Firm growth and innovation in UK city-regions

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Abstract

This paper draws on matched data from the Business Structure Database (BSD) and the Community Innovation Survey (CIS) to examine the impact of city-region characteristics on firm-level innovation and growth. We find substantial evidence in production sectors of spillovers from regional innovative inputs to firm-level innovation performance which then feeds through onto firm growth in employment and sales. In production sectors the positive effects of city-region measures of innovative inputs and external knowledge sourcing activities on firm-level innovation suggest that the quality and relevance of localised interactions between firms and employees in their city-regions is enhanced by proximity to a relatively high proportion of innovative and outward-looking firms in their own and related sectors. However, no similar city-region level impacts are found for firms in knowledge intensive services or Other Services. We speculate that the lack of evidence of such effects in knowledge-intensive services in particular reflects a tendency for firms and employees in these sectors to interact with other firms and employees on a wider geographic scale than is denoted by city-regions as they are defined in this study. In production sectors we find a positive relationship between firm innovation performance and a summary measure of socio-economic and labour market conditions (derived from indicators of skill levels, employment rates and the annual rate of growth in the working-age population). No such impact of city-regional skills and labour market conditions is found in service sectors but the innovation performance of firms in Other Services is restricted by regional skill shortages as is also the case in production sectors. These results suggest that estimates of the impact of regional effects on firm growth are sensitive to both the choice of sectors under investigation and the choice of geographical entity under consideration.

ABSTRACT

This paper draws on matched data from the Business Structure Database (BSD) and the Community Innovation Survey (CIS) to examine the impact of city-region characteristics on firm-level innovation and growth. We find substantial evidence in production sectors of spillovers from regional innovative inputs to firm-level innovation performance which then feeds through onto firm growth in employment and sales. In production sectors the positive effects of city-region measures of innovative inputs and external knowledge sourcing activities on firm-level innovation suggest that the quality and relevance of localised interactions between firms and employees in their city-regions is enhanced by proximity to a relatively high proportion of innovative and outward-looking firms in their own and related sectors. However, no similar city-region level impacts are found for firms in knowledge-intensive services or Other Services. We speculate that the lack of evidence of such effects in knowledge-intensive services in particular reflects a tendency for firms and employees in these sectors to interact with other firms and employees on a wider geographic scale than is denoted by city-regions as they are defined in this study. In production sectors we find a positive relationship between firm innovation performance and a summary measure of socio-economic and labour market conditions (derived from indicators of skill levels, employment rates and the annual rate of growth in the working-age population). No such impact of city-regional skills and labour market conditions is found in service sectors but the innovation performance of firms in Other Services is restricted by regional skill shortages as is also the case in production sectors. These results suggest that estimates of the impact of regional effects on firm growth are sensitive to both the choice of sectors under investigation and the choice of geographical entity under consideration.

JEL codes: J24, O32, R11

Keywords: productivity, innovation, regional economic activity

1. Introduction

Recent research has shown strong connections between firm growth and prior investments in innovation in the UK (Mason, Bishop and Robinson, 2009) and in other European countries (Hőlzl, 2008). These findings raise interesting questions about the extent to which firm growth benefits from knowledge spillovers and other externalities contributing to innovation at regional level since there is now a substantial literature on 'regional effects' on firm performance (see Rosenthal and Strange, 2004, and Crescenzi and Rodriguez-Pose, 2012, for overviews). In some cases research in this area identifies 'regional innovation systems' in which innovative firms benefit from proximity to each other and to region-specific labour markets, networks and institutions (Braczyk, Cooke and Heidenreich, 1998; Rodriguez-Pose and Crescenzi, 2008). Similarly, the related concept of an 'innovation ecosystem' has been associated with regional proximity between firms and other actors involved in innovation (Saxenian, 2006).

An innovation ecosystem can be defined as 'a permanent or temporary system of interaction and exchange among an ecology of various actors that enables the cross-pollination of ideas and facilitates innovation' (Luoma-aho and Halonen, 2010: 4). Clearly, geographical proximity between actors may be especially important for some forms of interaction such as informal face-to-face contacts and exchange of tacit knowledge. However, there is no reason in principle to expect firms to rely solely on regional networks and knowledge sources when engaging in innovative activity. On the contrary, many firms may choose to interact with customers, suppliers, universities and other actors on cross-regional, national and/or international scales. Therefore, it remains an open question for empirical researchers how much evidence of specifically regional effects on firm-level innovation and growth can be identified.

In this paper we explore this issue by drawing on UK firm-level data from the Community Innovation Survey (CIS) which have been matched against the Business Structure Database (BSD) and data for UK city-regions. As will be described in Section 3 below, the city-regions identified in our dataset have the advantage of being economically meaningful geographic units rather than simply being administrative units. This has been achieved by collecting Local Authority District (LAD)-level data

from a number of sources and then re-aggregating it to city-regions which largely correspond with commuting patterns for managers and high-skilled workers. Thus the geographical boundaries defined by city-regions delineate day-to-day travel areas for high-skilled workers who are most likely to be involved in innovation and knowledge-sharing. In terms of analysis of the scope for localised interactions which are relevant to firm performance, these attributes of city-regions represent an important contrast with broader regions (eg, former Government Office Regions in the UK) which are defined solely on the basis of political and/or administrative considerations.

To our knowledge this is the first research paper to take account of localised interactions at city-region level in analysis of firm growth and innovation in the UK. The paper is ordered as follows. Section 2 summarises relevant literature and sets out the main hypotheses to be tested. Section 3 describes our data sets and empirical specifications. Section 4 presents multivariate regression estimates of the impact of city-region characteristics on firm-level innovation and growth. Section 5 summarises our main findings.

2. Potential externalities at regional level

2.1 Industrial structure and urban scale

It is now common in research on regional effects on economic performance to distinguish between two different types of spillover at industry level:

1. Intra-industry spillovers: eg, transfer of knowledge and ideas between people working in the same industry; demonstration effects such as imitation of new products and processes; labour market effects such as improved access to a supply of trained staff with industry-specific skills; other input market effects such as easier and cheaper access to industry-specific services.

2. Inter-industry spillovers: eg, transfer of new technologies, management practices, ideas and 'solutions to problems' between people working in different industries; access to business services and infrastructure used by firms in many industries.

The scope for intra-industry spillovers – famously described at length by Marshall (1890) – is expected to be maximised in regions where particular industries are concentrated. By contrast, inter-industry spillovers are associated with industrial diversity (Jacobs, 1969) and the potential for them is expected to increase with urban scale and/or population density at regional level. Examples of so-called urbanisation or agglomeration spillovers of this kind include improved access to local pools of labour with transferable or generic skills and access to a wider range of business services in local areas.

Research in the last 20 years on the relative importance of industrial specialisation and urban scale/diversity at regional level has found some evidence of both types of effect on firm and industry performance. For example, Baptista and Swan (1998) find that UK firms are more likely to engage in innovation if they are located in regional clusters with relatively high levels of employment in their own industry. There is no significant effect from employment in other industries. Similarly, in the US Henderson (2003) finds that productivity in high-tech firms is positively associated with own-industry specialisation although the same is not true in more mature

machinery industries. He reports little evidence in either type of industry of firms benefiting from industrial diversity.

By contrast, Glaeser et al (1992) find that US industries grow more slowly in cities in which they are more heavily represented in terms of employment. This suggests that firm growth benefits from city diversity. Further light is shed on this issue by Duranton and Puga (2002) whose analysis of French manufacturing and business services data suggests that, while local industrial diversity is beneficial for firms' innovative performance, own-industry specialisation at local level is more helpful to performance once full production gets under way.

2.2 Intangible assets and external knowledge sourcing

Other factors which may affect regional economic performance include intangible assets such as skills, knowledge and social capital (eg, social norms and trust conducive to economic efficiency). Using administrative regional-level data for several European countries, Dettori et al (2012) find that measures of intangible assets of these kinds are positively associated with total factor productivity (a measure of the efficiency with which production inputs are combined). In general terms these effects may come about through intangible assets at regional level helping to create a favourable environment for firms to operate in.

Their findings are mirrored in several firm- and plant-level analyses. For example Galindo-Rueda and Haskel (2005) report that, after controlling for internal skills, wages and productivity at firm level are positively related to regional skills density in the UK. This conclusion holds after taking account of the potentially endogenous nature of firm location since high productivity firms may choose to locate in areas with high skills. In the US Moretti (2004) finds that, after controlling for internal human capital levels, productivity increases faster in plants located in US cities where the density of college graduates is growing relatively quickly than in similar plants located in cities where the proportion of graduates is growing more slowly.

The importance of regional differences in skill supplies also emerges in studies of European regions in which the extent and impact of regional externalities is found to

depend heavily on the strength of labour market and other institutions at regional level (Rodriguez-Pose and Crescenzi, 2008; Rodriguez-Pose and Comptour, 2012). In these papers the authors define what is termed a 'social filter' as a composite measure of regional characteristics relating to educational achievements, employment rates and demographic structure. They find the benefits of industrial clustering and the extent of spillovers from R&D spending at regional level to be closely related to these socio-economic conditions.

Making a related point, Artis et al (2009) note that the estimated effects of the concentration of employment on regional productivity are reduced if controls for intangible assets such as skills and knowledge (the latter proxied by patent applications) are introduced into their models. Riley and Robinson (2011) also find that the estimated effects of industrial diversity and urban scale on firm-level labour productivity diminish if account is taken of intangible capital assets at both firm and city-region levels.

The idea that regional performance benefits from firms' investments in skills and other intangible capital assets fits well with resource- and knowledge-based theories of the firm which suggest that persistent differences in firm performance arise because successful firms build up distinctive resources, capabilities and structures over time (Penrose, 1959; Nelson and Winter, 1982; Teece, Pisano and Shuen, 1997; Eisenhardt and Martin, 2001). In this perspective resources and capabilities are broadly defined to include intangible assets such as skills, tacit knowledge, access to external knowledge sources and relationships with innovation partners as well as the tangible assets arising from past investments in capital equipment and new product development.

However, as noted above, when it comes to external knowledge sourcing, there is no reason to expect firms to rely solely on within-regional networks and knowledge sources when seeking out ideas and knowledge that may be economically useful. Concepts such as 'local nodes in global networks' or 'pipelines to the outside world' capture the idea that firms may benefit simultaneously from being co-located with others in their industry or related industries while also having connections to other potential knowledge sources and innovation partners on national and international

7

scales (Amin and Thrift, 1992; Maskell et al, 2006). Drawing on Norwegian firm-level data, Fitjar and Rodriguez-Pose (2011) find that local interactions are not sufficient for innovative success which is strongly linked to diversity of international partners. Bathelt et al (2004) emphasise that participation in wide-ranging networks requires much higher levels of investment by firms than does engaging in localised interactions.

UK evidence also highlights the importance of knowledge search activities which extend beyond regional borders. The Community Innovation Survey asks firms about the extent to which they actively cooperate with innovation partners (such as suppliers, customers and universities) within their region – defined as within a 100 mile distance of each business – and on wider geographic scales. The CIS responses for 2006 showed 4% of firms which only had extra-regional partnerships of this kind, another 4% with a mix of regional and extra-regional partnerships and only 2% which relied solely on regional partners. Analysing these CIS data on innovation partnerships, Hewitt-Dundas (2011) finds that firms that collaborate with local universities differ in many ways from firms that collaborate with non-local universities. Where localised cooperation does occur, it is most likely to involve firms which are small or medium sized, which serve national rather than export markets and which are located in regions with strong industry-specific research bases.

Thus although some research studies emphasise the advantages of proximity for the exchange of tacit knowledge between firms and universities or firms and public laboratories (Acs et al, 1999; Arundel and Geuna, 2004), there is other evidence to suggest that some firms – particularly large and international-oriented firms – are prepared to search for academic research partners well beyond their immediate localities. For example, Laursen et al (2011)'s analysis of firm-university linkages in the UK suggest that, for R&D-intensive firms in particular, the perceived quality of university research matters more than geographical proximity when forming relationships, although firms are more likely to collaborate with local universities if they also meet their quality criteria. Similarly, Bishop et al (2009) find that geographic proximity between firms and universities in the UK is more strongly associated with university assistance to firms in solving specific problems rather than with formal university-business collaboration on research projects. Hence we

conclude that the extent and nature of localised interactions between firms and external partners such as universities is likely to vary systematically with firm characteristics such as size and export orientation, as is the impact of such interactions on firm performance.

2.3 Hypotheses

This research evidence points to a number of hypotheses which we are able to test using our UK firm-level data on innovation and growth performance and the characteristics of city-regions in which firms are located.

First, as noted above, available evidence suggests that we need to allow for the possibility that the effects of regional characteristics such as industrial specialisation or diversity on firm-level innovation may be very different from their effects on firm-level growth. For example, Duranton and Puga (2002) find that firm-level innovation is positively associated with local industrial diversity while both they and Henderson (2003) find that firm-level growth seems to benefit more from own-industry specialisation at regional level than from industrial diversity. One possibility is that diversity contributes more to innovation than to growth because it is at the pre-production stage of new product and process development that new ideas from disparate sources may prove beneficial. By contrast, once production of new goods or services is up and running, firms may derive more benefits from localised interactions with other firms engaged in similar activities.

