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Agglomeration, Innovation and Regional Development

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Agglomeration, Innovation and Regional Development:

Theoretical Perspectives and Meta-Analysis

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ABSTRACT

Innovation and technological change are central to the quest for regional development. In the globally-connected knowledge-driven economy, the relevance of agglomeration forces that rely on proximity continues to increase, paradoxically despite declining real costs of information, communication and transportation. Globally, the proportion of the population living in cities continues to grow and sprawling cities remain the engines of regional economic transformation. The growth of cities results from a complex chain that starts with scale, density and geography, which then combines with industrial structure characterised by its extent of specialisation, competition and diversity, to yield innovation and productivity growth that encourages employment expansion, and further urban growth through inward migration. This paper revisits the central part of this virtuous circle, namely the Marshall-Arrow-Romer externalities (specialisation), Jacobs externalities (diversity) and Porter externalities (competition) that have provided alternative explanations for innovation and urban growth. The paper evaluates the statistical robustness of evidence for such externalities presented in 31 scientific articles, all building on the seminal work of Glaeser et al. (1992). These articles yield 393 estimates of those externalities, which are characterized by their sign and statistical significance. We aim to explain variation in estimation results using study characteristics by means of ordered probit analysis. The evidence in the literature on the role of the specific externalities is rather mixed, although for each type of externality we can identify how various aspects of primary study design, such as the adopted proxy for growth, the data used, and the choice of covariates influence the outcomes.

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1. Introduction

During the last two decades there has been a remarkable volume of research devoted to both theoretical modelling and empirical verification of the causes of long-run economic development at spatial scales ranging from the global economy down to a local community (see, for example, Barro and Sala-i-Martin, 2004, for an overview of the field). One of the major drivers for this research activity was the realisation that development cannot be understood without investigating the characteristics, geography, causes, and consequences, of *innovation* – viz. the implementation of new or significantly improved products, processes, business practices, workplace organisation or external relations (OECD and Eurostat, 2005). Innovation takes place in dynamically diverse, geographically concentrated and imperfectly competitive spaces that can only be analysed by abandoning conventional assumptions of perfectly competitive markets and constant returns to scale. This realisation led to the development of "new" theories of growth, economic geography, trade and industrial organisation (see, for example, Krugman, 1995, and Brakman and Heijdra (2004)).

In the knowledge-driven globally-connected regional economy, agglomeration forces that rely on proximity continue to increase in importance. This occurs paradoxically despite declining real costs of information, communication and transportation. The relevance of agglomeration is revealed by the continuing urbanisation of the global population. About half the world population now lives in cities and this is expected to increase further to 60 percent by 2030 (UNFPA, 2007). Although the number of 'world cities' with populations of more than ten million inhabitants continues to increase, global urbanisation is primarily due through the growth of smaller cities of up to 500,000 inhabitants. While mega cities have hugely diverse economies, smaller cities may find a niche in specialized economies or clusters of connected activities (see, for example, Fujita and Thisse, 2002).

Understanding the existence and growth of mega and smaller cities and their surrounding hinterlands – that together make up functional regions – requires consideration of a wide range of factors that have been elaborated in the above mentioned 'new' theories of innovation and growth and that have been empirically tested in a large range of studies around the world.[1] The growth of cities results from a complex chain that starts with scale: endowments of labour, capital and knowledge. The productivity of the open urban economy depends also on spatial factors, internally through density and infrastructure and externally

[1] Many key contributions in the economics literature of the last two decades to understanding the growth of cities can be found in Acs (2006).

through spatial interaction with other cities and regions. Resources, production factors and geography then combine with an industrial structure characterised by specialisation, competition and diversity, to yield innovation and productivity growth that encourages employment expansion.

In the long run, new jobs can only be filled through natural increase of the urban population or through net inward migration. Given that rising real incomes in cities lead to lower fertility, urban population growth is in practice primarily driven by inward migration of workers who are often positively self-selected in terms of entrepreneurial abilities and skills. In the presence of economic diversity and increasing returns, capital and labour are not flowing in opposite directions, as in static neoclassical theory. Instead, the city attracts capital too. Many aspects of this self-reinforcing and virtuous process yield benefits that are external to individual market transactions and such externalities are therefore central to agglomeration processes (see Fujita and Thisse, 2002).

This paper revisits the issue of the importance of externalities that have provided alternative explanations for innovation and urban growth. Following the seminal contribution by Glaeser et al. (1992), a large volume of empirical research has tried to identify the roles of industrial concentration and specialisation (Marshall-Arrow-Romer (MAR) externalities, originally noted by Marshall, 1890), economic and social diversity leading to cross-sectoral spillovers (Jacobs externalities after Jacobs, 1969), and the intensity of competition (Porter externalities, after Porter, 1990). However, this research endeavour has only been partially successful. Glaeser (2000) concluded that the relative importance of such externalities remains largely unresolved. In their review of growth, development and innovation, Cheshire and Malecki (2004, p. 263) additionally noted that "an important element in any research agenda is a job of synthesis".

In this paper we therefore evaluate the statistical robustness of evidence for agglomeration externalities by means of a form of quantitative literature review, commonly referred to as *meta-analysis*, of 31 published articles that provide empirical evidence on the impact of agglomeration and innovation on the growth of cities. Meta-analysis is becoming increasingly popular in economics after having a longer tradition in bio-medical and behavioural sciences.[2] The analysed articles yield 393 indicators of the statistical significance of agglomeration externalities on growth. These so-called effect sizes are linked to study

[2] A special issue of the *Journal of Economic Surveys* (volume 19, number 3, 2005) provides a range of applications of meta-analysis in economics. See also Stanley (2001).

characteristics by means of an ordered probit analysis. The evidence in the literature on the role of the specific externalities is rather mixed, although for each type of externality we can identify clearly how various aspects of primary study design, such as the adopted proxy for growth, the data used, and the choice of covariates influence the outcomes. We find most clear-cut evidence for a positive effect of diversity, supporting Jacobs' view. Somewhat less conclusive evidence was found for a positive impact of competition on city growth. Regarding the effect of specialisation, the evidence is largely mixed.

