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Which Types of Relatedness Matter in Regional Growth?

Industry, Occupation and Education

Sofia Wixe^a and Martin Andersson^{b,c}

ABSTRACT

This paper provides a conceptual discussion of relatedness, which suggests a focus on individuals as a complement to firms and industries. The empirical relevance of the main arguments are tested by estimating the effects of related and unrelated variety in education and occupation among employees, as well as in industries, on regional growth. The results show that occupational and educational related variety are positively correlated with productivity growth, which supports the conceptual discussion put forth in the paper. In addition, related variety in industries is found to be negative for productivity growth, but positive for employment growth.

Keywords: Relatedness, variety, occupation, education, regional growth.

JEL Classification Codes: R12, R23, J24

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INTRODUCTION

Within the fields of urban economics, economic geography and regional science, there has been a long-standing debate on the effects of agglomeration economies on growth. Much work in this strand of research focuses on the question of whether industry specialisation or diversity is more important in promoting growth (BOSCHMA and IAMMARINO, 2009). GLAESER *et al.* (1992) and HENDERSON *et al.* (1995) led the way, and many researchers have followed in similar tracks. However, the point of departure for the present paper is FRENKEN *et al.* (2005; 2007), who took the question about regional diversity, or *variety*, one step further. Following NOTEBOOM (2000), they argue that, for knowledge spillovers to enhance growth, there needs to be some sort of cognitive proximity or complementarity between firms. A distinction was thus made between related and unrelated variety, where related variety is defined as within-industry diversity and unrelated variety as between-industry diversity. FRENKEN *et al.* (2007) is, in this regard, a seminal study, as it is one of the first to provide systematic evidence that it is not variety in general, but variety in related industries, that promotes regional employment growth. This finding has been confirmed in several studies using data from different countries and time periods (BOSCHMA and IAMMARINO, 2009; BOSCHMA *et al.*, 2012; HARTOG *et al.*, 2012).

A conceptual issue in relation to this concerns defining relatedness. In the present paper this question is addressed and it is argued that relatedness may have many dimensions. Arguments are put forth and some empirical support is provided that relatedness, framed at the level of individuals and here operationalised as the educational background and occupation of employees, is at least as important as relatedness in terms of industries. Indeed, the downsides of applying standard industrial classifications to approximate relatedness have been discussed critically in a number of papers, such as EJERMO (2005), BISHOP and GRIPAIS (2010), BRACHERT *et al.* (2011), DESROCHERS and LEPPÄLÄ (2011) and BOSCHMA *et al.* (2012).

In contemporary economies cities or regions tend to specialise in functions rather than in industries. Certain occupations are found in specific cities, due to headquarters and business services being localised in larger cities, while actual production takes place in more rural areas (DURANTON and PUGA, 2005). Larger cities are thus specialised in knowledge-intensive occupations over a wide range of industries, which implies that variety in occupations has the potential to be at least as important for growth as variety in industries. Because certain occupations are found in different cities, it is also likely that certain education types are found in those cities. Education and occupation are linked together, more so than education and industry. In many cases, higher education is undertaken to work within a certain range of occupations, rather than a specific industry. The relationship between education and occupation is still not clear-cut, with the consequence that education and occupation are measures of quite different things. Education measures the formal, theoretical background of employees, while occupation is a measure of what the employees actually do in their daily work. Indeed, occupation is commonly used as a proxy for the skills and abilities of the employees beyond their formal education (cf. AUTOR *et al.* (2003), BACOLOD *et al.* (2009) and ANDERSSON *et al.* (2014a)). However, as in FRENKEN *et al.* (2007), most research still focuses on the effect of industrial specialisation (or variety) on growth.

DURANTON and PUGA (2004) distinguish between three types of mechanisms behind agglomeration economies: *sharing* of e.g. fixed costs and risk, *matching* on the labour market, and *learning* due to knowledge spillovers and human capital accumulation. They also emphasise that the heterogeneity of workers and firms is the foundation for these effects to materialise. From this perspective, regional variety has the potential to give rise to agglomeration economies, which may stimulate innovation and growth. However, in a strict sense, both the matching and learning arguments emphasise individuals, rather than firms. Knowledge and information may not spill over between firms per se, but rather between

employees, who channel the knowledge to the firms. COHEN and LEVINTHAL (1990) discuss this in terms of firms' absorptive capacity. There are thus arguments in favour of framing issues of cognitive proximity and relatedness in terms of individuals. On these grounds, relatedness in terms of employee education and occupation are emphasised in the present paper. Previous research has indeed expanded the measures of related variety beyond industrial classifications (cf. BOSCHMA *et al.* (2012)), but the main focus is still on the industry or product level.

To test the empirical relevance of these ideas, data on Swedish regions are used to estimate the relationship between each dimension of relatedness and regional growth over a five-year period (2002-2007). The original work by FRENKEN *et al.* (2007) is followed and related and unrelated variety in terms of industries are computed, but also additional measures of related and unrelated variety, in terms of the occupation and education of the workers in each region, are included. The inclusion of the two individual-based measures of occupational and educational variety constitutes the main novelty in the empirical analysis. Furthermore, variables reflecting general agglomeration economies, as well as a selection of control variables, are included. The model is estimated for regional economies as a whole, as well as for manufacturing and service industries, respectively. This is motivated by the results from BISHOP and GRIPAIS (2010) and MAMELI *et al.* (2012), which show different effects of unrelated and related variety on employment growth in different industries.

The results show that the effects of related and unrelated variety differ considerably, both across the different dimensions of relatedness and across sectors. This confirms the importance of expanding the concept of relatedness beyond the industrial dimension. Occupational and educational related variety, in addition to industry relatedness, are found to matter in explaining regional productivity growth. Relatedness, in terms of sharing a common educational background, appears to be particularly correlated with productivity growth in the manufacturing sector. These results may be appreciated as a reflection of that

relatedness in terms of education and occupation stimulates matching processes in local labour markets, as well as local knowledge spillovers, i.e. two established micro-foundations for agglomeration economies. Hence, regions with a variety of jobs associated with related education and/or related tasks may facilitate matching externalities in the labour market, as well as inter-firm knowledge transfers through employee mobility. The results of FRENKEN *et al.* (2007) are also confirmed, namely that related industry variety is negatively associated with productivity growth, but positively associated with employment growth.

The paper is organised as follows. The next section provides further background and motivation for the paper, including related empirical research. This is followed by an overview of the data and the variables used in the empirical application. The empirical results are presented next, which support what has been argued in the previous parts of the paper. The final section summarises the paper and concludes.

BACKGROUND AND MOTIVATION

Relatedness based on firms or individuals

Recent contributions in economic geography and regional science hold that a local variety of related industries is crucial in fostering regional growth (FRENKEN *et al.*, 2007). The main argument in this literature is that effective knowledge transfers and spillovers between activities in a region require that they are cognitively related, though some cognitive distance is still needed to limit overlaps and to alleviate issues of lock-in (BOSCHMA, 2005). Variety in related activities is thus maintained to stimulate productive interactions and cross-fertilisations within a region, because it ensures cognitive proximity, while maintaining some distance (through variety). This line of reasoning builds on NOTEBOOM's (2000) conjecture of 'optimal cognitive distance'. NOTEBOOM states that 'information is useless if it is not new, but it is also useless if it is so new that it cannot be understood' (NOTEBOOM 2000, p.153). While the general line of

argument is clear, i.e. that there is a trade-off between cognitive distance for the sake of novelty and cognitive proximity for the sake of mutual understanding and absorptive capacity, the question is what constitutes relatedness in a regional context, i.e. what characteristics of a local economy affect cognitive proximity? This is an issue that is not only of academic interest, but is also important from a policy perspective. Any discussion of policy initiatives based on the idea of relatedness will, for example, bring with it a concern regarding what relatedness means, and how it can be defined and assessed.¹ The idea of relatedness has had quite a large impact on both the research and the policy communities, and it is also embedded in the European Union's current regional innovation policy concept of smart specialisation (cf. MCCANN and ORTEGA-ARGILÉS (2013)).

The majority of existing analyses put firms at the centre stage and frame discussions about relatedness in an inter-firm context. A main hypothesis is that relatedness between firms hinges on their industry affiliations, such that firms operating in similar industries have shared competences, and thus, cognitive proximity at the organisational level (cf. BOSCHMA and MARTIN (2010)). In view of this, empirical applications typically infer relatedness from pre-determined industry or product classification schemes (BOSCHMA *et al.*, 2012; FRENKEN *et al.*, 2007). Put simply, the potential for productive inter-firm knowledge transfers and spillovers is assumed to be higher when firms operate in industries that are closer to each other in the standard industrial classification system or produce similar products (VAN OORT, 2013).

