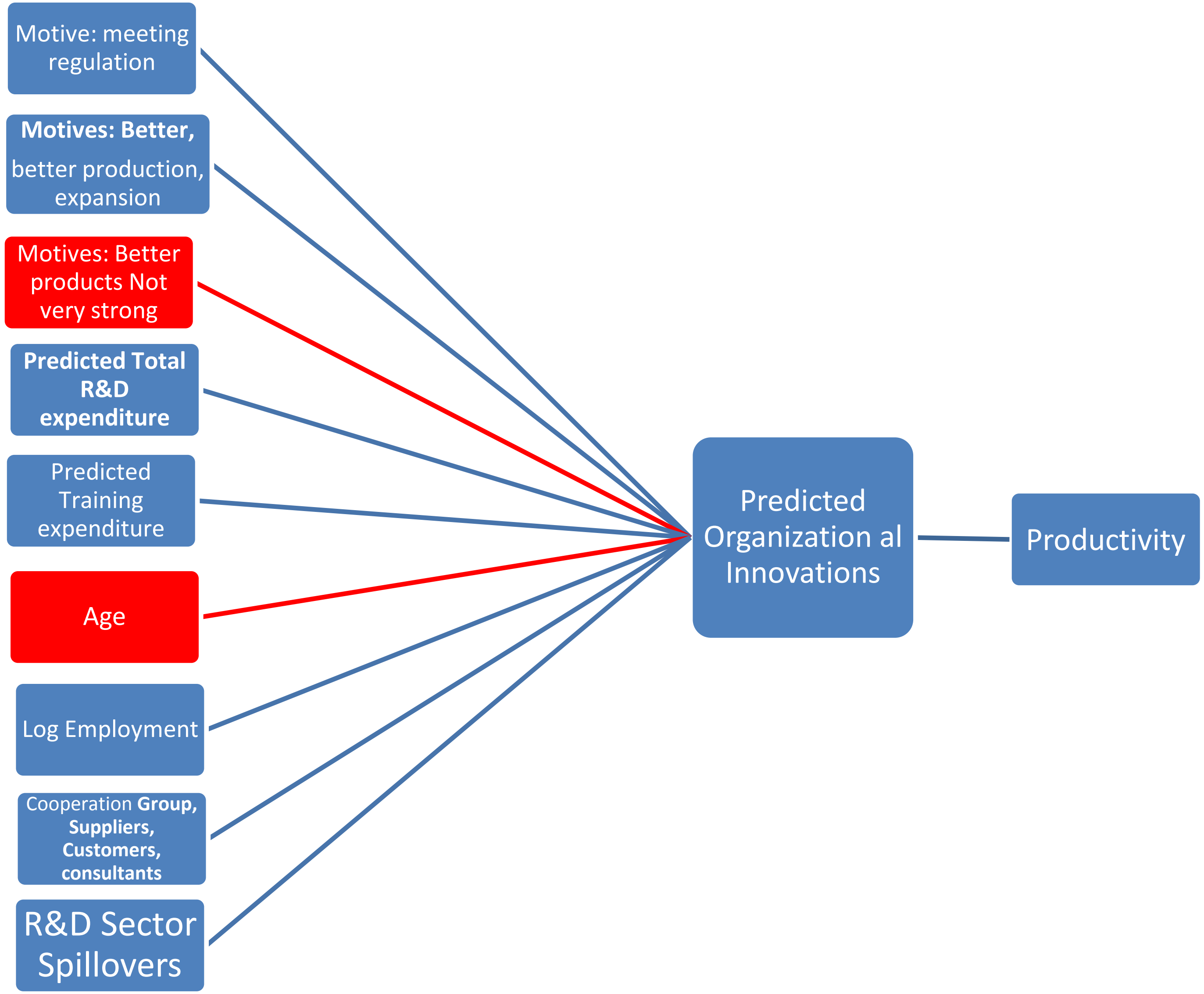
Flowchart 2: Determinants of predicted product innovations

Finally, we conclude the analysis of the second estimation stage by looking at the determinants of the probability of introducing organisational innovations. Again, we see that most of the effects are similar to those found in the analysis of the introduction of process and product innovations.

The main differences are that the motive to meet regulation has a small positive association with the probability of introducing an organisational innovation, whereas the motive to introduce better products has a negative association. Also, age has a small negative effect on the probability of introducing organisational innovations.

Sector specific productive knowledge spillovers generated by R&D are marginally significant for organisational innovations while those induced by training activities are not statistically significant.

The diagram below summarises the main associations with the probability of introducing an organisational innovation discussed above.



