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Knowledge spillovers and employment growth in Great Britain

SCALES
SCientific AnaLysis of Entrepreneurship and SMEs

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Summary

In recent decades, the importance of knowledge spillovers for the processes of innovation and economic growth has been widely recognized. Firms can improve their performance by implementing innovative ideas that were not originally developed in-house. In this way firms and hence economies may grow without having to use additional labour and capital inputs.

Although the importance of knowledge spillovers is undisputed, little is known about the size of spillover effects and what type of spillovers is more important for achieving growth: spillovers emerging *within* sectors (intra-sectoral spillovers) or spillovers emerging *between* sectors (inter-sectoral spillovers). Furthermore, the impact of local competition on innovation and growth is not straightforward, as there are both negative effects (relatively less benefits for the innovator due to higher spillovers, possibly resulting in less innovations) and positive effects (more innovations as it is necessary for firms to remain competitive in the market) involved. These issues are investigated in the present report, using a regional growth model based on Glaeser et al., 1992. In the model sectoral employment growth at the regional level is explained by specialization (a proxy for intra-sectoral spillovers), competition, diversity (a proxy for inter-sectoral spillovers) and some controls. By including these variables in the model, the empirical validity of three theories about knowledge spillovers and innovation can be tested.

The *first* theory is that of Marshall, Arrow and Romer (MAR). According to these economists, important spillovers primarily emerge among homogeneous enterprises, implying a positive impact of specialization on economic growth. As regards the role of competition, they assume a negative impact, due to the limited possibilities to internalize the externalities associated with innovation (i.e. spillovers), in case of fierce competition. The *second* theory is that of Porter. He assumes, like MAR do, a positive effect of specialization. As regards competition, however, Porter assumes a positive impact on growth, resulting from the sheer necessity for firms to innovate, as the alternative to innovation is demise. The *third* theory is developed by Jacobs. Like Porter, she assumes a positive effect of local competition. As regards knowledge spillovers, however, she emphasizes the importance of spillovers emerging among heterogeneous enterprises, implying a positive effect of diversity on economic growth.

We use a data set with information at six-sector level and at the spatial level of 60 British regions, covering entire Great Britain. Regional data are used because geographical proximity is considered important, as face-to-face contacts are assumed a necessary condition for knowledge spillovers to occur.

Results

We estimate the model both using a sample containing data of all sectors simultaneously (pooled regression) and using samples for each sector separately. We find evidence for a negative relationship between *specialization* and employment growth when we pool the various sectors of economy in one regression, while in the separate sector regressions, we find a negative effect or no effect at all. So, we find no support whatsoever for the occurrence of intra-sectoral knowledge spillovers. This finding is in line with Van Stel and Nieuwenhuijsen, 2001, who found no support for the MAR and Porter specialization hypothesis for the Netherlands. It might be the case that specialization contributes to static efficiency rather than to dynamic efficiency (i.e. growth).

We find strong support for a positive relationship between regional *competition* and employment growth, both in the pooled regression and in the separate sector regressions. Only for the construction sector the positive effect is not found. The effect is biggest for the production sector (which is dominated by manufacturing). This is in line with Van Stel and Nieuwenhuijsen, 2001, who found a positive effect of regional competition on growth for manufacturing for the Netherlands. The positive effect for manufacturing might be related to higher R&D expenses relative to other sectors, making competition especially important in manufacturing industries as it might encourage something like an 'innovation race'.

Diversity does not seem to be a dominant factor for regional sector growth in Great Britain. Only for the production sector, the empirical relationship is positive and thus supports the theory of Jacobs. For the other sectors, the effect is not significant. These results of diversity contradict the findings of Van Stel and Nieuwenhuijsen, 2001, who found no effect for manufacturing and a positive effect for service sectors. Perhaps this can be explained by the fact that in Great Britain the production sector takes a more central position in the economy (thereby benefiting from developments in other sectors), while in the Netherlands the service sectors take a more central position in the economy. However, we must be cautious as there are some differences between both studies. Notably, in the study for the Netherlands, growth is measured in terms of value added instead of employment.

To sum up, in the present study for Great Britain, we find a negative or zero effect of specialization on growth, and no effect for diversity (except for production where a positive effect is found). That is, we find no evidence for positive knowledge spillovers *within* sectors while positive knowledge spillovers *between* sectors are only found for the production sector. We do find a positive effect of regional competition on growth for all sectors of economy except for construction.

1 Introduction

Spillovers occur when an innovation implemented by a certain enterprise increases the performance of another enterprise without the latter benefiting enterprise having to pay (full) compensation. In the past decades there has been increasing recognition that spillovers contribute substantially to economic growth. According to the new growth theory (Lucas, 1988; Romer, 1986), spillovers are the engine of growth. Mackun and MacPherson, 1997, p.666, conclude that the relative importance of firms' in-house R&D compared to external technical activity may be declining. They suggest that external inputs (for example in the form of spillovers) can increase the productivity of in-house initiatives of firms.

There are various types of spillovers (transfers), such as knowledge spillovers, market spillovers and network spillovers.[1] The new growth theory primarily focuses on knowledge spillovers (Aghion and Howitt, 1992; Aghion et al., 1997; Romer, 1986). Knowledge (for example, obtained via R&D activities) accumulates, and this generates innovations in enterprises. Since enterprises benefit from each other's innovations and ideas, an economy may grow even in the event of maximum input of labour and capital. In other words, spillovers explain part of the phenomenon that economies grow faster than might be expected on the basis of labour and capital input growth.[2] The increasing role of knowledge and small firms in the modern economy (Audretsch and Thurik, 2000 and 2001) motivates the investigation of the effect of knowledge spillovers, as small firms usually are more dependent upon knowledge spillovers than large firms are.

Knowledge spillovers appear to be a local phenomenon (Audretsch and Feldman, 1996). Interaction between people and enterprises located in each other's proximity produce the highest likelihood of spillover effects. This seems surprising, considering the current state of information technology, where information can be diffused throughout the world at practically zero cost. Audretsch and Thurik, 1999, p.5, refer to a paradox, which they explain by distinguishing between information and knowledge. Information may be diffused simply and free of charge, with examples being the gold price in Tokyo, or the weather in New York. Knowledge, contrastingly, may not simply be coded. Knowledge diffusion primarily emerges by means of social contacts, for example during meetings or sales transactions.

The contribution of knowledge spillovers to economic growth has been demonstrated by several authors (e.g. Griliches, 1992; Soete and Ter Weel, 1999). There are, however, various conflicting theories as regards the exact mechanisms of spillovers,

1 For an extensive elaboration, see Jaffe, 1996.

2 In the remainder of this paper, the term spillovers denotes knowledge spillovers, unless stated otherwise.

with debates focusing on two questions. *First*, do spillovers primarily emerge within one sector or, alternatively, do spillovers emerge between different sectors? *Second*, does local competition have a negative impact on the amount of innovative activity because innovation externalities (spillovers) are considered too large, or alternatively, does local competition have a positive impact on the amount of innovative activity because firms are 'forced' to innovate to beat their competitors?

The present paper focuses on these questions, using a model of regional growth based on Glaeser et al., 1992. The model examines three possible determinants of regional sectoral growth, viz. specialization, diversity and competition. Specialization is hypothesized to facilitate spillovers between firms from the same sector, while diversity is hypothesized to facilitate spillovers between firms from different sectors. The impact of specialization and diversity on growth, therefore, indicates the importance of *intra*-sectoral and *inter*-sectoral spillovers, respectively. The third variable, competition, may have both positive and negative effects on the amount of innovative activity and hence on economic growth. In fact, this involves a trade-off between internalization of innovation externalities (local monopoly) and the necessity to innovate to remain competitive in the market (local competition). By including local competition as a possible determinant of economic growth, this trade-off can be tested.

Van Stel and Nieuwenhuijsen, 2001, estimate the above-mentioned model of Glaeser et al., 1992, for the Netherlands. To see whether the results found in that study are representative for other countries as well, in this study we estimate the model for Great Britain. We use data for 60 British regions, that provide information on 6 sectors, viz. agriculture, production, construction, trade & catering, transport & communication, and other services. The 60 regions cover the whole of Great Britain. The data cover the period 1981-1998.

The contribution of the current paper is threefold. *First*, while Glaeser et al., 1992, investigate knowledge spillovers in the United States in the period 1956-1987, the present study investigates knowledge spillovers in Great Britain in a more recent, hence more knowledge-intensive period (1981-1998). *Second*, considering that spillover mechanisms may work out differently for different sectors of economy, the current paper presents separate estimation results for five sectors of economy. *Third*, some improvements of the operationalizations of the variables with regard to those used by Glaeser et al., 1992, are applied in the present study.

The organization of this report is as follows. In section 2 we will discuss different theories concerning knowledge spillovers and competition. In section 3, the model as well as the data set will be presented. Also the differences between the present study and the study of Glaeser et al., 1992, are discussed. The estimation results will be given in section 4. In section 5 finally, we present a discussion and give some recommendations for future research.

