Department for **Innovation, Universities** & **Skills**

Absorptive Capacity and Regional Patterns of Innovation

Maria Abreu, Vadim Grinevich, Michael Kitson and Maria Savona[1]

---

[1]Centre for Business Research (CBR), University of Cambridge, Trumpington Street, CB2 1AG and Programme on Regional Innovation (PRI), Cambridge-MIT Institute, University of Cambridge, 10 Miller's Yard, Mill Lane, CB2 1RQ.
This paper is based on research supported by the Department for Innovation, Universities and Skills (DIUS). We would like to thank Ray Lambert, Meir Russ and Simona Iammarino and participants at the conferences listed below for comments on earlier versions of this paper: North American Regional Science Council (NARSC) conference, Toronto, November 16-18, 2006; the Future of Science, Technology and Innovation Policy: Linking Research and

Executive Summary

This paper considers whether differences in absorptive capacity at the firm-level are determinants of regional variations in innovation performance. Differences in firms' absorptive capacity are also due to sectoral and technological specificities. Both firms' absorptive capacity and sectoral structure differ widely across regions: this analysis focuses on the former while controlling for the latter aspect in order to evaluate regional differences in firms' propensity to innovate.

The empirical analysis is based on the use of two different and complementary firm-level databases covering UK enterprises. First, the UK Innovation Survey 2005 (UK CIS4) and second, the newly collected Small and Medium-sized Enterprises Survey carried out by the Centre for Business Research at the University of Cambridge. The use of two data sets allows for comparisons on a wide range of indicators on firms' absorptive capacity and for different types of innovation. The CIS4 database provides information on a large sample of firms while the CBR allows for more comprehensive details on firms' characteristics in terms of innovative strategies and absorptive capacity. Furthermore, the analysis incorporates complementary evidence based on in-depth case study analysis of thirteen companies included in the CBR data base.

The probability of introducing a product (good or service) or process innovation is estimated using a series of independent variables which capture the different aspects of firms' absorptive capacity while, at the same time, controlling for regional and sectoral specificities. The results

---

Practice, SPRU 40th Anniversary Conference, 11th-13th September, 2006; XVIth International Conference of RESER, 28-30th September 2006, Lisbon, Portugal; Innovation Economics Conference, DTI, London, 17 November 2006; Forum on Knowledge Exchange, Networks and Regional Innovation, Programme on Regional Innovation, Cambridge-MIT Institute, 6-7 December, 2006; Workshop on Agglomeration and Growth in Knowledge-based Societies, Kiel, Germany, April 20-21, 2007. The usual disclaimer applies.

of the analysis are broadly supportive of many of the hypotheses from the literature on absorptive capacity. The key findings are as follows:

- The presence of a larger share of R&D employees is positively associated with innovation, particularly for manufactured goods.
- The use of new management techniques has a significantly positive association with increased innovation activity.
- Collaborative behaviour is also associated with increased innovation activity. National and overseas collaborations are significantly associated with goods product innovation, while national collaborations are most important for service innovation.

This research shows that different forms of absorptive capacity are associated with different types of goods, service and process innovation. Furthermore, it suggests that policies that encourage the use of new management techniques, the training of managers and the development of networks across multiple geographies may improve the innovative behaviour of firms in all the regions of the UK.

Contents

List of Tables

1. Introduction

Economic policy in the industrialised countries has assigned increased importance to regional innovation as a means of increasing national economic growth (DTI, 2003, HoL, 2003). Although regional competitiveness is a problematic concept to define (Kitson, Tyler and Martin, 2004), evaluating regional variations in innovative performance provides important evidence to help shape regional policy.

There are significant regional disparities in the UK in terms of employment, productivity and innovation. Such disparities, which have been apparent over a long period and came to prominence in the interwar period, have been emphasised in much of the recent literature (see, for example, Keeble, 1996; Athreye and Keeble, 2002; Henley, 2005; Meliciani, 2006). In particular, the meta-region of the Greater South East (GSE), which includes the regions of London, Eastern and the South East of England, largely outperforms the rest of the country, and accounts for much of the aggregate productivity growth of the UK (Patacchini and Rice, 2007). The issue of whether, or how, to reduce the growing gap between the GSE and other slower-growing regions is therefore an important one for both regional economists and for policy makers. Most of the recent literature deals with regional innovation and growth differences within a 'Regional Innovation Systems' approach (RIS) (Breschi and Lissoni, 2001; Cooke, 2001; Carlsson, 2004; Edquist, 2004; Boschma and Frenken, 2005). This body of literature emphasises the growth-enhancing role of innovation and argues that most of the regional divergence in growth patterns can be attributed to the localised and intrinsically path-dependent nature of the innovation process, which hampers the diffusion of the benefits of innovation and makes the catching-up process a matter for policy intervention.

In line with this literature, this paper argues that regional differences in economic performance across UK can, at least in part, be explained by large differences in regional innovation performance. Unlike most existing contributions, however, in this analysis it is argued that the observed ‘regional innovation map’ in the UK is largely a result of the differences in regional sectoral structures and in variations in firms’ absorptive capacity.[2]

The GSE has the highest concentration of Knowledge-Intensive Business Services (KIBS), not only with respect to the rest of the UK but also as compared to the rest of the European Union. This may suggest a new model of innovation driven growth, led by business and financial services. The latter mostly rely on non-R&D innovation investments and have high employment and productivity returns (Cainelli, Evangelista, and Savona, 2006). The case of the GSE in the UK seems therefore to challenge the ‘Baumolian productivity slowdown argument’ (Baumol, 1967) associated with deindustrialisation and the growth of services. Additionally, the GSE also has the highest concentration of universities and public research institutions, which potentially sustain and facilitate the processes of knowledge spillovers across firms, enhancing their absorptive capacity and their innovation performance (Feldman, 1999; Jaffe, 1989; Jaffe, Traijtenberg and Henderson, 1993).

This paper focuses on differences in absorptive capacity at the firm-level as determinants of regional variations in innovation performance. Differences in firms’ absorptive capacity are, among other determinants, also due to sectoral and technological specificities (Schmidt, 2005; Freel and Harrison, 2006). Both firms’ absorptive capacity and sectoral structure differ widely across regions: this work focuses on the former while controlling for the latter aspect in order to evaluate regional differences in firms’ propensity to innovate.

This analysis uses two different data sources to test the relationship between firms’ absorptive capacity, regional specificities in terms of sectoral structure, and regional differences in innovation performance. First, an overall picture is provided by the latest UK Innovation Survey (CIS4), which is based on a representative sample of a large number of enterprises (over 16,000). Second, a more in depth exploration of different dimensions of firms’ absorptive

[2] For recent reassessments of the concept of absorptive capacity see Zahra and George (2002) and Doring and Schnellenbach (2006).

capacity and innovation performance at the regional level is undertaken using the 2004 Survey of Small and Medium-Sized Enterprises from the CBR (Centre for Business Research at the University of Cambridge), which provides a wider range of variables related to the characteristics and intensity of firms' absorptive capacity than that usually employed in the empirical literature (Schmidt, 2005; Zahra and George, 2002). Furthermore, the analysis incorporates complementary evidence based on in-depth case study analysis of thirteen companies included in the CBR data base.

This paper is organised as follows. Section 2 reviews the conceptual and empirical literature related to the concept of absorptive capacity. Section 3 provides a description of the data sets employed; while Section 4 discusses regional patterns of innovation across the UK. Section 5 presents the results of the empirical analysis: and Section 6 discusses the findings from the case study analysis. Section 7 summarises the findings and concludes by examining the implications for regional innovation policies.

2. The Absorptive Capacity Concept

The analysis of the processes of 'knowledge' concentration and the geographical distribution of innovative activities as determinants of regional differences of economic performance has blossomed in the last decade. This has generated new questions for policy makers on how to tackle the issue of regional disparities in growth rates (Breschi, 2000; Breschi and Lissoni, 2001; Martin and Sunley, 2006). Despite this growing interest, there is still no consensus around the conceptualisation and empirical assessment of the main determinants of regional differences in innovation and economic performance. Fractures arise in terms of both theoretical and methodological approaches and, as a consequence, on how to operationalise the assessment of the geographical heterogeneity in innovation and economic performance.

The concept of an 'innovation system', which first appeared in the beginning of the 1990s (Lundvall, 1992; Nelson, 1993), is now widely used (for a critical assessment of this literature, see, among others, Breschi and Lissoni, 2001; Cooke, 2001; Carlsson, 2004; Iammarino, 2005) and has become an appealing framework for policy makers, such that its advocates have been considered an 'epistemic community' (Sharif, 2006). This literature focuses on localised resources, localised institutions and the presence of an 'innovative milieu' which benefits from knowledge spillovers effects between firms and local institutions (Cooke, 2001). However, as argued by Doloreux and Parto (2004), it is hard to find a consensus on the geographical boundaries of a RIS. Furthermore, most of the literature is based on qualitative evidence, and it is crucial to provide sound empirical content, to enhance and facilitate the enormous policy potential of the RIS concept.

Since the seminal works of Cohen and Levinthal (Cohen and Levinthal, 1989; Cohen and Levinthal, 1990) and the widespread consensus around the propulsive role of 'knowledge' for innovative performance, the concept of absorptive capacity and knowledge spillovers has been widely employed at the level of firms and sectors (Cassiman and Veugelers, 2002; Schmidt, 2005; Veugelers, 1997), regions (Jaffe, Traijtenberg, and Henderson, 1993; Maurseth and Verspagen, 2002; Doring and Schnellenbach, 2006) and nations (Mowery and Oxley, 1995; Criscuolo and Narula, 2002; Narula, 2004; Kneller, 2005; Kneller and Stevens, 2006).

Absorptive capacity refers to the ability to assimilate and manage knowledge in order to improve innovation performance and competitive advantage. The concept, however, remains fuzzy, despite the burgeoning empirical literature trying to measure its various dimensions and attempting to relate it to more traditional innovation and economic performance indicators. In particular, it is commonly contended that greater absorptive capacity results in higher levels of intra-firm and inter-firm knowledge spillovers, where the latter also includes the transmission of knowledge between firms and other institutions such as universities and public research institutes. The empirical literature points to the importance of absorptive capacity when considering the mechanisms for knowledge transmission within a network of firms and other institutions. In this respect this literature shares some of the dimensions highlighted by the RIS literature mentioned above (Iammarino, 2005).

A number of empirical contributions have analysed the role of absorptive capacity at the firm-level (for a recent reassessment, see Zahra and George, 2002; Doring and Schnellenbach, 2006). Zahra and George (2002) employ all the dimensions used in the firm-level empirical literature and consider the process of acquisition, assimilation, transformation and exploitation of knowledge as all dimensions of absorptive capacity. Furthermore, they distinguish between 'potential' (acquisition and assimilation) and 'realised' (transformation and exploitation) absorptive capacity. Both aspects are important in assessing the magnitude of the absorptive capacity of firms, although they depend on different firm endowments and transmission channels. Potential absorptive capacity depends on the availability of relevant knowledge sources and the type of cooperation partners the firm has access to, while realised absorptive capacity depends on the degree of appropriability of the relevant technology.