Flowchart 3: Determinants of predicted organizational innovations

The First Stage: Predicted Intangibles to Innovations

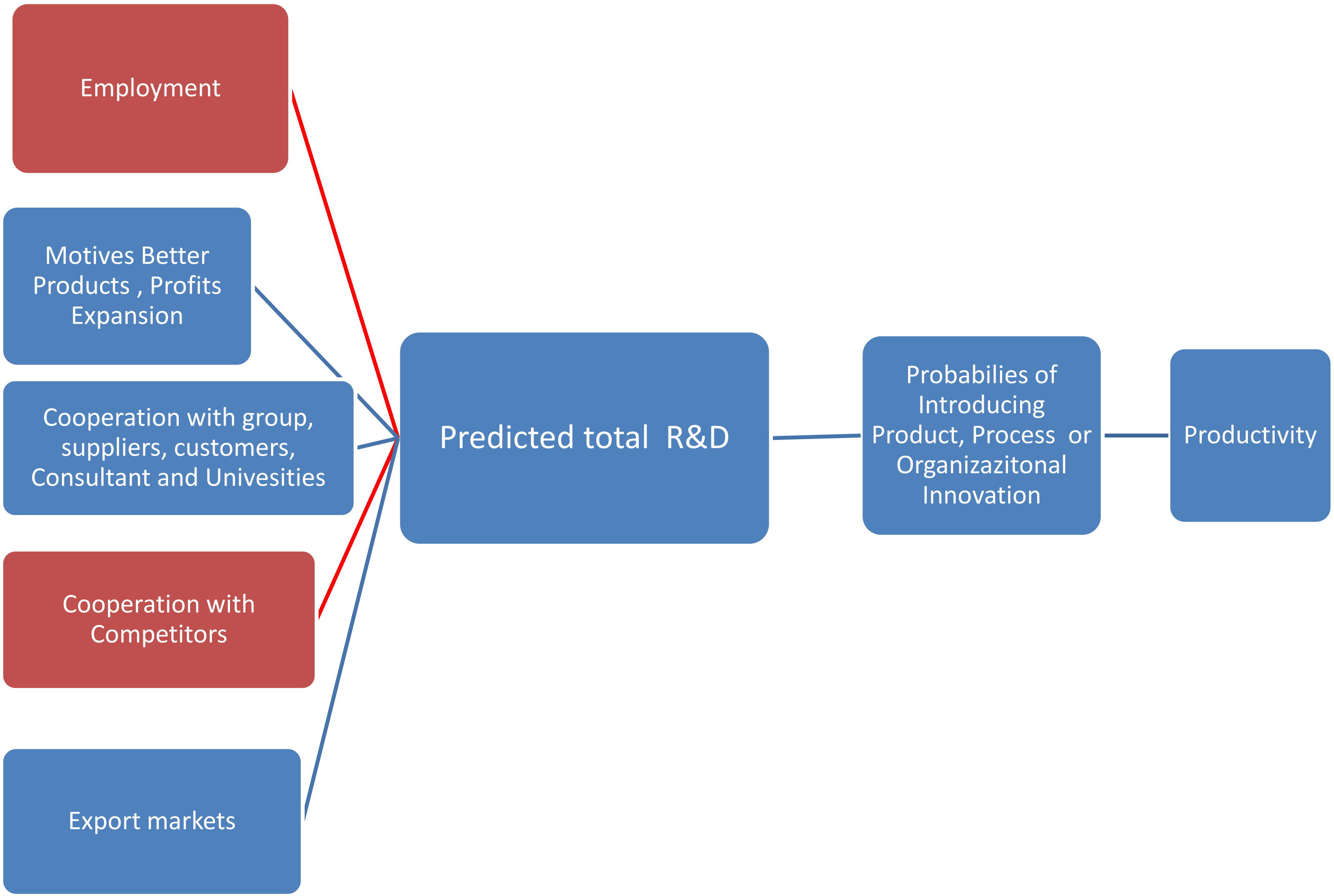
We now look one step back at the factors affecting the main variables related to the introduction of the different types of innovation.

We have seen that predicted total R&D expenditure had positive associations with the probability of introducing each one of the three possible innovations.

Our first stage estimates provide us with the relevant associations with the two dependent variables: predicted internal and external R&D expenditure that, together form the predicted total R&D expenditure used as an independent variable in stage two.

Predicted total R&D is positively affected by export activities and by the motives of introducing better products, improve profits and expansion. Cooperation with firms of the same business group, consultants, customers, suppliers and universities is also positively associated with predicted R&D.