In the next section we review theoretical perspectives on the nature of agglomeration externalities and their impact on growth and development. From this literature, several testable hypotheses can be derived. We subsequently turn in Section 3 to the empirical literature that has investigated the impact of agglomeration externalities. Central to this review is the approach adopted in the seminal paper by Glaeser et al. (1992), which has triggered the research agenda in this area and therefore deserves a relatively more detailed review than other contributions. In Section 4, we provide a statistically-based description of the available evidence using tools developed under the heading of meta-analysis. The final section sums up and suggests ways in which this literature can be fruitfully develop further from here on.

2. Theoretical perspectives on agglomeration externalities and growth

Considerable effort has been devoted in recent years to modelling the nature and impact of agglomeration (e.g., Fujita and Thisse, 2002). While some of these ideas go back already to Marshall (1890), agglomeration continues to attract attention because of the continuing urbanisation throughout the world noted earlier and the complexities of defining and measuring agglomeration effects.

Historically, agglomerations of economic activity resulted from the efficiency and strategic advantage of settlement at specific locations, usually determined by geography (access to water, other resources and the features of the landscape) and the interrelated development of trade routes. The benefits of such spatial concentration of economic activity in which all economic agents benefit from lower transaction and coordination costs are referred to as *localisation* externalities.

The second type of externality is that of urban scale and density. An increase in population increases aggregate demand and enables firms to expand output without efficiency or productivity improvements. In this respect, scale and density are interrelated but not identical. A greater scale of activity may be accommodated by increasing urban sprawl at constant density, while alternatively the current tendency for a return of knowledge workers to inner city living and working may increase urban core density without changing scale. Scale and density effects may be referred to as *urbanisation* externalities. The importance of these may be gauged from the ease with which, through demand effects, cities can absorb large numbers of immigrants over a very short period of time (such as in the Mariel boatlift, see e.g. Bodvarsson et al., 2007). A *fiscal* externality also exists in that public goods can be funded through a lower per capita lumpsum tax when the urban population increases. On the other hand, urbanisation externalities can also be negative and determine the limits to urban growth through pollution and congestion effects with respect to infrastructure and land use (e.g. Glaeser, 1998).

Glaeser et al. (1992) refer to the above externalities as *static* in that they explain the cross-sectional distribution of economic activity, levels of productivity and amenities, but not *changes* in sector-specific productivity due to, for example, knowledge spillovers. The latter are referred to as *knowledge* externalities and these dynamic externalities are the focus of the empirical analysis of Glaeser et al. (1992) as well as the analysis in the present paper.

To provide a basic framework for analysis, we will now turn to an illustration of the main dependencies between inputs, productivity, and utility using a simple model. We will then proceed to relate the analysis by Glaeser et al. (1992) to this framework. Most modern modelling of economic development starts from a general equilibrium perspective in which profit-maximising firms in any given region and sector determine output and inputs based on the productivity of resources and given factor prices. Specifically:

$$w_{irt} = \pi_{it} MPL(L_{firt}, K_{firt}, A_{firt}) \tag{1}$$

$$\rho_t = \pi_{it} MPK(L_{firt}, K_{firt}, A_{firt}) \tag{2}$$

in which f indexes the firm (1,2,..,F_{irt}), i indexes the industry (1,2,…,I), r indexes the region (1,2,..,R), w_{irt} refers to the wage paid to workers in industry i, region r at time t (each firm in a given local labour market pays the 'going' wage)[3], π_{it} refers to the price of a product

[3] So we assume, formally stated, that $w_{firt} = w_{irt}$ for each f. For simplicity, it is assumed that there is a one-to-one mapping between industries and occupations. Moreover, each industry produces only one commodity.

(assumed to be traded in global markets so that it is equal for each firm and region), ρ_t is the price of capital (which is equal everywhere due to the assumption of perfect international and inter-sectoral capital mobility), L_{firt} refers to the labour input, K_{firt} refers to the capital input, A_{firt} refers to the knowledge input, and *MPL* and *MPK* refer to the physical marginal products of labour and capital, respectively, which are functions of the inputs. These functions have the usual partial derivatives, i.e. $MPL_L < 0$, $MPL_K > 0$, $MPL_A > 0$, $MPK_L > 0$, $MPK_K < 0$ and $MPK_A > 0$. Capital is perfectly mobile and allocated such that the rate of return is equalised across sectors and regions. Workers are also mobile such that utility is equalised across space, and wage differentials reflect amenity differentials. Hence,

$$U_{irt} = \overline{U}_{it} = \varphi(w_{irt}, Q_{rt}) \tag{3}$$

in which workers of industry *i* reach the same utility $\overline{U}_{it}$ everywhere. Combining this supply side with demand equations for the *I* commodities, and with given nationwide factor endowments, an equilibrium can in principle be determined.

In order to study the dynamics of such an economy, it is clear that the neoclassical model developed by Solow (1956) and Swan (1956) of long-run growth in which the long-run steady state is determined by a given technology, by investment funded from local savings and by natural increases in the work force is not appropriate. Among the most important problems are the fact that we have an open system in which capital accumulation and spatial reallocation of workers depend on the development of knowledge across all regions. The long-run tendency of such a system depends on the endogeneity of technological change and the nature of the spatial interaction and spillovers (e.g., Nijkamp and Poot, 1998).