A recent attempt to operationalise the concept of absorptive capacity at the firm level attempts to account for its multidimensional aspects (Schmidt, 2005). Building upon Zahra and George (2002) and drawing upon the evidence provided by the Mannheim Innovation Panel, Schmidt summarises the main dimensions of absorptive capacity and suggests appropriate indicators for such dimensions. A firm's ability to assimilate and exploit external knowledge relies not only on R&D expenditures but also on prior knowledge embodied in human capital and individual skills; organisational structure and management practices; and the type and intensity of interactions and cooperation with external partners (other firms, universities and other public institutions). Three different types of absorptive capacity are identified:

- Absorptive capacity for intra-industry knowledge (necessary to capture knowledge from sources within the firm's industry);
- Absorptive capacity for inter-industry knowledge (for knowledge originating in other industries);
- Absorptive capacity for scientific knowledge (for knowledge related to cooperation with universities and public research institutes).

The distinction between the three types of absorptive capacity is a useful categorisation, since different types of knowledge sources require different types of absorptive capacity for the knowledge to be successfully assimilated. Following much of the firm-level empirical literature on the role of absorptive capacity as a determinants of innovation and economic performance (Zahra and George, 2002; Schmidt, 2005), this analysis uses a range of absorptive capacity indicators that might affect the innovation performance of firms, and assesses whether the relationships are influenced by the location of firms and the sectors in which they operate. In addition to indicators of R&D, this analysis looks at the impact of other factors such as human capital, management practices and the use of networks. Different organisational structures and management practices allow an organisation to stimulate and organize the transfer of knowledge across functions and between individuals, and from external sources (Aghion and Tirole, 1994; Cosh et al., 2004, Lam, 2005). Human resource management can also stimulate learning through reward systems and training which increase absorptive capacities (Daghfous, 2004). Williamson (1967) has argued that information can be lost or distorted as it is transferred through different hierarchal structures. Human resource management systems should lead to a more efficient transfer of knowledge and, therefore, higher absorptive capacity.

The use of networks, external partners and collaboration with others (see, for example, Nonaka and Takeuchi, 1995 and Pittaway et al, 2004) can be used to access a wider range of skills, inputs and competences (see Kitson and Wilkinson, 2003). Porter (1998) has stressed that proximity improves the effectiveness of collaboration and there may also be regional variations in the effectiveness of networks and intermediary organisations (see Baxter et al, 2005).

3. Measuring Absorptive Capacity: The CBR and CIS4 Surveys

The UK Innovation Survey (CIS4), and the Small and Medium-Sized Business Survey 2004, carried out by the Centre for Business Research (CBR) of the University of Cambridge both provide data on the characteristics of the innovative behaviour of firms in the UK. The rationale behind the use of two different databases is to provide a comprehensive and detailed picture of the relationship between differences in firms' absorptive capacity, sectoral and regional specificities and firms' propensity to innovate. The CIS provides a wide range of innovation variables for a large sample of enterprises (over 16,000), representative of the population of UK firms and stratified by size, sector and region. The CBR data cover a smaller sample of small and medium-sized enterprises, stratified by size, but provides a wider range of variables which are particularly informative in terms of management practices, organisational innovation and characteristics of the firms' work-forces (see Cosh and Hughes, 2007). The two databases therefore complement each other and allow verification of the results of the empirical analysis using a variety of measures of the determinants of absorptive capacity. The following variables which are used in this analysis have been selected based on previous theoretical and empirical works as key indicators of absorptive capacity and as important determinants of innovative behaviour.

- R&D expenditure
- Human capital. CIS4 provides data on the proportion of employees educated to degree level or above. The CBR data is the share of employees engaged in R&D.
- Management practices. CIS4 provides information on whether the enterprises have adopted new management techniques during the period under consideration. The CBR data includes more detailed measures of innovative management techniques such as total quality management, quality circles, performance-related pay and job rotation.
- Types of collaborations according to the partners' localisation, such as whether the firm has co-operated with regional, national or overseas partners. The definition of partners

includes other enterprises (clients, suppliers or competitors), higher education institutions, consultants and government agencies.

In addition to these variables, a number of other factors are included that have been theorised to influence innovation directly:

- The markets within which firms compete: whether regional, national or international. One hypothesis is that firms that compete mainly in national and international markets may face greater pressures or incentives to innovate.
- The presence of obstacles to innovation (financial, knowledge, market related or other).

Furthermore, a serious of control variables are used to capture other possible factors:

- Sector – to reflect technological specificity
- Regions - to capture locational effects not picked up in other variables
- Age
- Size
- Whether the firm has claimed tax credit for innovation activities. This variable is available from both the CIS4 and CBR data sets.
- The presence of government support programmes for innovation activities. The CBR data set includes information on whether the firm has received RDA or Business Link advice, and the CIS4 data set includes a set of variables indicating whether the firm has received local government, national government or EU public support.

The empirical analysis uses probit estimation, using the propensity to introduce a product, service or process innovation as dependent variables.

The CIS4 data set also provides an interesting proxy of the outcome of absorptive capacity in terms of how innovation is carried out. The CIS questionnaire asks firms whether they have developed innovation exclusively within the enterprise, mainly within the firm but in collaboration with other firms and institutions, or mainly through adoption from other firms and institutions. This allows an analysis of the influence of the variables outlined above on the propensity of the innovative firm to develop the innovation autonomously, in collaboration, or mainly by adoption.

4. Regional Variations in Absorptive Capacity

Tables 1 and 2 report the main innovation indicators by UK region for the CBR and the CIS4 samples respectively. The two samples present some differences in the ranking of the most innovative regions. These differences are likely to be due to the different firms' size classes covered by the two data sets, the different sectors covered in the two surveys (the CBR data is limited to manufacturing and business services), as well as to the sampling stratification issue raised above.[3]

In the CBR data the East Midlands and two of the Northern regions (North East and Yorkshire and Humberside) are those with highest percentage of innovative firms. Surprisingly, the regions in the Greater South East (London, Eastern and the South-East) only perform close to or below the national average although this result masks differences across different types of innovation. The CBR data indicates that firms in London, Eastern and Scotland were more likely than firms in other regions to introduce a service innovation, while firms in Eastern, Yorkshire and the South West were more likely to engage in process innovation. Goods innovation was particularly high in the North-East and Scotland.

According to the CIS4 data set, the regions of London, the South East and the East Midlands are, in general, the most innovative. When looking at the breakdown by type of innovative activity, the Eastern region, together with the Midlands and the North East performed best in terms of goods innovation, while London, the South East and the North East performed best in terms of service innovation. Rates of process innovation are greatest in the East and West Midlands, the South East, the North East and Northern Ireland.

Differences across regions also emerge when looking at the sectoral breakdown of innovation indicators using a classification based on Pavitt (1984), which was later extended to include

[3] In particular, CBR data covers firms from 1 to 499 employees, whereas CIS covers firms from 10 employees upwards.

services (Kristensen, 1999; Miozzo and Soete, 1999). Pavitt's sectoral classification distinguishes between high-tech sectors which supply the rest of the economy with technology ("science based" and "specialised suppliers"), high-tech sectors which are relatively innovative but have less of an impact on the rest of the economy ("scale intensive"), low-tech sectors that are mainly technology using ("supplier dominated" and "primary") and low- and high-tech service sectors.[4] Table 3 reports the main innovation indicators by Pavitt sectors for the CIS4 data set, and Table 4 reports innovation rates across Pavitt sectors and meta-regions (Greater South East, Middle England, Northern Way and Rest of the UK).

The sectoral breakdown of innovation indicators in the CIS4 sample (Table 3) shows that the specialised suppliers, science-based and KIBS sectors perform best in terms overall of innovation output. The specialised suppliers and science based sectors also have the highest percentages of goods innovation, while the information intensive and KIBS sectors dominate in terms of service innovation.

Table 4 reports the percentage of innovative firms broken down by Pavitt sector and by meta-region. The hypothesis of a specific sectoral structure advantage of the GSE is supported by the data, as the percentage of innovative firms belonging to the most innovative macro-sectors (specialised suppliers, science-based and KIBS) is higher in the GSE. Overall, the descriptive evidence suggests the presence of regional differences in innovation (particularly in the science-based and information intensive sectors) and that the hypothesis of the presence of a specific regional structure advantage needs to be explored in more depth, though we do not focus on this issue in the present paper.

---

[4] Primary includes mining and quarrying; Science Based includes the branch of chemicals; Specialised Suppliers includes the branch of machinery; Scale Intensive includes food, beverage and tobacco; metals; transport and communication; construction, electricity, gas and water; Information Intensive includes the branch of financial intermediation; KIBS includes R&D, computer and related, business services; Supplier Dominated includes textiles, clothing and leather; wood, paper and pulp; manufacturing n.e.c.; Traditional Services includes hotels and restaurants; real estate and renting of machinery; wholesale trade and repair of motor vehicles; retail trade.

5. Innovation and Absorptive Capacity: Multivariate Analysis

Absorptive Capacity as a Determinant of Innovation

The results of the multivariate probit estimations carried out using CBR and CIS4 data, are shown in Tables 5 and 6. The dependent variable is a dummy indicating whether a firm introduced a goods product, service product or process innovation. The CBR data also allows the distinction to be made between goods and service process innovation.[5]

The empirical model is a multivariate probit, which allows the binary dependent variables to be correlated. For instance, in the case of the CBR results presented in Table 5, the model allows for the possibility that a firm might be more likely to engage in goods process innovation if it has also introduced a goods product innovation. Allowing for correlation across the dependent variables improves the efficiency of the estimates (Greene, 2003, pp. 174-175). The results indicate that the dependent variables are correlated, justifying the use of the multivariate probit estimator. The coefficients in Tables 5 and 6 are the marginal effects of a change in each explanatory variable on the probability of introducing an innovation.

The results of the empirical analysis are broadly supportive of the hypotheses discussed in Section 3. For instance, the literatures suggest that a higher proportion of staff employed in R&D will result in a higher rate of innovation, particularly in goods product innovation and the results in Table 5, based on CBR data, support this hypothesis. The results show that the presence of a larger share of R&D employees is associated with a positive effect on goods product innovation, though not on service product or process innovation. Conversely, R&D expenditure per employee, has no statistically significant association with the propensity to

[5] The CIS4 questionnaire refers to the introduction of a "good" or service product, whereas the CBR questionnaire refers to the introduction of a "manufactured" or service product (and makes a distinction between manufacturing and service process). For consistency we use the CIS4 terminology, and refer to goods (product), service (product) and process innovation.

innovate, suggesting that it is the number of employees rather than expenditure on R&D that has the greatest effect on innovation. This is consistent with the predictions of the absorptive capacity literature, where it is argued that R&D employees play a dual role; they contribute directly to innovation but also help to build up the firm's absorptive capacity, which contributes to making innovative activities more productive (Cohen and Levinthal, 1989, 1990).