These considerations suggest that the following hypotheses are worth investigating:
H1: Firm innovation performance is positively related to measures of urban scale and diversity at regional level
H2: Firm growth in employment and sales is positively related to the level of own-industry specialisation at regional level

Second, we expect that localised interactions between firms and between employees in different firms may be more relevant and useful to firm performance, the more that other firms in the same regions have themselves engaged in innovative activities and succeeded in growing rapidly. These possibilities are examined by testing the

following hypotheses, again maintaining a distinction between innovation and growth performance:

H3: Firm innovation performance is positively related to regional indicators of firms' involvement in innovation

H4: Firm growth in employment / sales is positively related to business growth performance at regional level

A further hypothesis is suggested by the evidence cited above that many firms benefit in their innovation activities from access to knowledge sources and innovation partners outside their local regions (Bathelt et al, 2004; Fitjar and Rodriguez-Pose, 2011). This suggests that the value of localised interactions when they do occur may actually be increased by the presence of local firms with strong extra-regional and intermational connections which help to replenish the stock of knowledge and ideas which are in local circulation. This suggests that the following hypothesis is worthy of scrutiny:

H5: Firm innovation performance is positively related to regional indicators of firms' access to extra-regional knowledge sources

Finally, as discussed above, there is ample evidence that firm performance in respect of both innovation and growth tends to benefit from access to skills and the strength of labour market and other institutions at regional level (Moretti, 2004; Rodriguez-Pose and Crescenzi, 2008). Accordingly, we are also interested to test a sixth hypothesis:

H6: Firm innovation and growth performance is positively related to socio-economic and labour market conditions such as skill levels and employment rates at regional level

3. Empirical specifications and data sources

3.1 Modelling firm innovation and growth

In order to test these hypotheses we make use of a two-stage model of firm-level innovation and growth which enables us to differentiate very clearly between potential regional effects on innovative performance and regional effects on firm growth. In this model we specify:

(1) innovation success as a function of innovation inputs, innovation-related resources and capabilities and regional characteristics which may influence innovative performance

(2) firm growth as a function of innovation success, other firm characteristics relevant to growth performance and regional characteristics which may influence firm growth

As in our 2009 report for NESTA, this modelling design is influenced by the arguments made by Griliches (1979) and Crepon, Duguet and Mairesse (1998) for estimating structural models with separate equations to specify the determinants of innovative activity and the determinants of firm-level production which makes use of the knowledge generated by innovative activity. Multi-stage models of this kind are often used to examine the effects of different national settings on firm performance (see, for example, Janz et al, 2003 and Griffith et al, 2006) and it is straightforward to extend this approach, as we do here, to investigate the impact on firm performance of operating in different regions of the same country.

In more detail, in this two-stage model of firm innovation and growth, we first estimate an equation taking a measure of innovation success as dependent variable, with measures of firms' investments in the development of innovation-related capabilities and various regional characteristics entered as independent variables. Innovation success is here defined as the share of new products in total sales. Subsequently, the predicted values of innovation success generated by this regression are entered as independent variables in a second equation which estimates the determinants of firm growth, measured successively as growth in employment, sales and average sales per employee:

(3.1)

$$NPS_t = \beta_0 + \beta_1 \sum_j INN_{jt} + \beta_2 \sum_k X_{kt} + \beta_3 \sum_m INNREG_{mt} + \beta_4 \sum_c OTHREG_{ct} + \varepsilon_1$$

(3.2)

$$FG_{(t+3)/t} = \beta_0 + \beta_1 NPS\_pr_t + \beta_2 \sum_k X_{kt} + \beta_3 \sum_n BUSREG_{n(t+3)/t]} + \beta_4 \sum_c OTHREG_{ct} + \varepsilon_2$$

where NPS_t is the share of total sales attributable to new products at time t; INN_t is a vector of j firm-specific innovation inputs and capabilities; X_t is a vector of k firm-specific characteristics such as employment size, age, sector and involvement in exporting; $INNREG_t$ is a vector of n innovation inputs at regional and broad sectoral level [1]; $FG_{(t+3)/t}$ is a measure of firm growth between years t and t+3; $BUSREG_{(t+3)/t}$ is a vector of n indicators of business growth performance at regional level between years t and t+3; and $OTHREG_t$ is a vector of c other region-specific characteristics. Since NPS_t is left- and right-censored (ranging between 0-100), Equation 3.1 is estimated by Tobit methods. Equation 3.2 includes the predicted value of new product sales (NPS_pr_t) as an independent variable and is estimated by Ordinary Least Squares (OLS).

By evaluating the relationship between innovative success in year t and firm growth in a subsequent three-year period, we attempt to control for problems of simultaneity, ie, two-way interdependence between firm growth and innovation in the same time period. Furthermore, using the predicted value of the dependent variable in the first equation as a regressor in the second equation has the advantage of addressing other concerns about endogeneity between firm growth and innovation since the predicted values of the innovation success measure are not correlated with the error term in the second equation as might be expected if we used the actual values of this measure.

3.2 Data sources and descriptive statistics

Our main data source for measures of innovation success and innovative inputs is the Community Innovation Survey (CIS) 2004-06 which is matched against Business Survey Database (BSD) data on firm growth between 2006-09 and data for 45 city-

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[1] See below for further details of the broad sector groups for which different city-regional estimates of innovative inputs have been identified.

regions which account for just under 80% of total UK employment. This leaves us with a matched sample of 6761 firms, about 45% of the original CIS sample. Table 3.1 shows that the matched sample includes larger proportions of small firms and manufacturing firms than the original CIS sample while it has a smaller proportion of retail and wholesale firms. However, despite the attrition that has occurred, the matched sample still covers a wide range of size groups and sectors.

Table 3.1: Comparison of CIS sample and matched CIS-BSD sample, analysed by size group and sector

	CIS 2004-06	CIS 2004-06 matched to BSD 2006-09 in 45 city-regions
	Percent of firms in sample	
Employee size group:		
Under 20	33	31
20-49	23	26
50-99	14	15
100-249	8	7
250-499	12	10
500-999	5	6
1000+	5	6
TOTAL	**100**	**100**
Sector:		
Manufacturing	31	31
Other production	1	0
Construction	7	7
Retail and wholesale	15	10
Hotels and catering	6	4
Transport and communications	8	9
Financial services	3	3
Business services	27	34
Other services	1	1
TOTAL	**100**	**100**
n =	*14872*	*6761*

City-regions typically comprise large metropolitan areas – or contiguous metropolitan areas -- together with their surrounding hinterlands (Scott, 2005). Our own definition of British city-regions derives from Robson et al (2006) who made use of employment,

commuting, housing and retail data to identify 39 relatively self-contained city-regions in England and their constituent local authority districts (LADs). For reasons described in the notes to Figure 3.1, we reduced this list to 38 English city-regions and added seven more city-regions in Scotland, Wales and Northern Ireland. As Robson et al (2006) demonstrate, the city-regions identified according to their criteria tend to overlap with the commuting patterns of managers and professionals. Thus they delineate day-to-day travel areas for high-skilled workers who are more likely to be involved in innovation and knowledge-sharing than are low-skilled workers. For this reason we believe city-regions to be more relevant to investigations of firm performance than are smaller travel-to-work areas which tend to be dominated by the commuting patterns of lower-skilled workers. [2]

In terms of analysis of the scope for localised interactions which are relevant to firm innovation and growth, city-regions as they are defined here also represent an important contrast with regions which are defined solely on the basis of political and/or administrative considerations. Key variables in the city-regions dataset have been estimated using LAD-level data derived from a number of sources such as the Labour Force Survey (via NOMIS) and the BSD which have been reaggregated to city-region level. The dataset covers several indicators of social and economic conditions such as employment, inactivity and unemployment rates as well as measures of demographic change, workforce qualifications and industrial structure. As shown in Table 3.2, our sample of firms participating in the CIS are spread widely across all 45 city-regions but with larger groups of firms in more heavily populated city-regions such as Greater London.

Figures 3.1-3.2 show the marked contrasts which exist between city-regions in terms of our measure of innovation success (average share of new products in total firm sales) in 2006 and annual rates of growth in private sector employment in 2006-08. Some city-regions perform strongly on both measures (for example, Cambridge, York, Telford and Wrekin, Coventry and Ipswich) while others perform relatively poorly on both measures (for example, Birmingham, Carlisle, Kingston-upon-Hull,

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[2] There are currently 243 Travel-To-Work Areas in the UK which are defined such that at least 75 per cent of the resident economically active population actually work in the area while at the same time at least 75 per cent of everyone working in the area actually live in the area
(http://www.statistics.gov.uk/geography/ttwa.asp)

Leicester and Lincoln). Appendix Table A6 shows further contrasts which exist between city-regions in terms of interactions with supply-chain partners and universities and reported financial and skill constraints on innovation. Therefore, there is considerable interest in investigating whether and to what extent firm-level performance is influenced by the characteristics of the city-regions in which they operate.

Table 3.2: Matched CIS-BSD sample, analysed by city-region

	Number of firms in sample		*Number of firms in sample*
Birmingham/Sandwell/ Wolverhampton	682	Northampton	146
Bournemouth/Poole	135	Norwich	128
Brighton and Hove	47	Nottingham/Derby	365
Bristol/ S.Gloucester	270	Oxford	84
Cambridge	110	Peterborough	121
Carlisle	69	Plymouth	83
Chester	173	Portsmouth/ Southampton	164
Colchester	55	Preston	51
Coventry	134	Reading	108
Exeter	117	Sheffield	220
Greater London	2299	Stoke-on-Trent	134
Gloucester/Cheltenham	139	Swindon	93
Ipswich	108	Telford and Wrekin	88
Kingston upon Hull	140	Worcester	38
Leeds/Bradford	592	York	66
Leicester	248	Cardiff	573
Lincoln	89	Swansea	127
Liverpool	156	Aberdeen	154
Luton	71	Dundee	65
Manchester/Salford/Trafford	637	Edinburgh	179
Middlesbrough/Stockton	323	Glasgow	414
Milton Keynes	44	Belfast	380
Newcastle/Gateshead/ Sunderland	685		
		TOTAL	*11004*

Figure 3.1: Average share of new products in firms' total sales (%), 2006, analysed by city-region

Average share of new products in total sales (%), 2006
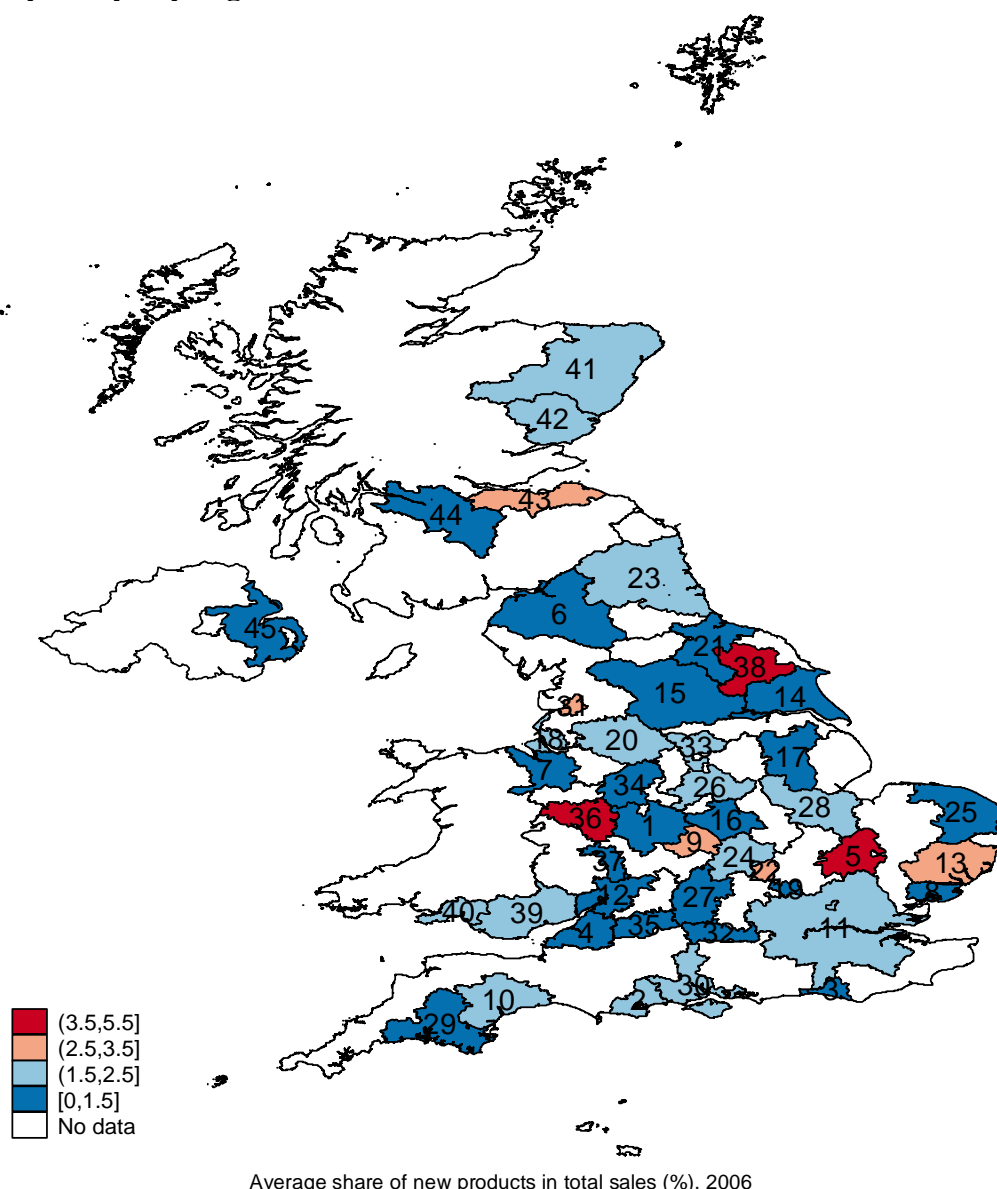
Source: Derived from Community Innovation Survey (CIS), 2006
Key to city-regions:
1.Birmingham/Sandwell/Wolverhampton 2.Bournemouth/Poole 3.Brighton & Hove 4.Bristol/S.Gloucester
5.Cambridge 6.Carlisle 7.Chester 8.Colchester 9.Coventry 10.Exeter 11.Greater London
12.Gloucester/Cheltenham 13.Ipswich 14.Kingston upon Hull 15.Leeds/Bradford 16.Leicester 17.Lincoln
18.Liverpool 19.Luton 20.Manchester/Salford/Trafford 21.Middlesbrough/Stockton 22.Milton Keynes
23.Newcastle/Gateshead/Sunderland 24.Northampton 25.Norwich 26.Nottingham/Derby 27.Oxford
28.Peterborough 29.Plymouth 30.Portsmouth/Southampton 31.Preston 32.Reading 33.Sheffield 34.Stoke-
on-Trent 35.Swindon 36.Telford and Wrekin 37.Worcester 38.York 39.Cardiff 40.Swansea 41.Aberdeen
42.Dundee 43.Edinburgh 44.Glasgow 45. Belfast
Notes: Definitions of English city-regions in terms of local authority districts are derived from Robson et
al, 2006, Chapter 2 (especially Figures 2.8 and 2.9). We are grateful to Brian Robson and colleagues for the
use of their LAD (local authority district) mapping to city-regions. Their Table 2.2 identifies 39
'destination nodes' which constitute the nuclei of city-regions in England. We have reduced this total to 38
English city-regions by combining Nottingham and Derby because of the overlap in commuting patterns
between these two cities and their surrounding areas. City-regions in Wales, Scotland and Northern Ireland
were identified with the aid of information in Belfast City Development Department (2005), Derek Halden
Consultancy (2002), Morgan (2006) and Statistics for Wales (2008).