First we can consider the growth in knowledge at the level of the firm. As in agent-based modelling (e.g., Zhang, 2003), the micro-level employment response of employers, following a productivity increase, determines one side of the motion in the system. Formally, the productivity growth can be described by:

$$A_{firt+1} = A_{firt} + \Delta A_{firt}(t, \mathbf{L}_t, \overline{A}_t) \tag{4}$$

in which ΔA_{firt} refers to the shift in the firm's knowledge input, which is a function of time (t), the distribution of employment across industries and regions represented by the $I \times R$ matrix $\mathbf{L}_t$ of which $\mathbf{L}_{irt}$ is a vector of length F_{irt} that contains employment by individual firms in that industry-region, and the economy-wide level of knowledge $\overline{A}_t$. Except for L_{firt}, the arguments of the function ΔA_{firt} are external to the firm's actions. The partial derivatives of ΔA_{firt} with respect to t and $\overline{A}_t$ are positive. The first of these relates to exogenous long-run technological change and the second to the economy-wide benefits of, e.g., a high level of education.[4] There are theoretically several mechanisms through which the matrix $\mathbf{L}_t$, the configuration of employment across firms, industries and regions, can affect productivity growth. These include the MAR, Porter and Jacobs externalities referred to earlier. The extent to which any of these externalities, or a combination, has a statistically significant impact on productivity growth (or its proxy) is the primary objective of the meta-analysis to which we turn later in this paper.

However, the actual employment decision of the firm is also a function of another set of externalities, namely those that affect the utility of workers (e.g., Glaeser, 1998). These can be positive or negative. Positive externalities of urban growth include the benefits of urban amenities, the enjoyment of cultural diversity and the fiscal externality of larger local tax revenues that enable lower local tax rates or higher quality recreational amenities (e.g., Florida, 2002). Negative externalities of urban growth include congestion, pollution, and a decline in social cohesion and an increase in social problems. Formally,

$$Q_{rt+1} = Q_{rt} + \Delta Q_{rt}(t, \mathbf{L}_t, \Delta K_{rt}, \overline{A}_{rt}) \tag{5}$$

The partial derivatives of the function ΔQ_{rt} may be expected to be negative with respect to t (depreciation of existing amenities), positive or negative with respect to regional investment ΔK_{rt} (dependent on whether this generates more amenities and infrastructure, or disutility, e.g. through visual pollution), and positive with respect to the local overall level of knowledge $\overline{A}_{rt}$ (education may reduce crime and improve social cohesion). It is hard to say *a priori* how a change in the matrix $\mathbf{L}_t$ would affect the quality of life in region r. Greater

[4] See, e.g., Nijkamp and Poot (2004) for a meta-analysis of evidence of the impact of the macro level of education on growth.

employment in ‘clean’ service sector firms might improve the quality of life, whereas greater employment overall may generate pollution and congestion externalities. On balance, we are assuming a negative net amenity externality of city output growth, which is consistent with much of the available empirical evidence. This implies that nominal wages must increase to compensate. The net effect on employment depends on the compensating growth in nominal wages. If the negative externality effect is relatively minor, the firm’s employment will increase. If the negative externalities are significant, firms can only attract workers when the offered wage increases substantially and employment will decline.

In order to describe the dynamics of the multiregional system in the simplest possible way, we consider a two-region case in which one of the two regions is affected by such positive and negative agglomeration externalities. The adjustments along the equilibrium growth path are illustrated in Figure 1.

[Insert Figure 1 about here]

The top half of the figure depicts the impact of the positive production externality. The bottom half depicts the impact of a negative utility externality. The left side depicts the agglomerated region (region 1) and the right side a region without agglomeration-linked externalities (region 2). The demand curves D_1 and D_2 are the horizontal aggregation of the value of marginal product curves represented by Equation (1). Labour supply is given by S_1 and S_2 respectively. In any period, profit maximisation implies equality of the wage and the value of the marginal product. Initial employment is E_1 and E_2 in regions 1 and 2, respectively. We are assuming that initially the real wage is w_0 everywhere, i.e. let us initially consider a situation with equal amenities in both regions and a labour market that is in equilibrium. This is depicted in the top-half of Figure 1 by the curves D_1, $S_{1,}$ D_2, and S_2. Starting from this situation, region 1 benefits from a positive productivity shocks per period, for example due to the greater scale of the agglomerated region yielding benefits from specialisation. This leads to a shift of Region 1’s demand curve to the right, to $D_1^{'}$ which puts upward pressure on the wage. As in standard labour market analysis, and assuming costless mobility, this generates both increasing labour force participation, hours worked and inward migration that offsets some of the upward pressure on wages (top half of Figure 1). Net migration equals $E_1^{'} - E_1 = E_2 - E_2^{'}$. In the new equilibrium, real wages are again equal and higher than initially by $w_0^{'} - w_0$ due to productivity having increased. Employment and the size of the economy of region 1 have increased while those of region 2 have decreased. It should be noted that this expansion of population and employment in region 1 may generate further dynamic externalities that may yield additional productivity growth and a further expansion of employment, i.e. a virtuous circle of urban expansion.

However, this basic story can be complicated along various dimensions. Let us, for example, look at a situation in which the expansion of employment in region 1 on balance has a negative utility externality effect on this region (we assume such effects absent in region 2 for ease of exposition). The negative externality effect leads to a leftward/upward shift in the labour supply curve of region 1 (bottom left of the figure) to S_1^*, as workers demand a compensating differential. The vertical shift in the supply curve is equal to the size of this compensating (equilibrium) differential. This pushes up wages in region 1 to some extent, and will lead to some withdrawal of labour, but utility is subsequently nonetheless still higher in region 2. The consequence is outward migration from region 1 to region 2 and a shift in region 1's supply curve to S_1^{**}. In the new equilibrium, the wage in region 2 has declined somewhat from w_0 to w_0^{**} and the wage differential between the regions $w_0^* - w_0^{**}$ is exactly the compensating differential that leads to equal utility everywhere.