These results are consistent with further findings using the CIS4 data, which are shown in Table 6, and which use the share of employees educated at the degree level (in science and non-science subjects, respectively) as a measure of human capital. The CIS4 results indicate that employing staff with a science degree significantly raises the probability of introducing a goods product or service product innovation. An increase in the share of staff with a degree in a subject other than science is associated with a positive increase in service product innovation, but not in goods product or process innovation.

The results based on the CBR data also indicate that training is an important component of innovative activity, although it is the training of non-scientific staff that is crucial for goods product innovation. In particular, the results show that the training of non-scientific staff is associated with a 14% increase in the probability of introducing a goods product innovation.

The use of new management techniques is often significantly associated with a higher level of service and process innovation (Table 6), although the composite measure has a negative association with goods innovation in the CIS4 data. This result, however, masks differences across different types of management techniques. Using the more detailed variables available from the CBR database, as shown in Table 5, indicates that the introduction of quality circles or job rotation are positively associated with goods product and goods process innovation with the effect being in the order of an increase of 10% in the probability of introducing an innovation. Service innovation is positively affected by total quality management techniques; the introduction of these techniques is associated with a 10.5% higher probability of introducing a service product innovation.

The association between collaborative behaviour and innovation is also important, a result that is confirmed by both the CIS4 and CBR data.[6] Table 5 shows that local collaborations are important for goods innovation (particularly goods process innovation), as are overseas collaborations. National collaborations, on the other hand, are most important for service innovation. The use of national collaborations is associated with a 14% increase in the probability of introducing a service innovation and is associated with a 9% increase in the probability of introducing a service process innovation). These results are broadly supported by the CIS4 regressions shown on Table 6, although the latter also indicate that national collaborations are important for all types of innovation.

With respect to the impact of policy, the results indicate that the R&D tax credit has a positive and statistically significant association with an increase in goods innovation, but not with service innovation. This result is also consistent with the evidence collected as part of the case study analysis, discussed below in Section 6. As shown in Table 5, the claiming of the R&D tax credit is associated with an increase of almost 23% in the probability of introducing a goods product innovation, and is associated with an increase of almost 14% in the probability of introducing a goods process innovation (the latter perhaps reflecting that firms that undertake product innovation also undertake process innovation). The results using CIS4 data broadly confirm these findings: Table 6 shows that claiming the R&D tax credit raises the probability of goods product innovation by 13%. Overall, these findings should be treated with caution as there are major issues in assigning causality. In particular, it may be the case that the propensity to innovate is not influenced by the availability of tax credits but those firms that do make R&D expenditures do, as rational behaviour suggests, claim the tax credit (see the discussion of the case study evidence below).

[6] There are differences in the definition of 'local' collaboration in the two data base. In the CBR questionnaire a 'local' collaboration is intended to be within 10 miles, whereas in CIS is within 100 miles.

With regards to government advice and public innovation policy, the results indicate that business advice from the Regional Development Agencies (RDAs) has had no statistically significant association with a change in innovation behaviour, whilst the CBR data indicates that the Business Link programme only has a positive association with goods process innovation.[7] The more general measures of public support in the CIS4 data set suggests that local public support is positively associated with an increase in service innovation, while national government support has a positive association with an increase in both goods product and goods process innovation. The results also indicate that EU public support is associated with a negative effect on product innovation. Again care should be taken in interpreting this finding - it may reflect that EU support is closely linked to the level of development of the region in which the firm is located, with less developed regions receiving the most support. Since less developed regions may be less innovative, EU public support may be associated with regions with low levels of innovation.

The results for the additional innovation variables included in the analysis are in line with previous findings in the innovation literature discussed in Section 2. Table 6 shows that higher levels of innovation are associated with the perception of firms that there are obstacles to innovation. This is a result that it consistent with analysis of earlier CIS surveys (Iammarino et al., 2007). This result is replicated in the CBR regressions (Table 5), although only in terms of a lack of available skilled labour on service process innovation. The presence of other obstacles to innovation has no statistically significant association with changes in innovation behaviour.

The CBR regressions also indicate that competing in international markets increases the probability of introducing a goods product innovation by almost 21%. The probability of introducing a goods product innovation is also higher for firms competing in the national market (the omitted category being the local market). These results are supported by the CIS4

---

[7] This result may reflect different rates of market penetration across sectors, see Bennett (2007).

regressions shown on Table 6; competing in a national or international market is associated with an increase in all types of innovation.

One of the hypotheses of this study is that differences in absorptive capacity and sectoral specificities can, to a large extent, explain regional differences in innovative performance. Our results confirm this hypothesis, after controlling for different measures of absorptive capacity and sectoral differences, none of the regional dummies are statistically significant in the case of the CBR regressions, while only London is significant in the CIS4 regressions, and then only for goods product and process innovation. The lack of significance of the regional dummies suggests that there are little or no purely locational variations in innovation behaviour apart from the variations that are due to the regional differences in the independent variables.

With regards to the sectoral differences, the dummies for the science-based, specialised suppliers, supplier-dominated and information intensive sectors are positive and statistically significant for the goods product and process innovation, but negative for service innovation, indicating that firms in these sectors are more likely to introduce a goods innovation and less likely to introduce a service innovation than a firm in the KIBS sector (the reference category). The regressions using CBR data (Table 5) also indicate that firms in traditional services sectors are less likely to introduce a service innovation and more likely to introduce a goods innovation than firms in the KIBS sector.

Open and Closed Innovation

There is now increasing emphasis on innovation as an ‘open’ process where firms use both internal and external sources of ideas and deploy multiple business models to improve corporate performance (Chesborough, 2003). This paradigm contrasts with the previously dominant ‘closed’ approach where firms relied on internal resources, and in particular the controlled environment of the corporate laboratory. As discussed in Section 3, questions 6 and 10 of the CIS4 questionnaire ask firms to indicate whether they have developed an innovation mainly within the firm, mainly in collaboration with other firms and institutions or mainly by adopting it from elsewhere[8]. It is, therefore, possible to test the effect of absorptive capacity on the probability of firms to use a 'closed' or 'open' strategy to innovate. A 'closed' innovation strategy is based on developing innovative products and processes mainly within the firm, whereas an 'open' strategy results from collaborations with other firms, institutions and customers. This distinction cuts across the concepts of 'potential' and 'realised' absorptive capacity (Zahra and George, 2002). Here the effect of absorptive capacity, as measured by the regressors described in Section 3, on firms' open versus closed innovation behaviour is analysed, and the results reported in Tables 7 and 8, which refer respectively to the probability of developing a product and process innovation. In Tables 7 and 8, the first column refers to innovation mainly within the firm ('closed' innovation strategy), the second to innovation mainly in collaboration ('open' innovation strategy), and the third to innovation mainly elsewhere and adopted by the respondent (innovation by 'adoption').

The analysis shows that different innovation strategies use different forms of absorptive capacity. Employment of scientists is important for product innovation by closed innovators. This is consistent with the notion that closed innovators require internal capacity whereas open innovators utilise technical ideas, skills and competences from outside the firm. Conversely, the employment of staff with a non-science degree is important for open innovators but is not important for closed innovators or adopters. This suggests that high levels of human capital are important for the open innovation process to facilitate the acquisition of ideas and practices from outside the firm.

Investment in training activities is positively correlated with the probability of developing innovation of all types, although the coefficients are highest for open innovators and lowest for adopters. This is consistent with the notion that closed innovators depend on internal competences whereas open innovators can utilise capabilities from outside the firm. The low

---

[8] This section is based on CIS4 data only as the CBR data does not allow the distinction to be made between open and closed innovation.

level of training for adopters can be explained by the relatively low levels of skills which may be required where innovation is a relatively passive process.

The adoption of organisational changes, such as changes in the organisational structure and the introduction of new marketing strategies, is positively and significantly related to the probability of developing closed innovation both in terms of products and processes. The adoption of new management techniques and marketing strategies increase the probability of carrying out process innovation, both in terms of closed and open innovators – although the effects are larger for the former Interestingly, organisational innovations emerge as having no correlation, or even negative in the case of changes in organisational structure, with adoptive innovative behaviour.

The results also indicate that collaborations at the national level are important for both product and process innovation, across all types of innovation strategies. The estimated effect is greatest for innovation in collaboration; the probability of introducing a product innovation is higher by 3.9 percentage points if the firm engages in national collaborations, and higher by 6.5 percentage points for process innovation. The effect of collaborations developed at the local level is positive for open innovators but not for closed innovators. As expected, the importance of both local and national collaborations is far more important for open innovators than for closed innovators or adopters. Tables 7 and 8 also show that establishing overseas collaborations has no statistically significant effect on the probability of developing a product or process innovation within the firm or in collaboration with other firms, but had a negative effect on developing a process innovation by adoption. This result may be interpreted as a negative correlation between the probability that a firm has an overseas network and the probability that it is a passive adopter.

The geographical extent of the destination market has a significant association with the probability of developing a closed innovation, for both product and process innovation; firms serving international markets are likely to be the most innovative. It also has a positive association with the probability of developing an open innovation in collaboration, although this result is confined to product rather than process innovation and the size of the effect is smaller compared to closed innovators. The location of markets has no statistically significant effect on the innovation behaviour of adopters.

Claiming the R&D tax credit has a strong positive effect on the probability of developing product innovation within the firm, but has a negative effect on the probability of developing innovation ‘openly’ (or by adoption) and no effect of on the probability of developing process innovation of any kind. This may be explained by low R&D expenditure by open innovators who may use inputs from others who have incurred R&D and other innovation expenditures

Strong sectoral specificities emerge for closed innovators - both for product and process innovation - whereas the tendency to develop open innovation or to adopt innovation from elsewhere turns out to be reasonably homogeneous across sectors (using Pavitt-based sectoral dummies). As expected, the macro-sectors which show a higher probability to use closed innovation (as compared to our reference KIBS) are the science-based, the specialised suppliers and supplier-dominated sectors.

Turning to the regional differences, the results show that no unexplained regional specificities remain, as the coefficients of the regional dummies are not significant in any of the estimations. The results, based on the CIS4 data, show that the indicators of absorptive capacity and other control variables explain all the regional differences in innovation across UK.

6. The Case Study Evidence

Selection of Cases: Rationale and Methodology

The econometric analysis outlined in the previous section provides a snapshot of the effect of various absorptive capacity factors on the innovative output of firms. However, absorptive capacity is a path dependent and cumulative phenomenon (Cohen and Levinthal, 1989, 1990). It is, therefore, critically important to understand the processes through which absorptive capacity evolves or is constrained; how conditioning factors interact; what is the role of key players; and whether local institutions, networks and policies make a difference? To address these questions, the econometric analysis is complemented with a case study approach. Furthermore, results from the case studies provide data to verify the choice of independent variables in the multivariate analysis above.