Figure 3.2: Average annual growth rate in private sector employment (%), 2006-08, analysed by city-region
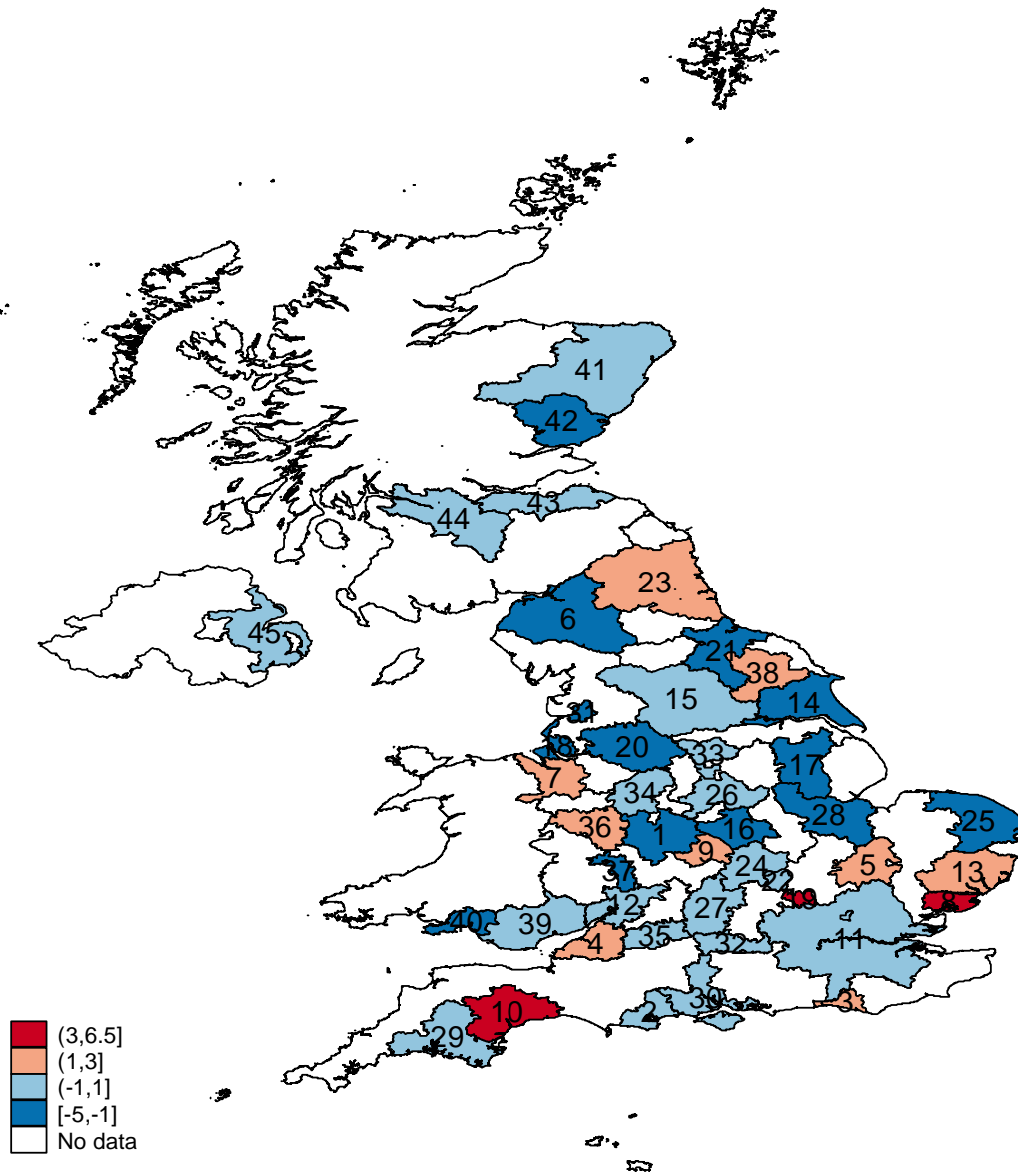
Average annual growth rate in private sector employment, 2006-08

Source: Derived from Labour Force Survey (NOMIS), 2006-08
Key to city-regions:
1.Birmingham/Sandwell/Wolverhampton 2.Bournemouth/Poole 3.Brighton & Hove 4.Bristol/S.Gloucester
5.Cambridge 6.Carlisle 7.Chester 8.Colchester 9.Coventry 10.Exeter 11.Greater London
12.Gloucester/Cheltenham 13.Ipswich 14.Kingston upon Hull 15.Leeds/Bradford 16.Leicester 17.Lincoln
18.Liverpool 19.Luton 20.Manchester/Salford/Trafford 21.Middlesbrough/Stockton 22.Milton Keynes
23.Newcastle/Gateshead/Sunderland 24.Northampton 25.Norwich 26.Nottingham/Derby 27.Oxford
28.Peterborough 29.Plymouth 30.Portsmouth/Southampton 31.Preston 32.Reading 33.Sheffield 34.Stoke-
on-Trent 35.Swindon 36.Telford and Wrekin 37.Worcester 38.York 39.Cardiff 40.Swansea 41.Aberdeen
42.Dundee 43.Edinburgh 44.Glasgow 45. Belfast
Notes: See Figure 3.1

3.3 Derivation of key variables

In the analysis that follows, we draw on the BSD for measures of firm size, age, sector and growth rates in employment and sales. Drawing on the CIS, we define a number of measures of innovative effort and innovation performance at both firm and city-region level. Where possible these measures are derived through principal-components factor analysis in order to reduce multicollinearity between related variables. However, for some measures relevant test statistics did not support the use of factor analysis and we therefore made use of simple additive scores or binary variables. The city-region estimates are calculated for three broad sector groups: production sectors, knowledge-intensive services and other services. [3]

Innovation intensity:

- Total spending on R&D and innovation-related machinery, software, knowledge acquisition, training, design and marketing as a percentage of firm turnover

Acquisition or development of innovation-related resources and capabilities:

- Importance of external knowledge sources, eg, customers, suppliers, universities and public laboratories [4]

- Geographic reach of external relationships with research partners and collaborators [5]

- Organisational innovation (eg, changes in corporate strategy or business structure or practices) [6]

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[3] Knowledge-intensive services are defined following Eurostat practice as: Air transport (SIC 2003 code 62), Travel agencies and tourism operators (633), Telecommunications services (642), Financial services (65-67), Computer services (72), R&D services (73), Legal, accounting, architectural, engineering, technical testing, advertising, labour recruitment and related business services (741-745) and Other professional and cultural services (91-92).

[4] Defined on a 0-3 scale with 3 denoting that the respective information source is of high importance; 2 = medium importance; 1 = low importance; 0 = not used.

[5] This variable was measured in the following way. For each firm reported innovation partners were allocated to a 0-3 scale where 3 denoted the partner's location in a foreign country; 2 = partner located in the UK at 100 miles distance or further; 1 = partner located in the UK at less than 100 miles distance; 0 = no innovation partnership. The respective scores for innovation partnerships with suppliers, customers, consumers, universities and public laboratories were then entered in a factor analysis to derive a summary measure of the geographic reach of each firm's relationships with research partners external to the firm. These five measures loaded onto a single factor with an eigenvalue in excess of one which explained 62% of their variation (Kaiser-Meyer-Olkin measure of sampling adequacy = 0.795).

In addition, we obtain information from the CIS on additional control variables to be entered into our model, for example, whether firms engage in exporting; the percentage share of the workforce which is qualified to university graduate level or above; and whether the firm experienced significant recent changes in employment or sales as a result of merger with another business or sale or closure of part of their own business.

We also include the following variables at city-region level:

(1) A measure of own-industry specialisation:

$OwnIndSpecialisation_c = E_{ic} / E_c$

where E_{ic} is employment in industry i in city-region c and E_c is total employment in city-region c.

(2) A measure of industrial diversity defined as follows:

$IndustrialDiversity_c = 1 - [\sum_i (E_{ic} / E_c)^2]$

where the second term on the right hand side of equation is a Herfindahl index which ranges from 0-1, with high values denoting employment concentrated in a small number of industries.

(3) Employment density (employees per square kilometre) as a proxy measure of urban scale and diversity

(4) The proportion of firms with 100 or fewer employees, designed to capture the possibility that a prevalence of small firms contributes positively to city-region growth, perhaps reflecting the entrepreneurial qualities of their owners (Glaeser et al, 1992).

(5) An indicator of firm size diversity, defined as the coefficient of variation of firm employment sizes in each city-region, intended to explore the proposition advanced

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[6] Derived from factor analysis of responses to survey questions about whether or not firms had implemented new or significantly changed corporate strategies, advanced management techniques, major changes to organisational structure or changes in marketing concepts or strategies. These four variables loaded onto a single factor with an eigenvalue in excess of one which explained 54% of their variation (Kaiser-Meyer-Olkin measure of sampling adequacy = 0.737).

by Agrawal et al (2012) that innovative performance at regional level benefits from the co-location of large and small firms [7]

(6) Indicators of perceived barriers to innovation resulting from financial constraints or difficulties in recruiting skilled labour

In all models we take natural logarithms of the following variables to help offset the highly skewed nature of their distributions: firm employment size, firm age, own-industry specialisation, industrial diversity, employment density, small firms' employment share and firm size diversity.

Finally we derive two summary measures of city-region attributes which are highly relevant to the hypotheses to be tested:

(7) Skills and labour market conditions: in the spirit of the 'social filter' measure proposed by Rodriguez-Pose and Crescenzi (2008), this measure is based on factor analysis of the following variables at city-region level in 2006: [8]

- Holders of NVQ or higher qualifications as a proportion of the total working-age population

- Employed persons as a proportion of total economically active persons

- Annual rate of growth in the working-age population: a variable which captures the net effects of age-related movements into and out of working-age populations as well as net migration in and out of city-regions by working-age people

(8) Business growth performance: derived from factor analysis of the following city-region level variables relating to firm employment growth between 2006-09: [9]

- Mean rate of firm growth in employment

- Mean rate of firm growth in sales

- Annual rate of growth in total private sector employment

- Annual rate of growth in total firm sales

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[7] Possible mechanisms by which such benefits may occur include spin-off firms generated by large firms and the development of specialised business services to meet the needs of small firms (Agrawal et al, 2012).

[8] These three indicators loaded onto a single factor with an eigenvalue in excess of one which explained 53% of the variation in the three variables (Kaiser-Meyer-Olkin measure of sampling adequacy = 0.596).

[9] These four measures loaded onto a single factor with an eigenvalue in excess of one which explained 56% of the variation in the four variables (Kaiser-Meyer-Olkin measure of sampling adequacy = 0.580).

In terms of bilateral correlations, Table 3.3 shows that innovation success at firm level is strongly positively correlated with both firm-level and city-region level measures of investment in innovation and the development of innovation-related capabilities (for example, through external knowledge sourcing and external relationships with research partners) (Column 1). Employment growth and sales growth at firm level are positively correlated with prior innovation success and with prior firm-level investments in innovation and the development of innovation-related capabilities. However, employment growth and sales growth at firm level are not generally correlated with city-region level indicators of these innovation inputs.

Table 3.3: Pairwise correlations between firm-level innovation and growth variables and city-region level variables (n=4884-6761)

	Innovation success (new products as a share of sales), 2006	Employment growth, 2006-09	Sales growth, 2006-09
Firm-level variables:			
Employment growth, 2006-09	0.04***	1.00	
Sales growth, 2006-09	0.05***	0.53***	1.00
Innovation intensity, 2004-06	0.16***	0.05***	0.02
External information sources: suppliers and customers, 2004-06	0.12***	0.07***	0.06***
External information sources: universities and public laboratories, 2004-06	0.13***	0.04***	0.05***
Organisational innovation, 2004-06	0.14***	0.04**	0.07***
External cooperation partners: distance-based measure, 2004-06	0.20***	0.03	0.05***
City-region level variables:			
Own-industry specialisation, 2006	-0.09***	0.00	0.01
Industrial diversity, 2006	0.01	0.02	0.01
Employment density, 2006	-0.04***	-0.03**	-0.03**
Skills and labour market conditions, 2006	0.00	-0.01	0.00
Small firms' share of employment (firms with under 100 employees), 2006	0.01	0.01	0.01
Firm size diversity, 2006	-0.03**	-0.02	-0.01
Innovation intensity, 2004-06	0.11***	-0.01	0.02
Organisational innovation, 2004-06	0.04***	-0.02	0.02*
External information sources: summary measure, 2004-06	0.09***	-0.03**	0.01
External cooperation partners: distance-based measure, 2004-06	0.12***	-0.01	0.02

Table 3.3 also shows a pattern of negative bilateral correlation between innovation success at firm level and city-region indicators of own-industry specialisation, industrial diversity and employment density while firm-level employment and sales growth are negatively correlated with employment density. In Section 4 we will explore whether similar correlations also arise in the context of multivariate analysis.