2 Theory

The model of Glaeser et al., 1992, departs from the assumption that knowledge spillovers at the regional level are of major significance as regards innovation and economic growth. More precisely formulated, Glaeser et al., 1992, assume that sectors in different regions may have different growth rates because knowledge spillovers work out more effectively in one region than in another. This is because different *types* of knowledge spillovers may emerge in different regions, viz. *intra*-sectoral spillovers versus *inter*-sectoral spillovers. Furthermore, the intensity of local competition may differ between regions. The model examines three theories as to the impact of knowledge spillovers and local competition on regional growth. In this section these theories are discussed.

Marshall, Arrow, Romer

The *first* theory is developed by Marshall, 1890; Arrow, 1962, and Romer, 1986, abbreviated as MAR. They assume that knowledge spillovers are most effective between homogeneous enterprises. So, spillovers primarily emerge within one sector. For a given region, this would imply that specialization in a limited number of activities may contribute to spillovers and growth. An example of this type of within-industry spillovers would be the microchip manufacturing industry in Silicon Valley (Glaeser et al., 1992, p.1130). The MAR economists further assume that the situation of a local monopoly is beneficial to economic growth, since in that case, the vast share of the yields generated by innovation benefits the innovator itself. That is, the externalities associated with innovation are internalized by the innovator. This would produce an additional incentive to innovate. In the MAR theory, regional sectoral growth is maximized if the sector is dominant in the region, and if local competition is not too strong.

Porter

The *second* theory is that of Porter, 1990, who agrees with MAR that knowledge spillovers between firms in specialized sectors (sectors which are concentrated in certain regions) stimulate economic growth. In contrast to MAR, however, Porter assumes that local competition has a positive impact on growth. In his view, competition accelerates imitation and upgrades innovation. Although competition decreases the relative benefits for the innovator (due to larger spillovers flowing to competitors), the amount of innovative activity will increase, because enterprises are ‘forced’ to innovate: enterprises that fail to improve products and production processes in due time will lose ground to their competitors and will ultimately go bankrupt. An example of fierce competition to innovate, resulting in growth, would be the Italian ceramics and gold jewelry industries (Glaeser et al., 1992, p.1128). So, while MAR emphasize the negative effect of competition on the amount of innovative activity, Porter assumes that the positive effect is dominating. An activity in which these two opposite sides of competition are very perceptible, is Formula One motor racing. In this driving competition for racing-cars, teams are always busy doing research and testing in order to make the cars faster. As the speed of Formula One cars increases year after year, it is clear that the positive effect of competition dominates in this industry. However, also the MAR argument is considered important, as teams do not want to give anything of their technology away to competitors. After a Formula One race, when all cars are parked in the 'parc firmé', this is sometimes very clear, when teams cover up their cars in order to make it impossible for the other teams to learn anything about the technology of their cars.

Jacobs

The *third* theory elaborating on the significance of local knowledge spillovers was developed by Jacobs, 1969. Jacobs' theory departs from the assumption that knowledge spillovers work out most effectively among enterprises that practise different activities. Primarily *inter-sectoral* knowledge transfers would thus be of significance. In her view, sectors will grow in regions where, besides the sector itself, various other sectors are important. In this philosophy, regions marked by a high degree of variety (diversity) will thrive.[1] As regards competition, Jacobs agrees with Porter, i.e. Jacobs assumes that local competition accelerates the adoption of new technologies and, consequently, stimulates economic growth.

[1] An example of this type of inter-sectoral spillovers would be the following: 'A San Francisco food processor invented equipment leasing when he had trouble finding financing for his own capital; the industry was not invented by the bankers' (Glaeser et al., 1992, p.1132).

3 Model and Data

3.1 Model

In this section the model to be estimated is described. Also the operationalizations of the variables specialization, competition and diversity, which are crucial to the model, are discussed.

The theories of MAR, Porter and Jacobs are tested using a model in which regional sectoral economic growth is explained by the regional variables specialization (S), competition (C) and diversity (D). Growth is measured in terms of employment.[1] We analyse growth over five different time periods, varying from 3 years to 17 years. We do this in order to investigate how much time is involved before the spillovers actually have an effect on (employment) growth. Effects on growth may not be perceptible immediately, for example because newly obtained knowledge has to be implemented in existing structures. Obviously, growth cannot entirely be explained by the three variables S, C and D. Therefore, we employ a number of control variables, the most important being national sector-growth. This variable corrects for demand shifts. If the demand for products of a given sector changes (at the national level), then for a given region, the demand for the products of that sector is also likely to change. As a result, growth of that sector in that region will be affected. This has nothing to do with the spillover effects that we want to investigate, so we include *national* sector growth as a control variable. By including this variable, merely *regional* sector growth is left to be explained. Indeed, regional sector growth is exactly what we want to explain (given the assumption that knowledge spillovers are a local phenomenon). So, national sector-growth is a useful control variable. Besides, we also investigate whether there are region-specific effects not covered by the model. For this purpose, we include region dummies. The model reads as follows:

(1) $$\Delta y_{i,r} = b_0 + b_1 S_{i,r} + b_2 C_{i,r} + b_3 D_{i,r} + g_1 \Delta y_{i,GB} + \sum_{k=2}^{60} g_k R_k + e_{i,r} ,$$

where:

Δy: average annual relative growth of employment over the periods 1981-84, 1981-87, 1981-91, 1981-95, and 1981-98, respectively

S: specialization in 1981

C: competition in 1981

[1] Real value added might be a better measure of economic growth in the context of studies about innovation and spillovers, such as the present one. However, we do not dispose of value added data at the spatial and sectoral aggregation level that we employ in the present study.

D: diversity in 1981

R: region-dummy

i: sectoral index (i=1,..,6)

r: regional index (r=1,..,60)

b : vector with parameters of main explanatory variables

g : vector with parameters of control variables

e : disturbance term

GB: indicator for Great Britain

The outlined theories of MAR, Porter and Jacobs as regards the effects of S, C and D may now be expressed in model hypotheses in terms of expected signs of the parameters b_1 to b_3. In MAR's theory, specialization has a positive effect on growth, and local competition a negative effect. According to Porter, both specialization and local competition positively affect growth. According to Jacobs, diversity as well as local competition generate positive effects on growth. In formulas (2a) to (4b), the various hypotheses are formally expressed in terms of null hypotheses H_0 and alternative hypotheses H_a:

(2a) $H_0: \quad b_1 = 0,$ $\quad H_a: \quad b_1 > 0$ (specialization; MAR)

(2b) $H_0: \quad b_2 = 0,$ $\quad H_a: \quad b_2 < 0$ (competition; MAR)

(3a) $H_0: \quad b_1 = 0,$ $\quad H_a: \quad b_1 > 0$ (specialization; Porter)

(3b) $H_0: \quad b_2 = 0,$ $\quad H_a: \quad b_2 > 0$ (competition; Porter)

(4a) $H_0: \quad b_2 = 0,$ $\quad H_a: \quad b_2 > 0$ (competition; Jacobs)

(4b) $H_0: \quad b_3 = 0,$ $\quad H_a: \quad b_3 > 0$ (diversity; Jacobs).

Operationalization of variables

It is important how the variables specialization, competition and diversity are defined, as the estimation results of equation (1) may be different for different variable operationalizations. The operationalizations employed in the present paper are discussed below. At the end of the current subsection we will discuss some alternative measures and we will show the advantages of our measures with regard to these alternatives.

Specialization

Specialization is defined as the employment share of the sector in the region, relative to the share of that sector in the whole country (in our case Great Britain). If a sector is overrepresented in a region (relative to the national employment share of that sector), then there are larger-than-average opportunities for within-sector spillovers to emerge, and according to MAR and Porter, this would stimulate growth of that sector in that region. The expression of specialization (S) reads as follows:

(5) $$S_{i,r} = \frac{Empl_{i,r} / Empl_{tot,r}}{Empl_{i,GB} / Empl_{tot,GB}},$$

where 'Empl' stands for employment and 'tot' for total. The value of the variable is expressed as a ratio in deviation from one, which figure corresponds to the national average employment share of the sector. Note that the value of S for a given sector is independent of the shares of the other sectors in the same region. That is, for a given region, small sectors may have larger values of S than large sectors. This is because we are only concerned with the relative extent of regional concentration for the sector under consideration. According to formula (5), there are many possibilities as regards within-sector spillovers if relatively many employees work in the same sector. This may be the case if in a sector a few relatively large enterprises operate, or, alternatively, if relatively many small enterprises operate.[1]

Competition

Competition is defined as the number of businesses in a sector in a region relative to the number of businesses in that sector in the whole country, adjusted for the size of the region. The (economic) size of a region is measured as total employment in that region. The variable assesses whether local (regional) competition is higher or lower than national competition. According to MAR, intensive local competition in a sector impedes economic growth in that sector. In case of intensive competition, MAR assume that enterprises limit their amount of innovative activities (e.g. by cutting down R&D expenses) because too much new knowledge spills over to competitors (i.e. externalities are considered too large). According to Jacobs and Porter, on the contrary, intensive local competition benefits economic growth, because enterprises are 'forced' to innovate (the alternative being demise). The expression of local competition (C) reads as follows:

1 Of course, inter-firm spillovers can not occur if one very large enterprise were to operate alone. In that case, the specialization variable would have to be fixed at zero, considering that the variable is used as an indicator of the facilitation for intra-sectoral spillovers. Our dataset does not comprise such a case.