The multiple-case design is based on a 2x2 innovation matrix, as shown in Figure 1, where four types of innovation patterns are considered along the two axes. The horizontal axis indicates whether a firm is involved in any collaboration activity for the purposes of innovation, while the vertical axis indicates the position of the firm in terms of R&D employees as a share of total employment. Put another way, the position of a given company within this matrix indicates the way it tries to strike a balance between internal capabilities and external opportunities to drive its innovation activity. The main focus of the case study research is to investigate how various absorptive capacity components are generated, accumulated and deployed by the firms across the innovation matrix quadrants to achieve their innovation targets.

To populate the matrix quadrants, 13 firms were selected from the CBR survey database[9]. They were approached and interviewed using a semi-structured questionnaire covering a number of absorptive capacity related issues such as R&D activities, employees' knowledge and skills, organisational structure and human resource management, as well as innovation activity characteristics, the role of external players, location and geography of collaboration.

Innovation Behaviour Patterns within the Quadrants

Tables 9 and 10 provide some basic information on the case study firms. The "high R&D and collaboration" group included two manufacturing companies (M1 and M2) from the semiconductor and organic chemicals sectors and one service-sector company (S1) specialising in software supply. In responding to the CBR questionnaire these firms indicated their involvement in different types of product and process innovation, with all the three having identified themselves as those introducing the goods product innovation which was new to the firm and the industry. Face-to-face interviews with CEOs of the respective firms provided some examples of how they viewed their innovation activities: M1 took advantage of its novel proprietary technology to supply integrated circuits into fibre-optic modules for the communications industry; M2 offers novel pharmaceutical intermediaries; and S1 has developed an overarching framework for how multiple technologies such as smart cards and

[9] An advantage of the CBR data is that allows further research into the individual firms in the database. This is not normally possible with other databases, such as CIS.

public key infrastructure and physical access systems need to be managed and consolidated from a single point.

The “high R&D and collaboration” group appears to benefit from iterative and interactive patterns of innovation. It is external sources for innovation such as market, customers and suppliers that play important role as sources for innovation for the firms within this group. Furthermore, an internal ability to understand and exploit these sources is also of great importance.

“…we study what our clients are doing, what they are buying and then we think about that, consider the literature, what the state of the world’s knowledge is and see how we can use or develop that within the company understanding what we believe our customers like and where we think they are going” (M2).

The “high R&D and no collaboration” group identified from the CBR database comprised two manufacturing firms (M3 and M4) from the semiconductor and medical instrument sectors; and two service sector companies (S2 and S3) providing consultancy in the field of architecture and engineering related activities. All the firms reported a wide range of innovation activities, with three of the four companies being involved in service product innovation that was new to the firm and industry (Table 10). Among the examples of innovations mentioned by the CEOs, were improving on a technology initially introduced by Apple (M3); transforming a large laboratory based medical device into a hand held unit available to patients in primary care and eliminating the need to attend a hospital to have tests (M4); application of novel information and visualisation technologies to develop significantly improved architecture and planning related service products (S2); and creating and developing new steel-related technologies, products and software for clients (S4).

Within the “high R&D and no collaboration” group the pattern of innovation tends to be linear. The firms are technology-led and their interactions with customers commonly only take place at the final stages of delivery. “We come up with the ideas and then make them theirs (customers’), so it’s not that much external” (M3). Similar to the previous group, both external and internal sources of innovation are highly valued by the firms, however, internal innovation capabilities appeared to be ranked higher by these firms compared to other sources of innovation.

The “no R&D and collaboration” group covered three service sector companies (S4, S5 and S6) providing management, technical, software and engineering consultancy. Similar to the previous case, the firms reported various types of innovations in the CBR Survey. The examples of innovation given by the CEOs were mainly concerned with developing software programmes and products in response to clients’ needs (S4); creating greater diversity of “front end” engineering services (S5); taking and putting together pieces of IT ideas and technologies in a way which is innovative, in a way that other people have not used” (S6).

Innovation activities in the “no R&D and collaboration” group were shaped through firms’ understanding of customers’ needs, positioning for those needs and respective training and developing of staff. “The skill is to spot what will be acceptable to customers, appeal to customers and will create a market” (S5). To some degree, innovation behaviour of these firms corresponds to that from the “high R&D & collaboration” group. However, instead of R&D personnel being the key factor of internal innovative capabilities, it is improved human capital, in the form of innovation related training and ICT, that plays an important role for these firms in order to succeed with their proactive innovation approach.

The “no R&D and no collaboration” group included three service sector firms (S7, S8 and S9) specialising in software supply, computer related activities and business services. Unlike other groups, innovations reported by the firms in this group were mainly new to the firm only. The innovation activities included bringing to the business advice industry new technologies and practices from other sectors and fields (S7); pioneering computerisation of distribution systems (S8); and developing protocols and systems for the internet (S9). This group of firms can be defined as reactive innovators responding mainly to external demands by customers, consultants and technical standards. Again, use of ICT, staff training, knowledge management, technical problem solving and even sporadic R&D were the mechanisms used to boost and sustain innovation activities.

Across-Quadrant Dynamics and Absorptive Capacity Indicators

It is worth emphasising that the case study typology was designed and populated using the respondents to the CBR Survey in 2004. Part of the value of conducting the interviews was to investigate whether there were any noticeable changes since 2004 in terms of R&D employees and collaboration activities within and/or between the groups. It was found that the R&D employees ratio appeared to remain relatively stable for all the firms concerned across all the quadrants, even though some minor fluctuations of this ratio were reported by some firms due to either the project-based nature of their activities or redistribution of human resources to achieve, for instance, marketing targets.

As far as collaboration activities for innovation are concerned, some interesting developments were observed. Some of the firms identified as engaging in “no collaboration” in 2004 are now trying to collaborate for innovation purposes. Some have been approached by local and national universities which might indicate the impact of the government measures to promote commercialisation of university research. However, it is mainly internal reasons rather than external pressures that have encouraged firms to collaborate for innovation. Some of the firms have become much more market-focused than they used to be; others seem to be unsatisfied with the way they exploit their innovation potential and they are now trying to deploy new knowledge management systems through collaborations with universities.

In terms of Figure 1, there appear to be no signs of vertical movements of the firms between quadrants, whereas there is some clear evidence on initially no-collaboration firms moving horizontally towards the collaboration quadrants (see Figure 2). The evidence concerning the geography of networking for innovation purposes revealed some interesting patterns. Most of the firms are extensively involved in different kinds of industry, professional and business networks at the regional, national and international levels. Innovation-related benefits from participating in regional networks, however, seem to be limited and are mainly related to obtaining general information on the activities of other organisations and firms in the area. Occasionally, some firms saw opportunities for innovation-related collaboration resulting from local and regional networking. What appears to be particularly valued by the firms across all quadrants, is their participation in national and international networks of a technical and professional nature. It is these networks that seem to provide “significant business leads and introductions” which facilitate product or process innovation.

The path-dependent or cumulative nature of absorptive capacity is often explained in terms of prior knowledge, experience and staff skills, which are thought to facilitate the use of knowledge (Schmidt, 2005) which is an important input to innovation. Given that all the cases investigated are related to innovating firms only, it was not surprising to find that the firms had acquired prior knowledge about their industry and/or core technology. This prior knowledge was obtained through a variety of channels such as the founders’ background and networks, workforce composition and learning from business partners. Across all the quadrants, employees in the firms have a high general level of education and the firms are well aware of the importance of staff training for innovation, and they provide either in house training or sending workers on external courses. The training budgets, however, tend to be small. Another related area where the firms believe they have sufficient expertise is in recruitment capabilities. They tend to be very selective and deploy recruitment channels that are specifically tailored to the firm's needs. Among such channels are specialised recruiters, recruitment agencies, word of mouth, referrals, contacts with universities, large-scale advertising and incentivising staff to approach potential recruits.

Following Cohen and Levinthal (1989 and 1990) and Schmidt (2005), a firm's absorptive capacity is not just the sum of its employees' knowledge and skills but also includes the way the firm organises the transfer of knowledge across departments, functions and individuals. It was interesting that all the firms, across all the quadrants, are familiar with, and trying to implement, a wide range of organisational structures and management techniques to stimulate knowledge exchange and boost innovation activities. The firms appear to be concerned with building up a strong corporate culture, a "one team" or "integrated company" culture supported by open workplace layouts to maximize learning and interaction among the personnel. The firms organise a significant number of internal workshops, seminars and presentations, which may involve senior management, to ensure that any available knowledge on developments within the industry and other relevant issues are disseminated through the organisation. Job rotation is widely used, but is understood and implemented by the firms as functional rotation exposing workers to different technologies, disciplines and perspectives and contributing to training. Total quality management practices are commonly introduced as a marketplace requirement. The firms are reluctant to set up a separate reward system for those who engage in product or process development, as this is expected from staff as part of their job specification. Most of the firms in the sample try to incorporate knowledge accumulation and sharing aspects into so-called career and knowledge objectives, continued professional development requirements, personal development plans and skill matrices.

Lack of finance and shortages of skilled labour were reported as the main barriers to innovation by most of the firms. Both barriers were thought to have national, rather than local, origins. Even though the firms acknowledged that there might be some location-specific factors which may hamper innovation - such as the level of infrastructure development, the composition of local labour market and the attractiveness of place - they were reluctant to attribute a decisive role to these factors.

Government policies to facilitate innovation in UK businesses seem to bring more benefits to manufacturing companies compared to those in the service sector. For instance, the widely debated R&D tax credit scheme is much appreciated by the manufacturing companies interviewed. They find it useful and easy to access, even though “it costs a lot of money for them to do all the filings and justifications”.

“There is some work we would not be able to do… would not be able to take the sorts of risks we currently take without having that sort of subsidy”. At the same time, some note “while we have not found it difficult to obtain R&D tax credits, the amount received has only been small (but still meaningful and gratefully received), and when we do make a profit this has greatly reduced the amount we receive! Thus if you are successful in making a profit the support for research activities is removed”.

It should be stressed, however, that access to R&D tax credits had no direct impact on the decision to innovate – this finding is consistent with other case study research (Kitson, 2005).

The service sector companies studied find it very difficult to qualify for R&D tax credits. Most applications of those who have tried were rejected. Some have had to resort to professional accounting firms to negotiate an acceptable settlement, but “that meant they had to pay 20% of that settlement to the accounting firm”[10].

Overall, the case study analysis provides support for the choice of absorptive capacity variables used in the multivariate analysis; it suggests that the statistical associations identified above are robust causal mechanisms. Furthermore, it shows at the level of the firm, the complex interactions between the various determinants of absorptive capacity. Additionally, it suggests that R&D may be a partial and incomplete indicator of innovation as many of the firms that did not engage in significant levels of R&D were producing innovative outputs.