4. Empirical findings

We now present the results of the two-stage regression analysis described above for All Sectors and for three sector groups in turn: production sectors, knowledge-intensive services and other services.

Tables 4.1-4.2 show Tobit estimates of innovation success in 2006 as a function of firm-specific innovative inputs and innovation-related capabilities, together with firm-level controls for variables including employment size, age, sector, export status and the graduate share of employment (Columns 1 and 4). We then go on to explore the impact of including city-region measures of own-industry specialisation, industrial diversity, employment density, small firms' share of employment, firm-size diversity and skills and labour market conditions together with city-region measures of innovative inputs (Columns 2-3 and 5-6).

In Tables 4.3-4.4 we present OLS estimates of firm growth in employment between 2006-09 as a function of predicted innovation success in 2006 together with firm-level controls and city-region level measures of business growth performance, own-industry specialisation, employment density, small firms' share of employment, firm-size diversity and skills and labour market conditions. In these growth models the firm-level controls include indicators of prior involvement in merger or divestment activity as well as employment size, age, sector, export status and the graduate share of employment. Tables 4.3-4.4 also show similar estimates of firm growth in sales and in average sales per employee between 2006-09.

4.1 Innovation performance

In All Sectors and in each of the three groups of sectors, innovation success is positively and significantly related to several innovative inputs at firm level, in particular, the intensity of spending on innovation-related activities and the resources devoted to organisational improvements and obtaining information from suppliers and customers (Tables 4.1-4.2, Columns 1 and 4). For example, in All Sectors a one standard deviation increase in innovation intensity is associated with a 4.4 percentage point (pp) increase in the innovation success measure (Table 4.1, Column 1). But some differences emerge between the sector groups. For example, external knowledge

sourcing from universities and public laboratories contributes significantly to innovation success in production sectors and knowledge-intensive services but not in Other Service sectors. Similar differences between sector groups emerge in relation to our distance-based measure of external innovation partnerships which takes account of the additional investment of resources required to work with partners located in other regions (at a distance of 100 miles or more which is the CIS definition of extra-regional). This measure of involvement with external partners on innovation projects is significantly and positively related to innovation success in production sectors and knowledge-intensive services but not in Other Services.

When we introduce city-region level variables to each of these models, some striking differences emerge between the sector groups. In particular, nearly all the city-region measures are statistically significant in the case of All Sectors and production sectors (Table 4.1, Columns 2 and 5) while very few of these variables signify in relation to knowledge-intensive services (Table 4.2, Column 2) or Other Services (Table 4.2, Column 5).

In production sectors innovation success is found to be significantly negatively related to the measure of own-industry specialisation at city-region level. For example, in these sectors a one standard deviation increase in the measure of own-industry specialisation is associated with a 1.4 pp decrease in innovation success (Table 4.1, Column 5). This suggests that, in common with the French manufacturing and business service firms analysed by Duranton and Puga (2002), innovation in UK production sectors does not benefit from localised concentration of firms in the same industry. This finding may also reflect the point made by Devereux et al (2004) that many of the most agglomerated industries in the UK are low-tech manufacturing industries which date back centuries and featured in Marshall (1890)'s analysis of industrial districts. The relative lack of innovation in these sectors may be driving the negative association between own-industry specialisation and innovation success in production sectors.

However, in contrast to Duranton and Puga (2002)'s evidence for France, innovation success in production sectors in the UK does not seem to benefit from different kinds of diversity. The innovation success measure is significantly negatively related to both

industrial diversity and firm size diversity in these sectors (Table 4.1, Column 5) and to an interaction term combining these two types of diversity (Column 6). Moreover, far from innovation success in production sectors benefiting from diversity in firm sizes, the results suggest that having a relatively large share of small firms may be a positive influence (Column 5). This fits with the strongly negative coefficient attached to employment size in all models shown in Table 4.1 and could reflect an important role for entrepreneurial small firms where they exist.

Innovation success in production sector firms is also found to be positively related to our summary measure of socio-economic and labour market conditions at city-region level (derived from indicators of skill levels, employment rates and the annual rate of growth in the working-age population) (Table 4.1, Column 5). This contrasts with the significant negative coefficient attached to this variable in the All Sectors model (Table 4.1, Column 2) and shows the importance of disaggregating our results by sector group. The result for All Sectors reflects the fact that the equivalent coefficient is negatively-signed but non-significant in both knowledge-intensive services and Other Services (Table 4.2, Columns 2 and 5).

To the extent that production sector firms (and their employees) engage in localised interactions with other firms and employees in their search for useful ideas and knowledge, our results suggest that these interactions are more relevant and beneficial to firm innovation, the more that other firms in their regions are themselves engaged in innovative activities. In production sectors innovation success at firm level is positively and significantly related to innovation inputs among other production sector firms in their city-regions as measured by intensity of spending on innovation, involvement in organisational innovation and cooperation with external innovation partners (Table 4.1, Column 5). For example, a one standard deviation increase in city-region level innovation intensity is associated with a 1.4 pp increase in innovation success at firm level in these sectors.

In spite of these findings, innovation success in production sectors is not significantly related to a summary measure of external knowledge-seeking at city-region level. However, when we introduce an interaction term combining the city-region indicators of external information-seeking activity and the distance-based measure of collaboration with external innovation partners, the coefficient on the interaction term

is positive and significant (Table 4.1, Column 6), suggesting that external information-seeking at city-region level is more likely to benefit individual production firms, the more that other production firms in their region with which they interact are outward looking in terms of their relationships with extra-regional partners. This could reflect the advantages of ideas and knowledge that are exchanged through localised interactions being regularly refreshed by contacts with extra-regional information sources. [10]

Table 4.2 presents similar estimates for knowledge-intensive services which include telecommunications, financial, computer, R&D, legal, accounting, architectural, engineering and advertising services. As noted above, innovation success at firm level in these service areas is strongly related to prior investments in innovation and the development of innovation-related capabilities at firm level as was found for production sectors. However, in marked contrast to production sectors, none of the city-region level variables relating to innovative inputs are statistically significant in the knowledge-intensive services model (Table 4.2, Columns 2-3).

Given the outward-looking orientation of innovative firms in knowledge-intensive services, it seems unlikely that firms in these service areas do not benefit from being part of innovation eco-systems. Hence the most likely explanation for our findings in relation to knowledge-intensive service firms is that their external interactions with other firms and organisations take place on a wider geographic scale than that denoted by city-regions. In a recent study of 'creative clusters' and innovation in the UK, Chapain et al (2010) highlight the importance of creative firms' access to global sources of innovation and their ability to engage in long-distance partnerships in real-time using on-line communications tools. [11] External factors such as skills and labour market conditions may also influence the prospects of innovation success on a wider geographic scale in knowledge-intensive services than in production sectors. If appropriate data sources can be identified, further research would be useful to

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[10] This finding of apparent complementarity between local and extra-regional information sources is at odds with results for Irish-based firms reported by Doran et al (2012). Further research would be necessary to understand UK-Ireland differences in this respect.
[11] The definition of 'creative' sectors followed by Chapain et al (2010) includes many sectors which we define as knowledge-intensive services, eg, advertising, architecture, computer software and radio and TV broadcasting.

investigate the geographic scope of innovation eco-systems that are most relevant to knowledge-intensive services.

In Other Services (which includes retail, hotels and catering and road and rail transport services) innovation success at firm level is positively and significantly related to firms' own investments in innovation, supply-chain interactions and organisational innovation (Table 4.2, Column 4), similar to findings for production sectors and knowledge-intensive services. However, in contrast to other sector groups, innovation success in Other Services is significantly negatively related to innovation intensity at city-region level (Table 4.2, Column 5). This may reflect competitive pressures from other innovative firms seeking customers for newly-developed services.

One striking characteristic of firms in Other Services is that innovation success is significantly adversely affected by financial constraints at city-region level. This is also the case to a lesser degree for production sector firms but no such regional effect of financial constraints is found for knowledge-intensive services. In what seems a surprising result, innovation success in Other Services is found to be significantly positively related to difficulties in recruiting employees with innovation-related skills. This contrasts with the expected negative association between innovation success and skill constraints which is found in production sectors. We conjecture that, in relatively low-innovation sectors such as retail, hotels and road and rail transport, the level of skills required to develop and sell new services is relatively low compared to production sectors and therefore Other Service firms engaging in innovation find it relatively easy to surmount recruitment difficulties. Lower skill and knowledge requirements may also explain why working with external cooperation partners has no significant effects on innovation success in Other Sectors.

What are the apparent effects of industrial structure and urban scale on innovation success in service sectors? In contrast to our findings for production sectors, innovation success in knowledge-intensive services and Other Services is not significantly related to own-industry specialisation (although the relevant coefficients on this variable are negatively-signed) (Table 4.2, Columns 2 and 5). In knowledge-intensive services innovation success is significantly negatively related to employment density but the coefficients attached to both industrial diversity and firm size diversity are non-significant (Table 4.2, Column 2). The only city-region level variable that signifies

positively in the knowledge-intensive services model is the small firms' employment share. As noted above, this effect is also found in production sectors but not in Other Services, pointing to a more important role for entrepreneurial small firms in more skill-intensive activities. In Other Services innovation success is significantly negatively related to employment density but not to any indicators of industrial structure at city-region level (Table 4.2, Column 5).

4.2 Firm growth performance

We now turn to the second-stage firm growth equations in which predicted values of innovation success are entered as independent variables. In all three groups of sectors, these indicators of prior innovation success signify very positively and strongly indeed (Tables 4.3-4.4), as expected from previous analysis of the relationship between innovation and firm growth (Mason et al, 2009). For example, in All Sectors a one standard deviation increase in innovation success is associated with a 0.9 pp increase in firm-level employment growth rates (Table 4.3, Column 1).

In general, firm-specific characteristics appear to dominate city-region effects on firm growth performance across all three groups of sectors (Tables 4.3-4.4). In addition to the effects of prior investments in innovation at firm level, firm growth in employment, sales and sales per employee all tend to be significantly affected by employment size, age of firm and involvement in prior merger activity or divestment or closure of plants. By contrast, after controlling for these firm-specific effects, hardly any of the city-region variables are found to significantly affect firm growth with the exception of employment density which is negatively related to growth in sales and sales per employee in Other Services.

One possible explanation for this pattern of findings is that, where city-region characteristics do affect firm growth, they do so primarily in an indirect way through their effects on innovative performance which then contributes substantially in a later time period to firm-level growth. This idea receives some partial support from re-running the firm growth models without including the predicted value of innovation success as a regressor (Tables 4.5-4.6). Across All Sectors the measure of business growth performance at city-region level now signifies positively in relation to both

employment and sales growth (Table 4.5, Columns 1-2). This is largely because of its effects in service sectors rather than in production sectors. In this alternative specification, both own-industry specialisation and the small firms' employment share are now found to be positively related to growth in sales and average sales per employee at firm level (Table 4.6, Columns 2-3). In addition, the summary measure of skills and labour market conditions now signifies negatively in the sales growth equation for knowledge-intensive services, suggesting that firm growth in these sectors may be adversely affected by regional competition for skilled labour in ways that do not apply to innovative performance.

4.3 Spatial dependence issues

As described above, to our knowledge this paper represents a first attempt to assess the impact of city-region characteristics on firm-level innovation and growth in the UK. It remains an open question whether the boundaries of city-regions as defined here contain the bulk of localised interactions between different firms and their employees that might affect performance or whether there are important spillovers of knowledge and ideas across city-region boundaries.

At the suggestion of a referee for an earlier version of this report, we first examined the possible impact of a 'London and South East effect' since productivity and growth are substantially higher in these regions are substantially higher than elsewhere in the UK. [12] This took the form of a sensitivity test in which each model was re-run with the inclusion of a new variable controlling for firms' location in London and the South East as well as in their own city-regions (see Appendix Tables A2-A5). In general, the inclusion of the London/South East indicator causes very little change to the patterns of inference in relation to city-region effects which we derived from results shown in Tables 4.1-4.6.

However, further investigation of the extent of any spatial dependence suggests that our results relating to city-region measures of industrial structure and urban scale are less robust than our results relating to other city-region characteristics. In order to test

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[12] ONS, Regional Economic Indicators, http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-300556

for the presence of spatial autocorrelation, we calculate Moran's I statistics for all city-region level variables. The results, shown in Table 4.7, suggest that the null hypothesis of zero autocorrelation is rejected for four variables: own-industry specialisation, industrial diversity, employment density and small firms' share of employment. By contrast, we cannot reject the hypothesis that there is no significant interdependence between city-regions for innovation-related variables nor for city-region measures of business growth performance, skills and labour market conditions or financial and skill constraints on innovation.

These findings strengthen the confidence that we can place in using city-region level data to examine regional effects on firm performance in relation to the latter set of variables. However, strong caveats need to be placed on our findings in relation to the apparent effects (or lack of effect) of own-industry specialisation, industrial diversity, employment density and small firms' share of employment. Further research, beyond the scope of this report, is needed to identify the geographical units of measurement which might best capture the regional effects of these potential influences on firm performance.