Following DESROCHERS and LEPPÄLÄ (2011), it may still be argued that the firm- and industry-level focus in the literature on relatedness downplays the fact that much of the learning and spillovers in regions occur at the level of individuals. That is, a case can be made that knowledge spillovers between firms in a region are, to a large extent, attributed to spillovers between their employees. Knowledge may flow between firms because their employees learn

from others in their local environment, or because employees move between them, which induces cross-fertilisations. For instance, the theoretical, as well as empirical, literature on human capital externalities and local non-market interactions (GLAESER and SCHEINKMAN, 2003; LUCAS JR., 1988; RAUCH, 1993) explicitly places social interactions between individuals at centre stage. Likewise, a large body of literature shows that the movements of individuals between firms is a key source of spillovers and transfers of knowledge and information (ALMEIDA and KOGUT, 1999; MASKELL and MALMBERG, 1999; POWER and LUNDMARK, 2004). It follows that the central ‘agents’ in the context of spillovers and knowledge transfers are not firms *per se*, but individuals. While this may seem like a trivial statement, the key point is that an emphasis on individuals has implications for the question of the dimension of relatedness that stimulates productive knowledge spillovers.

Accepting individuals as the main agents for knowledge spillovers suggests arguments in favour of framing issues of cognitive proximity in terms of individual skills, experiences and knowledge. The industry dimension can, from this perspective, be problematic on the grounds that the experiences and knowledge bases of individual employees have more to do with their occupational and educational backgrounds. Many firms have, for example, a sharp division of labour, pursuant to which individual employees work with narrowly defined and specialised tasks, often matched with their university degrees. Therefore, workers’ experiences and on-the-job learning may, to a large extent, be considered as occupation- and education-dependent, rather than industry-dependent. For example, a software engineer developing steering-systems for industrial robots at ABB Corporation may have cognitive proximity with a software engineer at an engineering service company, albeit the two industries are radically different as judged by their industrial classifications. The inter-firm job switching of personnel between such firms may also be large for the same reason. In many cases,

employers also put great weight on occupational- and task-specific experiences when hiring new personnel.

Furthermore, there is ample evidence that industries have very different occupational and educational compositions in different regions, a phenomenon dubbed ‘functional specialization’ by DURANTON and PUGA (2005). This means that the experiences, and hence, the position in the ‘cognitive space’ of workers in one and the same industry may be quite different across locations. This is a potentially important aspect that the traditional industry- and product-based measures of relatedness cannot capture. Occupational and educational relatedness should thus better reflect cognitive proximity at an individual level, because they depart from what employees actually do in their work, i.e. their immediate learning and experience context, as well as their knowledge base in terms of formal education. In this paper, the basic hypothesis is that this type of individual-level relatedness is at least as important as industry relatedness in providing a breeding ground for productive local knowledge spillovers and cross-fertilisations, and thus in influencing regional growth.

While this paper emphasizes relatedness in education and occupation for effective learning and knowledge spillovers between individuals, it is not neglected that industry belonging plays a role for relatedness. It may for example be argued that even though knowledge spillovers occur between individuals, new knowledge is exploited only if it fits the firm’s product portfolio, which relates to the industrial affiliation of the firm.

Similar ideas on the importance of individual skills are raised by NEFFKE and HENNING (2013) with the concept of skill relatedness. Highly-skilled individuals are especially likely to change jobs within industries that value the same types of skills. This implies that relatedness between industries can be determined based on cross-industry labour flows. NEFFKE and HENNING (2013) use this in order to explain the diversification strategies of firms, which determine regional industrial diversification. The results show that firms are more likely to

diversify into industries with which there is skill relatedness, than with industries without such relatedness or with relatedness in terms of standard industrial classifications.² BOSCHMA *et al.* (2013) investigate the importance of labour mobility across technologically related industries for regional growth, where technological relatedness is based on the skill relatedness measure developed by NEFFKE and HENNING (2013). BOSCHMA *et al.* (2013) find a positive effect on productivity growth from intra-regional labour flows between industries with a revealed relatedness in terms of skills. This strengthens our argument that relatedness in terms of individuals is an important complement to relatedness based on industry belonging. That two industries are skill-related in a local labour market, as revealed by a high intensity of inter-industry labour flows, could indeed be because firms in different industries require functionally similar tasks or tasks requiring related educational specialisations. Relatedness based on cross industry labour flows may hence reflect that employees change jobs based on their knowledge and skills, i.e. their occupational experience and education. In relation to these papers, the contribution of the present paper is different in that it studies relatedness in terms of the educational and occupational profile of regions, and tests their role in explaining regional growth, alongside industry relatedness.

Related empirical research

There are numerous empirical studies on the effects of agglomeration economies on growth. Most of them use a broad measure of industry diversity over the economy or region as a whole, that is, Jacobs externalities are measured as unrelated, rather than related, variety (cf. GLAESER *et al.* (1992), HENDERSON *et al.* (1995), DURANTON and PUGA (2000)). However, some studies acknowledge the complexity of diversity, particularly FRENKEN *et al.* (2007), who analyse the effects of unrelated and related industry variety on growth in employment, unemployment and productivity in Dutch regions. The results of the study show that, as expected, related variety

enhances employment growth, while unrelated variety is negatively related to unemployment growth. The productivity growth of a region is negatively associated with related variety.

Other studies have followed in the footsteps of FRENKEN *et al.* (2007). BISHOP and GRIPAIO (2010) conduct a similar study of British regions when analysing the effects of unrelated and related variety on employment growth in different industries. The results show that the effects of unrelated and related variety differ across the examined industries, of which nearly 50 per cent benefit from either one of the two forms of variety. Unrelated variety affects employment growth in a larger set of industries than related variety. Regarding regional employment growth in Germany, BRACHERT *et al.* (2011) find no effects from either unrelated or related variety. However, related variety in combination with functional specialisation, in terms of more “white collar” workers, positively influences employment growth. In addition, unrelated variety among “white collar” workers and “blue collar” workers, but not R&D workers, is found to enhance growth. When analysing growth in Spanish provinces, BOSCHMA *et al.* (2012) find that related variety has a positive effect on value added growth, while unrelated variety has no growth effect. The results also show that the positive effect is stronger when using indicators for related variety, not based only on product classifications. BOSCHMA *et al.* (2012) construct one measure based on PORTER’s (2003) cluster classification of industries and one based on export data. HARTOG *et al.* (2012) analyse the effects of related variety on employment growth in Finnish regions. The results show that related variety in general has no effect, but that related variety in high-tech industries positively influences employment growth. No growth effect is found from unrelated variety. A similar study of Italian regions is conducted by MAMELI *et al.* (2012), who, in addition, distinguish between manufacturing and service industries. They find that employment growth in general is positively associated with both related and unrelated variety. Regarding manufacturing, only unrelated variety is significant, while for service industries, only related variety is significant.

The concept of related and unrelated variety has been quite commonly applied in relation to international trade. SAVIOTTI and FRENKEN (2008) analyse the relationship between export variety and economic development in 20 OECD countries. An increase in the growth in related export variety is found to promote growth in GDP per capita, while an increase in the growth in unrelated export variety has a negative effect. However, past growth in unrelated export variety positively influences economic growth. Also, BOSCHMA and IAMMARINO (2009) consider export variety when analysing the effects on regional economic growth in Italy. Related, but not unrelated, export variety is found to significantly enhance value-added growth. In addition, as mentioned above, one of BOSCHMA *et al.*'s (2012) alternative measures of related variety is based on export data.

DATA AND VARIABLES

The regions referred to in the empirical part of the paper are the 290 municipalities in Sweden. In Sweden, these are the smallest geographical units used for administrative and self-governing purposes. All variables described below are measured at the municipal level.

Dependent variables

Two different dependent variables are employed: (i) employment growth and (ii) productivity growth. FRENKEN *et al.* (2007) find that related variety has a negative influence on productivity growth, but a positive influence on employment growth. They maintain that this is consistent with the idea that employment growth better reflects radical innovation, as such innovations are assumed to lead to the creation of new markets and employment. Productivity growth is instead associated with process innovations and growing capital intensity in the later stages of the product life cycle (cf. VAN OORT (2013)). The drivers for various types of innovation may differ, with the consequence that employment growth and productivity growth may be affected

differently by the same parameter. That related variety spurs employment growth and not productivity growth is thus, in many papers, taken as evidence that knowledge spillovers and innovation have more to do with employment growth. While this argument is conceptually appealing, it can also be argued that productivity is, after all, the main determinant for long-run growth (EASTERLY and LEVINE, 2002). A vast body of literature also documents the fundamental role played by innovation and new technology in stimulating productivity (HALL and MAIRESSE, 2006; LÖÖF and HESHMATI, 2002).³ Hence, there are also arguments that the productivity growth of a region is related to innovation. A defining characteristic of urban regions, which typically are more diversified, is indeed also higher productivity levels, not least in Sweden (cf. ANDERSSON and LÖÖF (2011)).