[10] The R&D tax credit allows companies to deduct up to 150% of qualifying expenditure on R&D activities when calculating their profit for tax purposes. SMEs can, in certain circumstances, surrender this tax relief to claim payable tax credits in cash from the HM Revenue & Customs. For further information see: www.hmrc.gov.uk/randd/

7. Conclusions and Implications for Policy

This research, using complementary data and complementary research methods, shows that different forms of absorptive capacity are associated with good, service and process innovation. The use the CIS4 allows analysis of large dataset, whereas analysis of CBR data allows a more detailed and disaggregated examination of those factors that may influence absorptive capacity. The case study analysis provides support for the multivariate analysis as it provides evidence that the independent variables, which were selected based on theory and previous studies, are appropriate indicators of causal mechanisms. Research based on a single methodology will always encounter limitations (eg identifying causation in multivariate analysis or the problem of sample size and statistical significance with case studies). The use of a multiple methodology approach helps to reduce such limitations and allows the cross-verification of findings.

Analysis of the CBR data shows that employing workers engaged in R&D is associated with a significant increase in innovation, particularly for manufactured goods. Conversely, R&D expenditure per employee has no statistically significant association with the propensity to innovate. This is important as it is R&D *expenditure* that is supported by Government policy, through the R&D tax credit, and not *employment* of staff engaged in R&D (although a large share of R&D expenditure comprises labour costs). Evaluating the impact of the R&D tax credit, in particular its additionality, is not an easy task. Although the multivariate analysis suggests a strong association between claiming the tax credit and innovation in manufacturing, the underlying causal mechanisms are not transparent. The case study analysis suggests that the benefit of the tax credit was that it improved cash-flow or net profits, but the decision to innovate was not directly influenced by the policy. Furthermore, the multivariate analysis suggests no relationship between innovation in services and the tax credit. The case study work and other research (NESTA, 2006) suggests this may be because many services sectors firms innovate by investing in inputs which are not classified as traditional R&D.

Overall, the evidence from the CBR data indicates that innovation requires the appropriate human capital. As the CBR data is based on employees engaged in R&D, this could reflect either of the ‘two faces’ of R&D – that is, these workers both undertake R&D and increase the firm’s absorptive capacity as they are able to assimilate and manage knowledge from outside the firm. The importance of the a latter is more clearly identified by the CIS data which shows that it is the share of employees with a science degree that significantly increases the probability to innovate. This strongly suggests the importance of human capital in raising absorptive capacity.

New management practices have a significantly positive association with increased innovation. The detailed decomposition of the CBR data shows that the different types of management practices are appropriate for different forms of innovation. A particular concern is the suggestion that the UK is slow to adopt new management techniques (Bloom and Van Reenen, 2005; EEF, 2001; McKinsey, 2002; Porter and Ketels, 2003) as this will slow the innovation process. What is needed is a better understanding of how different types of management practices encourage the innovation process and what are the barriers to a quicker and more widespread implementation of such practices.

The results also indicate that training is an important component of innovative activity, although it is the training of non-scientific staff that is crucial for goods and service product innovation. Overall, the evidence suggests that the training of scientists within the firm is not necessary to improve innovation performance. In particular, it is the training of managers that is important for innovation in the service sector. What is required, however, is further analysis of the types of training that are most effective – for instance do mangers benefit from better general management training or by more scientific training to improve their understanding of technology? (on the latter see, Oliver and Runde, 2006).

The association between collaborations and innovation is also important, a result that is confirmed by both the CIS4 and CBR data. The results show that national and overseas collaborations have a substantial relationship with goods product innovation, while national collaborations are most important for service innovation. Local collaborations have some significant associations with different types of innovation but in general they are not as important national and international collaborations. This suggests that the current policy focus in UK and its regions to develop local networks might be too narrow in scope and possibly detrimental in some sectoral and regional contexts. Much of the policy builds on the work of Porter who has stressed the importance of clusters which are:
'geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries, and associated institutions (for example universities, standards agencies, and trade associations) in particular fields that compete but also co-operate.' (Porter, 1998, p.197)

Furthermore, Porter argues that:

‘A cluster is form of geographic network that occurs within a geographic location, in which the proximity of firms and institutions ensures certain forms of commonality and increases the frequency and impact of interactions.’ (Porter, 1998, p, 226)

The limitation of Porter’s analysis is that it is based on mapping where firms are and not analysing what firms do. The focus on geographic concentrations that collaborate and that proximity increases the impact of interactions is misleading. The analysis of firms’ behaviour shows that the geographies of collaborative behaviour are multiple and that local collaborations and the use of local networks are only part of a series of relationships. It is important to distinguish between ‘bonding’ and’ bridging’ networks – the former may be based on frequent interaction at the local scale whereas the latter are outward looking and link geographically diverse economic actors and institutions. The latter may be more important for knowledge based activity especially when accessing specialised knowledge that is unlikely to be available locally.

A range of factors have been identified as important in determining the innovation behaviour of firms in the UK. One of the most important is the sector within which firms operate. The results of this analysis show that industry specific effects are large and significant whereas regional specific effects are not significant. This does not mean that there are no regional variations in absorptive capacity, as such variations are captured by the regional variations in those variables that drive absorptive capacity such as employment, management practices, training and the use of collaborative networks. The importance of industry specific effects shows that the innovative performance of a region will, in large part, be determined by its industrial composition. This has important implications as regional industrial structures evolve and develop slowly. As such, the innovation and growth performance of regions are likely to vary because of differences in industrial structure - and imposing similar performance targets for different regions is setting unrealistic expectations.

References

Aghion, P. and Tirole, J. (1994), ‘The Management of Innovation’, *The Quarterly Journal of Economics*, 109, 4, pp.1185-1209.

Athreye, S., and D. Keeble (2002), ‘Sources of Increasing Returns and Regional Innovation in the UK’, *Regional Studies*, 36.4, 345–357.

Baumol, W. (1967), ‘Macroeconomics of Unbalanced Growth: The Anatomy of an Urban Crisis’, *American Economic Review*, 57, 415–426.

Baxter, Tyler, P, Moore, B, Morrison, N, McGaffin, R, Otero-García, M and Poteete J (2005), ‘Policy and Encouraging Places: Encouraging Technology Based Development’, The Cambridge-MIT Institute, Programme on Regional Innovation Competitiveness Reports.

Bennett, R. J. (2007), ‘Government local and regional support for SMEs and Business Link’, in A. Cosh and A. Hughes (eds.), *British Enterprise: Thriving or Surviving? SME Growth, Innovation and Public Policy, 2001-2004,* Centre for Business Research, University of Cambridge.

Bloom, N. and Van Reenen, J. (2005), ‘Measuring and Explaining Management Practices Across Firms and Countries’, Advanced Institute of Management, Anglo-German Foundation and Economic and Social Research Council.

Breschi, S. (2000), ‘The Geography of Innovation: A Cross-sector Analysis’, *Regional Studies*, 34 (3), 213–229.

Breschi, S., and F. Lissoni (2001), ‘Knowledge Spillovers and Local Innovation Systems: A Critical Survey’, *Industrial and Corporate Change*, 10(4), 975–1005.

Cainelli, G., R. Evangelista, and M. Savona (2006), ‘Innovation and Economic Performance in Services. A firm-level Analysis’, *Cambridge Journal of Economics*, 30, 435–458.

Carlsson, B. (2004), ‘Innovation Systems: A Survey of the Literature from a Schumpeterian Perspective’, Paper for the International J.A. Schumpeter Society Conference, Milan, Italy.

Cassiman, B., and R. Veugelers (2002), 'R&D Cooperation and Spillovers: Some Empirical Evidence from Belgium', *American Economic Review*, 44 (3), 1169–1184.

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

Cohen, W. M., and D. A. Levinthal (1989), 'Innovation and Learning: The Two Faces of R&D', *The Economic Journal*, 99 (397), 569–596.

Cohen, W., and D. Levinthal (1990), 'Absorptive Capacity: A New Perspective on Learning and Innovation', *Administrative Science Quarterly*, 35 (1), 128–152.

Cooke, P. (2001), 'Regional Innovation Systems, Clusters and the Knowledge Economy', *Industrial and Corporate Change*, 10 (4), 945–974.

Cosh, A., Fu, X. and Hughes, A. (2004), 'Innovatability of small and medium enterprises and its determinants: evidence from UK survey data'. Centre for Business Research, University of Cambridge, mimeo.

Cosh, A and A. Hughes (eds) (2007), British Enterprise: Thriving or Surviving? SME Growth, Innovation and Public Policy, 2001-2004, Centre for Business Research, University of Cambridge.

Criscuolo, P., and R. Narula (2002), 'A Novel Approach to National Technological Accumulation and Absorptive Capacity: Aggregating Cohen and Levinthal', Discussion paper, MERIT Infonomics Research Memorandum 2002-016.

Daghfous, A. (2004), 'Absorptive Capacity and the Implementation of Knowledge-Intensive Best Practices', *SAM Advanced Management Journal*, 69 (2), pp. 21-27.

Doloreux, D., and S. Parto (2004), 'Regional Innovation Systems: A Critical Synthesis', Discussion paper, United Nations University INTECH Institute for New Technologies Discussion Paper Series.

Doring, T., and J. Schnellenbach (2006), 'What Do We Know about Geographical Knowledge Spillovers and Regional Growth? A Survey of the Literature', *Regional Studies*, 40.3, 375–395.

DTI (2003), Competing in the Global Economy: The Innovation Challenge, DTI Innovation Report.

Edquist, C. (2004), 'Systems of Innovation - A Critical Review of the State of the Art', in *Handbook of Innovation*. Oxford University Press.

EEF (2001), Catching up with Uncle Sam - EEF final report on UK and US manufacturing productivity, Engineering Employers Federation , London.

Feldman, M. P. (1999), 'The New Economics of Innovation, Spillovers and Agglomeration: A Review of Empirical Studies', *Economics of Innovation and New Technology*, 8, 5–25.

Freel, M. S., and R. T. Harrison (2006), 'Innovation and Cooperation in the Small Firm Sector: Evidence from 'Northern Britain', *Regional Studies*, 40.4, 289–305.

Greene, W.H. (2003), *Econometric Analysis*, Fifth Edition, Prentice Hall, New Jersey.

Henley, A. (2005), 'On Regional Growth Convergence in Great Britain', *Regional Studies*, 39.9, 1245–60.

HM Treasury (2000), Productivity in the UK: The Evidence and the Government's Approach, HM Treasury: London

HM Treasury (2005), Supporting Growth in Innovation: Enhancing the R&D Tax Credit, July, HM Treasury: London

HoL (2003), 'Science and the RDAs: SETing the regional agenda', House of Lords Select Committee on Science and Technology, 5th Report Session 2002-2003.

Iammarino, S. (2005), 'An Evolutionary Integrated View of Regional Systems of Innovation: Concepts, Measures and Historical Perspective', *European Planning Studies,* 13(4), pp. 495-517.

Iammarino, S., F. Sanna Randaccio, and M. Savona (2007), ‘The Perception of Obstacles to Innovation. Multinational and Domestic Firms in Italy’, Bureau d’économie Théorique et Appliquée - BETA Working Paper n. 12-2007.

Jaffe, A. (1989), ‘Real Effects of Academic Research’, *American Economic Review*, 79, 984–1001.