Table 4.1: Tobit estimates of firm innovation success, 2006: All Sectors and Production sectors

	(1)	(2)	(3)	(4)	(5)	(6)
	All sectors	All sectors	All sectors	Pro-duction sectors	Pro-duction sectors	Pro-duction sectors
Firm-level variables:						
Innovation intensity	0.5464***	0.5343***	0.5359***	0.4790***	0.4801***	0.4788***
	[0.029]	[0.028]	[0.028]	[0.020]	[0.018]	[0.017]
External information sources: suppliers and customers	0.0938***	0.0942***	0.0944***	0.0818***	0.0823***	0.0823***
	[0.003]	[0.003]	[0.003]	[0.002]	[0.002]	[0.002]
External information sources: universities and public laboratories	0.0175***	0.0175***	0.0172***	0.0044**	0.0060***	0.0058***
	[0.003]	[0.003]	[0.003]	[0.002]	[0.002]	[0.002]
Organisational innovation	0.0542***	0.0536***	0.0536***	0.0444***	0.0430***	0.0431***
	[0.002]	[0.002]	[0.002]	[0.001]	[0.001]	[0.001]
External co-operation partners: distance-based measure	0.0357***	0.0337***	0.0337***	0.0396***	0.0390***	0.0393***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Exporter	0.1016***	0.1035***	0.1027***	0.0677***	0.0708***	0.0701***
	[0.005]	[0.005]	[0.005]	[0.005]	[0.004]	[0.004]
Graduate share of employment	0.0814***	0.0740***	0.0728***	0.0099**	0.0074	0.0067
	[0.008]	[0.007]	[0.007]	[0.005]	[0.005]	[0.004]
Employment size (log)	-0.0230***	-0.0231***	-0.0231***	-0.0211***	-0.0219***	-0.0221***
	[0.002]	[0.002]	[0.002]	[0.001]	[0.001]	[0.001]
Age of firm (log)	-0.0103***	-0.0116***	-0.0122***	0.0023	0.0040**	0.0040**
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
City-region level variables:						
Own-industry specialisation (log)		-0.0065**	-0.0066**		-0.0103***	-0.0087***
		[0.003]	[0.003]		[0.002]	[0.002]
Industrial diversity (log)		-0.1188***	0.3391***		-0.0743***	0.4117***
		[0.004]	[0.004]		[0.003]	[0.003]
Employment density (log)		-0.0414***	-0.0490***		-0.0007	-0.0076***
		[0.001]	[0.001]		[0.001]	[0.001]
Skills and labour market conditions		-0.0064***	-0.0070***		0.0032***	0.0061***
		[0.001]	[0.001]		[0.001]	[0.001]
Small firms' share of employment (log)		-0.1419***	-0.2150***		0.0266***	-0.0646***
		[0.004]	[0.004]		[0.003]	[0.003]
Firm size diversity (log)		-0.0438***	0.6505***		-0.0136***	0.7234***
		[0.006]	[0.006]		[0.005]	[0.004]
Innovation intensity		-0.0191***	-0.0245***		0.0163***	0.0155***
		[0.003]	[0.002]		[0.002]	[0.002]

Organisational innovation		0.0142	0.0295**		0.0823***	0.1069***
		[0.013]	[0.013]		[0.014]	[0.013]
External information sourcing (summary measure)		0.0142	-0.0004		-0.012	-0.0335*
		[0.024]	[0.024]		[0.020]	[0.018]
External co-operation partners: distance-based measure		0.1272***	0.1525***		0.0948***	0.2675***
		[0.013]	[0.012]		[0.012]	[0.019]
Financial constraints on innovation		-0.3104***	-0.2927***		-0.0996***	-0.0790***
		[0.020]	[0.020]		[0.017]	[0.016]
Skill constraints on innovation		0.4119***	0.3344***		-0.0578***	-0.1187***
		[0.029]	[0.029]		[0.021]	[0.019]
External information sourcing * External co-operation partners (distance-based measure)			0.2110***			0.9327***
			[0.045]			[0.092]
Firm size diversity * Industrial diversity			-0.3882***			-0.4084***
			[0.004]			[0.002]
Observations	6,761	6,761	6,761	2,554	2,554	2,554
Pseudo R sqd	0.305	0.315	0.316	0.281	0.287	0.288
Log likelihood	-1216	-1198	-1197	-525.8	-522.1	-521.4

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%
Tobit estimates. The dependent variable is the proportion of sales in 2006 which was attributable to new products. Among independent variables, innovation-related measures refer to the 2004-06 period. Other city-region variables are for 2006. Robust standard errors in parentheses are corrected for clustering at city-region and broad sector levels. All models include sector dummies.

Table 4.2: Tobit estimates of firm innovation success, 2006: Knowledge-intensive services and Other services

	(1)	(2)	(3)	(4)	(5)	(6)
	Knowledge-intensive services	Knowledge-intensive services	Knowledge-intensive services	Other services	Other services	Other services
Firm-level variables:						
Innovation intensity	0.3654*	0.339	0.3389	0.8495***	0.7935***	0.7912***
	[0.201]	[0.209]	[0.207]	[0.233]	[0.232]	[0.234]
External information sources: suppliers and customers	0.0697***	0.0776***	0.0774***	0.1158***	0.1159***	0.1161***
	[0.021]	[0.020]	[0.020]	[0.026]	[0.028]	[0.028]
External information sources: universities and public laboratories	0.0655***	0.0627***	0.0620**	0.0074	0.0124	0.0114
	[0.022]	[0.024]	[0.024]	[0.020]	[0.020]	[0.020]
Organisational innovation	0.0877***	0.0851***	0.0854***	0.0489**	0.0490***	0.0488***
	[0.016]	[0.015]	[0.015]	[0.019]	[0.019]	[0.018]
External co-operation partners: distance-based measure	0.0442***	0.0426***	0.0436***	0.0081	0.0043	0.0043
	[0.010]	[0.009]	[0.009]	[0.015]	[0.014]	[0.013]
Exporter	0.1731***	0.1721***	0.1720***	0.1011***	0.1126***	0.1107***
	[0.062]	[0.062]	[0.062]	[0.039]	[0.037]	[0.037]
Graduate share of employment	0.0574	0.0499	0.0435	0.1677***	0.1308**	0.1303**
	[0.051]	[0.049]	[0.051]	[0.048]	[0.051]	[0.052]
Employment size (log)	-0.0404***	-0.0389***	-0.0403***	-0.0223	-0.0267	-0.0265
	[0.013]	[0.015]	[0.015]	[0.025]	[0.027]	[0.028]
Age of firm (log)	-0.0539**	-0.0679***	-0.0664***	-0.0067	-0.0121	-0.012
	[0.024]	[0.022]	[0.022]	[0.016]	[0.015]	[0.015]
City-region level variables:						
Own-industry specialisation (log)		0.0055	-0.0098		-0.0089	-0.0174
		[0.038]	[0.038]		[0.061]	[0.066]
Industrial diversity (log)		-0.1806	-0.0175		-0.1832	0.3186
		[0.202]	[0.896]		[0.135]	[0.773]
Employment density (log)		-0.0540**	-0.0572**		-0.0708***	-0.0770***
		[0.025]	[0.026]		[0.027]	[0.029]
Skills and labour market conditions		-0.0001	-0.0027		-0.0146	-0.014
		[0.026]	[0.027]		[0.014]	[0.014]
Small firms' share of employment (log)		0.9665*	0.77		-0.3568	-0.4068
		[0.533]	[0.631]		[0.252]	[0.294]
Firm size diversity (log)		0.1872	0.4158		-0.1092	0.617
		[0.126]	[1.262]		[0.105]	[1.125]

Innovation intensity		0.013	-0.0029		-0.0960**	-0.0932**
		[0.029]	[0.032]		[0.044]	[0.043]
Organisational innovation		0.0599	0.0864		-0.0169	0.0097
		[0.144]	[0.160]		[0.249]	[0.263]
External information sourcing (summary measure)		-0.2327	-0.302		0.1284	0.0676
		[0.234]	[0.258]		[0.154]	[0.214]
External co-operation partners: distance-based measure		0.2587	0.0836		0.3243	0.202
		[0.158]	[0.172]		[0.227]	[0.231]
Financial constraints on innovation		0.1545	-0.0421		-1.1788***	-1.1914***
		[0.389]	[0.460]		[0.388]	[0.385]
Skill constraints on innovation		0.4115	0.2712		1.1880**	1.2118***
		[0.497]	[0.516]		[0.482]	[0.443]
External information sourcing * External co-operation partners (distance-based measure)			0.9318			-0.5051
			[0.632]			[1.185]
Firm size diversity * Industrial diversity			-0.1157			-0.4076
			[0.684]			[0.637]
Observations	1,377	1,377	1,377	2,830	2,830	2,830
Pseudo R sqd	0.319	0.345	0.348	0.318	0.352	0.352
Log likelihood	-294.8	-283.4	-282.4	-355.1	-337.5	-337.3

Notes: See Table 4.1

Table 4.3: OLS estimates of firm growth in employment, sales and average sales per employee 2006-09: All Sectors and Production sectors

	(1)	(2)	(3)	(4)	(5)	(6)
	All sectors	All sectors	All sectors	Production sectors	Production sectors	Production sectors
	Employ-ment growth	Sales growth	Growth in sales per employee	Employ-ment growth	Sales growth	Growth in sales per employee
Firm-level variables:						
Innovation success – predicted value	0.1083***	0.1162***	0.0076	0.0992***	0.1134***	0.0142
	[0.021]	[0.023]	[0.022]	[0.032]	[0.041]	[0.029]
Exporter	-0.0065	-0.0186**	-0.0132	-0.0163*	-0.0151	0.0013
	[0.007]	[0.009]	[0.009]	[0.009]	[0.012]	[0.010]
Graduate share of employment	-0.0057	-0.0062	0.0003	-0.0077	-0.005	0.0027
	[0.006]	[0.008]	[0.009]	[0.007]	[0.010]	[0.010]
Previous merger activity	0.0328	0.0513**	0.0187	0.0715***	0.0788***	0.0073
	[0.024]	[0.020]	[0.017]	[0.018]	[0.026]	[0.020]
Previous sale or closure of plants	-0.1667***	-0.2412***	-0.0747***	-0.1386***	-0.2087***	-0.0701*
	[0.016]	[0.022]	[0.022]	[0.025]	[0.040]	[0.038]
Employment size (log)	-0.0204***	-0.0069	0.0137***	-0.0186***	-0.0063	0.0123***
	[0.005]	[0.005]	[0.003]	[0.006]	[0.007]	[0.004]
Age of firm (log)	0.006	-0.0096	-0.0152***	-0.009	-0.0308***	-0.0217***
	[0.006]	[0.006]	[0.005]	[0.007]	[0.006]	[0.006]
City-region level variables:						
Own-industry specialisation (log)	0.0004	-0.0034	-0.0037	0.0000	-0.0099	-0.0099
	[0.006]	[0.008]	[0.007]	[0.007]	[0.009]	[0.008]
Industrial diversity (log)	-0.142	-0.1243	0.0075	-0.0799	-0.0157	0.0642
	[0.168]	[0.189]	[0.160]	[0.209]	[0.228]	[0.217]
Employment density (log)	0.0053	-0.0021	-0.0067	-0.0034	-0.0007	0.0027
	[0.006]	[0.006]	[0.005]	[0.007]	[0.009]	[0.006]
Business growth performance	0.0048	0.0046	-0.0003	-0.0001	-0.0009	-0.0007
	[0.004]	[0.005]	[0.004]	[0.005]	[0.007]	[0.005]
Skills and labour market conditions	-0.0013	0.0008	0.0016	-0.0015	-0.0004	0.0011
	[0.003]	[0.003]	[0.003]	[0.003]	[0.004]	[0.003]
Small firms' share of employment (log)	0.0015	-0.0115	-0.006	-0.0753	-0.0215	0.0539
	[0.060]	[0.069]	[0.059]	[0.082]	[0.098]	[0.084]
Firm size diversity (log)	-0.2192	-0.1654	0.037	-0.1057	-0.0372	0.0685
	[0.247]	[0.286]	[0.239]	[0.319]	[0.345]	[0.327]
Firm size diversity * Industrial diversity	0.1184	0.0914	-0.0177	0.0631	0.0381	-0.025
	[0.137]	[0.161]	[0.134]	[0.176]	[0.196]	[0.183]

Observations	4,891	4,884	4,884	2,236	2,236	2,236
Adjusted R sqd	0.0659	0.0661	0.0229	0.0827	0.0756	0.0359
SEE	0.205	0.248	0.228	0.167	0.209	0.182

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%

OLS estimates. The dependent variable is the average annual rate of growth in firm-level employment/sales/average sales per employee between 2006-09. Independent variables refer to 2006 except for the business growth performance measure at city-region level which refers to the 2006-09 period. Robust standard errors in parentheses are corrected for clustering at city-region and broad sector levels. All models include sector dummies.