(6) $$C_{i,r} = \frac{B_{i,r} / Empl_{tot,r}}{B_{i,GB} / Empl_{tot,GB}},$$

where B stands for the number of businesses. Local competition of sector i in region r is thus defined as the region-size-adjusted number of businesses in the sector relative to the nation-wide number of businesses in that sector. The value of the variable is expressed as a ratio in deviation from one, which figure corresponds to the nation-wide (adjusted) number of businesses in the sector.

In our approach, specialization and competition are different concepts in that specialization deals with the clustering of workers while competition deals with the clustering of businesses (see formulas 5 and 6). Since the number of workers and the number of businesses may be positively correlated, the variables specialization and competition may also be correlated. In our dataset, the correlation between specialization and competition is 0.109, which is not high, so that the model generates reliable estimates of the effects of both variables (see Section 4). That is, the model outcomes do not suffer from multicollinearity problems.

Diversity

For a given sector in a given region, *diversity* is defined as the employment share of the three smallest sectors in the *remaining* five sectors in the region, adjusted for the employment share in the region of those five sectors.[1] The first factor measures diversity of the region (excluding the sector under study). A larger share of the smallest sectors implies a more diverse sector structure. Adjustment for the employment share of the remaining five sectors is required, since large sectors can benefit relatively less from spillovers from the remaining sectors, plainly because these remaining sectors are relatively small compared to the (large) sector under study. In other words, assuming an identical structure of the remaining sectors, the potential to benefit from inter-sectoral spillovers is relatively higher for a small sector under study than for a large sector under study. According to Jacobs, higher degrees of diversity generate higher growth rates. The expression of diversity (D) reads as follows:

(7) $$D_{i,r} = 100 \times \frac{\sum_{k=1}^{3} Empl_{-i[k],r}}{\sum_{-i} Empl_{i,r}} \times \frac{\sum_{-i} Empl_{i,r}}{Empl_{tot,r}} = 100 \times \frac{\sum_{k=1}^{3} Empl_{-i[k],r}}{Empl_{tot,r}},$$

with:

$Empl_{-i[k],r}$ Employment of k[th] smallest sector in region r, sector i excluded,

$\sum_{-i} Empl_{i,r}$ Total employment in region r, sector i excluded.

[1] In this report, the economy is disaggregated into six sectors.

Formula (7) shows that the two factors may be rewritten as one expression: the share of the three smallest sectors (*excluding* the sector under study) in total regional employment (*including* the sector under study). The variable is expressed in percentages.

Diversity is not to be interpreted as the counterpart of specialization. High levels of specialization may coincide with high levels of diversity. A sector may be relatively dominant in a region, while at the same time the remainder of that region may be marked by a high degree of diversity. However, because employment of the sector under study is part of the denominator in (7), there will be some negative correlation between the variables specialization and diversity. In fact, in our dataset, the correlation is -0.126. Again, this does not lead to multicollinearity problems (see Section 4).

Differences between the present study and the study by Glaeser et al., 1992

There are several ways to specify the concepts of specialization (S), competition (C) and diversity (D) in model variables. Glaeser et al., 1992, choose an alternative operationalization of local competition. They use the number of businesses per worker for a sector-region combination relative to the number of businesses per worker in the entire sector (whole country). This variable measures the inverse average business size but this may not be appropriate as a measure of local competition.[1] Furthermore, if a positive effect of the business size measure on growth is found, one may have found merely the effect that small firms grow faster than large firms. See for example Kleijweg and Nieuwenhuijsen, 1996. Also for specialization and diversity there are alternative operationalizations. Some measures, including those used by Glaeser et al., 1992, are discussed in Nieuwenhuijsen and Van Stel, 2000, pp.29-37. Still other measures are discussed in *Appendix 3* to this report. Among others, this includes a specialization measure based on employment density. Besides the operationalizations of the variables S, C and D, there are also other differences between the present study and that of Glaeser et al., 1992. While they investigate growth in the United States in the period 1956-1987, the present study investigates growth in Great Britain in a more recent, hence more knowledge-intensive period (1981-1998).[2] Furthermore, while Glaeser et al., 1992, consider only large two-digit sectors, we consider firms from all sectoral sizes, albeit at a higher level of aggregation. Consequently, we also include small sectors, which -on average- have a relatively high small firm presence. This is important for the purpose of the present study, because

1 For example, for a given sector in equally large regions, the inverse business size measure cannot distinguish between regions with 100 businesses with on average 5 workers, and regions with 20 businesses, also with on average 5 workers. Clearly, competition is more intense in regions with 100 businesses. The operationalization (6) employed in the present report takes account of that.

2 A similarity is that both studies measure growth in terms of employment. In Van Stel and Nieuwenhuijsen, 2001, growth is measured in terms of value added.

small firms usually are more dependent upon knowledge spillovers than large firms are.

3.2 Data

In the present report we use a data base with sector information at a relatively disaggregated spatial level, in which Great Britain is divided in 60 regions. The sectors of the regional economy considered are agriculture, production, construction, trade&catering, transport&communication, and other services.[1] The data cover the period 1981-1998. As we can see from the definitions of specialization, competition, and diversity, all variables are calculated from two basic variables: businesses and employment. In *Appendix 1* all relevant information concerning the basic data is given, including a list of the 60 regions. In the crude data files, there are some imperfections, such as missing data and changes in sectoral classifications in certain years. How we deal with these problems is described in *Appendix 2*.

Basically, there are 360 observations available (viz. 6 sectors times 60 regions). However, a number of observations is not used in the determination of the parameter estimates. The observations of the sector agriculture are not used because we consider this sector not appropriate to fit in the framework of a spillover model such as (1). Agriculture is too different from the rest of the economy.[2] Furthermore, the observations of the region Orkney/Shetland/Western Isles are dropped, because too much information is confidential. Of the remaining 295 observations (5 sectors times 59 regions), 2 extreme observations (outliers) from the variable specialization are removed, leaving 293 observations in the data set. The model is estimated on the basis of these 293 observations. Table 1 presents some descriptive statistics of the model variables.

[1] These are almost the same sectors as used for the Netherlands in Van Stel and Nieuwenhuijsen (2001). The differences are that they employ mining and manufacturing as separate sectors, while these two sectors are merged into the production sector in the current paper. Furthermore, they do not dispose of data for the agricultural sector whereas the present study does.

[2] However, because agriculture is undoubtedly part of the regional economy, the data of the sector are included in the various denominators of the model variables (i.e. total employment of a region), and in the numerator of the diversity variable (if it belongs to the smallest three sectors).

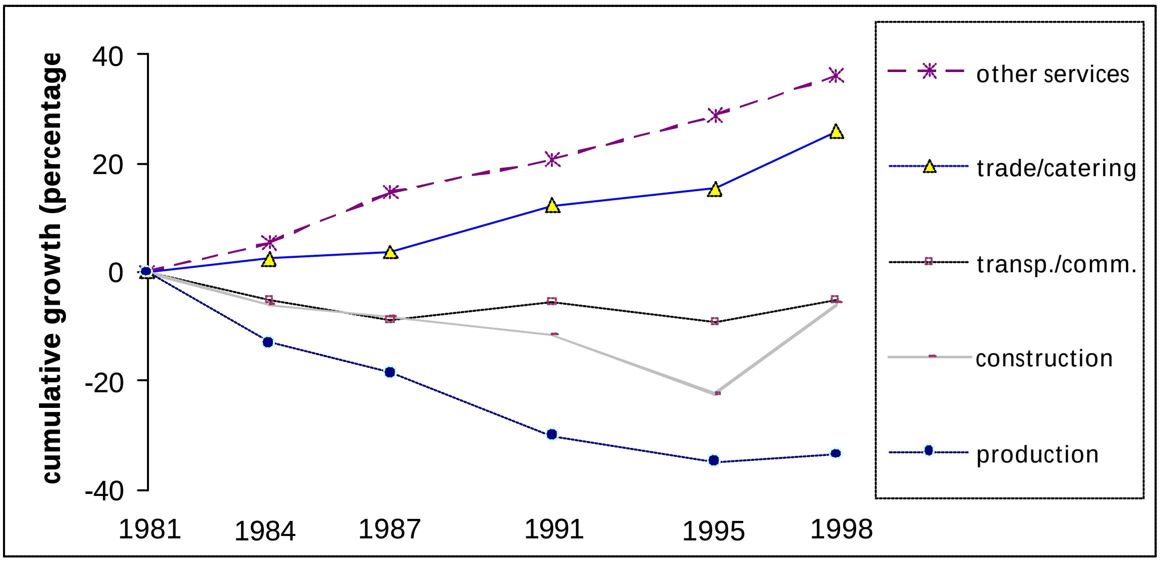
Table 1 Descriptive statistics of model variables (based on 293 observations)

Variable	Minimum	Maximum	Mean	Median	Standard deviation
Growth 1981-84*	-17.04	7.81	-0.77	-0.30	3.75
Growth 1981-87	-9.16	5.42	-0.38	-0.10	2.71
Growth 1981-91	-9.17	4.45	-0.07	0.41	2.34
Growth 1981-95	-7.90	3.57	-0.25	-0.00	2.17
Growth 1981-98	-6.60	3.68	0.24	0.50	1.84
Specialization (national average = 1)	0.42	1.58	0.98	0.96	0.19
Competition (national average = 1)	0.08	2.28	1.04	1.01	0.36
Diversity (%)	8.86	39.82	19.71	17.59	7.73

* Average annual growth of employment (%).