Jaffe, A. B., M. Traijtenberg, and R. Henderson (1993), ‘Geographic Localisation of Knowledge Spillovers as Evidence by Patent Citations’, *Quarterly Journal of Economics*, 108, 577–598.

Keeble, D. (1996), ‘Small Firms, Innovation and Regional Development in Britain in the 1990s’, *Regional Studies*, 31.3, 281–293.

Kitson, M. (2005), Corporate Responses to Macroeconomic Changes and Shocks, Final Report to the ESRC.

Kitson, M., Martin, R. and Tyler, P. (2004). ‘Regional Competitiveness: an Elusive but Key Concept?’, *Regional Studies*, Vol. 38.9, pp.991-999

Kitson, M. and Wilkinson, F. (2003), ‘The State of Competitiveness’, in Cosh, A and Hughes, A. (eds), *Enterprise Challenged: Policy and Performance in the British SME Sector, 1999-2002*, Centre for Business Research, University of Cambridge.

Kneller, R. (2005), ‘Frontier Technology, Absorptive Capacity and Distance’, Oxford *Bulletin of Economics and Statistics*, 67(1), 1–23.

Kneller, R., and P. Stevens (2006), ‘Frontier Technology and Absorptive Capacity: Evidence from OECD Manufacturing Industries’, *Oxford Bulletin of Economics and Statistics*, 68(1), 1–21.

Kristensen, F. (1999), ‘Towards a Taxonomy and Theory of the Interdependence between Learning Regimes and Sectorial Patterns of Innovation and Competition: an Empirical Analysis of an Elaborated Pavitt Taxonomy Applying Danish Data’, Paper presented at the 1999 DRUID Winter Conference, Seeland, Denmark.

Lam, L. (2005), ‘Organisational innovation’, in Jan Fagerberg, David C. Mowery and Richard R. Nelson, (eds), *The Oxford Handbook of Innovation*, Oxford University Press: Oxford

Lundvall, B. A. (ed.) (1992), National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning, London, Pinter.

Martin, R., and P. Sunley (2006), ‘Path Dependency and Regional Economic Evolution’, Discussion paper, Papers in Evolutionary Economic Geography, Utrecht University.

Maurseth, P., and B. Verspagen (2002), ‘Knowledge-spillovers in Europe: A Patent Citation Analysis’, *Scandinavian Journal of Economics*, 104, 531–545.

McKinsey (2002), *Reviving UK Manufacturing*, McKinsey & Company, London

Meliciani, V. (2006), ‘Income and Employment Disparities across European Regions: The Role of National and Spatial Factors’, *Regional Studies*, 40.1, 75–91.

Miozzo, M., and L. Soete (1999), ‘Internationalisation of Services: a Technological Perspective’, Paper presented at the 3rd International Conference on Technology Policy and Innovation 30 August-2 September, Austin, USA., Austin, USA. 3rd International Conference on Technology Policy and Innovation 30 August-2 September 1999.

Mowery, D., and J. Oxley (1995), ‘Inward Technology Transfer and Competitiveness: The Role of National Innovation Systems’, *Cambridge Journal of Economics*, 19, 67–93.

Narula, R. (2004), ‘Understanding Absorptive Capacity in an ’Innovation System’ Context: Consequences for Economic and Employment Growth’, Discussion paper, MERIT - Infonomics Research Memorandum N.3.

Nelson, R. (ed.) (1993), National Innovation Systems: A Comparative Analysis. Oxford University Press.

NESTA (2006), The Innovation Gap: Why policy needs to reflect the reality of innovation in the UK, National Endowment for Science, Technology and the Arts

Nonaka, I. and H. Takeuchi (1995), *The Knowledge-Creating Company*, New York.

Oliver, N. and Runde, J. (2006), ‘Creating Cross-Disciplinary Graduate Programmes in a Traditional Educational Environment’, Woking Paper, Centre for Competitiveness and Innovation, Judge Business School, University of Cambridge

Patacchini, E. and Rice, P. (2007), ‘Geography and Economic Performance: Exploratory Spatial Data Analysis for Great Britain’, *Regional Studies*, Vol. 41, No.4, pp. 489-508

Pittaway, L., Robertson, M., Munir, K., Denyer, D., and Neely, A. (2004), *Networking and Innovation in the UK: A Sytematic Review of the Literature*, Advanced Institute of Management, London

Porter, M (1998), *On Competition*, Boston Mass, Harvard Business School

Porter, M and Ketels, C. (2003), *UK Competitiveness: Moving to the Next Stage*, DTI Economics Paper No. 3, DTI

Schmidt, T. (2005), ‘What Determines Absorptive Capacity’, Paper presented at the DRUID Tenth Anniversary Summer Conference on ’Dynamics of Industry and Innovation: Organisations, Networks and Systems’.

Sharif, N. (2006), ‘Emergence and Development of the National Innovation System concept’, *Research Policy*, 35, 745–766.

Veugelers, R. (1997), ‘Internal R&D Expenditures and External Technological Sourcing’, *Research Policy*, 26, 303–315.

Williamson, O.E. (1967), ‘Hierarchical Control and the Optimum Firm Size’, *Journal of Political Economy*, 75 (2), pp.123-138.

Zahra, S., and G. George (2002), ‘Absorptive Capacity: A Review and Reconceptualisation and Extension’, *Academy of Management Review*, 27(2), 185–203.

Appendix

Table 1: Innovation statistics by region, CBR data

Region	Total firms	% Innovative firms	% Goods innovation	% Service innovation	% Process innovation
London	290	52.22	24.61	30.11	33.95
Eastern	257	52.87	27.87	32.52	43.32
South East	344	44.44	26.49	22.59	28.50
South West	181	56.88	31.08	30.35	42.04
West Midlands	185	50.72	28.92	19.86	35.40
East Midlands	139	53.09	26.40	18.82	41.45
Yorkshire	177	57.16	29.09	31.77	47.82
North West	203	46.17	25.94	23.90	26.56
North East	51	56.43	36.18	26.27	21.28
Wales	68	46.27	30.67	26.81	27.01
Scotland	111	56.92	35.11	38.87	34.01
Total	2,006	52.11	29.31	27.44	34.67

Source: Small and Medium-Sized Business Survey, 2004, Centre for Business Research (CBR), University of Cambridge.

Table 2: Innovation statistics by region, CIS4 data

Region	Total firms	% Innovative firms	% Goods innovation	% Service innovation	% Process innovation
London	1,394	33.03	14.45	22.42	16.11
Eastern	1,615	29.97	16.42	15.45	15.92
South East	1,906	33.38	15.89	19.81	16.69
South West	1,376	29.20	15.48	15.45	15.32
West Midlands	1,515	30.73	17.35	13.83	16.38
East Midlands	1,155	31.79	18.44	15.36	16.33
Yorkshire	1,573	29.34	15.81	16.37	14.78
North West	1,589	28.88	15.81	15.50	15.16
North East	813	29.99	16.12	17.74	16.33
Wales	955	26.93	15.74	13.37	15.20

Scotland	1,238	27.03	12.57	14.47	15.79
Northern Ireland	1,304	30.59	13.22	13.61	19.56
Total	16,433	30.07	15.61	16.11	16.13

Source: Fourth UK Community Innovation Survey (CIS4).

Table 3: Innovation statistics by Pavitt's sectors, CIS4 data

Sector	Total firms	% Innovative firms	% Goods innovation	% Service innovation	% Process innovation
Primary	197	24.91	11.85	10.16	20.41
Science Based	716	47.83	40.63	11.76	25.99
Specialised Suppliers	1,498	50.49	42.58	17.31	25.97
Scale Intensive	4,258	23.65	11.07	12.88	12.34
Supplier Dominated	1,489	37.08	23.11	15.38	22.48
Information Intensive	673	38.65	9.50	29.33	23.88
KIBS	3,028	44.87	16.07	28.51	26.30
Traditional Services	4,574	21.34	11.43	12.77	9.09
Total	16,433	36.10	20.78	17.26	20.81

Source: Fourth UK Community Innovation Survey (CIS4).

Table 4: Innovative firms (%) by Pavitt's sectors and meta-region, CIS4 data

Sector	GSE	Middle England	Northern Way	Scotland/ Wales / NI
Primary	23.21	34.84	25.00	20.65
Science Based	40.03	51.22	54.83	42.52
Specialised Suppliers	54.46	49.19	47.15	49.47
Scale Intensive	24.28	24.26	23.76	21.24
Supplier Dominated	37.86	36.91	36.62	36.26
Information Intensive	37.39	47.06	34.44	39.22
KIBS	44.48	43.76	42.63	53.04
Traditional Services	23.44	21.17	20.06	18.69

Greater South East comprises the South East, Eastern and London regions. Middle England comprises East Midlands, West Midlands and the South West regions. The Northern Way comprises North West, North East and Yorkshire and Humberside Regions. Source: Fourth UK Community Innovation Survey (CIS4).

Table 5: Multivariate Probit estimation results using CBR data

Variable	Goods Product Innovation	Service Product Innovation	Goods Process Innovation	Service Process Innovation
Fraction R&D Employees	0.181*	0.197	0.068	0.280*
	(0.078)	(0.111)	(0.094)	(0.117)
R&D Exp. per Employee	-0.000	-0.000	-0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Managerial Training	0.004	0.184**	0.015	0.104*
	(0.056)	(0.050)	(0.053)	(0.048)
Scientist Training	-0.032	-0.076	0.008	-0.082
	(0.058)	(0.053)	(0.056)	(0.050)
Other Employee Training	0.141**	-0.025	0.031	0.003
	(0.053)	(0.051)	(0.051)	(0.047)
Total Quality Management	0.042	0.105*	0.125**	0.057
	(0.045)	(0.042)	(0.043)	(0.039)
Quality Circles	0.125*	0.034	0.120*	0.044
	(0.056)	(0.053)	(0.055)	(0.050)
Job Rotation	0.087*	-0.004	0.103*	0.035
	(0.044)	(0.041)	(0.041)	(0.038)
Performance-Related Pay	-0.009	0.038	-0.010	0.017
	(0.044)	(0.040)	(0.042)	(0.037)
Collaborations: Local	0.019	0.041	0.140**	0.079
	(0.061)	(0.053)	(0.057)	(0.050)
Collaborations: National	0.091	0.143**	-0.020	0.092*
	(0.047)	(0.043)	(0.045)	(0.040)
Collaborations: Overseas	0.196**	-0.011	0.113*	0.019
	(0.052)	(0.049)	(0.052)	(0.046)
Limitations: Finance	0.077	-0.010	0.053	0.008
	(0.043)	(0.039)	(0.041)	(0.036)
Limitations: Skills	-0.009	0.036	-0.026	0.086*
	(0.051)	(0.047)	(0.050)	(0.042)
Limitations: Technology	0.085	0.023	0.045	0.072
	(0.045)	(0.042)	(0.043)	(0.039)
Limitations: Market	0.047	0.066	0.023	-0.048