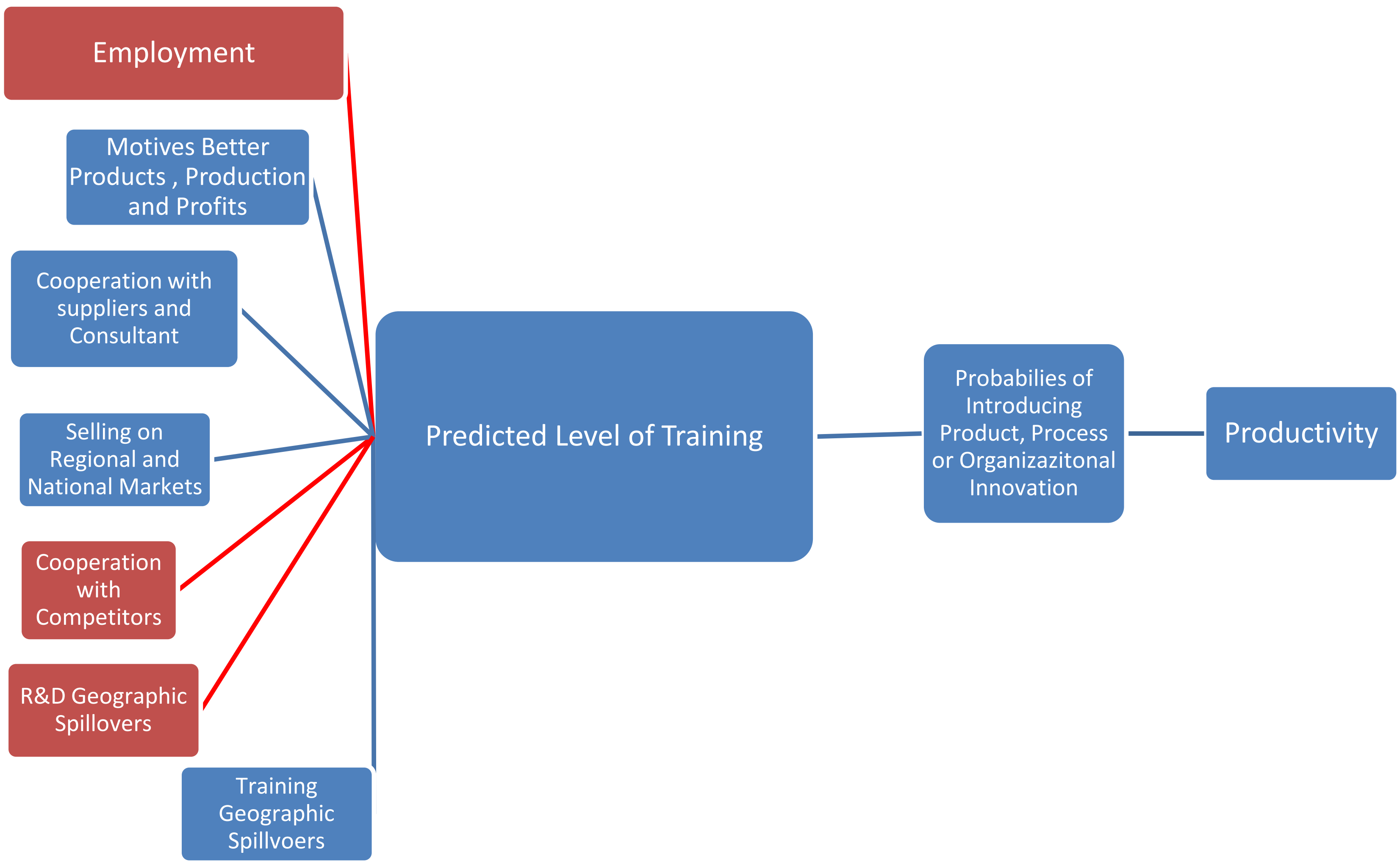
A negative association with R&D is instead given by cooperation with competitors and employment.



Flowchart 4: Determinants of the predicted total R&D

Moving to the determinants of the predicted level of training expenditure, we found that, apart from the similar results on the motivation and cooperation factors, there is a positive association with selling output on local and national markets. Considering the role played by geographic spillovers in relation to a firm's training intensity, our estimates show that R&D expenditure spillovers are significantly and negatively associated with the training intensity of a firm. Spillovers from training expenditure of other firms, again weighted inversely by the geographic distance between originating and receiving firms, are instead positively associated with the dependent variable indicating the presence of a pure positive spatial spillover effect.

The flowchart below summarises this set of relations.