Looking at the mean of average annual growth for the five periods in Table 1, we see that there was, in general, a decline of employment in the early 1980s, a recovery until the start of the 1990s, after that again a decline until the mid 1990s, and finally a quite strong recovery in the second half of the 1990s. In Figure 1, these general developments in employment are split up in sectors. We see that over the period 1981-98, employment has decreased the most in the production sector and has increased the most in other services (see Tables A3 and A4 in Appendix 1 to see which parts of economy belong to this sector). Furthermore, we see that especially the construction sector made a strong recovery in the second half of the 1990s.

Figure 1 Cumulative employment growth per sector for Great Britain, 1981-1998



Source: EIM based on NOMIS.

4 Estimation results

In this section the estimation results are discussed. First of all, the model is estimated with data for all sectors included in the estimation sample. We call this pooled estimation. However, we suspect that the spillover mechanisms may work out differently for different sectors of economy. Therefore, we also present estimation results for the sectors separately. Indeed, if the spillovers do work out very differently, then a pooled estimate is not useful since a pooled parameter is an average of the five sectors production, construction, trade&catering, transport&communication, and other services, which is less useful when the sectors are not comparable in terms of spillover effects. This point will be further addressed in section 4.2. In short, we must interpret the pooled estimates with great care. The regressions are computed for five periods separately in order to see how long it takes for the spillover mechanisms to have an effect on growth.

4.1 Pooled estimates

Equation (1) is estimated with ordinary least squares (OLS). We have a sample of 293 observations (see section 3.2). With respect to the region-specific dummies, we employ a top-down approach, i.e. we start with the inclusion of all dummies, and in a stepwise fashion delete the least significant dummies until all the explanatory dummy variables are significant at the 5% significance level. The stepwise method is better than a simultaneous method because the significance of deleting all non-significant dummies simultaneously may not be 5%. The result of the stepwise procedure is that different region-specific dummies are included for different time periods. Thus, we include dummies only for those regions where growth cannot be adequately explained without such a dummy. The models are diagnostically evaluated by various standard misspecification tests, such as tests for heteroskedasticity, autocorrelation, normality of the residuals and outliers. Observations with studentized residuals that exceed 3 in absolute value are deleted from the regressions. When the disturbances are normally distributed, but heteroskedasticity and/or serial correlation is still present, we use White heteroskedasticity consistent or Newey-West heteroskedasticity and autocorrelation consistent standard errors respectively.[1] The estimation results are given in Table 2.

1 Note that in this case autocorrelation refers to spatial autocorrelation as we have observations per region.

Table 2 Estimation results, dependent variable average annual growth of employment; **Pooled** [1,2]

Explanatory variable (parameter)	1981-1984	1981-1987*	1981-1991**	1981-1995*	1981-1998*
Constant (b_0)	3.35	1.66	1.49	0.35	0.94
	(3.58)	(2.45)	(2.67)	(0.85)	(2.87)
Specialization (b_1)	-4.47	-2.29	-1.24	-0.68	-1.60
	(-5.59)	(-3.98)	(-2.75)	(-1.93)	(-5.18)
Competition (b_2)	1.59	0.85	0.39	0.50	1.04
	(3.49)	(3.01)	(1.60)	(2.84)	(6.48)
Diversity (b_3)	-0.03	-0.02	-0.02	-0.01	-0.02
	(-1.49)	(-1.10)	(-1.07)	(-0.91)	(-2.12)
Macro growth sector (g_1)	0.86	0.88	0.88	0.94	0.90
	(12.84)	(18.26)	(22.51)	(25.23)	(23.99)
Number of included observations	289	288	288	285	287
R^2	0.54	0.68	0.72	0.81	0.78
Number of included regional dummies	8	16	7	16	10

Impact on average annual growth in %-points of one standard deviation increase in Specialization, Competition or Diversity

Variable	1981-1984	1981-1987	1981-1991	1981-1995	1981-1998
Specialization	-0.84	-0.43	-0.23	-0.13	-0.30
Competition	0.57	0.31	0.14	0.18	0.37
Diversity	-0.25	-0.12	-0.12	-0.08	-0.13

1 T-values between parentheses.

2 * denotes White heteroskedasticity consistent standard errors.

** denotes Newey-West HAC consistent standard errors.

Specialization

Looking at the results, we see that the estimate of the specialization parameter is statistically significant at 5% and has a negative sign in all regressions. This means that sectors that are more heavily concentrated in the region than in Great Britain as a whole grow slower, which is the opposite of the theories of MAR and Porter who predict a positive sign (see hypotheses 2a and 3a). Thus there seems to be evidence against the importance of *intra*-sectoral knowledge spillovers.

The finding that specialization does not have a positive impact on regional sector growth seems to contradict the experience that many regions are marked by high levels of concentration of homogeneous enterprises. But many reasons other than growth opportunities may account for these high concentration levels. Marshall (1890) mentions the possibility to jointly utilize production factors (e.g. highly skilled staff). Henderson (1986) explains a high level of business concentration of a certain sector in a certain region by a relatively high demand for the products of that sector in that region, favouring business startups in such regions because of low transport costs. By and large, the above explanations state that specialization emerges because of the *static* efficiency thus achieved. The present study, however, investigates *dynamic* efficiency (i.e. growth). We find no evidence that this is achieved by specialization as well. See also Glaeser et al., 1992, p.1129.

Competition

The estimate of the competition parameter b_2 is positive and statistically significant in all regressions except in the period 1981-1991. We may therefore conclude that MAR's theory on competition is rejected, see (2b). Enterprises do not limit innovative activity out of fear that their efforts employed will spill over to competitors. Instead, the results seem to confirm the theories of Porter and Jacobs, i.e. enterprises innovate to a higher extent so as not to incur a backlog compared to competitors. The higher levels of innovation, in turn, lead to higher growth rates.

Diversity

A diverse economic environment of a sector does not appear to have a positive effect on growth. The parameter estimate has a negative sign in all regressions, but the estimate is only significant over the last period (1981-1998). We may therefore conclude that the effect of diversity on regional economic growth is nil, in contrast to the theory of Jacobs. There is no empirical support for the hypothesis that higher degrees of regional diversity generate higher (inter-sectoral) spillovers and higher growth rates. Consequently, when looking at pooled estimation outcomes, it does not seem necessary that different enterprise types should locate in each other's proximity to capitalize on ideas they do not develop themselves since they exercise very different business activities. Once more we note that these results might be different for separate sectors of the economy. We can conclude however that there is no dominant diversity effect over all sectors simultaneously.

Size of the effects

In the previous paragraph we considered only the statistical significance of the estimated parameters and not the size of the effect. Regarding the size of the effect, we compute the effect on average annual growth in percent points if specialization, competition or diversity were to increase by one standard deviation. We do this because the measurement units adopted for the variables are not trivially interpretable (specialization and competition are expressed as a ratio in deviation from one and diversity is in percents) and the size of the effects, as measured by multiplying the regression coefficients by a one standard deviation increase of the explanatory variable, can be interpreted independently of the measurement units employed.

From Table 1, we see that the standard deviation of specialization in our data set equals 0.19. For the period 1981-1984, the estimate of the specialization parameter equals -4.47. So, a ceteris paribus increase of one standard deviation has an effect on average annual growth of 0.19 $\times$ -4.47 = -0.84 %-point (see the second panel of Table 2). When the measure of competition rises by one standard deviation, average annual growth over the period 1981-1984 increases by 0.57 %-point. For the variable diversity the effect is -0.25 %-point. From these results, it appears that specialization and competition have the largest effects on regional growth, consistent with the significance of the parameters. The values for the other time periods can be found in Table 2. These values fluctuate somewhat over the five periods, but remarkably, the effects are largest for the shortest period (1981-1984), suggesting that short term effects of spillovers are important. Again, results might differ between sectors.

4.2 Sectoral estimates

As noted before, the spillover mechanisms may work out differently for different sectors of economy. That is why we also estimate equation (1) separately per sector (again for five time periods and using ordinary least squares). These regressions each contain 59 observations and the variables specialization, diversity, competition, and a constant have been included in the model (note that the variable macro growth sector now coincides with the constant term). Additionally, we include the explanatory variable initial employment in 1981. In the pooled estimates, this variable is not significant, but it may be the case that high initial employment in a sector in a region leads to slower growth of that sector's employment (because large sectors have less potential to grow even further, especially proportionally). We choose to delete this variable if it is not significant in the sectoral estimates. For scaling purposes, this variable is expressed in millions of workers. The models are once again diagnostically evaluated by various misspecification tests, as indicated previously. The general results for the parameters can be found in Table 3, and more detailed results are in Tables A6 to A10 in *Appendix 4*. Table 3 presents the common pattern of the statistical significance and signs of the estimated parameters over the five time periods.