In the base-line models, productivity growth is measured as the ratio between the average labour productivity in 2007 and 2002, while employment growth is measured as the ratio between the total numbers of employed for the same set of years. However, a region may exhibit a higher growth rate because it has a relatively large share of one or more fast growing industries. As a robustness test, a shift-share procedure for both productivity growth and employment growth is applied. This implies that the growth in each 2-digit industry is weighted by the industry's national share of production, in the case of productivity growth, and by the industry's share of employment, in the case of employment growth. This imposes the same industrial structure in all regions and produces industry-adjusted growth rates.⁴ In addition, the robustness of the results are tested by measuring productivity growth and employment growth for a longer time period, namely 2002 to 2011⁵. This also relates to the findings by SAVIOTTI and FRENKEN (2008) that the growth effect of related variety is instant, while unrelated variety requires more time. Further robustness tests, including spatial modelling and panel data estimations, are presented in the next section.

Productivity growth and employment growth are constructed for the whole private sector of the regional economy, as well as for the manufacturing sector and the service sector separately. The development in the public sector is more difficult to relate to spatial characteristics, because it is largely dependent on political decisions. Also, agriculture, fishery and mining are excluded, because these industries are more or less spatially bounded by immobile resources. This leaves the industries in standard industrial classification (SIC) codes 15 to 74, of which 15 to 45 belong to the manufacturing sector (including construction), while 50 to 74 are service industries.

Independent variables

All independent variables are measured for the year 2002, unless otherwise specified. The six independent variables of main interest are related variety in industries, education and occupation, and unrelated variety in industries, education and occupation. The entropy (or the Shannon index) approach is commonly applied in measuring variety (cf. JACQUEMIN and BERRY (1979), and ATTARAN (1986)). This is also the method used by FRENKEN *et al.* (2007) to measure unrelated and related variety. The entropy measure has desirable properties, in that it takes the relative abundance of groups into account, and not only the absolute presence of them. The entropy for unrelated variety measures between diversity, while the entropy for related variety measures within diversity, in e.g. industries. This is possible due to the decomposable nature of the entropy measure. All entropies are calculated using employment in each group. The data is limited to employed individuals between 20 and 64 years of age with a positive income.

For industries, the 2-digit and the 5-digit SIC codes are used where each 5-digit industry belongs to a specific 2-digit industry⁶. Following ATTARAN (1986), let S_g denote the 2-digit sets where $g = 1, \dots, G$. E_g denotes the share of employees working in the 2-digit industry

g , where E_g is measured as the share of total regional employment. Furthermore, let E_{ig} denote the share of employees working in the 5-digit industry i , where $i = 1, \dots, I$, where E_{ig} is measured as the share of employment in the respective 2-digit industry g .

Unrelated variety in industries measures the distribution of employees between 2-digit industries. Using the entropy approach, unrelated variety (UV) is calculated as follows:

$$UV = - \sum_{g=1}^G E_g \ln E_g. \quad (1)$$

The range of UV is from 0 to $\ln G$ where zero variety is reached when all employees work in the same 2-digit industry, that is, when one $E_g = 1$ while the rest are zero. Maximum variety, i.e. $\ln G$, is reached when there is an equal distribution of employees over all 2-digit industries, that is, all E_g are identical. (ATTARAN, 1986)

In the same manner, the distribution of employees between 5-digit industries within each 2-digit industry is calculated as follows:

$$H_g = - \sum_{i=1}^I E_{ig} \ln E_{ig}. \quad (2)$$

The interpretation of Equation 2 is the same as for Equation 1, with the difference that variety is measured within each 2-digit industry, rather than between the 2-digit industries. Hence, there is zero within variety when all employees in 2-digit industry g work in the same 5-digit industry i , where $i \in S_g$. Accordingly, maximum variety for industry g , $\ln I$, is achieved when there is an equal distribution of employees over all 5-digit industries i , where $i \in S_g$.

The information about the degree of within variety for each 2-digit industry g , i.e. H_g , is weighted by the relative size of industry g . Summing over all g gives the entropy measure

for related variety in industries (RV), regarding the region as a whole. These two steps are formally shown by Equation 3.

$$RV = \sum_{g=1}^G E_g H_g \quad (3)$$

Increases in the values obtained by Equations 1 and 3 imply increases in unrelated and related variety, respectively.

Unrelated and related variety for the educational and the occupational dimensions are calculated as above, with the difference that the educational and the occupational codes are used, instead of the SIC codes. When constructing the measures for educational variety, a combination of education length and specialisation is used. Employees are first categorised as either having three or more years of higher education or not. After this categorisation, education specialisation is used at the 2- and 4-digit levels. This implies that employees belonging to the same 2-digit educational code *and* having three or more years of higher education are seen as related. Education focus is divided in 26 different 2-digit levels, the maximum possible G for the educational dimension is hence 52. Table A1 provides an overview of the educational groups at the 2-digit level. The number of employees, as well as the number of subgroups (4-digit codes), differ among these groups. Social and behavioural science has 14 subgroups, of which economics and political science are two. As another example, subgroups of engineering (construction) are e.g. architecture, plumbing and structural engineering.

Regarding the occupational dimension, occupational codes at the 1- and 3-digit levels are used, instead of the educational codes. Occupations are divided in 12 different 1-digit levels, which implies that the maximum possible G for the occupational dimension is 12. Table A2 provides an overview of the occupational groups, where other professionals and associate professionals are e.g. lawyers, economists and other occupations related to the social sciences.

Figures A1-3 in Appendix 2 provide maps of Sweden, showing the distribution of related and unrelated variety over municipalities in 2002. These can also be compared to Figure A4, which presents the population density in Sweden.

Besides unrelated and related variety, the presence of general urbanisation economies, measured as population density, Porter externalities or competition measured as firms per employee, and localisation economies or specialisation, are controlled for. There are various approaches to measure specialisation, both in absolute and relative terms. In the context of localisation economies, absolute specialisation is relevant, because it is the absolute agglomeration of employees belonging to the same industry that has the potential to give rise to knowledge spillovers. Because an increase in unrelated variety in industries implies a decrease in absolute industrial specialisation the entropy for unrelated variety in industries is also used as a proxy for industrial specialisation (as in AIGINGER and DAVIES (2004)). The entropy measure is not as commonly applied to measure specialisation as e.g. the Herfindahl index, but the two are strongly correlated (PALAN, 2010).

In addition, growth in the capital-labour ratio is included as a control variable, and size effects are controlled for by introducing absolute values for 2002. All independent variables, besides population density, are calculated for industry 15-74 as a whole, but also for the manufacturing sector and the service sector separately. Appendix 3 provides tables with descriptive statistics for the variables regarding the private sector as a whole, as well as for the manufacturing sector and the service sector separately. To reduce heteroscedasticity, as well as to facilitate the interpretation of the coefficients to be estimated, all variables are log transformed. Appendix 4 presents correlation matrices over all independent variables for the total private sector, the manufacturing sector and the service sector. Regarding the private sector as a whole, unrelated variety in occupation is especially strongly correlated with industrial related variety. To avoid problems with multicollinearity, unrelated variety in occupation is

excluded when estimating models for the private sector. In addition, the initial employment level is excluded throughout due to problems with multicollinearity. With these exceptions, correlation between explanatory variables is not an issue, which is confirmed by post diagnostic tests for multicollinearity.

MODEL AND EMPIRICAL ESTIMATIONS

The model used as a point of departure for the empirical estimations is given by equation 4:

$$Growth_r = \alpha + RV_r\beta_1 + UV_r\beta_2 + Control_r \beta_3 + \varepsilon_r \quad (4)$$

in which $Growth_r$ refers to growth in either productivity or employment in municipality r . RV_r is a row vector of related variety in industries, education and occupation, respectively, and UV_r is the corresponding vector for unrelated variety. $Control_r$ contains the set of control variables, which depends on the $Growth$ variable in question, and ε_r is the usual error term. The parameters are estimated by ordinary least squares (OLS), with robust standard errors in case heteroscedasticity is detected.

Table 1 presents the results for the private sector as a whole, concerning both time periods (2002-2007 and 2002-2011), as well as adjusted growth models for 2002-2007.

Table 1. Estimated coefficients for productivity growth and employment growth in the private sector.

Variables	1a Productivity 2002-2007	1b Productivity Adjusted 2002-2007	1c Productivity 2002-2011	2a Employment 2002-2007	2b Employment Adjusted 2002-2007	2c Employment 2002-2011
RV Industry	-.139*** (.050)	.012 (.073)	-.081* (.042)	.085*** (.027)	.172*** (.046)	.159*** (.035)
UV Industry	-.035 (.115)	.300* (.179)	-.099 (.093)	-.029 (.072)	.098 (.134)	-.048 (.095)
RV Education	.271*** (.085)	.324*** (.114)	.214** (.088)	-.026 (.055)	-.102 (.115)	-.006 (.074)
UV Education	.354** (.153)	.277 (.235)	.308*** (.119)	.086 (.083)	-.092 (.190)	.271** (.111)
RV Occupation	.147 (.172)	.186 (.206)	.266** (.117)	-.084 (.069)	.012 (.135)	-.170* (.092)
UV Occupation	-	-	-	-	-	-
Competition	-.019 (.027)	-.079* (.046)	.029 (.025)	.056*** (.017)	-.095** (.038)	.111*** (.022)
Population density	.000 (.007)	.027*** (.009)	.014*** (.005)	-.003 (.003)	.022*** (.007)	-.002 (.005)
Capital-labor growth	.152*** (.032)	.048 (.042)	.112*** (.023)	-.017 (.015)	-.072** (.032)	-.010 (.018)
Productivity 2002	-.223*** (.058)	-.141* (.084)	-.407*** (.065)			
Constant	1.20*** (.395)	.043 (.551)	2.52*** (.414)	.162* (.094)	-.273 (.201)	.127 (.124)
F-value	10.64***	12.92***	15.35***	8.67***	10.63***	21.17***
R ²	.274	.176	.408	.198	.237	.376
Moran's I p-value	.270	.363	.240	.345	.052	.008
Observations	290	290	290	290	290	290

Notes: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in brackets, robust standard errors in Model 1a, 1b, 1c and 2b. Due to multicollinearity, UV Occupation is excluded.