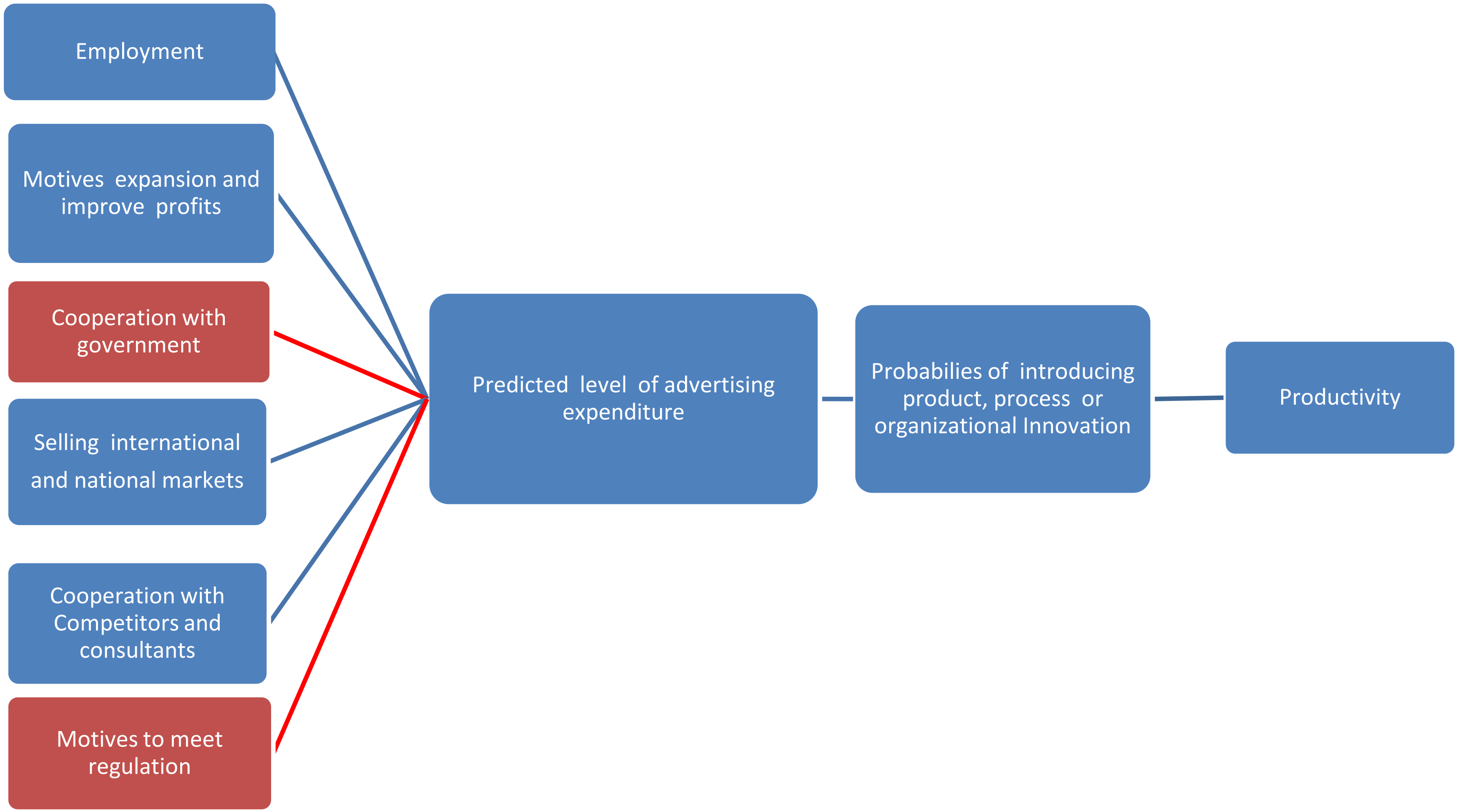
Flowchart 5: Determinants of predicted level of training

The last intangible activity we considered in our first stage of estimation was the predicted level of advertising expenditure. Our estimates show that a focus on regional markets has a negative association with advertising intensity, while participation to national and international markets has a positive association with it. Clearly, these associations could go in different ways, as the participation to international markets might well require a higher advertising intensity.

Employment has a predominately positive association with this intangible. This association is noticeably different from the negative one that employment had with the other intangibles. The incentives for expansion and improved profits were positively associated with the predicted level of advertising intensity, confirming the intuition that advertising is a necessary investment required to reach new markets.

The motive to meet regulation has a negative relation with advertising as the targets of advertising expenditure are consumers rather than regulators.

By looking at the cooperation, we found that cooperation with suppliers had a positive association with a firm's advertising intensity. The cooperation with competitors and with consultants showed a positive and significant association with the predicted level of advertising intensity.



Flowchart 6: Determinants of the predicted level of advertising

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Appendix

Full Regression Tables

First Stage Full Estimation Results[6]

Tobit Model I	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Dependent Variable Internal R&D / over Turnover model					
Regional Markets	0.0262	-0.0882	0.440*	0.713**	0.505***
	(0.11)	(-0.39)	(1.82)	(2.07)	(4.10)
National Markets	0.723***	0.362	0.980***	1.148**	0.952***
	(3.47)	(1.34)	(2.63)	(2.51)	(6.25)
EU Markets	0.456**	0.910***	0.527*	0.136	0.521***
	(1.99)	(3.18)	(1.92)	(0.30)	(3.17)
International Markets	0.938***	1.084***	0.926***	0.940***	1.037***
	(4.76)	(4.30)	(3.15)	(3.08)	(8.33)
Log Total Employment	-0.560***	-0.653***	-0.941***	-0.850***	-0.776***
	(-4.58)	(-4.70)	(-5.75)	(-5.21)	(-5.80)
age	0.0418	-0.0182	0.0625	0.0593	0.0227
	(1.18)	(-0.43)	(1.39)	(0.99)	(0.92)