Table 3 Dominant sign and significance of sectoral parameters for the variables specialization, competition and diversity

	Production	Construction	Trade & Catering	Transport & Communication	Other services
Specialization	0	0 / -	0	-	-
Competition	+	0	0 / +	+	+
Diversity	+	0	0	0	0

\+ means significant at 5% and sign > 0.

\- means significant at 5% and sign < 0.

0 means not significant.

Looking at Table 3, we see that the results vary considerably between different sectors. This indicates that the pooled estimates must be interpreted with care, since only an average effect for the five different sectors is determined. For example the diversity effect was not significant with pooled sectors. However, as we can observe from Tables 3 and A6 (Appendix 4), this effect is clearly positive for the production sector. At the pooled level, the results of the other four sectors dominate the results of the production sector, so that this positive effect for production disappears. The sectoral results will be discussed below.

4.2.1 Specialization

According to Table 3, the effect of specialization is either zero or negative for all five sectors in our data set. As we saw earlier with the pooled estimates (section 4.1), we thus find no empirical support for the importance of *intra*-sectoral spillovers. It seems to be the case that the effect of specialization on employment growth is more or less the same for all sectors. We refer to section 4.1 for a general discussion.

4.2.2 Competition

We think that the different effects per sector of local competition on growth can be explained by means of two distinct characteristics of a sector.

The *first* sector characteristic is the possibility to protect innovations. In industries where innovations can be easily protected (and the returns 'appropriated'), there is no impediment for firms to undertake R&D activities, and hence, the MAR argument is not valid in such industries.

The *second* sector characteristic that may influence the effect of competition on growth is the maturity of the sector. In industries at the beginning of the life cycle, there are more things yet to be learned by firms, and hence more growth yet to be achieved. Therefore, one might argue that particularly in young industries, local competition stimulates a process of innovations, rapid adoption of these innovations, new innovations, etcetera, which process in turn leads to growth (consistent with Porter).

We will now discuss the sign of the competition parameter in Table 3 for each sector, taking the above into account.

Production

For the sector production (which consists mainly of manufacturing), the sign of competition is positive. Looking at Table A6 in Appendix 4, we see that the effect is also quite large. A one standard deviation increase of the competition variable yields an average growth of +1.66%-point per year over the period 1981-1984. Over longer periods of time the effect is smaller though (for instance +0.68%-point over 1981-1991). In fact, the sector characteristics discussed above, which may influence the effect of competition, are both consistent with a strong positive effect for the production sector. *First*, because often very specific products are invented in manufacturing industries, innovations can be protected relatively easy by means of patents. So, there is no reason to slow down R&D activities. *Second*, at lower aggregation levels within the production sector, there are often many young high-tech industries. Particularly in these industries there are many possibilities for spillovers to occur, and this occurrence is stimulated by local competition. Hence it is no surprise that the positive effect of competition on growth in the production sector is larger than for any other sector in our data set.

Construction

According to our estimations, competition does not play a role in explaining regional growth in the construction sector.[1] We explain this using the first sector characteristic mentioned above. Innovations in the construction sector may be very hard to protect from competitors, as the building place is simple to approach for outsiders (as opposed to for example a factory hall). So with many competitors nearby there may be few incentives to undertake R&D activities (consistent with MAR). As a result the sector might be not so innovative, so that growth is hardly determined by our measures of specialization, competition and diversity.

Trade and Catering

This sector is comprised of wholesale, retail, repairs, and hotels and restaurants. Like the construction sector, there is hardly an effect of competition. It may be very diffi-

[1] An exception is the period 1981-1998 in which competition does have a significant positive effect on growth. However, comparing this outcome with the non-significant estimate for 1981-1995, this outcome must be (statistically) related to the sudden large increase in construction's employment in the late 1990s, see Figure 1. We do not believe that this sudden increase has something to do with the situation in 1981. Therefore we consider the 1981-1998 outcome as coincidental.

cult to protect innovations from competitors in this sector too, as anyone can simply walk into a store or restaurant. This may lead to less innovations and hence less spillovers. So, in this sector too, growth is hardly determined by our measures of specialization, competition and diversity.

Transport and communication

For this sector we find a positive effect of competition. It may be the case that innovations can be protected relatively easy because the most important features of the products in this sector are stored in computer software. Think for example of routing schemes and other logistic processes for transport firms. With many competitors nearby, it is important to constantly improve upon the most efficient routing schemes, and hence a process of imitation and further improvements in the sense of Porter may emerge. Considering the fast rising impact of ICT on the production process in the transport sector in the last 25 years, the argument is especially valid for our sample period 1981-1998. In this sense, the transport sector may even be seen as a 'young' industry.[1]

Other services

This sector is comprised of areas such as financial intermediation, renting, business activities, public administration, community services, social and personal services, education, health and social work. The effect of local competition on employment growth is positive. In the service industries (tacit) knowledge is often very important and hence, innovations may be protected relatively easy. Think for example of ways of giving an advice by a firm of consultants. With the rise of ICT there are many young industries within this sector and this also stimulates innovation and spillovers in case of fierce local competition.

4.2.3 Diversity

Production

Looking at Table 3, we see that diversity, our proxy for *inter*-sectoral spillovers, has a positive effect for the production sector, and no effect for the other sectors. We think that this may be due to the fact that the production sector takes a very central position in the British economy. Many production firms act as supplier for firms in the other four sectors. These production firms can get ideas for new innovative products from their customers.

Furthermore, production processes can benefit from the computer science industry, such as CAD/CAM, flexible automation, etcetera. So, the more diverse the region is,

[1] Because the transport and communication sector is dominated by transport (not by communication), we also have to interpret our results for this sector in terms of the transport sector.

the more inter-sectoral spillovers occur, explaining the positive estimate. The effect of a one standard deviation increase of the diversity variable fluctuates around about +0.6%-point per year.

Other sectors

It may be the case that there is not so much interaction between firms of the other four sectors, even if they are located nearby. This might explain the zero effect of diversity for the other sectors. For these sectors the theory of Jacobs is not supported.

Particularly for a sector like trade&catering, the zero effect is surprising at first sight. One is inclined to think that this sector might benefit from technological developments such as email, for example by being able to reach more potential clients.[1] Adopting new marketing strategies invented elsewhere might also contribute to increased profits. These hypotheses imply that trade&catering could be subject to *inter*-sectoral knowledge spillovers. However, the estimation results imply that this is not the case. But perhaps these developments (email and marketing strategies) have more the character of information than the character of knowledge (see again Audretsch and Thurik, 1999, p.5), contradictory to the assumption that knowledge spillovers are a local phenomenon. Businesses are not dependent on the proximity of other businesses to acquire this kind of information. This may explain the non-significance of diversity for this sector.

Time needed for spillovers to affect growth

In sectors where significant effects are found, it is often the case that these effects emerge relatively fast (i.e. already for the 1981-1984 period). However, looking at the estimation results, no definite conclusions can be drawn on the time needed for spillovers to have an effect on growth. This may be due to our method of measurement. It seems reasonable to assume that the sector structure in a region does not change very much in a few years time. So the variables specialization, competition and diversity as we measure them in 1981 may be strongly correlated with the same variables if we would have measured them in, say, 1976. So for example, if we find an effect of diversity in 1981 on growth 1981-1984, it might be the case that the actual spillovers causing this growth already found place in 1976, and that this effect is (erroneously) ascribed to the diversity variable in 1981. In such a case, it looks like the spillover already has an effect within three years time, while it actually took 8 years time to affect growth.

1 Notice however that the rise of e-commerce found place outside our sample period, i.e. after 1998.

5 Discussion

The results presented in this report should be interpreted with some caution since there are a number of limitations to our approach. In this section we discuss two limitations. Furthermore, we give some suggestions for further research.

First, as mentioned earlier, a clear drawback is that no information is available on the growth of real value added. This is a better measure of performance than the growth of employment. Real value added can grow for example while labour inputs decline by labour saving technological progress. We will illustrate this with an example. Consider the aggregate production function (see for example Burda and Wyplosz, 1997),

(8) $$Y = A \cdot F(K, L),$$

where *Y* denotes total output of an economy, *F(.;.)* is a well behaved production function that describes how an economy's capital stock *K* and employed labour *L* produce the total output of an economy (for example a Cobb-Douglas function), multiplied by a factor *A* called total factor productivity. Let us assume that regional growth can be captured by a simple Higgs neutral production function like (8), so that Y measures total output of the region. This can be decomposed (via Solow decomposition) as,

(9) $$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + a\,\frac{\Delta K}{K} + (1-a)\,\frac{\Delta L}{L},$$

so that economic growth is decomposed into three components. First, technological progress is captured by the rate of increase of total factor productivity $\Delta A/A$. Second, capital accumulation contributes to growth in proportion to its income share in GDP, denoted by a. Third, increases in the labour force also raise output in proportion to its share in GDP $(1-a)$. Now, when the decline in employment growth is dominated by the term $\Delta A/A$ via labour saving technological progress, economic growth can occur, while labour growth declines. The foregoing analysis implies that we cannot be certain that our conclusions with employment growth as dependent variable are completely valid.