The results show that the relationships between the different dimensions of related and unrelated variety and growth differ considerably, which provides evidence of the importance of distinguishing between various forms of variety. This suggests that it is necessary to carefully specify the dimension(s) of relatedness to which one is referring when discussing the role of relatedness in regional growth and development. As in FRENKEN *et al.* (2007), related variety in industries is found to be positively associated with employment growth, for both time periods, as well as for adjusted growth, while it is negative for unadjusted productivity growth, albeit weakly so for the longer time period. The results for related variety in education are consistent when it comes to growth in productivity. An increase in related variety in education is associated with higher productivity growth.⁷ This effect is also detected for both time periods for unrelated variety in education. A comparison between Model 1a and 1c shows that, for 2002-2007, related variety in education is stronger in significance than unrelated variety in education, while the opposite is true for 2002-2011. In addition, unrelated variety in education is positively related to employment growth over the longer time period. These findings support those of SAVIOTTI and FRENKEN (2008), that the effect of unrelated variety is better detected over longer time periods.

Hence, the results for related variety in industries for the Swedish economy are in line with FRENKEN *et al.*'s (2007) findings for the Netherlands. The higher employment growth in regions with greater related variety in industries is consistent with the argument that related variety in industries spurs knowledge spillovers, which, in turn, influence employment growth. The finding that adjusted productivity growth is positively associated with related, but not unrelated, variety in education may be interpreted as a reflection that there may need to be complementarity in educational background among employees for knowledge spillovers to be productive. For instance, a mechanical engineer may learn more from a materials engineer than a sales representative, regardless of their industry. One reason for this could be that they share

a common knowledge base due to similar educational backgrounds. A common knowledge base could also be a result of having similar occupations. However, a positive association between related variety in occupation and productivity growth is found only over the longer time period, 2002-2011, while the association with employment growth over the same time period is negative (albeit only weakly significant). This may be interpreted as if externalities from occupation based interactions are weaker, which may be because the occupational groups are more broadly defined (compare Tables A1 and A2), and hence, that relatedness is not as strong as for education.

Tables 2 and 3 present the corresponding results for the manufacturing sector and the service sector, respectively.

Table 2. Estimated coefficients for productivity growth and employment growth in the manufacturing sector.

Variables	3a Productivity 2002-2007	3b Productivity Adjusted 2002-2007	3c Productivity 2002-2011	4a Employment 2002-2007	4b Employment Adjusted 2002-2007	4c Employment 2002-2011
RV Industry	-.093** (.037)	.213*** (.060)	-.042 (.040)	.062* (.037)	-.026 (.093)	.068* (.041)
UV Industry	.019 (.066)	.415*** (.108)	-.106* (.063)	-.007 (.067)	.212 (.168)	-.202*** (.073)
RV Education	.431*** (.083)	.531*** (.134)	.338*** (.080)	.163** (.082)	.152 (.205)	.289*** (.089)
UV Education	.238 (.145)	.175 (.236)	.205 (.160)	-.106 (.148)	-.457 (.370)	-.112 (.161)
RV Occupation	.087 (.089)	-.159 (.144)	.102 (.102)	-.060 (.091)	.123 (.226)	.088 (.098)
UV Occupation	-.147 (.143)	-.104 (.233)	.496*** (.143)	.036 (.146)	.628* (.364)	-.075 (.159)
Competition	.026 (.022)	-.126*** (.035)	.011 (.023)	.079*** (.022)	-.023 (.054)	.153*** (.023)
Population density	-.005 (.007)	.038*** (.011)	-.011 (.007)	-.016** (.007)	.047*** (.017)	.000 (.007)
Capital labour growth	.160*** (.022)	-.009 (.036)	.160*** (.024)	-.015 (.022)	-.057 (.056)	-.028 (.019)
Productivity 2002	-.220*** (.042)	-.083 (.068)	-.422*** (.066)			
Constant	1.43*** (.263)	-.335 (.426)	2.55*** (.404)	.317*** (.106)	-.364 (.265)	.463*** (.115)
F-value	12.35***	15.37***	22.73***	5.81***	3.91***	12.38***
R ²	.307	.355	.515	.158	.112	.285
Moran's I p-value	.127	.000	.430	.449	.144	.021
Observations	290	290	290	290	290	290

Notes: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in brackets, robust standard errors in Model 3c.

Table 3. Estimated coefficients for productivity growth and employment growth in the service sector.

Variables	5a Productivity 2002-2007	5b Productivity Adjusted 2002-2007	5c Productivity 2002-2011	6a Employment 2002-2007	6b Employment Adjusted 2002-2007	6c Employment 2002-2011
RV Industry	-.140*** (.050)	-.155 (.105)	-.104*** (.038)	.240*** (.058)	.211 (.139)	.413*** (.048)
UV Industry	-.294* (.160)	.029 (.319)	-.140 (.115)	-.037 (.181)	-.219 (.454)	.087 (.145)
RV Education	.080 (.090)	.201 (.217)	-.065 (.079)	.036 (.152)	.175 (.237)	-.444*** (.098)
UV Education	.254 (.214)	.263 (.332)	.129 (.136)	.115 (.216)	.009 (.407)	.664*** (.151)
RV Occupation	.294*** (.084)	.414** (.203)	.275*** (.085)	-.159 (.118)	-.202 (.192)	-.276*** (.092)
UV Occupation	-.194 (.269)	-.466 (.562)	-.308 (.244)	-.292 (.343)	.297 (.605)	-.270 (.255)
Competition	-.030 (.029)	.051 (.079)	.034 (.032)	.013 (.043)	-.099 (.077)	.035 (.035)
Population density	.013** (.006)	.022* (.013)	.032*** (.005)	-.001 (.007)	.018 (.016)	-.004 (.006)
Capital labour growth	.065** (.030)	.095** (.042)	.073*** (.020)	-.009 (.020)	-.076 (.050)	-.023 (.018)
Productivity 2002	-.482*** (.096)	-.278* (.162)	-.497*** (.072)			
Constant	3.20*** (.576)	1.92* (1.05)	3.49*** (.479)	.148 (.261)	-.218 (.354)	-.327 (.215)
F-value	9.47***	2.33**	17.60***	2.86***	2.19**	12.63***
R ²	.233	.077	.368	.111	.078	.289
Moran's I p-value	.004	.248	.001	.018	.274	.000
Observations	290	290	290	290	290	290

Notes: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in brackets, robust standard errors in Model 5a, 5c, 6a and 6b.

The results for the manufacturing sector and the service sector in Tables 2 and 3 show both similarities and differences from the private sector as a whole, which points to the importance of distinguishing between different parts of the economy. The positive association between related variety in industries and employment growth is found for both time periods in both sectors. However, the size and the significance of the effect are stronger in the service sector, which suggests a relatively greater effect of related industrial variety on service industries. This is consistent with MAMELI *et al.* (2012), who find an effect of related variety in industries for the service sector only. The difference between sectors also holds for the negative association between related variety in industries and productivity growth, which is more evident in the service sector. In addition, unrelated variety in industries is found to be negatively associated with growth in manufacturing over the longer time period. Because unrelated variety in industries measures inverse industrial specialisation, this implies that localisation economies are found for the manufacturing sector, although these effects seem to materialise after a relatively long time. However, the conclusions for manufacturing regarding variety in industries are rather tentative, because when using industry-adjusted growth rates, the association with both related and unrelated industrial variety is positive and highly significant.

As shown in Table 2, the positive productivity effect from related variety in education is robust for the manufacturing sector. In addition, this variable is positively associated with employment growth in manufacturing for both time periods. Hence, related variety in education seems to be an important factor in general and for the manufacturing sector in particular. The results for related variety in occupation show no clear association with growth in the manufacturing sector, which was also the case for the private sector as a whole. However, Table 3 shows that related variety in occupation has a significant positive association with productivity growth in the service sector, regarding both time periods as well as adjusted growth. This may be interpreted as if cognitive proximity among employees is important for

productivity growth in both sectors. For manufacturing, relatedness in terms of educational background still matters, while, for services, it is relatedness in current occupation.