The combined effect of the positive and negative externalities (excluding further flow on effects of migration on productivity) in any given period is the sum of the shifts in the top half and bottom half of Figure 1. It can be seen that in the example there is overall an employment decline in region 2 (given by $(E_2 - E_2^{'}) - (E_2^* - E_2)$), while employment in region 1 is growing (given by $(E_1^{''} - E_1) - (E_1 - E_1^{**})$). Wages in the agglomerated region will increase by $w_0^{'} - w_0 + (w_0^* - w_0)$, while those in the non-agglomerated region may increase or decline a little by $(w_0^{'} - w_0) - (w_0 - w_1^{**})$ (since economy-wide total factor productivity growth is also not incorporated here).

In summary, we expect in the real world the positive effects in the agglomerated region to outweigh the negative effects on balance (as is consistent with the continued urbanisation observed worldwide). The combination of the effects is then likely to lead to both greater employment (due to the demand effect of the positive agglomeration externalities) as well as higher wages (to compensate for the negative externalities). It is the employment effect that is exploited in the empirical research by Glaeser et al. (1992).

The productivity shift on the right hand side of Equation (4) has one component that depends on time only. Neoclassical growth theory considers this to be secular rate of technological change that applies throughout the economy and which is assumed constant over time and regions. Recently, however, there is increasing recognition that major innovations occur through the emergence of *general purpose technologies* at discrete, and unpredictable, points in time. Examples of these are the introduction of programmable computing networks in the 20th century and of biotechnology and nanotechnology in the 21st century (Lipsey et al., 2005). More generally, innovation, technological change and the adaptation of workers and firms change productivity and equilibrium outcomes through Equations (4) and (5) in complex ways that besides neoclassical modelling can also be analysed from evolutionary perspectives (e.g. Nelson and Winter, 2002).[5]

Given the model outlined above, the structure of the matrix $\mathbf{L}_t$ above provides proxies of measures that might be indicative of MAR, Porter and Jacobs externalities. This is the approach adopted by Glaeser et al. (1992) and several subsequent authors. The simplest measures of specialisation (S_{irt}), competition (C_{irt}) and diversity (D_{irt}) are respectively:[6]

$$S_{irt} = \frac{\sum_f L_{firt} \Big/ \sum_f \sum_i L_{firt}}{\sum_r \sum_f L_{firt} \Big/ \sum_r \sum_f \sum_i L_{firt}} \qquad (6)$$

$$C_{irt} = \frac{F_{irt} \Big/ \sum_f L_{firt}}{\sum_r F_{irt} \Big/ \sum_r \sum_f L_{firt}} \qquad (7)$$

$$D_{rt} = 1 - \sum_i \frac{\left(\sum_f L_{firt} \right)^2}{\left(\sum_j \sum_f L_{fjrt} \right)^2} \qquad (8)$$

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[5] See also Mulder et al. (2001) for a comparison of neoclassical, endogenous and evolutionairy models of economic growth.

[6] With respect to specialisation, some authors consider simplified relative measures such as $\frac{\sum_f L_{firt}}{\sum_r \sum_f L_{firt}}$, or even just absolute measures such as $\sum_f L_{firt}$.

Equation (6) is just the definition of a location quotient, whereas Equation (7) relates the inverse of firm size in a particular region and industry to the inverse of firm size in the national economy in that sector. Equation (8) is one minus the Herfindahl index of regional concentration of employment across sectors. In each region, this diversity measure is identical across industries. An industry-specific measure D_{irt}, used by Glaeser et al. is the fraction of region *r*'s employment in the five largest industries other than industry *i*. A range of other, more advanced, measures is possible (see, for example, Maurel and Sedillot, 1999). It should also be noted that the measures above are essentially non-spatial (or, more precisely, topologically invariant) and that spatial interaction in the model is entirely by means of factor mobility (which is assumed costless).[7] Naturally, innovation diffusion is an explicitly spatial process that is not adequately captured in the simple measures above.

Glaeser et al. (1992) argue that the way in which the measures above affect employment growth depends on the type of externality considered. For example, under MAR externalities specialisation has a positive impact on productivity. Moreover, in these theories innovation is typically undertaken by large and dominant firms that can internalise the knowledge externalities. The impact of competition and diversity on growth would then be negative. In the context of Porter externalities, specialisation and competition are both positive forces, but diversity is not. Jacobs (1969) emphasised the importance of competition and diversity, while downplaying specialisation. These ideas are summarised in Table 1. The expected effects of localisation and urbanisation externalities (the latter including fiscal and environmental externalities) are also included in this table and are static in nature. Localisation externalities are not expected to create productivity growth in mature industries, but are at the heart of explanations for why cities grew large in the past and why they exist in the first place. This also holds for urbanisation externalities (including fiscal externalities) which typically have had a positive effect on employment, although they are increasingly dampened by congestion and pollution effects.

[Insert Table 1 around here]

The theoretical literature has an empirical counterpart that aims at testing the hypotheses that are summarized in Table 1. This empirical literature strongly builds on the

[7] See Duranton and Overman (2005) and de Dominicis et al. (2007) for studies that incorporate the spatial dimension more explicitly in an analysis of concentration.

seminal contribution by Glaeser et al. (1992). In the next section, we provide a qualitative overview of this literature and the results obtained therein. Section 4 subsequently turns to a more in-depth description of the available empirical evidence on the various externalities and aims to provide an explanation for the variation in observed outcomes of the different studies.

3. A short review of recent empirical literature on agglomeration and growth

This section first discusses the way in which Glaeser et al. (1992) have simplified the model discussed in the previous section in order to arrive at a simple reduced-form equation that could be tested empirically. Next, we turn to a first description of the studies that were conducted following the seminal contribution by Glaeser et al. Apart from discussing the criteria that we adopted for including papers in the database underlying our meta-analysis, we also characterise those papers in terms of their outcomes, regional scope, and the operationalisation of the dependent variable in the analysis (viz. urban growth).