6 Regional and Macro-sector dummy parameters values have not been reported but were included in the estimations.

Tobit Model I	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
age2	-0.00151	0.000214	-0.00177*	-0.00142	-0.000938
	(-1.63)	(0.21)	(-1.78)	(-1.10)	(-1.63)
Motive: Better products	1.240***	0.531	-0.682	2.687**	0.578**
	(3.35)	(0.70)	(-1.01)	(2.20)	(2.07)
Motive: Better production	-0.0524	-0.379	0.664	-1.461	-0.0298
	(-0.18)	(-0.83)	(0.83)	(-1.52)	(-0.14)
Motive: Improve Profit	1.429***	0.713	0.543	-0.351	1.052***
	(3.86)	(1.21)	(0.53)	(-0.28)	(2.98)
Motive: Meet Regulation	-0.281	0.747	0.0986	4.312***	-0.0504
	(-1.09)	(1.48)	(0.23)	(3.12)	(-0.22)
Motive: Expansion	0.857***	0.834*	1.667***	-0.735	0.836***
	(4.32)	(1.75)	(3.41)	(-0.93)	(4.78)
R&D Geog. Spillover	0.0155	-0.0583	-0.112	-0.00767	0.0270
	(0.14)	(-0.59)	(-0.86)	(-0.06)	(0.54)
Training Geog. Spillover	-0.0153	0.0921	0.0829	0.0983	-0.0292
	(-0.14)	(0.68)	(0.57)	(1.05)	(-0.54)
Coop - Group	-0.0480	0.603*	0.202	0.709*	0.381**
	(-0.15)	(1.68)	(0.66)	(1.74)	(2.08)
Coop - Suppliers	0.928**	-0.0183	0.507**	0.308	0.476***
	(2.46)	(-0.06)	(2.18)	(0.97)	(2.85)
Coop - Customers	0.227	0.581	0.611**	0.613**	0.556***
	(0.52)	(1.55)	(2.26)	(2.38)	(3.44)
Coop - Other firms	-1.047*	-0.574*	-1.050***	-0.285	-0.854***

Tobit Model I	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
	(-1.89)	(-1.69)	(-2.82)	(-0.66)	(-3.09)
Coop - Consultants	0.614*	0.712*	0.880***	0.881	0.756***
	(1.89)	(1.79)	(2.70)	(1.64)	(3.54)
Coop - Universities	1.653***	0.728*	0.557	1.126**	1.151***
	(2.75)	(1.78)	(1.13)	(2.49)	(3.69)
Coop - Government	0.622	-0.0946	-0.633	-0.138	-0.156
	(1.28)	(-0.23)	(-1.51)	(-0.23)	(-0.56)
Subsidies over turnover	0.0239	0.00739	-0.0161	0.00895	0.00627
	(1.04)	(0.15)	(-0.56)	(0.17)	(0.33)
Observations	7719	5718	5580	4828	23845
Pseudo R-squared	0.118	0.121	0.168	0.264	0.136

Tobit Model II	(CIS-2004)	IS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Dependent Variable External R&D / over Turnover model					
Regional Markets	0.0278	-1.054***	-0.0773	0.527**	0.0226
	(0.15)	(-5.11)	(-0.44)	(2.08)	(0.28)
National Markets	0.218	-0.803**	0.574**	0.915***	0.220
	(1.14)	(-2.54)	(2.45)	(2.64)	(1.53)
EU Markets	0.191	0.771***	0.574**	-0.202	0.371***

Tobit Model II	(CIS-2004)	:IS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
	(0.74)	(2.73)	(2.52)	(-0.70)	(2.60)
International Markets	0.855***	0.409	0.270	0.577**	0.614***
	(3.57)	(1.52)	(1.29)	(2.26)	(5.47)
Log Total Employment	-0.686***	-0.683***	-0.735***	-0.455***	-0.774***
	(-4.66)	(-3.78)	(-5.21)	(-3.31)	(-5.47)
age	0.0237	-0.0237	-0.000951	-0.0196	-0.00824
	(0.74)	(-0.43)	(-0.03)	(-0.40)	(-0.37)
age2	-0.000913	0.000499	-0.0000935	0.000224	-0.0000693
	(-1.05)	(0.38)	(-0.12)	(0.20)	(-0.13)
Motive: Better products	0.720**	0.986	-1.409	-0.602	0.356
	(2.01)	(1.64)	(-1.04)	(-0.58)	(1.25)
Motive: Better production	0.112	-0.147	-0.216	2.466**	0.0218
	(0.38)	(-0.37)	(-0.47)	(2.08)	(0.10)
Motive: Improve Profit	0.915**	0.278	2.042*	0.442	0.790**
	(2.26)	(0.52)	(1.82)	(0.39)	(2.25)
Motive: Meet Regulation	-0.0762	0.767*	-0.654	-0.713	-0.0887
	(-0.34)	(1.90)	(-1.53)	(-0.64)	(-0.51)
Motive: Expansion	0.0600	-0.288	1.107	0.683	0.114
	(0.25)	(-0.53)	(1.45)	(0.78)	(0.51)
R&D Geog. Spillover	-0.0967	-0.0542	0.0192	0.0134	0.0155
	(-1.02)	(-0.65)	(0.20)	(0.15)	(0.38)
Training Geog. Spillover	0.0903	0.136	-0.00296	-0.155**	-0.0301
	(0.92)	(1.18)	(-0.04)	(-2.24)	(-0.76)