Table 4.4: OLS estimates of firm growth in employment, sales and average sales per employee 2006-09: Knowledge-intensive services and Other Services

	(1) Knowledge-intensive services	(2) Knowledge-intensive services	(3) Knowledge-intensive services	(4) Other services	(5) Other services	(6) Other services
	Employment growth	Sales growth	Growth in sales per employee	Employment growth	Sales growth	Growth in sales per employee
Firm-level variables:						
Innovation success – predicted value	0.0917**	0.1068**	0.0149	0.1069***	0.1171***	0.0103
	[0.043]	[0.045]	[0.051]	[0.033]	[0.030]	[0.035]
Exporter	0.0276*	-0.0182	-0.0505***	-0.0133	-0.0241	-0.0108
	[0.015]	[0.019]	[0.015]	[0.013]	[0.017]	[0.016]
Graduate share of employment	-0.0041	-0.0039	0.0036	0.0049	-0.0063	-0.0112
	[0.022]	[0.027]	[0.024]	[0.010]	[0.010]	[0.012]
Previous merger activity	0.0097	0.0113	0.0013	0.0043	0.0532	0.0489*
	[0.070]	[0.031]	[0.049]	[0.028]	[0.034]	[0.028]
Previous sale or closure of plants	-0.1831***	-0.2967***	-0.1136***	-0.1793***	-0.2337***	-0.0543*
	[0.042]	[0.032]	[0.038]	[0.018]	[0.030]	[0.032]
Employment size (log)	-0.0331*	-0.0144	0.0195***	-0.008	0.0059	0.0140**
	[0.017]	[0.017]	[0.006]	[0.005]	[0.007]	[0.006]
Age of firm (log)	0.0249	0.0126	-0.0109	0.0089	-0.0035	-0.0124
	[0.015]	[0.017]	[0.010]	[0.006]	[0.009]	[0.008]
City-region level variables:						
Own-industry specialisation (log)	0.0056	0.0369	0.0324	0.01	0.0176	0.0076
	[0.015]	[0.026]	[0.023]	[0.019]	[0.025]	[0.024]
Industrial diversity (log)	-0.1784	-0.269	-0.1224	-0.0275	-0.2415	-0.214
	[0.517]	[0.500]	[0.335]	[0.309]	[0.324]	[0.199]
Employment density (log)	0.0254	0.0056	-0.0169	0.001	-0.0172*	-0.0182***
	[0.016]	[0.016]	[0.013]	[0.010]	[0.009]	[0.004]
Business growth performance	0.022	0.0181	-0.0038	0.0024	0.0008	-0.0016
	[0.013]	[0.011]	[0.009]	[0.005]	[0.007]	[0.005]
Skills and labour market conditions	-0.006	-0.0115	-0.008	0.0028	0.0053	0.0025
	[0.011]	[0.010]	[0.009]	[0.005]	[0.006]	[0.003]
Small firms' share of employment (log)	0.0649	0.1757	0.1355	0.0273	-0.1289	-0.1563**
	[0.153]	[0.131]	[0.101]	[0.101]	[0.085]	[0.075]
Firm size diversity (log)	-0.2578	-0.3906	-0.1877	-0.0932	-0.3343	-0.2411
	[0.758]	[0.762]	[0.512]	[0.476]	[0.506]	[0.315]
Firm size diversity * Industrial diversity	0.1134	0.1962	0.1133	0.0508	0.1713	0.1205
	[0.434]	[0.438]	[0.295]	[0.266]	[0.281]	[0.174]

Observations	1,084	1,077	1,077	1,571	1,571	1,571
Adjusted R sqd	0.0684	0.0693	0.0225	0.0577	0.0592	0.0104
SEE	0.273	0.312	0.283	0.197	0.249	0.245

Notes: See Table 4.3

Table 4.5: OLS estimates of firm growth in employment, sales and average sales per employee 2006-09: All sectors and production sectors
Excluding predicted value of innovation success as regressor

	(1)	(2)	(3)	(4)	(5)	(6)
	All sectors	All sectors	All sectors	Production sectors	Production sectors	Production sectors
	Employment growth	Sales growth	Growth in sales per employee	Employment growth	Sales growth	Growth in sales per employee
Firm-level variables:						
Exporter	0.0163**	0.0063	-0.0111*	0.0068	0.0085	0.0017
	[0.007]	[0.007]	[0.007]	[0.009]	[0.011]	[0.008]
Graduate share of employment	0.0106*	0.0098	-0.0003	0.0035	0.0056	0.0021
	[0.006]	[0.007]	[0.008]	[0.006]	[0.010]	[0.011]
Previous merger activity	0.0413*	0.0600***	0.0189	0.0858***	0.0885***	0.0027
	[0.025]	[0.019]	[0.018]	[0.019]	[0.025]	[0.022]
Previous sale or closure of plants	-0.1667***	-0.2411***	-0.0745***	-0.1324***	-0.2052***	-0.0728*
	[0.016]	[0.021]	[0.021]	[0.025]	[0.040]	[0.038]
Employment size (log)	-0.0212***	-0.0082*	0.0132***	-0.0205***	-0.0089	0.0116***
	[0.005]	[0.005]	[0.003]	[0.007]	[0.007]	[0.004]
Age of firm (log)	0.0046	-0.0149**	-0.0193***	-0.0117*	-0.0324***	-0.0207***
	[0.005]	[0.006]	[0.004]	[0.006]	[0.008]	[0.007]
City-region level variables:						
Own-industry specialisation (log)	-0.0009	-0.0038	-0.0028	-0.0014	-0.0117	-0.0103
	[0.006]	[0.008]	[0.006]	[0.007]	[0.008]	[0.007]
Industrial diversity (log)	-0.0632	-0.1346	-0.0799	-0.0118	0.0181	0.0299
	[0.157]	[0.171]	[0.166]	[0.225]	[0.205]	[0.198]
Employment density (log)	0.0017	-0.0023	-0.0034	-0.0036	0.0017	0.0053
	[0.005]	[0.006]	[0.005]	[0.007]	[0.008]	[0.005]
Business growth performance	0.0076**	0.0075*	-0.0002	0.0053	0.0063	0.001
	[0.004]	[0.004]	[0.004]	[0.005]	[0.006]	[0.004]
Skills and labour market conditions	-0.0013	-0.0002	0.0006	0.0007	0.0001	-0.0006
	[0.003]	[0.003]	[0.003]	[0.003]	[0.004]	[0.003]
Small firms' share of employment (log)	0.022	0.0415	0.026	-0.058	0.0133	0.0713
	[0.063]	[0.073]	[0.060]	[0.091]	[0.092]	[0.078]
Firm size diversity (log)	-0.0679	-0.1512	-0.0972	0.0394	0.0584	0.019
	[0.236]	[0.262]	[0.251]	[0.349]	[0.312]	[0.297]
Firm size diversity * Industrial diversity	0.0324	0.082	0.0574	-0.0208	-0.0192	0.0016
	[0.132]	[0.149]	[0.142]	[0.194]	[0.180]	[0.165]

Observations	5,430	5,421	5,421	2,433	2,433	2,433
Adjusted R sqd	0.0495	0.0557	0.0245	0.0574	0.0645	0.034
SEE	0.213	0.258	0.234	0.183	0.223	0.183

Notes: See Table 4.3

Table 4.6: OLS estimates of firm growth in employment, sales and average sales per employee 2006-09: Knowledge-intensive services and other services
Excluding predicted value of innovation success as regressor

	(1)	(2)	(3)	(4)	(5)	(6)
	Knowledge-intensive services	Knowledge-intensive services	Knowledge-intensive services	Other services	Other services	Other services
	Employment growth	Sales growth	Growth in sales per employee	Employment growth	Sales growth	Growth in sales per employee
Firm-level variables:						
Exporter	0.0485***	0.0124	-0.0407***	0.0063	-0.0034	-0.0097
	[0.010]	[0.012]	[0.011]	[0.011]	[0.014]	[0.011]
Graduate share of employment	0.0102	0.0143	0.007	0.0224**	0.0103	-0.0121
	[0.015]	[0.022]	[0.022]	[0.009]	[0.010]	[0.012]
Previous merger activity	0.0054	0.0146	0.0088	0.014	0.0637*	0.0497
	[0.067]	[0.027]	[0.053]	[0.028]	[0.035]	[0.030]
Previous sale or closure of plants	-0.1898***	-0.2949***	-0.1052***	-0.1802***	-0.2371***	-0.0570*
	[0.042]	[0.031]	[0.036]	[0.017]	[0.027]	[0.030]
Employment size (log)	-0.0369**	-0.0197	0.0179***	-0.0075*	0.0065	0.0140**
	[0.014]	[0.014]	[0.006]	[0.004]	[0.006]	[0.005]
Age of firm (log)	0.0193	-0.0045	-0.0227**	0.0088*	-0.0093	-0.0181***
	[0.015]	[0.015]	[0.010]	[0.005]	[0.008]	[0.006]
City-region level variables:						
Own-industry specialisation (log)	0.0113	0.0475*	0.0371*	-0.0108	0.0148	0.0256
	[0.016]	[0.025]	[0.021]	[0.020]	[0.023]	[0.024]
Industrial diversity (log)	-0.1542	-0.5548	-0.4245	0.1592	-0.1148	-0.274
	[0.430]	[0.444]	[0.380]	[0.275]	[0.303]	[0.196]
Employment density (log)	0.021	0.0067	-0.0119	-0.0055	-0.0223**	-0.0168***
	[0.014]	[0.015]	[0.015]	[0.008]	[0.009]	[0.004]
Business growth performance	0.0193	0.0183*	-0.0009	0.0069*	0.0014	-0.0055
	[0.012]	[0.010]	[0.010]	[0.004]	[0.005]	[0.004]
Skills and labour market conditions	-0.0077	-0.0188**	-0.0132	0.0016	0.0055	0.004
	[0.009]	[0.009]	[0.008]	[0.005]	[0.005]	[0.003]
Small firms' share of employment (log)	0.2327*	0.4488***	0.2371**	-0.0197	-0.1798**	-0.1601**
	[0.119]	[0.110]	[0.112]	[0.085]	[0.068]	[0.068]
Firm size diversity (log)	-0.1757	-0.7843	-0.6494	0.217	-0.1242	-0.3412
	[0.642]	[0.686]	[0.575]	[0.432]	[0.472]	[0.305]
Firm size diversity * Industrial diversity	0.0759	0.4304	0.3773	-0.124	0.0521	0.1761
	[0.372]	[0.397]	[0.336]	[0.240]	[0.262]	[0.169]

Observations	1,224	1,215	1,215	1,773	1,773	1,773
Adjusted R sqd	0.0583	0.0618	0.0275	0.0474	0.0471	0.0151
SEE	0.277	0.328	0.299	0.197	0.247	0.245

Notes: See Table 4.3

Table 4.7: Measures of global spatial autocorrelation for city-region level variables

	Moran's I	E(I)	sd(I)	z	p-value (1-tail test)
Own-industry specialisation (log)	0.013	-0.023	0.025	1.462	0.072
Industrial diversity (log)	0.042	-0.023	0.025	2.558	0.005
Employment density (log)	0.036	-0.023	0.026	2.285	0.011
Small firms' share of employment (log)	0.036	-0.023	0.026	2.290	0.011
Business growth performance	-0.036	-0.023	0.026	-0.500	0.308
Skills and labour market conditions	0.002	-0.023	0.026	0.946	0.172
Firm size diversity (log)	-0.053	-0.023	0.026	-1.179	0.119
Innovation intensity	-0.047	-0.023	0.025	-0.963	0.168
Organisational innovation	-0.027	-0.023	0.026	-0.161	0.436
External information sourcing (summary measure)	-0.027	-0.023	0.026	-0.152	0.44
External co-operation partners: distance-based measure	-0.011	-0.023	0.024	0.503	0.308
Financial constraints on innovation	-0.011	-0.023	0.026	0.448	0.327
Skill constraints on innovation	-0.042	-0.023	0.026	-0.752	0.226

5. Summary and assessment

5.1 Overview of research findings

This paper has drawn on matched data from the Business Structure Database (BSD) and the Community Innovation Survey (CIS) to examine the impact of 'regional effects' on firm-level innovation and growth. We focussed on city-regions whose geographical boundaries delineate day-to-day travel areas for high-skilled employees (those who are most likely to be involved in innovation and knowledge-sharing). It was hoped that working with data for these geographical areas would provide a rich basis for analysis of the effects of localised interactions between firms and their employees on firm performance.

Our reading of recent theoretical and empirical literature on regional effects on economic performance suggested that some regional characteristics may affect firm-level innovation more than growth, and vice versa. Accordingly, we set out several hypotheses to be tested which distinguish between these two firm performance outcomes. The first two hypotheses focussed on the potential effects of city-region differences in industrial diversity and urban scale. Hypothesis 1 posited that firm innovation performance is positively related to urban scale and diversity at regional level while Hypothesis 2 posited that firm growth in employment and sales is positively related to the level of own-industry specialisation at regional level.

In general, we found very little support for either of these hypotheses. However, tests of spatial autocorrelation pointed to significant interdependence between city-regions on our measures of industrial diversity, urban scale and own-industry specialisation which could cause significant bias in our results. Therefore, it seems likely that city-regions as defined here are not the most appropriate geographical unit of measurement for testing the effects of industrial structure and urban scale on firm performance. Further research, beyond the scope of this report, is needed to identify the geographical units of measurement which might best capture regional effects of these kinds.

By contrast, tests of spatial autocorrelation strengthened our confidence that city-region level data can be used to assess the effects on firm performance of regional measures of innovative activity, business growth performance, skills and labour market conditions and financial and skill constraints on innovation. Accordingly, we go on to assess the implications of our results for hypotheses relating to those variables.

Given the extensive information available from the CIS on firms' own innovation inputs, we were interested to examine what effects – over and above firms' own innovative efforts -- localised interactions between firms and between employees in different firms at regional level might have on firm-level innovative performance. Accordingly, we sought to test Hypothesis 3 which posited that firm innovation performance is positively related to regional indicators of firms' involvement in innovation. The intuition behind this hypothesis was that local interactions may be more relevant and useful to firm innovation, the more that other firms in their regions have themselves engaged in innovative activities.

In production sectors there is strong evidence to support this hypothesis in that innovation success at firm level is found to be positively and significantly related to innovation inputs among other production sector firms in their city-regions as measured by intensity of spending on innovation, involvement in organisational innovation and cooperation with external innovation partners. However, we find no support for Hypothesis 3 in either knowledge-intensive services or Other Services.

Given the outward-looking orientation of innovative firms in knowledge-intensive services (as indicated by measures of external knowledge seeking and innovation partnerships with other firms and organisations), we speculate that in these sectors external interactions of this kind may take place on a wider geographic scale than that denoted by city-regions. Further research would be useful to investigate the geographic scope of innovation eco-systems that are most relevant to knowledge-intensive services. In Other Services (which includes retail, hotels and catering and road and rail transport services) we find that innovation success (new products as a proportion of sales) is actually negatively related to innovation intensity at city-region

level. This may reflect competitive pressures from other innovative firms seeking customers for newly-developed services.

Another potential effect of localised interactions between firms and their employees is that successful growth performance in some firms may 'rub off' on their neighbours in some way. Put another way, the value and relevance to firm growth of localised interactions with other firms may be greater, the more that firms and their employees are exposed to local firms which have themselves succeeded in growing rapidly. This possibility was examined by testing Hypothesis 4 which posited that firm growth in employment and sales is positively related to business growth performance at regional level. We found no evidence in any sector group of direct support for this hypothesis, in large part because firm-specific characteristics such as innovative activity, employment size and age appear to dominate city-region effects on firm growth performance.