3.1 The Glaeser approach

The study by Glaeser et al. (1992) builds on a very simple neoclassical model describing the functioning of an economy. The model can be seen as a simplified version of the general equilibrium model described in Section 2. Central in their approach is a production function with 'technology' (A) and 'labour' (l) as inputs. Under perfect competition, profit maximisation of individual firms results in equality of the marginal value product and the wage rate. Under the assumption of a simple Cobb-Douglas production function in which α is the production elasticity of labour, one arrives at the labour demand function:

$$l_t = \left(\frac{\alpha A_t}{w_t} \right)^{\frac{1}{1-\alpha}} \quad (9)$$

Taking logs on both sides, one can easily arrive at an expression in growth rates:

$$(1-\alpha)\log\left(\frac{l_{t+1}}{l_t}\right) = \log\left(\frac{A_{t+1}}{A_t}\right) - \log\left(\frac{w_{t+1}}{w_t}\right) \quad (10)$$

This equation simply states that the growth rate of employment – ceteris paribus – positively depends on the growth of the state of technology and negative on the growth rate of wages.

The growth rate of technology is subsequently assumed to depend on a national and a local component. The latter is explained from the three externalities identified in Section 2, describing the impacts of specialisation, competition and diversity. So we arrive at:

$$\log\left(\frac{A_{t+1}}{A_t}\right)=\left(\frac{A_{t+1,national}}{A_{t,national}}\right)+g(specialisation, competition, diversity) \qquad (11)$$

In order to test their empirical relevance of the various externalities, a dataset is constructed of growth rates of employment in a range of cities (MSA's) and mature industries.[8] These growth rates are subsequently regressed on a range of explanatory variables, among which the proxies for the three externalities are of key interest. Other explanatory variables are the aggregate growth of the industry considered at the national level, initial employment in the city-industry, and a dummy indicating presence in the south to allow for some sort of spatial heterogeneity. Overall, the results of the Glaeser study appear particularly consistent with the Jacobs perspective. The effect of specialisation as proxied by the location quotient of the city-industry is significantly negative. The effect of competition is positive, which is in line with both the views expressed by Jacobs as well as Porter.

The study by Glaeser et al. (1992) was extended in a wide array of directions. It has been applied to different regions and different time periods, different proxies for the externalities have been used, growth has been operationalised in different ways, different estimation techniques have been used, etc. etc. Not surprisingly, there different approaches have led to different conclusions on the relevance of the various externalities in explaining growth. The aim of the remainder of this paper is to provide an up-to-date account of the available studies and their results. Subsequently, we will try to get a hand on the sources of variation in the observed outcomes.

3.2 Selection and first characterisation of individual studies

In order to acquire a systematic and representative set of journal articles, we used Web of Science (www.isiknowledge.com) to select all articles that cited either Glaeser et al. (1992) or both Porter (1990) and Jacobs (1969). The result was a set of 318 articles covering the period up to April/May 2006. Our selection method results in a well-defined list, which is collected in a quick, efficient, and reproducible manner. However, a consequence of this

[8] Only the six largest industries in each MSA are incorporated in the analysis.

selection procedure is that it results in a list containing only journal articles. Mostly, no (as yet) unpublished articles, books or book chapters have been included. Furthermore, Web of Science has a bias towards journals written in the English language. To reduce the effects of the two negative effects associated with our selection method, we used the technique of snowballing, viz. carefully scanning through the references of the articles we included. This resulted in four more studies, which Web of Science had not provided us with (among which one French and one Italian).

We subsequently went through all the 322 articles, including in our database only those articles adopting a quantitative approach and including one or more variables corresponding to any of the three variables for specialization, diversity and competition that Glaeser et al. (1992) introduced. In total, 31 articles were found to match Glaeser et al.'s methodology to a sufficient degree, giving us 393 different estimates. [9] They show considerable variation in the direction and significance of the effects found. Table 2 provides information on the studies included, the country to which the analysis pertains, the number of estimates provided by each study, and some characteristics of the dependent variable (viz. whether growth is defined in terms of employment, innovation, productivity, or otherwise). The Table provides a first impression on the variation that is present in the studies. In the next section, we turn to a more elaborate statistical analysis of the available evidence.

[Insert Table 2 around here]

4. Meta-analysis

Meta-analysis provides the researcher with a useful toolkit to study the sources of variation of study outcomes on particular topic. For excellent overviews of meta-analysis as a tool as well as for recent applications, see for example Florax et al. (2002) and Stanley (2001). This section will proceed by first summarizing the available evidence by means of a simple vote count. Subsequently, we describe the results of our attempt to explain the observed variation in outcomes.

[9] These estimates were derived from 202 estimated equations, where most equations provided information on more than one externality. The number of estimated equations per study included in the database varies between 1 and 22 (see Table 2).

4.1 Vote counting

In order to get a first impression of the estimated effects of specialisation, competition and diversity, we have categorised all the available estimates into four classes, viz. significantly negative, insignificantly negative, insignificantly positive and significantly positive. Ideally, we would have used a more refined effect size such as a (semi-) elasticity capturing the effects of specialisation, competition and growth. In the research under consideration, the heterogeneity in terms of both the dependent variable as well as the proxies used for our key variables of interest is so large, that the construction of a common metric to characterise the available empirical evidence is not feasible (or, stated differently, leaves us with extremely small samples). As an aside, our approach implicitly builds on the assumption that all studies – regardless of the exact definition of their dependent variable – are informative on the determinants of growth. In other words, they require us to believe in a positive (possibly sequential) relationship between innovations,[10] patents, productivity and employment growth. For the moment, we will just make this assumption notwithstanding the fact that there is substantial theoretical literature on the relationships between growth, productivity, R&D, unemployment, etc.[11]

The results of this vote-counting exercise are given in Table 3. Several results emerge. First, regarding specialisation there is no clear-cut evidence in the literature regarding its impact on the growth of cities. Although 70% of the available estimates are statistically significant, of those about half are negative (the other half of course being positive). Regarding competition, results are somewhat clearer. Here 60% of the estimated effect sizes are statistically significant and about two-thirds are positive, which is in line with Porter's hypothesis on the importance of competition in promoting urban growth. Finally, we consider the effects of diversity. Here only 50% of the estimates are statistically significant. Out of those, however, more than 75% point at a positive effect of diversity on urban growth.