Additional results for the service sector indicate that related variety in both education and occupation are negatively associated with employment growth over the longer time period. In general, the results for related variety imply that productivity and employment benefit from different sources of relatedness. More specifically, employment growth is positively related to the more conventional measure of related variety, which is based on industry codes. This points in the same direction as FRENKEN *et al.* (2007), HARTOG *et al.* (2012) and MAMELI *et al.* (2012), who all find similar results, albeit using somewhat different approaches. Productivity growth, on the other hand, is positively associated with related variety in education and occupation, which in the present paper is claimed to be more likely to reflect the knowledge base of the employees, e.g. due to functional specialisation (DURANTON and PUGA, 2005). Because most previous studies measure growth in terms of employment and do not construct measures based on education and occupation, the possibility for comparisons is still limited.

Regarding the control variables, the results show a positive association between higher levels of competition and employment growth in both time periods. This holds for the private sector as a whole, as well as for manufacturing. However, the effect is negative for adjusted growth in the private sector and adjusted productivity growth in the manufacturing sector. Population density shows mostly positive effects, especially for productivity growth in service firms. How much of this effect that is actually due to density is questionable, because this could be driven by selection stemming from more productive firms and individuals being more prone to locate in more urbanised regions (BALDWIN and OKUBO, 2006; COMBES *et al.*, 2008). As expected, growth in the capital-labour ratio is positively associated with growth in

productivity, while initial productivity levels are negatively associated with productivity growth.

Further robustness tests

Because municipalities may influence each other, there is a potential issue of spatial dependence. This is tested for by Moran's I on the residuals from the OLS regressions in Tables 1-3. In the presence of spatial autocorrelation, the coefficients from the OLS regressions are inefficient, and a typical remedy is to estimate the models with a spatial error component and/or spatial lag by maximum likelihood (ML). Spatial models are thus estimated as a robustness check. More information about these models, as well as the results from the estimations are presented in Appendix 5. From comparing the results in Table A9 with the results presented in the present section, the conclusion is that the results are robust, and that, even when there is spatial autocorrelation, as indicated by Moran's I, it does not have any major impact on the results. One minor difference is that population density loses significance when modelling spatial dependence.

When applying cross-sectional data, there is always an issue of unobservable factors influencing both the independent and the dependent (growth) variables. This is dealt with by running estimations with regional fixed effects using a panel data set for 2002-2011, where growth is measured on a two-year basis. Because regional variables have a tendency to change slowly over time, also pooled OLS estimations are applied on the panel data. Tables A10 and A11 present the results from the panel estimations.

Regarding the pooled OLS estimations the results are consistent with, or even strengthens, the conclusions from Tables 1-3. However, the OLS estimations account only for the cross-sectional variation. When instead looking at the variation over time within regions, which is what the within-transformation in the fixed effects model achieves, the association

between employment growth and related variety in industries turns negative. This implies that regions with increasing related variety in industries see a decrease in their employment growth over time, which may indicate that there is something else in the regions that drives both related variety in industries and employment growth. In addition, unrelated variety in industries is found to be negatively associated with regional growth in both productivity and employment, which indicates that no positive effects from increasing the industrial variety of a region are detected. This strengthens the argument that it may, in many cases, be important to look beyond the industrial dimension. Regarding related variety in education, the positive association with productivity is reinforced in the fixed effects estimations. In addition, a negative association with employment growth is found, which again indicates that the drivers for employment growth and productivity growth differ. The positive relationship between related variety in occupation, which is detected above, especially for the service sector, is not found when accounting for within variation. One reason for the differences in the results may be that growth is measured for only two years (to get a reasonably long panel). Another potential explanation is the relatively low within variation in the variety variables, as shown by Table A12, which indicates that regional fixed effects may not be the most suitable approach.

CONCLUSIONS

In this paper the role that different dimensions of relatedness play in regional growth is tested. The focus, in this regard, is on occupational, educational and industrial variety. While most analyses of regional variety put firms and industries on centre stage, in this paper it is argued that there are strong reasons to also consider individuals and their occupations and education profiles. A main reason for this is that spillover phenomena involving knowledge and information primarily pertain to individuals. Based on this reasoning, relatedness between individuals in terms of education and occupation may be at least as important as industries in

stimulating knowledge spillovers and regional growth. To test the empirical relevance of these arguments, measures of educational and occupational variety (related and unrelated) is added to the basic empirical model of FRENKEN *et al.* (2007) and the importance of each dimension of relatedness is estimated.

As in previous studies, related variety in industries is found to be positively associated with growth in employment, and negatively associated with growth in productivity. These results are consistent for the private sector as a whole, as well as for manufacturing and service industries separately, albeit stronger for the service sector than for the manufacturing sector. However, the main contribution is that the paper shows a strong positive relationship between related variety in education and productivity growth, in the private sector in general and the manufacturing sector in particular, while related variety in occupation is positively related to productivity growth in the service sector. These results broadly support that relatedness, in terms of education and occupation of employees, is conducive to knowledge spillovers that stimulate the productivity growth of a region. The potential of productive interactions between employees in a region is hence greater when there is related variety in their knowledge base. This follows from the same line of thinking as DESROCHERS and LEPPÄLÄ (2011), who emphasise the role of individual occupation, skills and background in knowledge spillovers.

The result that educational and occupational relatedness matter over and above industry relatedness for productivity growth supports the conceptual discussion put forth in the paper. These findings also bear on policy, in the sense that they illustrate the multi-dimensional nature of the notion of relatedness. The recent policy concept of smart specialisation suggests, for instance, that regions should focus on locally strong areas and develop into areas that are related to them. The way in which relatedness is conceptualised clearly plays a crucial role in such efforts. Relatedness in industries and relatedness in employee education and skills may

not necessarily go hand-in-hand, especially because many regions are functionally specialised, such that the functions within a given industry differ widely across regions (c.f. DURANTON and PUGA (2005)). That relatedness goes beyond the industrial dimension is hence important to consider for policy makers at regional, national and EU level. In addition, the results indicate that the type of related variety to promote in a region may depend on the desired outcome, e.g. productivity growth versus employment growth.

While the results in this paper are consistent with the idea that knowledge spillovers work better in contexts in which related variety is high, it should be stated that the analysis does not inform us about the mechanisms behind this. For example, it is not known whether the estimated relationships reflect pure knowledge spillovers, better local matching efficiency, or embodied knowledge flows mediated by local inter-firm labour mobility. Related variety in industries, education or occupation could stimulate any of these mechanisms. Further work may focus on untangling the mechanism behind the empirical regularity of a strong association between related variety and growth.

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NOTES

1. For example, FRENKEN *et al.* (2007, p.696) conclude: “*Regional policies based on supporting related variety reduce the risk of selecting wrong activities because one takes existing regional competences as building blocks to broaden the economic base of the region.*” Picking the ‘right’ activity obviously necessitates knowledge and understanding of what constitutes relatedness.
2. Because this characterisation of relatedness is derived from actual flows of labour it is sensitive to changes in labour flows between years and differences in labour flows between regions. In addition, if employees in certain occupations are more likely to switch jobs than employees in other occupations, there is a risk that relatedness between industries is not properly captured by labour flows. When instead focusing on the educational background and current occupation of employees, regardless of the industry boundaries, the definition of relatedness is time-invariant and insensitive to changes in the market.
3. In fact, it has also been argued that productivity growth may be used as an innovation indicator (HALL, 2011).
4. See Appendix 1 in VAN STEL and STOREY (2004) for an illustration of the shift-share procedure.
5. 2011 is the last year available in the data set. Due to changes in the standard industrial classifications, it is not possible to construct industry-adjusted growth rates for the longer time period.

6. An example: Industries 15111 and 15120 are sub-industries of industry 15.
7. The same patterns are found when conducting the analysis at the level of functional regions. However, due to few observations at this level, as well as recent research showing that agglomeration economies, in particular concerning knowledge spillovers, attenuate sharply with distance (cf. BALDWIN *et al.* (2008) and ANDERSSON *et al.* (2014b)), municipalities are chosen as the level of analysis.

REFERENCES

- AIGINGER K. and DAVIES S. W. (2004) Industrial specialization and geographic concentration: Two sides of the same coin? Not for the European Union, *Journal of Applied Economics* **7(2)**, 231-248.
- ALMEIDA P. and KOGUT B. (1999) Localization of knowledge and the mobility of engineers in regional networks, *Management Science* **45(7)**, 905-917.
- ANDERSSON M., KLAESSON J. and LARSSON J. P. (2014a) The sources of the urban wage premium by worker skills: Spatial sorting or agglomeration economies?, *Papers in Regional Science* **93(4)**, 727-747.
- ANDERSSON M., KLAESSON J. and LARSSON J. P. (2014b) How local are spatial density externalities? Neighborhood effects in agglomeration economies, *Regional Studies*, forthcoming.
- ANDERSSON M. and LÖÖF H. (2011) Agglomeration and productivity: Evidence from firm-level data, *The Annals of Regional Science* **46(3)**, 601-620.
- ANSELIN L. (2003) Spatial econometrics, in BALTAGI B. H. (Ed), *A companion to theoretical econometrics*, pp. 310-330. Wiley-Blackwell, Oxford.
- ATTARAN M. (1986) Industrial diversity and economic performance in U.S. areas, *The Annals of Regional Science* **20(2)**, 44-54.
- AUTOR D. H., LEVY F. and MURNANE R. J. (2003) The skill content of recent technological change: An empirical exploration, *The Quarterly Journal of Economics* **118(4)**, 1279-1333.
- BACOLOD M., BLUM B. S. and STRANGE W. C. (2009) Skills in the city, *Journal of Urban Economics* **65(2)**, 136-153.