However, given the particularly strong effects of prior innovation success in all three sector groups, it is possible that some city-region characteristics such as the performance of neighbouring firms affect firm growth in an indirect way, operating through effects on innovative performance which then contributes substantially in a later time period to firm-level growth. When we ran firm growth models without including prior innovation success as a regressor, both employment and sales growth were found to be positively related to business growth performance at city-region level.

At the same time it is important to realise that benefiting from knowledge spillovers at regional level does not prevent many firms from also benefiting in their innovation activities from access to knowledge sources and innovation partners *outside* their local regions. In order to explore this issue, we examined evidence relating to Hypothesis 5 that firm innovation performance is positively related to regional indicators of firms' access to extra-regional knowledge sources. We find strong support for this hypothesis in production sectors where an interaction term combining the city-region indicators of external information-seeking activity and the distance-based measure of collaboration with external innovation partners is positively and significantly related to innovation success at firm level. This suggests that external information-seeking at city-region level is more likely to benefit individual production firms, the more that other production firms in their region with which they interact are

outward looking in terms of their relationships with extra-regional partners. This could reflect the advantages of ideas and knowledge that are exchanged through localised interactions being regularly refreshed by contacts with extra-regional information sources. However, we found no evidence to support Hypothesis 5 in either knowledge-intensive services or Other Services. In the case of knowledge-intensive services in particular, we speculate again that city-regions may not capture the geographic scale on which knowledge exchange relevant to innovation takes place.

Finally, in the light of research evidence that firm performance in general tends to benefit from access to skills and the strength of labour market and other institutions at regional level, we examined evidence relating to Hypothesis 6, namely, that firm innovation and growth performance is positively related to socio-economic and labour market conditions such as skill levels and employment rates at regional level.

We find support for this hypothesis in relation to innovation success in production sector firms but not in either knowledge-intensive services or Other Services. Production sectors were also the only sector group in which we find the expected negative association between innovation success and regional-level skill constraints. By contrast, regional skill constraints have no direct effect on innovation success in knowledge-intensive sectors while in Other Services regional skill constraints are positively related to innovation success, suggesting that innovative firms in these sectors are able to surmount recruitment difficulties with relative ease. This may reflect relatively limited skills requirements in Other Services compared to production sectors and knowledge-based services.

In summary, firm growth depends heavily on prior success in innovation which in turn is strongly influenced by the extent and nature of firms' own efforts in developing innovation-related skills and capabilities. When models of firm performance take full account of firms' own investments in the development of intangible assets of this kind, this tends to reduce the measured impact of city-region characteristics on firm growth. After controlling for a wide range of firm-level innovation inputs, we find that city-regional influences on innovation and subsequent growth performance are strong in production sectors but not in knowledge-intensive

services or Other Services. Future research in this area should aim to examine how far this apparent variation between sector groups reflects differences in the importance of regional spillovers in general and how far it reflects differences in the geographical range of innovation eco-systems relevant to firm growth in different sectors.

5.2 Main implications for policy and future research

1. Firm growth depends heavily on firms' prior investments in innovation and the development of innovation-related capabilities.

2. The most important regional effects on firm growth tend to operate indirectly through their contributions to innovation success at firm level.

3. Where strong regional effects on firm performance can be identified, this should not be taken as evidence that localised interactions and knowledge exchange between firms are all-important. On the contrary, where regional innovation eco-systems exist, they may well be strengthened by local firms' making use of extra-regional information sources which help refresh and replenish the stock of ideas and knowledge which circulate within regions.

4. Skill supplies feature strongly among regional effects on innovation performance and, indirectly, on firm growth. In some sectors innovation success at firm level is positively related to regional measures of socio-economic and labour market conditions such as skill levels and employment rates. There is also evidence in some sectors of innovation success at firm level being restricted by regional skill shortages.

5. The strongest evidence of city-regional effects on innovation success at firm level is found in production sectors. In knowledge-intensive services, it seems likely that city-regions may not capture the geographic scale on which knowledge exchange relevant to innovation takes place. Further research would be useful in order to experiment with data for other geographical entities which might be more relevant to firm growth in knowledge-intensive services.

6. Further research would also be useful to identify the geographical units of measurement which best capture the regional effects of own-industry specialisation, industrial diversity and urban scale on firm performance.

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STATISTICAL ANNEX

Table A1: Descriptive statistics for variables used in regression analysis

	Obs	Mean	Std. Dev.
Firm-level variables:			
Innovation success, 2006	6761	0.02	0.08
Employment growth, 2006-09	4891	-0.01	0.21
Sales growth, 2006-09	4884	0.01	0.26
Growth in average sales per employee, 2006-09	4884	0.03	0.23
Innovation intensity, 2004-06	6761	0.02	0.06
External information sources: suppliers and customers, 2004-06 (0-3 scale)	6761	1.83	1.23
External information sources: universities and public laboratories, 2004-06 (0-3 scale)	6761	0.41	0.76
Organisational innovation, 2004-06 (factor score)	6761	0.00	1.00
External cooperation partners: distance-based measure, 2004-06 (factor score)	6761	0.03	1.05
Exporter, 2006	6761	0.29	0.45
Graduate share of employment, 2006	6761	0.33	0.42
Employment size (log), 2006	6761	3.98	1.46
Age of firm (log), 2006	6761	2.58	0.89
Merger activity, 2004-06	6761	0.04	0.18
Sale or closure of plants, 2004-06	6761	0.07	0.25
Manufacturing	6761	0.31	0.46
Other production	6761	0.00	0.06
Construction	6761	0.07	0.25
Retail and wholesale	6761	0.10	0.31
Hotels and catering	6761	0.04	0.21
Transport and communications	6761	0.09	0.29
Financial services	6761	0.03	0.17
Business services	6761	0.34	0.48
Other private services	6761	0.01	0.10
City-region level variables:			
Own-industry specialisation (log), 2006	6761	1.00	1.31
Industrial diversity (log), 2006	6761	1.76	0.15
Employment density (log), 2006	6761	5.65	0.72
Skills and labour market conditions, 2006 (factor score)	6761	-0.02	1.00
Small firms' share of employment (firms with under 100 employees) (log), 2006	6761	1.74	0.05
Firm size diversity (log), 2006	6761	1.18	0.21
Innovation intensity, 2004-06	6761	1.80	0.87
Organisational innovation, 2004-06 (derived from firm-level factor scores)	6761	-0.21	0.30
External information sources: summary measure, 2004-06 (derived from firm-level factor scores)	6761	-0.18	0.18
External cooperation partners: distance-based measure, 2004-06 (derived from firm-level factor scores)	6761	0.00	0.14
Financial constraints on innovation, 2004-06	6761	0.32	0.09
Skill constraints on innovation, 2004-06	6761	0.20	0.06
Business growth performance, 2006 (factor score)	6761	0.01	1.00

Table A2: Tobit estimates of firm innovation success, 2006: All Sectors and Production sectors
Including control variable for London/South East location

	(1) All sectors	(2) All sectors	(3) Pro-duction sectors	(4) Pro-duction sectors
Firm-level variables:				
Innovation intensity	0.5356***	0.5374***	0.4754***	0.4744***
	[0.028]	[0.027]	[0.018]	[0.018]
External information sources: suppliers and customers	0.0940***	0.0943***	0.0824***	0.0824***
	[0.003]	[0.003]	[0.002]	[0.002]
External information sources: universities and public laboratories	0.0177***	0.0174***	0.0064***	0.0062***
	[0.003]	[0.003]	[0.002]	[0.002]
Organisational innovation	0.0537***	0.0536***	0.0432***	0.0432***
	[0.002]	[0.002]	[0.001]	[0.001]
External co-operation partners: distance-based measure	0.0338***	0.0339***	0.0387***	0.0389***
	[0.001]	[0.001]	[0.001]	[0.001]
Exporter	0.1037***	0.1029***	0.0708***	0.0701***
	[0.005]	[0.005]	[0.004]	[0.004]
Graduate share of employment	0.0749***	0.0738***	0.0065	0.006
	[0.007]	[0.007]	[0.004]	[0.004]
Employment size (log)	-0.0232***	-0.0231***	-0.0225***	-0.0226***
	[0.002]	[0.002]	[0.001]	[0.001]
Age of firm (log)	-0.0112***	-0.0118***	0.0039**	0.0039**
	[0.002]	[0.002]	[0.002]	[0.002]
City-region level variables:				
London / South East	-0.0205***	-0.0279***	0.0308***	0.0278***
	[0.005]	[0.005]	[0.004]	[0.003]
Own-industry specialisation (log)	-0.0068**	-0.0070**	-0.0072***	-0.0060***
	[0.003]	[0.003]	[0.002]	[0.002]
Industrial diversity (log)	-0.1499***	0.3876***	-0.0342***	0.4456***
	[0.004]	[0.004]	[0.003]	[0.003]
Employment density (log)	-0.0373***	-0.0449***	-0.0049***	-0.0115***
	[0.001]	[0.001]	[0.001]	[0.001]
Skills and labour market conditions	-0.0043***	-0.0041***	-0.0001	0.0029***
	[0.001]	[0.001]	[0.001]	[0.001]
Small firms' share of employment (log)	-0.1028***	-0.1752***	-0.0297***	-0.1164***
	[0.004]	[0.004]	[0.003]	[0.003]
Firm size diversity (log)	-0.0410***	0.7893***	-0.0202***	0.7126***

	[0.006]	[0.006]	[0.004]	[0.004]
Innovation intensity	-0.0195***	-0.0258***	0.0158***	0.0148***
	[0.003]	[0.002]	[0.002]	[0.002]
Organisational innovation	0.0169	0.0352***	0.0757***	0.0996***
	[0.014]	[0.013]	[0.014]	[0.013]
External information sourcing (summary measure)	0.0174	0.0022	-0.0178	-0.0379**
	[0.024]	[0.024]	[0.019]	[0.018]
External co-operation partners: distance-based measure	0.1195***	0.1457***	0.1171***	0.2779***
	[0.012]	[0.012]	[0.012]	[0.020]
Financial constraints on innovation	-0.3195***	-0.3056***	-0.0766***	-0.0594***
	[0.020]	[0.019]	[0.017]	[0.016]
Skill constraints on innovation	0.4306***	0.3528***	-0.0977***	-0.1539***
	[0.029]	[0.029]	[0.020]	[0.018]
External information sourcing * External co-operation partners (distance-based measure)		0.2193***		0.8687***
		[0.046]		[0.096]
Firm size diversity * Industrial diversity		-0.4639***		-0.4060***
		[0.004]		[0.002]
Observations	6,761	6,761	2,554	2,554
Pseudo R sqd	0.315	0.316	0.287	0.288
Log likelihood	-1198	-1197	-521.7	-521.1

Notes: See Table 4.1

Table A3: Tobit estimates of firm innovation success, 2006: Knowledge-intensive services and Other services
Including control variable for London/South East location

	(1) Knowledge-intensive services	(2) Knowledge-intensive services	(3) Other services	(4) Other services
Firm-level variables:				
Innovation intensity	0.3399*	0.3376*	0.7939***	0.7912***
	[0.205]	[0.204]	[0.232]	[0.234]
External information sources: suppliers and customers	0.0768***	0.0767***	0.1159***	0.1161***
	[0.020]	[0.020]	[0.028]	[0.028]
External information sources: universities and public laboratories	0.0652***	0.0647***	0.012	0.0111
	[0.023]	[0.024]	[0.020]	[0.020]
Organisational innovation	0.0859***	0.0863***	0.0491***	0.0488***
	[0.015]	[0.015]	[0.019]	[0.019]
External co-operation partners: distance-based measure	0.0421***	0.0429***	0.0044	0.0043
	[0.009]	[0.009]	[0.014]	[0.013]
Exporter	0.1794***	0.1789***	0.1126***	0.1107***
	[0.063]	[0.063]	[0.037]	[0.037]
Graduate share of employment	0.0553	0.0485	0.1304**	0.1302**
	[0.048]	[0.050]	[0.052]	[0.052]
Employment size (log)	-0.0390***	-0.0404***	-0.0267	-0.0265
	[0.015]	[0.015]	[0.027]	[0.027]
Age of firm (log)	-0.0682***	-0.0668***	-0.0122	-0.012
	[0.022]	[0.022]	[0.015]	[0.015]
City-region level variables:				
London / South East	-0.1556**	-0.1542**	0.0122	0.0096
	[0.066]	[0.070]	[0.064]	[0.065]
Own-industry specialisation (log)	0.0233	0.0093	-0.0094	-0.0175
	[0.036]	[0.036]	[0.061]	[0.066]
Industrial diversity (log)	-0.3747	0.3232	-0.1609	0.2942
	[0.233]	[0.945]	[0.153]	[0.787]
Employment density (log)	-0.0107	-0.0207	-0.0730**	-0.0781**
	[0.029]	[0.029]	[0.031]	[0.032]
Skills and labour market conditions	0.0181	0.0165	-0.0152	-0.0146
	[0.026]	[0.028]	[0.015]	[0.015]
Small firms' share of employment (log)	1.1538**	0.9489	-0.3843	-0.419
	[0.542]	[0.620]	[0.278]	[0.306]

Firm size diversity (log)	0.2065*	1.2337	-0.1086	0.5549
	[0.111]	[1.416]	[0.105]	[1.196]
Innovation intensity	-0.0087	-0.0231	-0.0945**	-0.0916**
	[0.025]	[0.028]	[0.044]	[0.044]
Organisational innovation	-0.0108	0.0273	-0.0309	-0.0012
	[0.136]	[0.153]	[0.265]	[0.279]
External information sourcing (summary measure)	-0.1838	-0.2637	0.137	0.0696
	[0.215]	[0.239]	[0.168]	[0.218]
External co-operation partners: distance-based measure	0.2321	0.0994	0.326	0.1923
	[0.160]	[0.174]	[0.227]	[0.224]
Financial constraints on innovation	0.2412	0.105	-1.1730***	-1.1903***
	[0.363]	[0.434]	[0.384]	[0.383]
Skill constraints on innovation	0.5623	0.4635	1.1861**	1.2202***
	[0.448]	[0.454]	[0.481]	[0.447]
External information sourcing * External co-operation partners (distance-based measure)		0.7722		-0.5486
		[0.624]		[1.173]
Firm size diversity * Industrial diversity		-0.5663		-0.3725
		[0.773]		[0.673]
Observations	1,377	1,377	2,830	2,830
Pseudo R sqd	0.35	0.352	0.352	0.352
Log likelihood	-281.5	-280.6	-337.5	-337.3