[Insert Table 3 around here]

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[10] Arundel and Hollanders (2006) stress that the relationship between R&D, invention and innovation is a lot less clear than is often supposed among policy makers. We could include R&D expenditure as an extra stage before innovations, using some kind of knowledge production function, but R&D was not to be found in the studies under consideration here (see Griliches, 1979, and Cameron, 1996, for an analysis of the effectiveness of R&D).

[11] See, for example, Daveri and Tabellini (2000) and de Groot (2000) for some examples of studies in this area of research.

Taken together, the first results of our meta-analysis tend to re-confirm the conclusions in Glaeser et al. (1992). There is substantial evidence for positive and significant effects of diversity and competition on urban growth, whereas the results regarding the effects of specialisation are highly ambiguous. In the next sub-section, we will provide a more detailed statistical analysis of the estimates that have been found in the literature and we will aim at explaining the sources of the variation that is present.

4.2 Meta-regression analysis

The previous discussions have pointed at the fact that both theoretically as well as empirically, there is lack of clear-cut evidence on the importance of the three dynamic externalities driving economic growth. This sub-section aims to take the descriptive analysis in the previous section one step further by considering the relevance of several sources of heterogeneity. We proceed by first describing the potential sources of heterogeneity in study outcomes. Next, we describe the results of an ordered probit analysis and we conclude with a discussion of the main results.

4.2.1 Sources of variation in estimated effect sizes

Some of the sources of variation were already identified in Table 2. They relate to the way in which the dependent variable in the analysis has been measured (viz. employment growth, productivity growth, patents or innovations or other measures), the level of regional aggregation and the country covered in the analysis. Further heterogeneity is present in the sectoral coverage in the analysis. In our meta-analysis, we operationalise the characteristics of the dependent variable by means of several dummies and a continuous variable. The dummies measure whether the dependent variable is measured in terms of employment, patents or innovations, or productivity. Sectoral coverage is measured by two dummies that indicate whether the analysis is exclusively focused on the high-tech sector and whether the service sector has been included, respectively. Finally, we add a variable capturing the average population density of the units of observation included in the primary analysis. This captures in a simple and fairly comparable way an essential element of the regional aggregation of the analysis.[12]

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[12] This variable describing the mean population density of the regions included in the study was constructed based on data on the regions included in the primary analyses (mainly from national statistical offices). We have also considered the average surface area and population size separately, but that did not lead to different results. Details are available upon request.

A second set of factors that might affect the outcomes of the analyses concerns the empirical operationalisation of the key variables of interest, viz. specialisation, competition and diversity. First, the results for, for example, specialisation might be affected by the inclusion (or not) of a proxy for competition of diversity. Second, the exact empirical operationalisation can matter. Considering specialisation, it is likely to matter whether specialisation is measured as a location quotient (viz. the share of a sector in regional employment relative to the national average) or just as a share in regional employment or total sectoral employment. For competition, different measures are used, among which number of establishments in a sector and the inverse of the average firm size in a sector feature most prominently. Regarding diversity, the crucial distinction is between studies that use the share of, for example, the five largest sectors and studies that use more continuous variables such as a relative diversity index, a Herfindahl index or a Gini coefficient. All these differences are captured by simple dummy variables.

A final set of factors that we consider relates to other data-characteristics and the presence of additional control variables. These are the period covered by the analysis (captured by the mean year of the analysis to which the data pertain), the length of the period covered (to distinguish between more long-run and short-run effects), the region covered in the analysis (taking Europe as the omitted category and considering Asia and the USA by means of dummies), the inclusion (or not) of investments, educational variables, wages and geographical variables as controls in the primary analysis, the estimation technique (distinguishing between panel and cross-sectional approaches), and the year of publication of the study.

4.2.2 Results from the ordered probit analysis

In this section, we present the estimation results aimed at uncovering the factors explaining the direction and statistical significance of estimates obtained from the primary studies on the impact of specialisation, competition and diversity on urban growth. We estimate an ordered probit model distinguishing between the four ordered categories that were introduced in Section 4.1. The estimation of an ordered probit model is common practice in a situation where the construction of a common metric to characterise the variation in the underlying primary studies is problematic. A downside of it is that it neglects information on the extent of statistical significance which is contained in, for example, the t-statistics of the estimated coefficients.[13]

The ordered probit model assumes the presence of a latent variable, y^* that can be explained by a set of explanatory variables x_i such that:

$$y^* = \sum_i \beta_i x_i + \varepsilon \tag{12}$$

where ε is an error term that is assumed to be normally and i.i.d. distributed. We only have information on the categorical variable *y* consisting of the four categories discussed above, This observed variable has the following structure:

$$\begin{aligned} y &= 0 \quad if \quad y^* \le \mu_1 \\ y &= 1 \quad if \quad \mu_1 < y^* \le \mu_2 \\ y &= 2 \quad if \quad \mu_2 < y^* \le \mu_3 \\ y &= 3 \quad if \quad y^* > \mu_3 \end{aligned} \tag{13}$$

where the μ-parameters are estimated by the model, along with the β's. It is important to note that the interpretation of the estimated coefficients of an order probit analysis is not straightforward, since the estimated coefficients only convey information on changes in the probability of finding an estimated in the extreme left and right category. In order to facilitate the interpretation, we will focus our discussion of the results on the marginal effects which represent the change in the probably of finding an estimate in one of the four categories in response to a change of one of the explanatory variables.

The results of our ordered probit analysis are given in Table 4. The results for the variation in the effects of specialisation, competition and diversity on urban growth are given in the three respective columns. The explanatory variables capture the sources of variation that were discussed in Section 4.2.1. For specialisation, competition and diversity, respectively, 60%, 53% and 59% of the observations are predicted correctly by our model.