Second, the sectoral aggregation level strongly determines the meaning of the variables specialization, competition and diversity. Interpretations of results are conditional upon the aggregation level applied. For example, as regards the competition variable, the question arises whether the six-sector classification adopted in the present paper is appropriate. By defining the entire production industry as one sector (mainly comprised of manufacturing), one implicitly assumes that businesses in, for instance, the metal industry compete with businesses in the food industry. This is implausible.

Despite these limitations, we argue that the present study provides some important insights concerning the mechanisms of knowledge spillovers and innovation like the important role of regional competition in stimulating innovation and economic growth. Future research should concentrate on doing comparable exercises for more countries to see if there are differences. Policy makers may want to base policy measures concerning regional firm clustering on the empirical findings of more countries. Since the sectoral aggregation level applied is crucial in this type of research, it may be worthwhile to perform the regressions while defining the variables specialization, competition and diversity at lower aggregation levels.

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Appendix 1: Data sources

The variables that are used in this report are all constructed from a database which contains four basic variables: startups, closures, number of enterprises, and employment. This database was constructed by EIM. These four variables are available at the sectoral (1-digit) and regional (British NUTS3) aggregation level for the period 1980-99. By and large, each of these four variables is available on a yearly basis according to uniform regional and sectoral classifications, for the whole period 1980-99. Achieving this uniformity is not straightforward, since the crude data were delivered according to different regional and sectoral classifications. In this appendix the exact regional and sectoral aggregation levels, at which the four variables are available in the EIM-data set, are presented. Also, the linking operations that were performed on the crude data, are described in detail. Furthermore, the data sources and some characteristics of the variables are described. Among other things, this includes some definitional problems concerning the comparability over time of the startup and closure data.

Basic data

In Tables A1a and A1b, we give an overview of the different classifications (regional and sectoral), according to which the four variables are available in the basic data files. Also, the exact years for which the variables are available (for employment there are some missing years), are tabulated.

Table A1a Available years and classification schemes in basic data files: startups, closures and number of enterprises [a]

Period	Available years	Regional classification	Sectoral classification
1980-1993	All	pre-LGR [b]	VTC [c]
1994-1999	All	post-LGR	SIC92

[a] The figures of these variables are supplied by Small Business Service.

[b] LGR = local government reorganisation 1995-98.

[c] VTC = VAT Trade Classification. This is effectively SIC68.

Table A1b Available years and classification schemes in basic data files: employment [a]

Period	Available years	Regional classification	Sectoral classification
1980-1991	1981; ’84; ‘87; ’89; ‘91	pre-LGR [b]	SIC80
1991-1999	1991; ’93; ’95-‘98	pre-LGR	SIC92

[a] The figures of this variable are supplied by Nomis.

[b] LGR = local government reorganisation 1995-98.

Startups, closures and number of enterprises: source and description

The figures on startups, closures, and number of enterprises are supplied by Small Business Service (SBS). This organisation publishes yearly figures on VAT registrations, VAT deregistrations, and the stock of VAT registered enterprises, based on data from the Inter-Departmental Business Register (IDBR; this register is administered by the Office for National Statistics). See SBS (2000). The VAT-registrations and VAT-deregistrations represent the number of enterprises registering and deregistering for VAT each year. Because there is a turnover threshold for VAT (£52,000 in 2000, for example), the very smallest one person businesses are excluded from the figures. The stock of VAT registered enterprises represents the number of enterprises registered for VAT at the start of the year.

Limitations of VAT data

There are a number of limitations concerning the comparability over time of these VAT data. The most important one is the fact that the above mentioned VAT registration threshold changes over time. By and large, the threshold changes have been roughly inflationary. However, in 1991 and 1993 there were large increases in the threshold. This implies that the 1980-91, 1992-93 and 1994-99 data are not on the same footing. As in the current research, only pre-1991 VAT data are used, our analyses do not suffer from these intertemporal incomparabilities. For a detailed outline on (other) limitations of the VAT data, see Keeble et al. (1990, Chapter 4).

Employment: source and description

The figures on employment are taken from the Census of Employment (until 1993) and the Annual Employment Survey (from 1995 onwards) and are supplied by Nomis. The employment figures only relate to employees. Self-employed workers and unpaid family workers are thus excluded from the data. This implies a disadvantage of this data source. For instance, employees who decide to start their own company are not counted any more because their employment status changes to self-employed. This is not desired, since in both cases the person has a job, and should be included in an employment count. The employment figures include both full-time and part-time employees, and relate to the situation in September of each year.

Regional aggregation level and classification schemes

The regional aggregation level employed in our data set is the British NUTS3 level. This involves the county level in England and Wales, and the local authority region level in Scotland. We thus have data at the level of the 64 regions which are listed in Table 2 of Ashcroft et al. (1991, p. 397). In the period 1995-98, a local government reorganisation took place in Great-Britain. The five tier NUTS level classification was reviewed, and the so-called unitary authorities (UAs) were introduced. In the old classification, Great Britain was divided into a number of counties (England and Wales) and local authority regions (Scotland). In the new classification England is divided into a number of counties *and* a number of UAs, while Wales and Scotland have moved toward a classification entirely in UAs. Due to boundary changes, most new regions are not comparable with the old regions. As can be seen from Table A1a, the data on startups, closures and number of enterprises for the years 1994-99 were delivered according to the new regional classification. We convert the new regions into old regions so that the variables are comparable over time for the whole period 1980-99. For the English regions, this is not a problem, since the data in the basic file are given in terms of both the new and the old regions ('former counties'). But for Wales and Scotland no variables for the period 1994-99 are given in terms of the old classification. Therefore, a linking operation has to be performed. For Scotland, this is a straightforward operation, since all 'old' local authority regions are the aggregate of one or more 'new' UAs, leaving no overlapping areas. For Wales, unfortunately, there *are* overlapping areas. We must combine some Welsh 'old' counties, so that no overlapping 'new' UAs remain. See Table A2.

Table A2 Aggregation scheme for Welsh counties

Label	pre-LGR based counties [a]
North/Mid Wales	Gwynedd Clwyd Powys
Dyfed	Dyfed
West Glamorgan	West Glamorgan
South/East Wales	Mid Glamorgan South Glamorgan Gwent

[a] LGR = local government reorganisation 1995-98.

From Table A2 we see that in two cases, three counties had to be taken together to avoid overlap, and that in two other cases the regions remain unchanged. The number of Welsh regions thus reduces from eight to four. As a result, the total number of regions in our data set reduces from 64 to 60. These 60 regions comprise 46 English counties, 4 Welsh regions (see Table A2), and 10 Scottish local authority regions.

In the latter group of regions, the Orkney, Shetland and Western Isles are combined into one region. The 60 regions cover the whole of Great Britain.

Sectoral aggregation level and classification schemes

At the regional level described above, the four variables are all available at the sectoral 1-digit level. However, from Tables A1a and A1b, we see that three different sectoral classifications circulate: SIC68, SIC80, and SIC92. These classifications are all different, see Table A3.

Table A3 Three Standard Industrial Classifications: 1-digit level labels [a]

SIC68	SIC80	SIC92
agriculture, forestry and fishing	**0** agriculture, forestry and fishing	**AB** agriculture; forestry and fishing
production	**1** energy/water supply industries	**CE** mining and quarrying; electricity, gas and water supply
construction	**2** extraction/manufacture: minerals/metals	**D** manufacturing
motor trades	**3** metal goods/vehicle industries, etc	**F** construction
wholesale	**4** other manufacturing industries	**G** wholesale, retail and repairs
retail	**5** construction	**H** hotels and restaurants
catering	**6** distribution, hotels/catering; repairs	**I** transport, storage and communication
transport and communication	**7** transport/communication	**J** financial intermediation
finance and professional services	**8** banking, finance, insurance, leasing, etc	**K** real estate, renting and business activities
business and other personal services	**9** other services	**LO** public administration; other community, social and personal services
		MN education; health and social work

[a] Similarities in covered parts of the economy across columns are coincidental.

We can make the following linking diagrams between the three classifications. See Tables A4a and A4b. *By and large*, there are no overlapping sectors in these diagrams.

Table A4a Relation SIC68-SIC92 classifications

SIC68-sectors	SIC92-sectors (codes)
agriculture, forestry and fishing	AB
production	CDE
construction	F
trade [a]	G
catering	H
transport and communication	I
other services [b]	JKLMNO

[a] This is an aggregate of three SIC68 sectors: motor trades; wholesale; retail.

[b] This is an aggregate of two SIC68 sectors: finance and professional services; business and other personal services.

Table A4b Relation SIC68-SIC80 classifications

SIC68-sectors	SIC80-sectors (codes)
agriculture, forestry and fishing	0
production	1, 2, 3, 4
construction	5
trade and catering [a]	6
transport and communication	7
other services	8, 9

[a] This is an aggregate of the two sectors of the same name from Table A4a.