Notes: See Table 4.1

Table A4: OLS estimates of firm growth in employment, sales and average sales per employee 2006-09: All Sectors and Production sectors
Including control variable for London/South East location

	(1)	(2)	(3)	(4)	(5)	(6)
	All sectors	All sectors	All sectors	Production sectors	Production sectors	Production sectors
	Employment growth	Sales growth	Growth in sales per employee	Employment growth	Sales growth	Growth in sales per employee
Firm-level variables:						
Innovation success – predicted value	0.1082***	0.1161***	0.0077	0.0992***	0.1138***	0.0146
	[0.021]	[0.022]	[0.022]	[0.031]	[0.041]	[0.029]
Exporter	-0.0066	-0.0187**	-0.0132	-0.0164*	-0.0152	0.0013
	[0.007]	[0.009]	[0.009]	[0.009]	[0.012]	[0.010]
Graduate share of employment	-0.0062	-0.0066	0.0003	-0.0079	-0.0052	0.0027
	[0.006]	[0.008]	[0.008]	[0.007]	[0.010]	[0.010]
Previous merger activity	0.0327	0.0512**	0.0187	0.0717***	0.0789***	0.0073
	[0.024]	[0.020]	[0.017]	[0.018]	[0.026]	[0.020]
Previous sale or closure of plants	-0.1669***	-0.2414***	-0.0747***	-0.1387***	-0.2088***	-0.0701*
	[0.016]	[0.022]	[0.022]	[0.025]	[0.040]	[0.038]
Employment size (log)	-0.0204***	-0.0069	0.0137***	-0.0187***	-0.0063	0.0123***
	[0.005]	[0.005]	[0.003]	[0.006]	[0.007]	[0.004]
Age of firm (log)	0.0059	-0.0097	-0.0152***	-0.009	-0.0308***	-0.0217***
	[0.006]	[0.006]	[0.005]	[0.007]	[0.006]	[0.006]
City-region level variables:						
London / South East	0.0155	0.0133	-0.0016	0.0104	0.0075	-0.0029
	[0.012]	[0.011]	[0.011]	[0.023]	[0.014]	[0.019]
Own-industry specialisation (log)	0.0007	-0.0031	-0.0037	0.0011	-0.0092	-0.0102
	[0.006]	[0.008]	[0.007]	[0.008]	[0.010]	[0.009]
Industrial diversity (log)	-0.1563	-0.1378	0.0083	-0.0874	-0.0201	0.0673
	[0.167]	[0.187]	[0.160]	[0.208]	[0.223]	[0.215]
Employment density (log)	0.0036	-0.0037	-0.0066	-0.0039	-0.001	0.0029
	[0.006]	[0.007]	[0.005]	[0.007]	[0.009]	[0.006]
Business growth performance	0.0065	0.0059	-0.0005	0.0013	0.0003	-0.001
	[0.004]	[0.005]	[0.004]	[0.006]	[0.008]	[0.005]
Skills and labour market conditions	-0.0028	-0.0005	0.0017	-0.0023	-0.001	0.0013
	[0.004]	[0.004]	[0.003]	[0.004]	[0.004]	[0.003]
Small firms' share of employment (log)	-0.0199	-0.0297	-0.0038	-0.086	-0.0292	0.0567
	[0.061]	[0.071]	[0.062]	[0.083]	[0.103]	[0.088]
Firm size diversity (log)	-0.2706	-0.2116	0.0408	-0.1327	-0.0549	0.0778
	[0.245]	[0.279]	[0.242]	[0.326]	[0.328]	[0.328]

Firm size diversity * Industrial diversity	0.1452	0.1156	-0.0196	0.0768	0.0469	-0.0299
	[0.137]	[0.158]	[0.136]	[0.180]	[0.187]	[0.183]
Observations	4,891	4,884	4,884	2,236	2,236	2,236
Adjusted R sqd	0.0659	0.066	0.0227	0.0825	0.0753	0.0355
SEE	0.205	0.248	0.229	0.167	0.209	0.182

Notes: See Table 4.3

Table A5: OLS estimates of firm growth in employment, sales and average sales per employee 2006-09: Knowledge-intensive services and Other Services
Including control variable for London/South East location

	(1)	(2)	(3)	(4)	(5)	(6)
	Knowledge-intensive services	Knowledge-intensive services	Knowledge-intensive services	Other services	Other services	Other services
	Employment growth	Sales growth	Growth in sales per employee	Employment growth	Sales growth	Growth in sales per employee
Firm-level variables:						
Innovation success – predicted value	0.0926**	0.1069**	0.014	0.1070***	0.1173***	0.0103
	[0.042]	[0.045]	[0.051]	[0.033]	[0.030]	[0.035]
Exporter	0.0260*	-0.0189	-0.0496***	-0.0134	-0.0243	-0.0108
	[0.014]	[0.019]	[0.015]	[0.013]	[0.017]	[0.016]
Graduate share of employment	-0.006	-0.0049	0.0045	0.0047	-0.0066	-0.0112
	[0.022]	[0.027]	[0.025]	[0.010]	[0.010]	[0.012]
Previous merger activity	0.0078	0.0112	0.003	0.0044	0.0532	0.0489*
	[0.070]	[0.031]	[0.049]	[0.028]	[0.034]	[0.028]
Previous sale or closure of plants	-0.1835***	-0.2969***	-0.1134***	-0.1796***	-0.2340***	-0.0544*
	[0.042]	[0.032]	[0.039]	[0.018]	[0.030]	[0.032]
Employment size (log)	-0.0332*	-0.0144	0.0195***	-0.0081	0.0059	0.0140**
	[0.017]	[0.017]	[0.006]	[0.005]	[0.007]	[0.006]
Age of firm (log)	0.0248*	0.0126	-0.0108	0.0089	-0.0035	-0.0124
	[0.015]	[0.017]	[0.010]	[0.006]	[0.009]	[0.008]
City-region level variables:						
London / South East	0.0466*	0.0206	-0.0244	0.0081	0.01	0.0019
	[0.026]	[0.031]	[0.021]	[0.019]	[0.015]	[0.013]
Own-industry specialisation (log)	-0.0014	0.0343	0.0366	0.0086	0.0159	0.0073
	[0.016]	[0.028]	[0.023]	[0.018]	[0.024]	[0.024]
Industrial diversity (log)	-0.1935	-0.2835	-0.1198	-0.0259	-0.2399	-0.214
	[0.499]	[0.494]	[0.335]	[0.314]	[0.324]	[0.198]
Employment density (log)	0.0196	0.002	-0.0149	0.0001	-0.0184*	-0.0185***
	[0.016]	[0.016]	[0.014]	[0.010]	[0.010]	[0.005]
Business growth performance	0.0281*	0.02	-0.0077	0.0037	0.0024	-0.0013
	[0.015]	[0.013]	[0.010]	[0.006]	[0.007]	[0.005]
Skills and labour market conditions	-0.0095	-0.0132	-0.0064	0.0022	0.0045	0.0023
	[0.012]	[0.011]	[0.009]	[0.006]	[0.006]	[0.003]
Small firms' share of employment (log)	-0.0165	0.1385	0.1761	0.0148	-0.1445	-0.1592*
	[0.154]	[0.139]	[0.120]	[0.114]	[0.092]	[0.081]
Firm size diversity (log)	-0.3695	-0.454	-0.1392	-0.1046	-0.3489	-0.2443

	[0.709]	[0.724]	[0.500]	[0.485]	[0.504]	[0.308]
Firm size diversity * Industrial diversity	0.168	0.2286	0.0907	0.056	0.178	0.122
	[0.410]	[0.419]	[0.291]	[0.270]	[0.280]	[0.171]
Observations	1,084	1,077	1,077	1,571	1,571	1,571
Adjusted R sqd	0.0683	0.0685	0.022	0.0571	0.0587	0.00974
SEE	0.273	0.312	0.283	0.197	0.249	0.245

Notes: See Table 4.3

Table A6: Measures of innovative outputs, foreign market exposure, interactions with supply-chain partners and universities and reported financial and skill constraints on innovation at city-region level, 2006

	Product innovation	Process innovation	High use of supply-chain information	Regional supply-chain partners	Non-regional supply-chain partners	High-medium use of university or public lab information	High-medium financial constraints	High-medium skill constraints	N =
Birmingham/ Sandwell/Wolves	0.21	0.14	0.39	0.05	0.09	0.06	0.28	0.19	682
Bournemouth/ Poole	0.28	0.13	0.39	0.04	0.09	0.10	0.30	0.17	135
Brighton&Hove	0.18	0.08	0.44	0.04	0.07	0.13	0.33	0.26	47
Bristol/ S.Gloucester	0.22	0.12	0.40	0.05	0.08	0.06	0.31	0.17	270
Cambridge	0.34	0.19	0.44	0.04	0.21	0.17	0.33	0.30	110
Carlisle	0.21	0.13	0.49	0.06	0.06	0.09	0.41	0.15	69
Chester	0.22	0.12	0.42	0.06	0.08	0.08	0.34	0.16	173
Colchester	0.29	0.15	0.42	0.13	0.17	0.16	0.32	0.11	55
Coventry	0.22	0.11	0.35	0.08	0.09	0.09	0.28	0.15	134
Exeter	0.31	0.17	0.42	0.04	0.11	0.06	0.35	0.16	117
Greater London	0.21	0.12	0.38	0.05	0.09	0.08	0.31	0.18	2299
Gloucester/ Cheltenham	0.22	0.13	0.47	0.07	0.11	0.05	0.36	0.20	139
Ipswich	0.20	0.11	0.30	0.08	0.12	0.05	0.24	0.14	108
Kingston upon Hull	0.15	0.11	0.30	0.03	0.06	0.09	0.29	0.15	140
Leeds/Bradford	0.21	0.12	0.34	0.04	0.10	0.09	0.27	0.16	592
Leicester	0.22	0.13	0.35	0.05	0.09	0.09	0.27	0.16	248
Lincoln	0.21	0.12	0.35	0.02	0.07	0.09	0.27	0.12	89

	Product innovation	Process innovation	High use of supply-chain information	Regional supply-chain partners	Non-regional supply-chain partners	High-medium use of university or public lab information	High-medium financial constraints	High-medium skill constraints	N =
Liverpool	0.18	0.13	0.39	0.05	0.10	0.07	0.32	0.16	156
Luton	0.24	0.08	0.47	0.05	0.10	0.08	0.32	0.16	71
Manchester/ Salford/Trafford	0.22	0.13	0.43	0.05	0.08	0.11	0.32	0.18	637
Middlesbrough/ Stockton	0.18	0.11	0.42	0.04	0.07	0.08	0.37	0.13	323
Milton Keynes	0.27	0.20	0.37	0.13	0.08	0.04	0.24	0.13	44
Newcastle/ Gateshead/ Sunderland	0.20	0.13	0.40	0.04	0.09	0.09	0.33	0.16	685
Northampton	0.26	0.11	0.45	0.04	0.08	0.12	0.32	0.20	146
Norwich	0.25	0.15	0.37	0.03	0.09	0.06	0.25	0.22	128
Nottingham/Derby	0.21	0.12	0.39	0.06	0.11	0.09	0.30	0.17	365
Oxford	0.19	0.12	0.34	0.03	0.08	0.07	0.31	0.11	84
Peterborough	0.21	0.11	0.38	0.07	0.11	0.09	0.28	0.18	121
Plymouth	0.26	0.17	0.41	0.05	0.11	0.08	0.36	0.21	83
Portsmouth/ Southampton	0.16	0.08	0.30	0.03	0.06	0.05	0.24	0.13	164
Preston	0.17	0.11	0.39	0.03	0.10	0.09	0.34	0.18	51
Reading	0.24	0.18	0.41	0.05	0.10	0.09	0.34	0.21	108
Sheffield	0.28	0.16	0.44	0.12	0.13	0.08	0.30	0.19	220
Stoke-on-Trent	0.25	0.14	0.41	0.03	0.08	0.11	0.26	0.14	134
Swindon	0.20	0.12	0.37	0.02	0.10	0.06	0.32	0.14	93
Telford and Wrekin	0.30	0.18	0.37	0.05	0.11	0.09	0.30	0.25	88

	Product innovation	Process innovation	High use of supply-chain information	Regional supply-chain partners	Non-regional supply-chain partners	High-medium use of university or public lab information	High-medium financial constraints	High-medium skill constraints	N =
Worcester	0.25	0.13	0.35	0.05	0.08	0.08	0.40	0.15	*38*
York	0.24	0.23	0.40	0.05	0.07	0.09	0.28	0.23	*66*
Cardiff	0.23	0.15	0.42	0.04	0.10	0.10	0.31	0.22	*573*
Swansea	0.22	0.15	0.38	0.05	0.09	0.06	0.27	0.17	*127*
Aberdeen	0.15	0.10	0.36	0.03	0.06	0.06	0.31	0.19	*154*
Dundee	0.17	0.07	0.37	0.02	0.05	0.04	0.26	0.26	*65*
Edinburgh	0.20	0.14	0.39	0.06	0.08	0.07	0.32	0.23	*179*
Glasgow	0.22	0.13	0.38	0.03	0.09	0.09	0.30	0.18	*414*
Belfast	0.21	0.10	0.27	0.09	0.06	0.10	0.34	0.25	*380*
MEAN	0.22	0.13	0.39	0.05	0.09	0.08	0.31	0.18	*11004*

Source: Derived from Community Innovation Survey
Note: Excludes 3539 observations outside urban areas