- BALDWIN R. E. and OKUBO, T. (2006) Heterogeneous firms, agglomeration and economic geography: Spatial selection and sorting, *Journal of Economic Geography* **6(3)**, 323-346.
- BISHOP P. and GRIPAIO P. (2010) Spatial externalities, relatedness and sector employment growth in Great Britain, *Regional Studies* **44(4)**, 443-454.
- BOSCHMA R. (2005) Proximity and innovation: A critical assessment, *Regional Studies* **39(1)**, 61-74.
- BOSCHMA R., ERIKSSON R. and LINDGREN U. (2014). Labour market externalities and regional growth in Sweden: The importance of labour mobility between skill-related industries, *Regional Studies* **48(10)**, 1669-1690.
- BOSCHMA R. and IAMMARINO S. (2009) Related variety, trade linkages, and regional growth in Italy, *Economic Geography* **85(3)**, 289-311.
- BOSCHMA R. and MARTIN R. (2010) The aims and scope of evolutionary economic geography, in BOSCHMA R. and MARTIN R. (Eds) *The handbook of evolutionary economic geography*. Edward Elgar, Cheltenham.
- BOSCHMA R., MINONDO A. and NAVARRO M. (2012) Related variety and regional growth in Spain, *Papers in Regional Science* **91(2)**, 241-256.
- BRACHERT M., KUBIS A. and TITZE M. (2011). Related variety, unrelated variety and regional functions: Identifying sources of regional employment growth in Germany from 2003 to 2008, *IWH-Diskussionspapiere No. 2011(15)*.
- COHEN W. M. and LEVINTHAL D. A. (1990) Absorptive capacity: A new perspective on learning and innovation, *Administrative Science Quarterly* **35(1)**, 128-152.
- COMBES P.-P., DURANTON, G. and GOBILLON L. (2008) Spatial wage disparities: Sorting matters!, *Journal of Urban Economics* **63(2)**, 723-742.

- DESROCHERS P. and LEPPÄLÄ S. (2011) Opening up the 'Jacobs spillovers' black box: Local diversity, creativity and the processes underlying new combinations, *Journal of Economic Geography* **11(5)**, 843-863.
- DURANTON G. and PUGA D. (2000) Diversity and specialisation in cities: Why, where and when does it matter?, *Urban Studies* **37(3)**, 533-555.
- DURANTON G. and PUGA D. (2004) Micro-foundations of urban agglomeration economies, in HENDERSON J. V. and JACQUES-FRANÇOIS T. (Eds) *Handbook of regional and urban economics*, Vol. 4, pp. 2063-2117. Elsevier, Amsterdam.
- DURANTON G. and PUGA D. (2005) From sectoral to functional urban specialisation, *Journal of Urban Economics* **57(2)**, 343-370.
- EASTERLY W. and LEVINE R. (2002) It's not factor accumulation: Stylized facts and growth models, in LOAYZA N. and SOTO R. (Eds) *Economic growth: Sources, trends and cycles*, 1 ed., Vol. 6, pp. 61-114. Central Bank of Chile.
- EJERMO O. (2005) Technological diversity and jacobs' externality hypothesis revisited, *Growth and Change* **36(2)**, 167-195.
- FRENKEN K., OORT F. G. V., VERBURG T. and BOSCHMA R. A. (2005). *Variety and regional economic growth in the Netherlands*: Ministry of Economic Affairs, The Netherlands.
- FRENKEN K., VAN OORT F. and VERBURG T. (2007) Related variety, unrelated variety and regional economic growth, *Regional Studies* **41(5)**, 685-697.
- GLAESER E. L., KALLAL H. D., SCHEINKMAN J. A. and SHLEIFER A. (1992) Growth in cities, *Journal of Political Economy* **100(6)**, 1126-1152.
- GLAESER E. L. and SCHEINKMAN J. A. (2003) Non-market interactions, in DEWATRIPONT M., HANSEN L. P. and TURNOVSKY S. J. (Eds) *Advances in economics and econometrics: Theory and applications*, Vol. 3, pp. 339-370. Cambridge University Press, Cambridge.

- HALL B. H. (2011). Using productivity growth as an innovation indicator, *Report for the High Level on Measuring Innovation, DG Research, European Commission*.
- HALL B. H. and MAIRESSE J. (2006) Empirical studies of innovation in the knowledge-driven economy, *Economics of Innovation and New Technology* **15(4-5)**, 289-299.
- HARTOG M., BOSCHMA R. and SOTARAUTA M. (2012) The impact of related variety on regional employment growth in Finland 1993–2006: High-tech versus medium/low-tech, *Industry and Innovation* **19(6)**, 459-476.
- HENDERSON V., KUNCORO A. and TURNER M. (1995) Industrial development in cities, *Journal of Political Economy* **103(5)**, 1067-1090.
- JACQUEMIN A. P. and BERRY C. H. (1979) Entropy measure of diversification and corporate growth, *The Journal of Industrial Economics* **27(4)**, 359-369.
- LUCAS JR. R. E. (1988) On the mechanics of economic development, *Journal of Monetary Economics* **22(1)**, 3-42.
- LÖÖF H. and HESHMATI A. (2002) Knowledge capital and performance heterogeneity: A firm-level innovation study, *International Journal of Production Economics* **76(1)**, 61-85.
- MAMELI F., IAMMARINO S. and BOSCHMA R. (2012) Regional variety and employment growth in Italian labour market areas: Services versus manufacturing industries, *Papers in Evolutionary Economic Geography*: Utrecht University.
- MASKELL P. and MALMBERG A. (1999) Localised learning and industrial competitiveness, *Cambridge Journal of Economics* **23(2)**, 167-185.
- MCCANN P. and ORTEGA-ARGILÉS R. (2013) Smart specialization, regional growth and applications to European Union cohesion policy, *Regional Studies*, 1-12.
- NEFFKE F. and HENNING M. (2013) Skill relatedness and firm diversification, *Strategic Management Journal* **34(3)**, 297-316.

- NOTEBOOM B. (2000) *Learning and innovation in organizations and economies*. Oxford University Press, Oxford.
- PALAN N. (2010). Measurement of specialization - the choice of indices, *FIW Working Paper No 62*.
- PORTER M. (2003) The economic performance of regions, *Regional Studies* **37(6-7)**, 545-546.
- POWER D. and LUNDMARK M. (2004) Working through knowledge pools: Labour market dynamics, the transference of knowledge and ideas, and industrial clusters, *Urban Studies* **41(5/6)**, 1025-1044.
- RAUCH J. E. (1993) Productivity gains from geographic concentration of human capital: Evidence from the cities, *Journal of Urban Economics* **34(3)**, 380-400.
- SAVIOTTI P. and FRENKEN K. (2008) Export variety and the economic performance of countries, *Journal of Evolutionary Economics* **18(2)**, 201-218.
- VAN OORT F. (2015) Unity in variety? Agglomeration economics beyond the specialization-diversity controversy, in KARLSSON C., ANDERSSON M. and NORMAN T. (Eds) *Handbook of research methods and applications in economic geography*, pp. 259-271. Edward Elgar, Cheltenham.
- VAN STEL A. and STOREY D. (2004) The link between firm births and job creation: Is there a upas tree effect?, *Regional Studies* **38(8)**, 893-909.

APPENDIX 1

Table A1. Educational codes.

Educational code (Sun2000Inr)	Education focus	No of 4-digit codes	No of employees
01a	General education: General	1	472,842
01b	General education: Social science	1	128,566
01c	General education: Natural science	1	36,053
01x	General education: Other	1	22,799
14	Pedagogics and teaching	37	28,102
21	Arts and media	19	37,086
22	The humanities	22	23,983
31	Social and behavioural science	14	34,546
32	Journalism and information	8	7,823
34	Business	15	386,942
38	Law and legal science	3	16,614
42	Biology and environmental science	6	4,421
44	Physics, chemistry and geoscience	5	7,934
46	Mathematics and natural science	4	13,020
48	Computer science	6	35,928
52	Engineering: Technical, mechanical, chemical and electronics	33	613,848
54	Engineering: Manufacturing	26	45,855
58	Engineering: Construction	19	131,365
62	Agriculture	19	32,736
64	Animal healthcare	2	545
72	Healthcare	53	56,520
76	Social work	14	31,189
81	Personal services	14	75,257
84	Transport services	6	45,287
85	Environmental care	5	860
86	Security	14	8,137
<i>Total:</i>			2,298,258

Table A2. Occupational codes.