The six-sector classification in the left column of Table A4b is the classification that is employed in the EIM-dataset. All variables from the basic data files have been aggregated towards this six-sector level according to the linking diagrams in the above tables. In this way we have a data set with uniform sectors for the whole period 1980-99.

As we saw earlier, the variables have also been made available at a uniform spatial (regional) classification. In summary, the EIM-data set for Great Britain contains the four variables startups, closures, number of enterprises and employment. Apart from some missing years for employment, these variables are available on a yearly basis for the whole period 1980-99, at relatively disaggregated sectoral and spatial aggregation levels (6 sectors, 60 regions), and according to uniform sectoral and regional classifications.

We end this appendix with a listing of the 60 regions of Great Britain in our data set.

1	Cleveland	31	Berkshire
2	Durham	32	Buckinghamshire
3	Northumberland	33	East Sussex
4	Tyne and Wear	34	Hampshire
5	Cheshire	35	Kent
6	Lancashire	36	Oxfordshire
7	Cumbria	37	Surrey
8	Greater Manchester	38	West Sussex
9	Merseyside	39	Isle of Wight
10	Humberside	40	Avon
11	North Yorkshire	41	Devon
12	South Yorkshire	42	Dorset
13	West Yorkshire	43	Wiltshire
14	Derbyshire	44	Cornwall and Isles of Scilly
15	Leicestershire	45	Gloucestershire
16	Nottinghamshire	46	Somerset
17	Lincolnshire	47	North/Mid Wales *
18	Northamptonshire	48	Dyfed
19	Hereford and Worcester	49	West Glamorgan
20	Shropshire	50	South-East Wales *
21	Staffordshire	51	Central
22	Warwickshire	52	Dumfries and Galloway
23	West Midlands	53	Fife
24	Bedfordshire	54	Grampian
25	Cambridgeshire	55	Highland
26	Essex	56	Lothian
27	Hertfordshire	57	Strathclyde
28	Norfolk	58	Tayside
29	Suffolk	59	Borders
30	Greater London	60	Orkney/Shetland/Western Isles

* See Table A2 for underlying regions.

Appendix 2: Dealing with missing data and different SICs

In the data set described in Appendix 1 there are some missing data for employment (apart from the years missing between 1980 and 1999; see Table A1b). For reasons of confidentiality, we do not dispose of the employment figures of certain sectors in certain regions for certain years. In this appendix we describe how we compute employment growth in these cases.[1] Furthermore, we describe how we compute sectoral growth over periods in which the sectoral classification changes (i.e. growth 1981-95 and 1981-98).

Missing data

When there are missing data for a certain region, this occurs mostly for some subsectors within the production sector: sectors 1 and/or 2 of the SIC80 classification, and sectors C and/or E of the SIC92 classification (see Table A3). Now, if for a certain region information about one or two production subsectors (1, 2, 3 or 4) in the SIC80 classification is not available, we use the growth rate of the remaining sectors for which information *is* available. Analogously, if information about C and/or E in the SIC92 classification is not available then we use the growth rate of the remaining subsectors. Since the implicit assumption of this procedure is that the growth rate of the missing subsectors equals the growth rate of the nonmissing subsectors, we make sure that the growth figure for production is based on the bulk of the production sector: it must be based on at least the aggregate of sectors 3 and 4 (SIC80) or sector D (SIC92). By using this criterion we lose the observations of the region Orkney/Shetland/Western Isles.

Different Standard Industrial Classifications

As we can see in Table A1b, the employment data are available according to different standard industrial classifications before and after 1991. This gives some inconvenience in computing growth over the periods 1981-95 and 1981-98. We compute the growth rate over the period 1981-95 by multiplying the growth rate over 1981-91 by the growth rate over 1991-95 and similarly for 1981-98 (note that the 1991 data are available for both SICs). So for example, to calculate growth over 1981-98 for the sector production, we multiply growth over 1981-91 of (the aggregate of) subsectors 1, 2, 3 and 4, and growth over 1991-98 of (the aggregate of) subsectors C, D and E. See Tables A4a and A4b. We do this because the sectoral linking schemes are not *precisely* one-to-one as suggested by Tables A4a and A4b.

[1] Fortunately, for the year 1981, there are no missing data so that we have no problems with computing the model variables specialization, competition and diversity.

Appendix 3: Alternative operationalizations

In Nieuwenhuijsen and Van Stel (2000), some alternative measures of the variables specialization, competition and diversity are discussed. In this appendix, we discuss two more operationalizations of specialization and diversity. We also perform regressions with these alternatively constructed variables.

Specialization

In this report, the variable specialization is defined as:

(10a) $$S_{i,r} = \frac{Empl_{i,r} / Empl_{tot,r}}{Empl_{i,GB} / Empl_{tot,GB}}$$

An alternative that might be of use is the following:

(10b) $$S_{i,r} = \frac{Empl_{i,r} / A_r}{Empl_{i,GB} / A_{GB}}$$

where A denotes the area of a region. This measure thus uses a different scaling variable (area of a region instead of total employment of a region) which might be more appropriate to asses knowledge spillovers inside one sector. We illustrate this with an example.

Example

Suppose, for a certain sector X, we have the next situations in two different regions.

Region A: employment sector X = 100; employment remainder region A = 10
Region B: employment sector X = 1,000; employment remainder region B = 10,000

According to definition (10a), specialization for sector X is higher in region A than in region B: 100/110 versus 1000/11000. But, is this true? The interpretation of a higher level of specialization is that there are more possibilities for spillovers inside one sector (in this case sector X). In region B there are more workers active inside sector X than in region A, so one might argue that there are more possibilities for spillovers in sector B and that the value for region B should therefore be higher than the value for region A. This is not the case with measure (10a) and therefore one might argue that this operationalization is not appropriate. In this line of reasoning, measure (10a) wrongly takes account of the number of workers outside the sector, as it does not matter how many workers are active outside the sector for the possible occurrence of *intra*-sectoral spillovers.

Now, suppose that regions A and B have the same area, than according to (10b), we get that the level of specialization is much higher for region B in the example. The suitability of alternative (10b) depends on the assumption that, within a region, enterprises are more or less evenly distributed over the area of the region. When this condition is satisfied, it looks like area is a good scaling variable, given the local nature of knowledge spillovers (it is important that enterprises are located in each other's proximity). However, this assumption may not be appropriate for Great Britain. Counties often are rural and have only one large city where all economic activity is taking place, thus violating the assumption. This might be the reason that we found a poorer fit in regressions in which we used measure (10b) for specialization, while leaving other variables unchanged. Data on the area of regions were obtained from ONS (Office for National Statistics). Given the poorer fit of the regressions using area as scaling variable, we adopt measure (10a) as the best choice with respect to the specialization variable.

Diversity

For diversity we have used the following definition:

(11a) $$D_{i,r} = 100 \times \frac{\sum_{k=1}^{3} Empl_{-i[k],r}}{\sum_{-i} Empl_{i,r}} \times \frac{\sum_{-i} Empl_{i,r}}{Empl_{tot,r}} = 100 \times \frac{\sum_{k=1}^{3} Empl_{-i[k],r}}{Empl_{tot,r}}$$

For a given sector, diversity should say something about the spread of the other sectors in the region. The larger the share of the three smallest (other) sectors, the more diverse the region is (and the more chance that inter-sectoral spillovers occur). There is some arbitrariness in choosing the smallest three, so that it could be interesting to look at a measure that uses all sectors in the region, such as the following Herfindahl-index type of variable:

(11b) $$D_{i,r} = 100 \times \left(1 - H_{-i,r}\right) \times \frac{\sum_{-i} Empl_{i,r}}{Empl_{tot,r}}$$

with:

$$H_{-i,r} = \sum_{-i} \left(\frac{Empl_{i,r}}{\sum_{-i} Empl_{i,r}} \right)^2$$

We illustrate the difference between (11a) and (11b) with an example.

Example

Suppose we consider a certain sector, say sector 1, where the sector structures in the regions A, B and C are as follows, in terms of employment.

sector	region A	region B	region C
1	10	10	10
2	40	18	35
3	45	18	30
4	2	18	5
5	2	18	10
6	1	18	10
total region	100	100	100

For measure (11b) with regard to sector 1 this boils down to the following values for diversity:

region A: 100 x (1-(0.198+0.25+0.0005+0.0005+0.0001)) x (90/100) = 49.6
region B: 100 x (1-(5 x 0.04)) x (90/100) = 72
region C: ... = 63.9

Now suppose that in region A, the sectors 2 and 3 are not distributed as 40 and 45, but as 5 and 80. Then, measure (11a) stays unchanged (the three smallest have not changed), while measure (11b) now becomes 18.5 instead of 49.6. This is due to the fact that these two sectors are now less evenly distributed and this influences the value of diversity according to (11b).