	(0.048)	(0.042)	(0.045)	(0.041)
Limitations: Other	-0.099	-0.000	-0.075	0.018
	(0.051)	(0.047)	(0.048)	(0.044)
Claimed Tax Credit	0.228**	0.032	0.138**	-0.046
	(0.052)	(0.050)	(0.052)	(0.045)
Business Advice: Bus. Link	0.031	0.013	0.102*	0.019
	(0.046)	(0.042)	(0.043)	(0.039)
Business Advice: RDA	-0.023	-0.101	-0.014	-0.080
	(0.065)	(0.056)	(0.062)	(0.052)
Market: Regional	0.109	0.055	-0.068	0.028
	(0.079)	(0.073)	(0.075)	(0.067)
Market: National	0.146*	0.044	0.036	0.057
	(0.069)	(0.063)	(0.066)	(0.057)
Market: International	0.207**	0.021	-0.061	-0.021
	(0.076)	(0.075)	(0.076)	(0.068)
Age (Years)	-0.001	-0.001	-0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Size (Employees, Ln)	0.016	0.042*	0.049**	0.016
	(0.019)	(0.017)	(0.018)	(0.016)
Ownership: Partnership	-0.246*	-0.221**	-0.333**	0.015
	(0.101)	(0.084)	(0.067)	(0.103)
Ownership: Company	-0.189*	-0.089	-0.196*	-0.033
	(0.096)	(0.095)	(0.099)	(0.091)
Science Based	0.405**	-0.295**	0.316**	-0.200**
	(0.051)	(0.047)	(0.064)	(0.049)
Specialised Suppliers	0.340**	-0.222**	0.319**	-0.068
	(0.050)	(0.047)	(0.053)	(0.048)
Scale Intensive	0.284**	-0.279**	0.273**	-0.161**
	(0.059)	(0.046)	(0.062)	(0.048)
Supplier Dominated	0.279**	-0.181**	0.359**	-0.046
	(0.056)	(0.052)	(0.055)	(0.054)
Information Intensive	-0.053	-0.040	-0.114	-0.078
	(0.233)	(0.173)	(0.204)	(0.161)
Traditional Services	0.006	-0.100	0.159	-0.145
	(0.322)	(0.255)	(0.307)	(0.183)
Region: London	-0.169	0.048	0.034	0.164

	(0.141)	(0.135)	(0.140)	(0.142)
Region: Eastern	-0.138	-0.014	0.093	0.024
	(0.145)	(0.135)	(0.142)	(0.137)
Region: South East	-0.175	0.005	0.027	0.171
	(0.139)	(0.131)	(0.137)	(0.139)
Region: South West	-0.141	0.084	0.138	0.180
	(0.151)	(0.143)	(0.150)	(0.149)
Region: West Midlands	-0.106	-0.053	0.120	0.210
	(0.149)	(0.132)	(0.145)	(0.144)
Region: East Midlands	-0.149	-0.060	0.067	0.111
	(0.150)	(0.137)	(0.150)	(0.151)
Region: Yorkshire	-0.215	-0.010	0.138	0.217
	(0.137)	(0.138)	(0.145)	(0.148)
Region: North West	-0.173	-0.009	-0.032	-0.014
	(0.141)	(0.135)	(0.138)	(0.134)
Region: Wales	-0.201	0.170	-0.133	0.298
	(0.157)	(0.161)	(0.145)	(0.164)
Region: Scotland	-0.153	-0.045	-0.041	0.060
	(0.156)	(0.142)	(0.151)	(0.153)
Observations	826	826	826	826
Log likelihood	-1664.25			
Wald chi2	560.05**			
LR chi2	325.08**			

Standard errors in parentheses.* significant at 5%; ** significant at 1%. Coefficients report unconditional marginal effects. For dummy variables coefficients report the effect of a discrete change of the dummy variable from 0 to 1. Standard errors computed using the delta method (Greene, 2003, pp.710-715). Omitted category for the sectoral dummies is Knowledge Intensive Business Services (KIBS); omitted category for the regional dummies is the North East.

Table 6: Multivariate Probit estimation results using CIS4 data

Variable	Goods Innovation	Service Innovation	Process Innovation
Fraction Emp. with Science Degree	0.045*	0.067**	0.015
	(0.023)	(0.021)	(0.023)
Fraction Emp. with Other Degree	0.013	0.064**	-0.001
	(0.021)	(0.018)	(0.021)
R&D Expenditure per Employee	0.002**	-0.001	0.001*
	(0.000)	(0.001)	(0.000)
Training	0.090**	0.124**	0.168**
	(0.007)	(0.007)	(0.008)
New Management Techniques	-0.023**	0.024**	0.049**
	(0.008)	(0.009)	(0.010)
New Organisational Structure	0.030**	0.049**	0.040**
	(0.009)	(0.009)	(0.009)
New Marketing Strategies	0.121**	0.100**	0.098**
	(0.010)	(0.009)	(0.010)
Collaborations: Local	0.004	0.069**	0.051**
	(0.013)	(0.014)	(0.014)
Collaborations: National	0.111**	0.069**	0.117**
	(0.016)	(0.014)	(0.016)
Collaborations: Overseas	0.095**	0.002	0.029
	(0.018)	(0.014)	(0.016)
Obstacles: Finance	0.054**	0.065**	0.059**
	(0.008)	(0.008)	(0.008)
Obstacles: Knowledge	0.020*	0.025**	0.018*
	(0.008)	(0.008)	(0.008)
Obstacles: Market	0.037**	0.015	0.000
	(0.008)	(0.008)	(0.008)
Obstacles: Other	-0.018*	-0.002	-0.010
	(0.008)	(0.007)	(0.008)
Local and Regional Public Support	0.022	0.033*	0.023
	(0.146)	(0.014)	(0.015)

Central Govt. Public Support	0.083**	0.036	0.117**
	(0.022)	(0.019)	(0.024)
EU Public Support	-0.051**	0.032	-0.026
	(0.019)	(0.026)	(0.023)
Claimed Tax Credit	0.134**	-0.026	-0.012
	(0.031)	(0.019)	(0.022)
Market: National	0.060**	0.035**	0.031**
	(0.011)	(0.009)	(0.010)
Market: International	0.154**	0.034**	0.067**
	(0.011)	(0.010)	(0.011)
Age	0.002	-0.025*	-0.000
	(0.010)	(0.010)	(0.010)
Size (Employees, Ln)	0.007**	-0.004*	0.018**
	(0.002)	(0.002)	(0.003)
Ownership Structure	0.014	0.011	0.010
	(0.008)	(0.007)	(0.008)
Primary	0.038	-0.107**	-0.028
	(0.040)	(0.015)	(0.029)
Science Based	0.329**	-0.115**	-0.030
	(0.027)	(0.008)	(0.016)
Specialised Suppliers	0.288**	-0.106**	-0.050**
	(0.021)	(0.008)	(0.012)
Scale Intensive	0.076**	-0.076**	-0.078**
	(0.014)	(0.008)	(0.010)
Supplier Dominated	0.222**	-0.080**	-0.002
	(0.020)	(0.009)	(0.013)
Information Intensive	-0.010	0.022	-0.004
	(0.020)	(0.017)	(0.018)
Traditional Services	0.112**	-0.062**	-0.086**
	(0.014)	(0.009)	(0.010)
Region: London	-0.041*	0.008	-0.041*
	(0.017)	(0.019)	(0.018)
Region: Eastern	0.016	0.003	-0.011
	(0.020)	(0.018)	(0.020)
Region: South East	-0.018	-0.007	-0.028
	(0.019)	(0.018)	(0.019)

Region: South West	0.009	0.023	-0.009
	(0.019)	(0.018)	(0.019)
Region: West Midlands	0.015	-0.036	0.003
	(0.022)	(0.019)	(0.022)
Region: East Midlands	0.040	0.007	0.010
	(0.023)	(0.019)	(0.021)
Region: Yorkshire	0.028	-0.016	0.008
	(0.021)	(0.018)	(0.020)
Region: North West	0.023	0.002	-0.010
	(0.020)	(0.019)	(0.019)
Region: Wales	0.023	-0.015	-0.003
	(0.021)	(0.017)	(0.020)
Region: Scotland	-0.005	-0.020	0.043
	(0.019)	(0.018)	(0.022)
Region: Northern Ireland	0.012	-0.002	-0.010
	(0.020)	(0.018)	(0.019)
Observations	13640	13640	13640
Log likelihood	-16178.41		
Wald chi2	6512.65**		
LR chi2	1022.06**		

Standard errors in parentheses.* significant at 5%; ** significant at 1%. Coefficients report unconditional marginal effects. For dummy variables coefficients report the effect of a discrete change of the dummy variable from 0 to 1. Standard errors computed using the delta method (Greene, 2003, pp.710-715). Omitted category for the sectoral dummies is Knowledge Intensive Business Services (KIBS); omitted category for the regional dummies is the North East.

Table 7: Open, Closed and Adoptive Product Innovation: Probit estimation results using CIS4 data

	Product Innovation (within the firm)	Product Innovation (in collaboration)	Product Innovation (through adoption)
Fraction Emp. with Science Degree	0.100**	-0.021	-0.021
	(0.023)	(0.013)	(0.011)
Fraction Emp. with Other Degree	0.035	0.024*	0.009
	(0.020)	(0.011)	(0.007)
R&D Expenditure per Employee	0.002**	-0.000	-0.002*
	(0.000)	(0.000)	(0.001)
Training	0.101**	0.035**	0.020**
	(0.008)	(0.004)	(0.003)
New Management Techniques	-0.002	0.005	-0.001
	(0.009)	(0.005)	(0.003)
New Organisational Structure	0.039**	0.008	-0.002
	(0.009)	(0.005)	(0.003)
New Marketing Strategies	0.121**	0.017**	0.006
	(0.010)	(0.005)	(0.004)
Collaborations: Local	0.020	0.025**	-0.001
	(0.013)	(0.008)	(0.005)
Collaborations: National	0.039**	0.066**	0.014*
	(0.014)	(0.010)	(0.007)
Collaborations: Overseas	0.001	0.008	-0.000
	(0.015)	(0.008)	(0.006)
Obstacles: Finance	0.062**	0.014**	0.009**
	(0.008)	(0.005)	(0.003)
Obstacles: Knowledge	0.026**	0.002	0.005
	(0.008)	(0.004)	(0.003)
Obstacles: Market	0.018*	0.011*	0.009**