ISCO/SSYK code	Occupation	No of 3-digit codes	No of employees
0	Militaries	1	1,108
1	Managers, legislators and senior officials	6	161,747
21 & 31	Physical, mathematical and engineering science professionals and associate professionals	9	305,502
22 & 32	Life science and health professionals and associate professionals	7	20,810
23 & 33	Teaching professionals and associate professionals	7	21,563
24 & 34	Other professionals and associate professionals	17	342,487
4	Office and customer services clerks	8	279,692
5	Salespersons, demonstrators, personal and protective services workers	7	248,388
6	Market-oriented skilled agricultural and fishery workers	5	7,192
7	Extraction, building, metal, machinery, handicraft and related trades workers	16	345,793
8	Stationary-plant, machine, mobile-plant and related operators	20	400,299
9	Sales and services elementary occupations, agricultural, mining, transport and related labourers	10	189,147
<i>Total:</i>			2,323,728

APPENDIX 2

Figure A1. Quantile maps of related and unrelated variety, the private sector, 2002 (darker colour implies greater variety).

Figure A2. Quantile maps of related and unrelated variety, the manufacturing sector (darker colour implies greater variety).

Figure A3. Quantile maps of related and unrelated variety, the service sector (darker colour implies greater variety).

Figure A4. Quantile map of the population density in Sweden 2002 (darker colour implies greater population density).

APPENDIX 3

Table A3. Descriptive statistics for the private sector.

	Mean	Std. dev.	Min	Max
Productivity growth 02-07	1.26	.181	.824	2.31
Productivity growth adjusted 02-07	1.14	.411	.519	5.70
Productivity growth 02-11	1.38	.194	.849	2.35
Employment growth 02-07	1.07	.089	.805	1.45
Employment growth adjusted 02-07	1.03	.165	.539	1.82
Employment growth 02-11	1.06	.136	.735	1.67
RV Industry	1.31	.374	.427	2.17
UV Industry	2.67	.243	1.63	3.11
RV Education	1.28	.140	.959	1.64
UV Education	2.32	.191	1.84	3.06
RV Occupation	1.55	.134	.859	1.83
UV Occupation	1.97	.125	1.57	2.29
Competition	.158	.059	.055	.375
Pop. density	125	419	.257	4,040
Capital-labour growth 02-07	1.18	.421	.352	4.47
Capital-labour growth 02-11	1.38	.599	.362	8.17
Productivity 02	521	107	250	1,070
Employment 02	8,480	24,500	301	353,000

Table A4. Descriptive statistics for the manufacturing sector.

	Mean	Std. dev.	Min	Max
Productivity growth 02-07	1.30	.245	.711	2.96
Productivity growth adjusted 02-07	1.01	.387	.432	4.90
Productivity growth 02-11	1.44	.331	.630	3.94
Employment growth 02-07	1.04	.167	.502	1.86
Employment growth adjusted 02-07	1.15	.670	.346	6.42
Employment growth 02-11	.978	.186	.491	1.74
RV Industry	1.08	.330	.137	1.95
UV Industry	1.92	.313	.701	2.57
RV Education	1.28	.172	.893	1.71
UV Education	2.08	.159	1.68	2.71
RV Occupation	1.52	.193	.558	1.86
UV Occupation	1.67	.144	1.17	1.98
Competition	.114	.069	.019	.470
Capital-labour growth 02-07	1.25	.569	.308	4.59
Capital-labour growth 02-11	1.71	4.73	.121	81.3
Productivity 02	545	152	196	1,350
Employment 02	3,500	6,120	105	67,700

Table A5. Descriptive statistics for the service sector.

	Mean	Std. dev.	Min	Max
Productivity growth 02-07	1.22	.214	.861	2.84
Productivity growth adjusted 02-07	1.25	.695	.566	9.97
Productivity growth 02-11	1.35	.184	.876	2.61
Employment growth 02-07	1.09	.139	.532	1.63
Employment growth adjusted 02-07	1.28	2.00	.443	4.08 ^a
Employment growth 02-11	1.17	.156	.562	1.76
RV Industry	1.62	.336	.638	2.38
UV Industry	2.16	.135	1.467	2.47
RV Education	1.17	.149	.765	1.54
UV Education	2.46	.172	1.93	3.17
RV Occupation	1.21	.148	.723	1.54
UV Occupation	2.05	.075	1.58	2.32
Competition	.224	.059	.053	.370
Capital-labour growth 02-07	1.15	.563	.272	6.83
Capital-labour growth 02-11	1.40	.704	.315	7.02
Productivity 02	475	63.4	333	823
Employment 02	4,980	18,900	195	285,000

Notes: ^a The actual maximum is 34.6, an extreme value which is due to a change in the SNI code for one firm. The results in Table 3, estimation 6b are robust to the exclusion of this observation.

APPENDIX 4

Table A6. Correlation matrix for independent variables (in logarithmic form), the private sector.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. RV Industry	1											
2. UV Industry	.634	1										
3. RV Education	.378	.237	1									
4. UV Education	.599	.349	.520	1								
5. RV Occupation	.401	.585	.109	.053	1							
6. UV Occupation	.716	.601	.506	.684	.189	1						
7. Competition	.272	.236	-.268	.168	-.166	.369	1					
8. Pop. density	.375	.066	.355	.466	.028	.283	-.173	1				
9. Capital-labour growth 02-07	-.103	-.096	-.128	-.133	-.056	-.117	.024	-.104	1			
10. Capital-labour growth 02-11	-.119	-.015	-.208	-.131	-.006	-.105	.031	-.159	.605	1		
11. Productivity 02	-.006	-.126	.432	.136	.035	.030	-.439	.388	-.255	-.338	1	
12. Employment 02	.576	.361	.615	.511	.394	.370	-.500	.613	-.115	-.146	.408	1

Table A7. Correlation matrix for independent variables (in logarithmic form), the manufacturing sector.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. RV Industry	1											
2. UV Industry	.430	1										
3. RV Education	.168	.129	1									
4. UV Education	.240	.178	.341	1								
5. RV Occupation	.528	.662	.171	.196	1							
6. UV Occupation	.453	.482	.480	.479	.393	1						
7. Competition	.521	.080	-.215	-.027	.044	.162	1					
8. Pop. density	.156	.033	.359	.519	.108	.343	-.112	1				
9. Capital-labour growth 02-07	-.021	-.071	-.025	-.094	-.072	-.143	-.016	-.068	1			
10. Capital-labour growth 02-11	-.069	-.014	-.051	-.051	-.048	-.116	-.028	-.061	.532	1		
11. Productivity 02	-.135	-.063	.395	.196	.011	.159	-.388	.315	-.190	-.283	1	
12. Employment 02	.179	.318	.530	.449	.376	.339	-.571	.551	-.014	.009	.406	1

Table A8. Correlation matrix for independent variables (in logarithmic form), the service sector.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. RV Industry	1											
2. UV Industry	.426	1										
3. RV Education	.573	.354	1									
4. UV Education	.440	.366	.717	1								
5. RV Occupation	.664	.520	.625	.532	1							
6. UV Occupation	.431	.599	.292	.306	.417	1						
7. Competition	-.275	-.112	-.606	-.416	-.524	.103	1					
8. Pop. Density	.542	.183	.398	.438	.513	.130	-.330	1				
9. Capital-labour growth 02-07	-.115	-.187	-.223	-.118	-.145	-.092	-.108	-.054	1			
10. Capital-labour growth 02-11	-.204	-.259	-.294	-.199	-.242	-.167	-.179	-.172	.575	1		
11. Productivity 02	.407	.169	.489	.400	.475	.116	-.491	.553	-.273	-.388	1	
12. Employment 02	.725	.449	.775	.647	.761	.240	-.743	.608	-.141	-.252	.563	1

APPENDIX 5

In the spatial error model, the error term of equation 5, ε_r , is replaced by u_r where:

$$u_r = \lambda W_r' u + v_r$$

in which W_r is a spatial weight matrix, taking the travel time distances between municipalities into account. λ is the spatial error coefficient, which is equal to zero when there is no spatial correlation in the error terms. The spatial lag model includes a spatially lagged dependent variable as an additional explanatory variable. Hence, $\rho W_r' Growth$ is introduced on the right hand side of Equation 5. ρ is the spatial coefficient, which is zero when there is no spatial dependence, implying that the municipal growth is independent of the growth in neighbouring municipalities. (ANSELIN, 2003) Model selection is based on maximum likelihood values, which implies that, in each case, the model with the largest log likelihood value is presented.

Table A9. Estimated coefficients for the spatial models regarding productivity growth and employment growth.