Tobit Model II	(CIS-2004)	:IS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Coop - Group	0.330	0.166	0.594**	0.0870	0.373**
	(1.12)	(0.55)	(2.53)	(0.39)	(2.43)
Coop - Suppliers	0.648***	0.308	0.443**	0.625***	0.533***
	(2.61)	(0.78)	(2.28)	(2.67)	(3.70)
Coop - Customers	0.121	-0.0160	0.00116	-0.0541	-0.00339
	(0.51)	(-0.03)	(0.00)	(-0.36)	(-0.02)
Coop - Other firms	-0.796	0.0670	-0.538**	-0.372	-0.435**
	(-1.54)	(0.18)	(-2.15)	(-1.38)	(-2.05)
Coop - Consultants	1.319***	0.879**	1.091***	0.897***	1.063***
	(4.17)	(2.25)	(4.78)	(3.32)	(7.32)
Coop - Universities	1.204***	0.364	0.00606	0.395*	0.630***
	(3.16)	(0.99)	(0.03)	(1.70)	(3.96)
Coop - Government	-0.113	0.695	-0.150	0.318	0.0872
	(-0.29)	(1.64)	(-0.58)	(1.39)	(0.39)
Subsidies over turnover	-0.0703	-0.0552	-0.0198	-0.0575	-0.0650**
	(-0.78)	(-0.85)	(-0.86)	(-0.78)	(-2.04)
Observations	7719	5718	5580	4828	23845
Pseudo R-squared	0.155	0.125	0.244	0.272	0.152

Tobit Model III	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Dependent Variable Training Expenditure / over Turnover					
Model					

Tobit Model III	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
model					
Regional Markets	0.0540	0.158***	0.0563	0.284***	0.344***
	(0.99)	(2.59)	(1.13)	(2.98)	(6.98)
National Markets	0.198***	0.109	0.158**	0.143	0.280***
	(3.02)	(1.26)	(2.56)	(1.60)	(5.86)
EU Markets	0.0679	0.0744	0.0632	-0.160	0.0456
	(0.77)	(0.74)	(1.19)	(-1.55)	(0.86)
International Markets	0.0691	-0.125	0.0357	0.148	0.0166
	(0.65)	(-1.19)	(0.56)	(1.43)	(0.29)
Log Total Employment	-0.218***	-0.207***	-0.221***	-0.238***	-0.297***
	(-4.66)	(-4.43)	(-6.00)	(-4.16)	(-6.19)
age	-0.0180	-0.00510	-0.00492	0.0107	-0.00551
	(-1.43)	(-0.50)	(-0.36)	(0.67)	(-0.78)
age2	0.000382	0.000321	0.0000903	-0.000208	0.000102
	(1.20)	(1.15)	(0.29)	(-0.62)	(0.62)
Motive: Better products	0.447***	0.0694	-0.392**	0.973***	0.259***
	(3.81)	(0.44)	(-1.97)	(3.36)	(3.02)
Motive: Better production	0.195**	0.106	0.210	0.129	0.181***
	(2.16)	(0.83)	(1.55)	(0.37)	(2.66)
Motive: Improve Profit	0.319***	0.242	0.319	0.614	0.249***
	(3.35)	(1.24)	(1.46)	(0.72)	(3.18)
Motive: Meet Regulation	0.203**	0.162	0.0880	-0.800	0.122**
	(2.47)	(1.28)	(0.78)	(-0.73)	(2.22)
Motive: Expansion	0.0463	0.185	0.115	-0.0907	-0.0200
	(0.67)	(1.42)	(1.17)	(-0.27)	(-0.32)

Tobit Model III	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
R&D Geog. Spillover	0.0170	-0.00784	-0.0239	0.0315	-0.0506***
	(0.60)	(-0.24)	(-1.05)	(1.22)	(-3.24)
Training Geog. Spillover	-0.0199	-0.0187	0.00255	-0.0477*	0.0472***
	(-0.68)	(-0.41)	(0.11)	(-1.75)	(2.89)
Coop - Group	-0.101	0.116	-0.00710	0.0870	-0.00666
	(-0.93)	(1.22)	(-0.12)	(1.61)	(-0.12)
Coop - Suppliers	0.356***	0.0707	0.183***	0.145*	0.178***
	(3.27)	(0.52)	(2.74)	(1.90)	(3.34)
Coop - Customers	0.0535	0.0379	0.105	0.117*	-0.0208
	(0.64)	(0.34)	(1.58)	(1.71)	(-0.41)
Coop - Other firms	0.109	0.163	-0.0902	0.138	0.115*
	(0.93)	(1.43)	(-1.29)	(1.35)	(1.78)
Coop - Consultants	0.0780	0.154	0.111	0.161	0.105*
	(0.60)	(1.16)	(1.38)	(1.22)	(1.70)
Coop - Universities	0.0401	0.0562	0.0587	0.0220	0.109
	(0.39)	(0.32)	(0.65)	(0.24)	(1.63)
Coop - Government	0.0480	-0.0792	0.00886	0.113	0.0465
	(0.34)	(-0.47)	(0.08)	(0.87)	(0.59)
Subsidies over turnover	-0.0361**	-0.00161	0.00690	0.0129	-0.00275
	(-2.42)	(-0.18)	(1.32)	(1.05)	(-0.35)
Observations	7719	5718	5580	4828	23845
Pseudo R-squared	0.074	0.061	0.231	0.295	0.100