[Insert Table 4 around here]

[13] We refer to Koetse et al. (2006) for an example of an analysis along those lines and a comparison with a more simple ordered-probit analysis.

Before turning to a detailed discussion of the interpretation of these results, we compute the marginal effects. These facilitate the comparison of the outcomes for the different explanatory variables (see, for example, Greene, 2000, p. 878). The results are described in Table 5. All marginal effects are taken at the mean value of all other variables.[14] For the dummy variables, the marginal effects describe the increase in the probability of finding an outcome in one of the four categories of the dependent variable between the situation in which the value for a particular dummy is equal to zero and the situation in which it is one. For the continuous variables, the marginal effects are associated with an increase of the dependent variable by one. In case of the standardised variables, these correspond to an increase of the dependent variable by one standard deviation.

[Insert Table 5 around here]

4.2.3 Discussion of the results

In this sub-section, we will discuss the most important results of our analysis as described in Tables 4 and 5. Let us first turn to the results regarding the characteristics of the dependent variable. For all three effects, the chances of finding significantly positive effects are substantially larger when measuring growth in terms of employment than in terms of productivity. This casts some doubts on the appropriateness of using employment as a proxy for technological development. Also interesting is that diversity tends to have a strong positive effect if growth is measured in terms of innovation. This underlines the theory of Duranton and Puga (2001) who argue that innovation benefits from diversified or 'nursery' cities. Finally, studies that exclusively focus on the high-tech sector tend to find particularly strong and positive effects of diversity on urban growth. This confirms the notion that the effect of diversity on urban growth is heterogeneous with respect to the sector considered.

Regarding the regions that are considered, we find that population density significantly and positively affects the chances of finding positive effects of specialisation on urban growth. This is an indication that indeed the level of spatial aggregation tends to matter for observed outcomes. Furthermore, the effects of specialisation, competition and diversity are hardly different between Europe and the USA. This result suggests that flexibility of goods and labour markets that differentiates – among many other factors – the USA from

[14] Alternatively, we could have evaluated at the median. This turns out to have only limited impact on the outcomes. Details are available upon request.

Europe has limited impact on the strength with which agglomerative forces function. These similarities are in contrast to Asia where the chances of finding positive effects for specialisation are limited whereas the chances of finding positive effects for diversity are relatively large.

A third set of results points at the potential importance of the time dimension. Both the effect of the length of the period covered in the analysis as well as the use of panel techniques (as opposed to pure cross-section techniques) are indicative in this respect. For specialisation in particular, it turns out that using cross-section techniques considering longer time periods tends to increase the chances of finding significantly positive effects. This can be interpreted as an indication that especially the effects of specialisation take time before they result in urban growth (using the fact that cross-section techniques and the consideration of long time periods help in identifying true long-run effects in primary analyses). We can also reason that apparently agglomeration forces still overcome negative externalities in the long run, and that therefore our findings support Glaeser's statement that cities are not dying (Glaeser, 1998).

A fourth set of results relate to the specification of the key variables of interest. Apart from the fact that the inclusion of specialisation, competition and diversity evidently have an impact on the estimated effects of the key variable of interest, two results stand out in particular. First, measuring specialisation as a location quotient (viz. relative to a national average) has a significantly positive effect on the chance if finding a positive effect of specialisation. This brings us to a more theoretical discussion as to whether it is absolute or relative size that matters in explaining variation in urban growth. It is not evident which is the preferable proxy for specialisation and scale. What is clear, however, is that the choice that is made tends to affect the outcome of the analysis substantially. Second, it stands out that studies that proxy diversity by means of a simple measure capturing the employment share of the five largest sectors tend to find more positive effects of diversity than studies that use more refined measures to characterise diversity.

Finally, the inclusion of proxies for physical and human capital affect the outcomes for especially specialisation and also diversity, whereas the inclusion of wages has a limited effect on the variation in outcomes in the primary studies. There also is no discernible effect of the year of publication.

5. Conclusions

This paper has reviewed the theoretical background behind the empirical analysis of the growth of cities and subsequently looked into the available empirical evidence on the importance of three externalities in explaining urban growth, viz. MAR externalities, Porter externalities and Jacobs externalities. The latter was done by means of a meta-analysis. The overall evidence of the meta-analysis based on a simple counting of conclusive effect sizes reveals that relatively many primary studies conclude in favour is significantly positive effects of diversity and competition on growth. No clear-cut evidence was found for the effects of specialisation.

The meta-regression analysis points at several fruitful directions for further research. First, we found quite some strong indications for sectoral, temporal and spatial *heterogeneity* of the effects of specialisation, competition and diversity on urban growth. Such heterogeneity typically remains unnoticed in primary studies which tend to focus the analysis on a specific region, sector or time period. It calls, for example, for research focusing on the dependency of the strength of agglomerative forces on the stage of development of the region, but also of the sector. This may enhance our insights into challenging questions as to whether in the knowledge-driven post-industrial economy of producer and consumer services characterised by many young and small firms, Jacobs externalities are more important. Second, the level of regional *aggregation* matters for the strength with which the agglomeration forces are operational. This gives rise to interesting questions regarding the transmission mechanisms through which the externalities function. More theoretical as well as empirical work investigating these issues is warranted. We also found that including *control variables* on investments or capital stock and education has substantial effects on our key variables of interest. Similar effects may be expected from factors such as social capital and trust, risk-taking and entrepreneurship, R&D policies and institutions. More research on the role of such factors in determining the strength with which agglomerative forces are operating is warranted. Finally, we confirm the need for more attention to the *specification* of the key variables of interest. Again, further theoretical as well as empirical research along these lines is called for.