Variables	2b' Private Employment ML(lag) Adjusted 2002-2007	2c' Private Employment ML(error) 2002-2011	3b' Manufacturing Productivity ML(error) Adjusted 2002-2007	4c' Manufacturing Employment ML(error) 2002-2011	5a' Services Productivity ML(error) 2002-2007	5c' Services Productivity ML(error) 2002-2011	6a' Services Employment ML(error) 2002-2007	6c' Services Employment ML(lag) 2002-2011
RV Industry	.166*** (.047)	.151*** (.035)	.202*** (.058)	.056 (.040)	-.150*** (.050)	-.100** (.041)	.226*** (.051)	.402*** (.046)
UV Industry	.090 (.128)	-.048 (.093)	.406*** (.099)	-.204*** (.072)	-.273* (.153)	-.177 (.126)	-.003 (.155)	.135 (.141)
RV Education	-.035 (.103)	-.001 (.079)	.571*** (.140)	.305*** (.097)	.124 (.110)	-.028 (.090)	.082 (.111)	-.405*** (.095)
UV Education	-.092 (.148)	.289** (.114)	.214 (.232)	-.117 (.163)	.291* (.166)	.175 (.138)	.151 (.168)	.644*** (.146)
RV Occupation	-.005 (.123)	-.162* (.090)	-.163 (.139)	.101 (.096)	.289*** (.098)	.260*** (.080)	-.198** (.100)	-.293*** (.089)
UV Occupation	-	-	-	-.054 (.155)	-.262 (.270)	-.343 (.220)	-.366 (.273)	-.325 (.246)
Competition	-.093*** (.030)	.112*** (.023)	-.142*** (.037)	.156*** (.024)	-.015 (.038)	.047 (.031)	.016 (.037)	.034 (.034)
Population density	.015** (.007)	-.004 (.006)	.026* (.015)	-.002 (.009)	.013* (.007)	.031*** (.006)	-.002 (.007)	-.008 (.005)
Capital labour growth	-.069*** (.027)	-.013 (.018)	-.022 (.036)	-.027 (.018)	.064*** (.020)	.074*** (.016)	-.011 (.019)	-.025 (.017)
Productivity 2002			-.124* (.068)		-.498*** (.077)	-.512*** (.064)		
Constant	-.249 (.167)	.115 (.122)	-.160 (.424)	.464*** (.115)	3.32*** (.503)	3.62*** (.422)	.160 (.226)	-.354* (.207)
Spatial coefficient	.314** (.147)	.343** (.172)	.434*** (.153)	.309* (.181)	.346** (.164)	.437*** (.160)	.353* (.182)	.443*** (.137)
R ²	.244	.369	.344	.284	.245	.378	.108	.302
Observations	289	289	289	289	289	289	289	289

Notes: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in brackets. R² is a pseudo-R² corresponding to the variance ratio. The number of observations is 289 due to the island municipality Gotland having no neighbours.

APPENDIX 6

Table A10. Estimated coefficients for productivity growth and employment growth in the private sector, the manufacturing sector and the service sector, two-year panel, 2002-2011, pooled OLS estimation.

Variables	13 Private Productivity	14 Private Employment	15 Manufacturing Productivity	16 Manufacturing Employment	17 Services Productivity	18 Services Employment
RV Industry	-.050*** (.015)	.051*** (.008)	-.032** (.015)	.025*** (.008)	-.038** (.015)	.079*** (.015)
UV Industry	-.109** (.045)	.018 (.023)	-.020 (.028)	-.049*** (.015)	-.162*** (.042)	.091* (.049)
RV Education	.247*** (.035)	-.042*** (.016)	.292*** (.033)	.013 (.018)	-	-
UV Education	.167*** (.051)	-.016 (.024)	.122** (.058)	-.158*** (.032)	.362*** (.048)	.033 (.031)
RV Occupation	.118** (.057)	-.089*** (.023)	.041 (.049)	.012 (.022)	.108*** (.034)	-.046* (.024)
UV Occupation	-	-	-.001 (.062)	.000 (.036)	-.105 (.081)	-.241*** (.085)
Competition	-.014* (.009)	.022*** (.004)	.001 (.007)	.029*** (.005)	-.021** (.010)	.035*** (.007)
Population density	.008*** (.002)	.000 (.001)	-.001 (.003)	.004*** (.001)	.017*** (.003)	-.001 (.001)
Capital-labour growth	.077*** (.011)	-.030*** (.006)	.110*** (.012)	-.034*** (.006)	.087*** (.008)	-.021*** (.005)
Productivity	-.290*** (.028)		-.247*** (.025)		-.395*** (.050)	
Constant	1.70*** (.178)	.088*** (.028)	1.48*** (.146)	.184*** (.024)	2.29*** (.293)	.135*** (.048)
F-value	24.09***	26.64***	24.43***	20.40***	24.56***	8.18***
R ²	.161	.099	.172	.074	.267	.058
Observations	2,320	2,320	2,320	2,320	2,320	2,320

Notes: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in brackets, robust standard errors in Model 13-15, 17-18. Due to multicollinearity, UV Occupation is excluded in Model 13-14 and RV Education is excluded in Model 17-18.

Table A11. Estimated coefficients for productivity growth and employment growth in the private sector, the manufacturing sector and the service sector, two-year panel, 2002-2011, fixed effects estimation.

Variables	19 Private Productivity	20 Private Employment	21 Manufacturing Productivity	22 Manufacturing Employment	23 Services Productivity	24 Services Employment
RV Industry	.051 (.076)	-.160*** (.043)	-.108* (.061)	-.151*** (.041)	-.002 (.064)	-.129** (.056)
UV Industry	-.423*** (.142)	-.348*** (.088)	-.254*** (.089)	-.221*** (.065)	-.348*** (.135)	-.018 (.086)
RV Education	.483*** (.136)	-.156* (.080)	.410*** (.122)	-.543*** (.102)	-	-
UV Education	.786*** (.177)	-.654*** (.120)	.712*** (.178)	-.792*** (.139)	1.41*** (.129)	-.053 (.060)
RV Occupation	.115 (.127)	-.038 (.073)	.120 (.107)	.017 (.080)	-.006 (.082)	-.063 (.057)
UV Occupation	-	-	-.301*** (.113)	.034 (.101)	.055 (.173)	-.284 (.248)
Competition	.373*** (.059)	.596*** (.030)	.407*** (.048)	.492*** (.035)	.149** (.059)	.515*** (.029)
Population density	.276* (.165)	.018 (.078)	.105 (.224)	.277* (.145)	.519*** (.170)	-.274*** (.103)
Capital-labour growth	.044*** (.010)	-.022*** (.007)	.077*** (.015)	-.026*** (.009)	.059*** (.008)	-.015** (.006)
Productivity	-.928*** (.043)		-.850*** (.047)		-.896*** (.050)	
Constant	5.24*** (.622)	2.08*** (.308)	5.67*** (.902)	1.06** (.511)	3.05*** (.567)	2.07*** (.399)
F-value	93.52***	59.05***	68.76***	45.04***	114.8***	48.54***
R ² (within)	.507	.304	.478	.290	.524	.217
Observations	2,320	2,320	2,320	2,320	2,320	2,320

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in brackets. Due to multicollinearity, UV Occupation is excluded in Model 19-20 and RV Education is excluded in Model 23-24.

APPENDIX 7

Table A12. Descriptive statistics for the panel data, the private sector.

Variable		Mean	Std. Dev.	Min	Max	Observations
Productivity growth	overall	1.07	.136	.393	2.71	N = 2,320
	between		.037	.956	1.27	n = 290
	within		.131	.295	2.62	T = 8
Employment growth	overall	1.03	.062	.713	1.39	N = 2,320
	between		.030	.937	1.13	n = 290
	within		.055	.760	1.26	T = 8
RV Industry	overall	1.35	.353	.409	2.27	N = 2,320
	between		.349	.430	2.18	n = 290
	within		.059	1.11	1.65	T = 8
UV Industry	overall	2.66	.228	1.61	3.11	N = 2,320
	between		.223	1.69	3.06	n = 290
	within		.049	2.37	2.88	T = 8
RV Education	overall	1.36	.146	.959	1.79	N = 2,320
	between		.134	1.05	1.70	n = 290
	within		.059	1.18	1.50	T = 8
UV Education	overall	2.44	.197	1.84	3.18	N = 2,320
	between		.181	1.91	3.13	n = 290
	within		.078	2.25	2.66	T = 8
RV Occupation	overall	1.56	.126	.823	1.85	N = 2,320
	between		.122	.860	1.82	n = 290
	within		.034	1.34	1.78	T = 8
UV Occupation	overall	1.99	.112	1.57	2.29	N = 2,320
	between		.109	1.65	2.26	n = 290
	within		.026	1.80	2.11	T = 8
Competition	overall	.168	.063	.055	.425	N = 2,320
	between		.062	.058	.393	n = 290
	within		.010	.115	.232	T = 8
Population density	overall	129	435	.241	4,410	N = 2,320
	between		435	.249	4,170	n = 290
	within		16.4	-76.0	463	T = 8
Capital-labour growth	overall	1.09	.301	.105	7.63	N = 2,320
	between		.110	.814	1.97	n = 290
	within		.280	-.774	6.76	T = 8
Productivity	overall	593	139	250	1,950	N = 2,320
	between		116	413	1,280	n = 290
	within		76.3	147	1,520	T = 8
Employment	overall	8690	25,100	212	384,000	N = 2,320
	between		25,100	264	358,000	n = 290
	within		1,230	-10,300	34,600	T = 8