Note that we still have to correct for the size of the remaining sectors. Suppose region A is distributed as 10, 18, 18, 18, 18, 18 for sector 1 until 6 and region B as 90, 2, 2, 2, 2, 2. For sector 1, the factor $(1-H_{-i,r})$ is the same in both regions (because of the identical structure of the *remainder* of the region). However the possibilities for spillovers are larger in region A, because the remainder of the region makes out 90% of total employment in the region, so there are many other firms to take knowledge from. But in region B sector 1 itself makes out 90% of the total region and the remainder of the region is very small. Even though the remainder is very diverse, there are still little possibilities to benefit from inter-sectoral spillovers, simply because there are few other firms.

Regressions with alternative measure (11b)

When we perform regressions with (11b) instead of (11a), leaving other variables unchanged, the results are invariant under the diversity measure for some sectors, while for other sectors, there are differences. In Table A5 below, we give the general pattern of results over the different time periods for the sectors production, construction, trade&catering, transport&communication, and other services (compare with Table 3).

Table A5 Dominant sign and significance of sectoral parameters for the variables specialization, competition and diversity, with alternative measure for diversity

	Production	Construction	Trade & Catering	Transport & Communication	Other services
Specialization	0 /+	0 / -	0	-	-
Competition	+	0	0 / +	0 / +	+
Diversity	+	0	0	0	0

+ means significant at 5% and sign > 0.

- means significant at 5% and sign < 0.

0 means not significant.

Comparing Table A5 with Table 3, we can infer that the only important difference occurs for the sign of specialization for the sector production, which now tends to be positive. With diversity measure (11b), the theories of MAR and Porter on specialization are supported, contrary to our earlier findings. Nevertheless, we conclude that the results in the report are quite robust with respect to the diversity measure.

Appendix 4: Sector estimations

Table A6 Estimation results, dependent variable average annual growth of employment; sector **Production** [1,2]

Explanatory variable (parameter)	1981-1984	1981-1987	1981-1991	1981-1995	1981-1998
Constant (b_0)	-9.85	-8.06	-8.64	-8.28	-5.37
	(-3.03)	(-3.14)	(-3.73)	(-3.81)	(-2.95)
Specialization (b_1)	-0.77	-0.09	1.33	1.16	0.20
	(-0.47)	(-0.07)	(1.13)	(1.05)	(0.21)
Competition (b_2)	5.53	4.21	2.28	2.69	2.26
	(5.36)	(5.16)	(3.09)	(3.89)	(3.90)
Diversity (b_3)	0.19	0.16	0.24	0.21	0.14
	(1.65)	(1.76)	(2.91)	(2.66)	(2.11)
Employment 1981	-8.53	-7.42	-9.00	-7.42	-6.85
	(-3.25)	(-3.58)	(-4.80)	(-4.23)	(-4.64)
Number of observations	59	59	59	59	59
R^2	0.43	0.43	0.46	0.43	0.45

Impact on average annual growth in %-points of one standard deviation increase in specialization, competition or diversity

Variable	1981-1984	1981-1987	1981-1991	1981-1995	1981-1998
Specialization	-0.18	-0.02	0.30	0.26	0.04
Competition	1.66	1.26	0.68	0.81	0.68
Diversity	0.65	0.55	0.82	0.70	0.47

1 T-values between parentheses.

2 No correction for heteroskedasticity needed.

Table A7 Estimation results, dependent variable average annual growth of employment; sector **Construction** [1,2]

Explanatory variable (parameter)	1981-1984	1981-1987	1981-1991	1981-1995	1981-1998
Constant (b_0)	5.95	2.39	0.25	-3.41	0.19
	(1.38)	(1.17)	(0.14)	(-2.46)	(0.20)
Specialization (b_1)	-3.48	-4.23	-0.83	0.91	-2.01
	(-0.80)	(-2.67)	(-0.62)	(0.87)	(-2.81)
Competition (b_2)	0.08	-0.30	-1.48	-0.50	1.19
	(0.04)	(-0.32)	(-1.81)	(-0.76)	(2.66)
Diversity (b_3)	-0.16	0.04	0.06	0.07	0.02
	(-0.65)	(0.47)	(0.90)	(1.34)	(0.72)
Employment 1981			-21.2	-18.6	-11.9
			(-2.18)	(-2.43)	(-2.28)
Number of observations	58	58	58	58	58
R^2	0.06	0.13	0.10	0.18	0.49

Impact on average annual growth in %-points of one standard deviation increase in specialization , competition or diversity

Variable	1981-1984	1981-1987	1981-1991	1981-1995	1981-1998
Specialization	-0.60	-0.72	-0.14	0.16	-0.34
Competition	0.03	-0.11	-0.54	-0.18	0.43
Diversity	-0.69	0.15	0.25	0.29	0.11

1 T-values between parentheses.

2 No correction for heteroskedasticity needed.

Table A8 Estimation results, dependent variable average annual growth of employment; sector **Trade & Catering** [1,2]

Explanatory variable (parameter)	1981-1984	1981-1987	1981-1991	1981-1995	1981-1998
Constant (b_0)	2.78	1.53	2.10	1.72	1.89
	(1.40)	(0.97)	(2.45)	(1.92)	(2.38)
Specialization (b_1)	-2.45	-0.05	-0.95	-0.94	-0.37
	(-1.14)	(-0.03)	(-1.04)	(-0.96)	(-0.43)
Competition (b_2)	0.66	0.81	0.98	0.93	0.52
	(0.66)	(1.04)	(2.29)	(2.07)	(1.32)
Diversity (b_3)	-0.00	-0.11	-0.03	-0.04	-0.04
	(0.66)	(-1.61)	(-0.90)	(-1.07)	(-1.32)
Employment 1981	-	-	-3.34	-	-
			(-2.78)		
Number of observations	58	58	58	58	58
R^2	0.02	0.07	0.23	0.08	0.05

Impact on average annual growth in %-points of one standard deviation increase in specialization, competition or diversity

Variable	1981-1984	1981-1987	1981-1991	1981-1995	1981-1998
Specialization	-0.34	-0.01	-0.13	-0.13	-0.05
Competition	0.23	0.32	0.34	0.32	0.18
Diversity	-0.005	-0.34	-0.11	-0.14	-0.15

[1] T-values between parentheses.

[2] No correction for heteroskedasticity needed.

Table A9 Estimation results, dependent variable average annual growth of employment; sector **Transport & Communication** [1,2]

Explanatory variable (parameter)	1981-1984	1981-1987	1981-1991	1981-1995	1981-1998
Constant (b_0)	-2.33	-3.97	0.66	1.81	2.24
	(-0.64)	(-1.76)	(0.44)	(1.34)	(1.47)
Specialization (b_1)	-4.72	-3.36	-3.23	-3.34	-2.98
	(-2.24)	(-2.39)	(-2.54)	(-4.09)	(-3.27)
Competition (b_2)	2.02	0.93	1.22	1.52	1.62
	(1.35)	(0.96)	(2.15)	(2.63)	(2.46)
Diversity (b_3)	0.12	0.19	0.02	-0.04	-0.06
	(0.97)	(2.37)	(0.49)	(-0.84)	(-1.04)
Number of observations	58	58	59	57	59
R^2	0.18	0.25	0.21	0.32	0.24

Impact on average annual growth in %-points of one standard deviation increase in specialization, competition or diversity

Variable	1981-1984	1981-1987	1981-1991	1981-1995	1981-1998
Specialization	-1.00	-0.71	-0.68	-0.71	-0.63
Competition	0.70	0.32	0.42	0.52	0.56
Diversity	0.53	0.80	0.10	-0.17	-0.24

[1] T-values between parentheses.

[2] No correction for heteroskedasticity needed.

Table A10 Estimation results, dependent variable average annual growth of employment; sector **Other services** [1,2]

Explanatory variable (parameter)	1981-1984	1981-1987	1981-1991	1981-1995	1981-1998
Constant (b_0)	5.32	5.26	3.30	3.08	3.38
	(2.57)	(4.94)	(4.61)	(4.46)	(5.15)
Specialization (b_1)	-5.22	-4.02	-2.58	-2.29	-2.54
	(-2.44)	(-3.71)	(-3.43)	(-3.15)	(-3.80)
Competition (b_2)	2.64	1.69	1.11	1.27	1.48
	(3.64)	(4.62)	(4.59)	(5.45)	(6.55)
Diversity (b_3)	-0.04	-0.04	0.03	0.00	-0.03
	(-0.61)	(-1.15)	(1.16)	(0.13)	(-1.31)
Employment 1981	-	-	-0.722	-0.749	-
			(-1.75)	(-1.88)	
Number of observations	58	59	59	59	59
R^2	0.21	0.31	0.37	0.40	0.45

Impact on average annual growth in %-points of one standard deviation increase in specialization, competition or diversity

Variable	1981-1984	1981-1987	1981-1991	1981-1995	1981-1998
Specialization	-0.66	-0.51	-0.33	-0.29	-0.32
Competition	0.99	0.63	0.41	0.47	0.55
Diversity	-0.14	-0.14	0.09	0.01	-0.10

[1] T-values between parentheses.

[2] No correction for heteroskedasticity needed.

Appendix 5: List of Research Reports

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H9409	Verslag van de derde mondiale workshop Small Business Economics; Tinbergen Instituut, Rotterdam, 26-27 augustus 1994; M.A. Carree en M.H.C. Lever
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