	(0.008)	(0.005)	(0.003)
Obstacles: Other	-0.015	-0.001	-0.003
	(0.008)	(0.004)	(0.003)
Local and Regional Public Support	0.027	0.025**	0.003
	(0.015)	(0.009)	(0.006)
Central Government Public Support	0.062**	0.027*	-0.012*
	(0.021)	(0.012)	(0.005)
EU Public Support	-0.055**	0.017	0.009
	(0.020)	(0.014)	(0.015)
Claimed Tax Credit	0.105**	-0.021**	-0.015*
	(0.029)	(0.008)	(0.007)
Market: National	0.052**	0.016**	0.004
	(0.010)	(0.006)	(0.003)
Market: International	0.126**	0.028**	-0.002
	(0.011)	(0.006)	(0.004)
Age	-0.018	-0.007	0.006
	(0.010)	(0.006)	(0.003)
Size (Employees, Ln)	0.006*	0.000	-0.002*
	(0.003)	(0.001)	(0.001)
Ownership Structure	0.008	0.014**	-0.000
	(0.008)	(0.005)	(0.003)
Primary	-0.086**	-0.019	-0.007
	(0.024)	(0.015)	(0.011)
Science Based	0.061**	0.014	0.011
	(0.020)	(0.011)	(0.009)
Specialised Suppliers	0.065**	0.013	-0.009*
	(0.015)	(0.008)	(0.005)
Scale Intensive	-0.025*	0.005	-0.001
	(0.011)	(0.006)	(0.004)
Supplier Dominated	0.044**	-0.002	0.001
	(0.015)	(0.008)	(0.006)
Information Intensive	-0.014	0.032*	0.001
	(0.018)	(0.013)	(0.007)
Traditional Services	-0.046**	0.006	0.021**

	(0.011)	(0.007)	(0.006)
Region: London	-0.028	0.001	-0.001
	(0.018)	(0.011)	(0.007)
Region: Eastern	0.003	0.013	0.009
	(0.019)	(0.012)	(0.008)
Region: South East	-0.024	-0.002	0.002
	(0.019)	(0.011)	(0.008)
Region: South West	0.012	0.014	0.003
	(0.019)	(0.012)	(0.007)
Region: West Midlands	-0.009	-0.002	-0.005
	(0.021)	(0.012)	(0.007)
Region: East Midlands	0.018	0.009	0.000
	(0.021)	(0.013)	(0.007)
Region: Yorkshire	-0.002	0.011	-0.003
	(0.019)	(0.012)	(0.007)
Region: North West	0.011	0.011	-0.002
	(0.020)	(0.012)	(0.007)
Region: Wales	0.002	-0.000	0.001
	(0.020)	(0.011)	(0.007)
Region: Scotland	-0.038*	0.007	0.004
	(0.018)	(0.012)	(0.008)
Region: Northern Ireland	-0.009	0.016	-0.004
	(0.019)	(0.013)	(0.006)
Observations	13639	13639	13639
Log likelihood	-5881.13	-3150.75	-1821.46
LR chi2	2659.74**	899.81**	237.77**
Pseudo R2	0.18	0.13	0.06

Standard errors in parentheses.* significant at 5%; ** significant at 1%. Coefficients report marginal effects. For dummy variables coefficients report the effect of a discrete change of the dummy variable from 0 to 1. Omitted category for the sectoral dummies is Knowledge Intensive Business Services (KIBS); omitted category for the regional dummies is the North East.

Table 8: Open, Closed and Adoptive Process Innovation: Probit estimation results using CIS4 data

	Process Innovation (within the firm)	Process Innovation (in collaboration)	Process Innovation (through adoption)
Fraction Emp. with Science Degree	0.020	-0.011	0.008
	(0.017)	(0.011)	(0.009)
Fraction Emp. with Other Degree	-0.010	0.020*	-0.010
	(0.015)	(0.010)	(0.008)
R&D Expenditure per Employee	0.001**	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
Training	0.089**	0.048**	0.017**
	(0.006)	(0.004)	(0.003)
New Management Techniques	0.022**	0.014**	0.001
	(0.007)	(0.005)	(0.003)
New Organisational Structure	0.038**	0.004	-0.008**
	(0.007)	(0.004)	(0.003)
New Marketing Strategies	0.057**	0.016**	0.007*
	(0.007)	(0.005)	(0.004)
Collaborations: Local	0.023*	0.018**	-0.006
	(0.010)	(0.007)	(0.004)
Collaborations: National	0.010	0.065**	0.017*
	(0.010)	(0.010)	(0.007)
Collaborations: Overseas	0.019	0.004	-0.010**
	(0.012)	(0.007)	(0.004)
Obstacles: Finance	0.032**	0.013**	0.008**
	(0.006)	(0.004)	(0.003)
Obstacles: Knowledge	0.010	0.002	0.004
	(0.006)	(0.004)	(0.003)
Obstacles: Market	0.003	-0.004	0.001

	(0.006)	(0.004)	(0.003)
Obstacles: Other	0.004	-0.005	-0.007*
	(0.006)	(0.004)	(0.003)
Local and Regional Public Support	0.008	-0.000	0.013
	(0.011)	(0.006)	(0.007)
Central Government Public Support	0.045**	0.034**	0.004
	(0.016)	(0.012)	(0.007)
EU Public Support	-0.019	-0.003	-0.005
	(0.015)	(0.010)	(0.008)
Claimed Tax Credit	0.007	-0.012	0.000
	(0.016)	(0.008)	(0.008)
Market: National	0.025**	0.003	0.004
	(0.008)	(0.005)	(0.004)
Market: International	0.057**	0.003	0.006
	(0.008)	(0.005)	(0.004)
Age	-0.014	0.000	0.010**
	(0.008)	(0.005)	(0.003)
Size (Employees, Ln)	0.008**	0.006**	0.000
	(0.002)	(0.001)	(0.001)
Ownership Structure	0.003	0.011**	-0.005
	(0.006)	(0.004)	(0.003)
Primary	-0.041*	0.018	0.008
	(0.017)	(0.019)	(0.014)
Science Based	-0.032**	0.000	0.012
	(0.010)	(0.008)	(0.008)
Specialised Suppliers	-0.029**	-0.007	-0.007
	(0.008)	(0.006)	(0.004)
Scale Intensive	-0.055**	-0.011*	-0.000
	(0.007)	(0.005)	(0.004)
Supplier Dominated	-0.018*	-0.006	0.025**
	(0.009)	(0.006)	(0.008)
Information Intensive	-0.016	0.004	0.010
	(0.012)	(0.009)	(0.009)
Traditional Services	-0.056**	-0.013**	-0.003

	(0.007)	(0.005)	(0.004)
Region: London	-0.013	-0.018*	-0.002
	(0.014)	(0.007)	(0.007)
Region: Eastern	-0.014	0.000	0.007
	(0.013)	(0.009)	(0.008)
Region: South East	-0.016	-0.008	0.002
	(0.014)	(0.009)	(0.008)
Region: South West	-0.006	-0.009	0.010
	(0.014)	(0.008)	(0.009)
Region: West Midlands	-0.001	0.006	0.000
	(0.016)	(0.011)	(0.008)
Region: East Midlands	0.011	-0.014	0.015
	(0.016)	(0.008)	(0.010)
Region: Yorkshire	0.005	0.004	-0.003
	(0.015)	(0.010)	(0.007)
Region: North West	0.004	-0.012	0.003
	(0.015)	(0.008)	(0.008)
Region: Wales	-0.000	-0.006	0.006
	(0.015)	(0.009)	(0.009)
Region: Scotland	0.014	0.022	-0.000
	(0.016)	(0.013)	(0.007)
Region: Northern Ireland	-0.007	0.003	-0.002
	(0.014)	(0.010)	(0.007)
Observations	13639	13639	13639
Log likelihood	-4548.79	-2837.48	-1678.11
LR chi2	1793.76**	999.56**	192.10**
Pseudo R2	0.16	0.15	0.05

Standard errors in parentheses.* significant at 5%; ** significant at 1%. Coefficients report marginal effects. For dummy variables coefficients report the effect of a discrete change of the dummy variable from 0 to 1. Omitted category for the sectoral dummies is Knowledge Intensive Business Services (KIBS); omitted category for the regional dummies is the North East.

Table 9: Characteristics of Case Study Firms

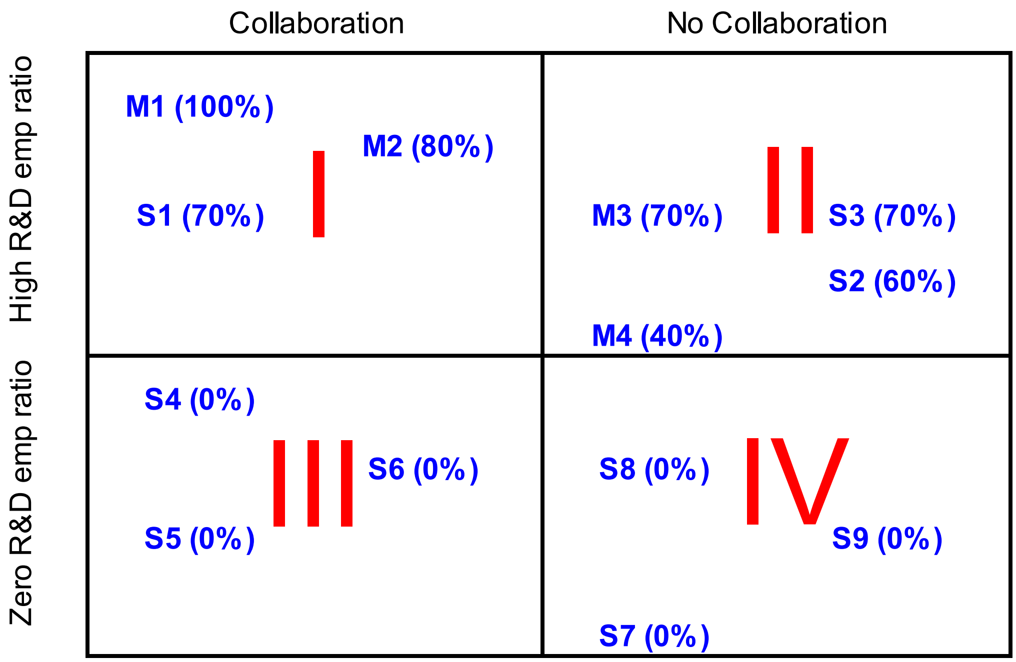
	I	II	III	IV
Turnover (£mln)	2.1; 3.0 & 3.8	4.5; 9.0; 9.7 & 14	3.2; 7.9 & 16.6	2.2; 3.5 & 14.5
Number of employees	40; 43 & 68	60; 120; 124 & 99	20; 100 & 175	23; 130 & 260
Age (years)	6-17	14-23	21-30	16-22
Location	EM & SW	SE & SW	EM, NW & SE	EM, NW & SE
Sectors	Semiconductor, Organic Chemicals & Software Supply	Semiconductor, Medical Instruments, Engineering and Architectural Activities	Management, Technical and Software Consultancy and Engineering Activities	Business Services, Software Supply and Computer Related activities

Table 10: Firms' Innovation Activities by Type and Group

Innovation reported		I	II	III	IV
new to the firm and industry	goods product	3	2	1	
	service product		3	2	
	goods process	1			
	service process			1	1
new to the firm only	goods product		1		

	service product	1	1	1	3
	goods process		2	1	
	service process	1	1	2	2

Figure 1: Innovation Matrix



M and S denote manufacturing and services companies respectively
% in brackets is R&D employees fraction = (R&D employees/Total Employees)*100

Figure 2: Quadrant dynamics