Tobit Model IV	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Dependent Variable Advertising Expenditure / over Turnover					
Regional Markets	0.0918	-0.122	-0.0288	-0.307**	-0.0948
	(1.12)	(-1.02)	(-0.31)	(-2.53)	(-1.42)
National Markets	0.128	0.211**	-0.0366	0.333	0.143**
	(1.22)	(2.25)	(-0.30)	(1.50)	(2.27)
EU Markets	0.118	-0.0201	0.169	-0.162	0.0598
	(0.84)	(-0.23)	(1.16)	(-0.67)	(0.75)
International Markets	0.262***	0.0643	0.0489	-0.0819	0.111*
	(2.72)	(0.57)	(0.33)	(-0.78)	(1.68)
Log Total Employment	0.0103	0.0687**	0.129***	-0.0205	0.0536**
	(0.21)	(2.34)	(3.56)	(-0.41)	(2.12)
age	-0.0104	-0.0149	-0.0139	-0.0772*	-0.0140
	(-0.41)	(-0.77)	(-0.61)	(-1.88)	(-1.17)
age2	0.000202	0.000469	0.000193	0.00141*	0.000261
	(0.30)	(0.96)	(0.40)	(1.87)	(0.99)
Motive: Better products	-0.186*	0.182	0.155	-0.239	-0.108
	(-1.82)	(0.69)	(0.45)	(-0.84)	(-1.12)
Motive: Better production	0.00401	-0.220	0.212	-0.308	-0.00488
	(0.04)	(-1.44)	(1.17)	(-0.48)	(-0.05)
Motive: Improve	0.273**	-0.356	0.0239	0.474	0.221**

Tobit Model IV	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Profit					
	(2.22)	(-1.62)	(0.13)	(0.95)	(2.25)
Motive: Meet Regulation	-0.187**	0.0909	-0.121	0.0162	-0.176**
	(-2.23)	(0.69)	(-0.92)	(0.04)	(-2.15)
Motive: Expansion	0.255***	0.433**	0.0808	0.225	0.280***
	(2.89)	(2.57)	(0.33)	(0.60)	(3.73)
R&D Geog. Spillover	0.0289	0.0809**	0.0100	-0.000229	0.0152
	(0.60)	(2.04)	(0.32)	(-0.01)	(0.79)
Training Geog. Spillover	-0.0506	-0.0700	0.0303	-0.0143	-0.0101
	(-0.92)	(-1.58)	(0.96)	(-0.46)	(-0.44)
Coop - Group	-0.148	0.0149	0.132	-0.688	-0.165
	(-0.83)	(0.10)	(0.88)	(-1.38)	(-1.25)
Coop - Suppliers	0.112	0.234	-0.220	0.244*	0.0828
	(0.76)	(1.36)	(-1.27)	(1.82)	(1.02)
Coop - Customers	-0.270	-0.260	-0.173	0.391	-0.108
	(-1.64)	(-1.54)	(-0.72)	(0.66)	(-0.66)
Coop - Other firms	0.241	0.00253	0.0454	0.487	0.192**
	(1.34)	(0.01)	(0.26)	(1.63)	(1.98)
Coop - Consultants	0.256	0.120	0.345*	0.117	0.254**
	(1.30)	(0.47)	(1.75)	(0.68)	(2.22)
Coop - Universities	-0.00413	0.163	-0.340**	-0.170	-0.129
	(-0.02)	(0.82)	(-2.51)	(-0.86)	(-1.16)

Tobit Model IV	(CIS-2004)	(CIS- 2006)	(CIS- 2008)	(CIS- 2010)	Pooled
Coop - Government	-0.148	-0.322	-0.0346	-0.405	-0.214**
	(-0.69)	(-1.46)	(-0.19)	(-1.55)	(-2.01)
Subsidies over turnover	0.0512***	0.00829	-0.00296	0.00719	0.0155
	(2.75)	(0.78)	(-0.26)	(0.69)	(1.34)
Observations	7719	5718	5580	4828	23845
Pseudo R-squared	0.009	0.009	0.007	0.011	0.006

Second Stage Multi-Probit Estimation Results

Second Stage Pooled estimation, Predicted Innovation Outcomes, CIS (2004-2010).

Second Stage Pooled estimation Predicted Innovation Outcomes CIS (2004-2010)	Process innovation Training Spillovers	Process innovation R&D Spillovers	Product innovation Training Spillovers	Product innovation R&D Spillovers	Organisational innovation Training Spillovers	Organisational innovation R&D Spillovers
Predicted Total R&D expenditure /Sales	0.0421***	0.0377***	0.0757***	0.0735***	0.0133*	0.0124*
	-3.08	-2.95	-6.01	-6.09	-1.85	-1.75
Predicted Training expenditure /Sales	0.110*	0.117**	0.147**	0.102	0.249***	0.223***
	-1.72	-1.98	-2.31	-1.63	-5.17	-4.63
Predicted advertising expenditure /Sales	-0.0783**	-0.059	-0.0625*	-0.0411	0.0164	0.0273
	(-2.02)	(-1.53)	(-1.77)	(-1.17)	-0.54	-0.89
Subsidies over turnover	0.0177*	0.0209**	0.0287***	0.0320***	0.00187	0.00137
	-1.91	-2.19	-4.52	-4.93	-0.24	-0.16
Log Total Employment	0.160***	0.154***	0.151***	0.137***	0.227***	0.216***
	-7.62	-7.63	-8.05	-7.36	-16.33	-15.48
R&D Sector Spillover		0.0187***		0.00673		0.00749*
		-3.32		-1.34		-1.65
Training Sector Spillover	0.0151**		-0.00234		0.00596	
	-2.11		(-0.36)		-1.01	
age	-0.00784	-0.00672	-0.00771	-0.00919	-0.0144**	-0.0145**

Second Stage Pooled estimation Predicted Innovation Outcomes CIS (2004-2010)	Process innovation Training Spillovers	Process innovation R&D Spillovers	Product innovation Training Spillovers	Product innovation R&D Spillovers	Organisational innovation Training Spillovers	Organisational innovation R&D Spillovers
	(-0.98)	(-0.85)	(-1.02)	(-1.25)	(-2.21)	(-2.23)
age2	0.000161	0.00014	0.000134	0.000185	0.000174	0.000182
	-0.83	-0.73	-0.73	-1.02	-1.09	-1.14
Motive: Better products	0.513***	0.530***	0.680***	0.698***	-0.149*	-0.133
	-4.27	-4.43	-8.3	-8.58	(-1.72)	(-1.55)
Motive: Better production	0.676***	0.671***	0.0194	0.0182	0.200***	0.208***
	-7.22	-7.17	-0.27	-0.26	-2.7	-2.8
Motive: Improve Profit	0.305***	0.297**	0.302***	0.309***	0.0611	0.058
	-2.6	-2.55	-3.37	-3.51	-0.67	-0.64
Motive: Meet Regulation	-0.330***	-0.320***	-0.365***	-0.356***	0.230***	0.233***
	(-4.54)	(-4.44)	(-5.38)	(-5.39)	-3.84	-3.92
Motive: Expansion	0.0346	0.0354	0.377***	0.379***	0.284***	0.281***
	-0.48	-0.49	-5.56	-5.66	-4.65	-4.63
Regional Markets	0.0154	0.0216	-0.103**	-0.0994**	0.104***	0.107***
	-0.35	-0.5	(-2.56)	(-2.50)	-3.11	-3.24
National Markets	0.147***	0.137***	0.0485	0.0437	0.280***	0.279***
	-3.02	-2.85	-1.07	-0.98	-7.67	-7.68
EU Markets	0.0892	0.0943*	0.186***	0.192***	0.0255	0.0192
	-1.63	-1.74	-3.69	-3.85	-0.56	-0.42
International Markets	0.00402	-0.00727	0.127**	0.130**	0.123**	0.126***
	-0.07	(-0.13)	-2.42	-2.5	-2.56	-2.63

Second Stage Pooled estimation Predicted Innovation Outcomes CIS (2004-2010)	Process innovation Training Spillovers	Process innovation R&D Spillovers	Product innovation Training Spillovers	Product innovation R&D Spillovers	Organisational innovation Training Spillovers	Organisational innovation R&D Spillovers
Coop - Group	0.113*	0.119*	0.0896	0.0927	0.233***	0.234***
	-1.71	-1.84	-1.31	-1.39	-3.42	-3.45
Coop - Suppliers	0.290***	0.289***	0.241***	0.246***	0.134**	0.141**
	-4.32	-4.36	-3.62	-3.75	-2.01	-2.13
Coop - Customers	0.159**	0.160**	0.272***	0.291***	0.244***	0.243***
	-2.44	-2.51	-4.29	-4.71	-3.87	-3.87
Coop - Other firms	0.0316	0.00571	0.0377	0.0345	-0.063	-0.0408
	-0.38	-0.07	-0.47	-0.43	(-0.78)	(-0.50)
Coop - Consultants	-0.0183	-0.0157	-0.0401	-0.0301	0.204**	0.192**
	(-0.23)	(-0.20)	(-0.50)	(-0.38)	-2.53	-2.4
Coop - Universities	0.0491	0.0574	-0.126	-0.124	-0.0123	-0.00423
	-0.51	-0.6	(-1.34)	(-1.33)	(-0.13)	(-0.05)
Coop - Government	-0.0883	-0.0721	-0.147	-0.131	-0.0664	-0.0656
	(-0.86)	(-0.72)	(-1.48)	(-1.32)	(-0.68)	(-0.67)
Observations	23555	23828				

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Any enquiries regarding this publication should be sent to:

Department for Business, Innovation and Skills
1 Victoria Street
London SW1H 0ET
Tel: 020 7215 5000

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