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Figure 1. The dynamics of agglomeration externalities and interregional equilibrium

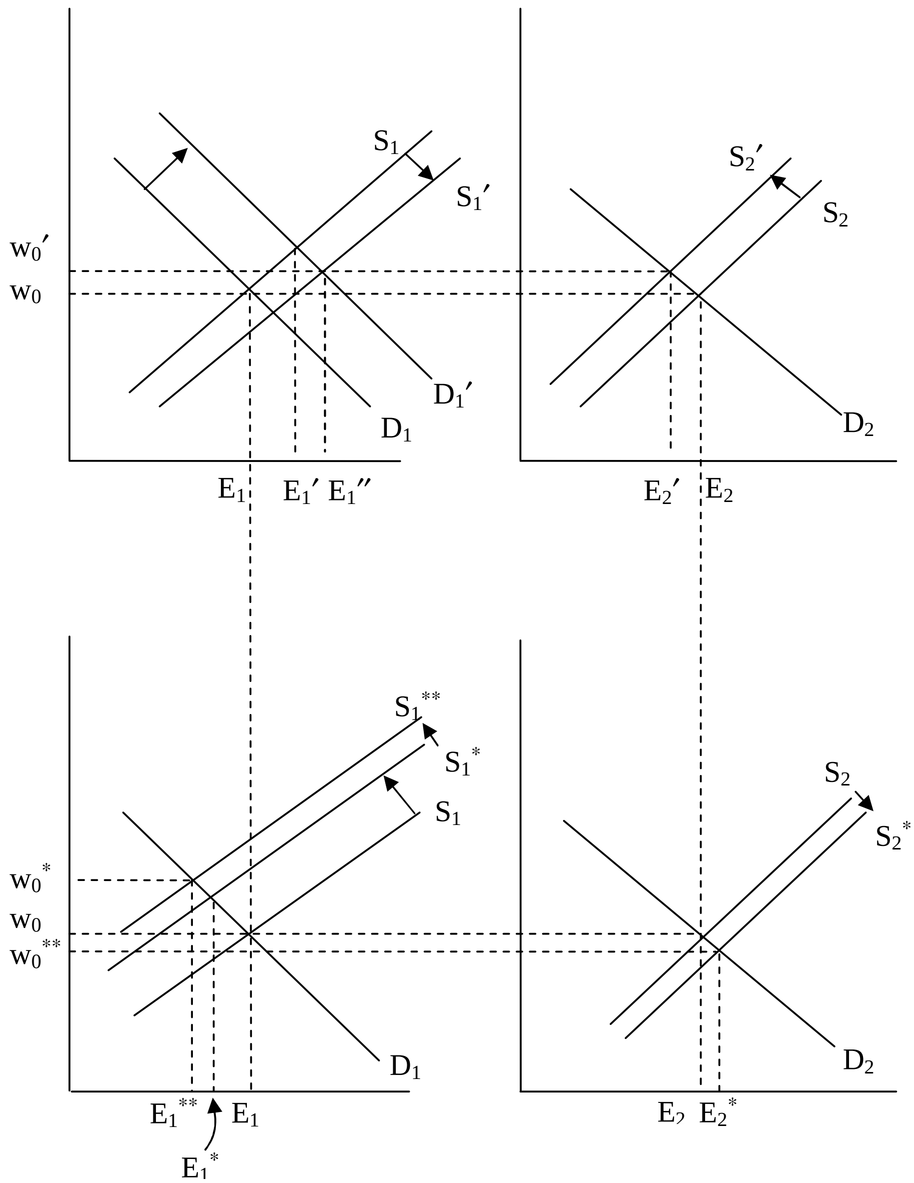

Table 1. The effect of agglomeration externalities on employment

Type of externality		Measured by	Effect on employment growth		
			MAR	Porter	Jacobs
Dynamic	Knowledge externality	Specialisation	+	+	−
		Competition	−	+	+
		Diversity	−	−	+
Static	Localisation externality	Geography; Infrastructure		+	
	Urbanisation externality	Aggregate demand, metropolitan population		+	

Table 2. List of included studies and number of meta-observations

study	# est. eqs	Conclusions			Characteristics		
		SPEC	COMP	VARY	country	Regions	dependent
Sonobe and Otsuka (2006)	18	○	n.a.	○	Taiwan	Townships	9× empl., 9× other
Andersson et al. (2005)	12	n.a.	+	++	Sweden	LMAs	patents or innovations
Boschma and Weterings (2005)	5	○	n.a.	–	Netherlands	NUTS3	patents or innovations
Acs and Armington (2004)	3	—	○	n.a.	USA	LMAs	employment
Combes et al. (2004)	6	n.a.	○	+	France	LMAs	other
Greunz (2004)	4	++	n.a.	++	Europe	NUTS2	patents or innovations
Lee et al. (2005)	5	—	++	++	South Korea	regions/counties	productivity
Malpezzi et al. (2004)	4	n.a.	n.a.	++	USA	SMAs	other
Mukkala (2004)	6	+	n.a.	n.a.	Finland	NUTS4	productivity
Serrano and Cabrer (2004)	22	–	n.a.	○	Spain	Provinces	productivity
van der Panne (2004)	3	++	—	○	Netherlands	ZIP regions	patents or innovations
van Oort and Atzema (2004)	3	+	+	+	Netherlands	Municipalities	other
King et al. (2003)	7	–	++	○	USA	States	employment
Rosenthal and Strange (2003)	18	+	○	—	USA	ZIP regions	12× empl., 6× other
Batisse (2002)	6	—	○	+	China	Provinces	other
Dekle (2002)	8	—	○	○	Japan	Prefectures	4× empl., 4× prod.
Massard and Riou (2002)	4	–	n.a.	–	France	Départements	patents or innovations
Staber (2001)	3	++	n.a.	—	Germany	circles of 10 km	Other
Combes (2000)	4	—	–	○	France	LMAs	Employment
Baptista and Swann (1999)	4	+	○	–	2× UK, 2× USA	CSO regions, states	Employment
Cainelli and Leoncini (1999)	4	++	++	++	Italy	Provinces	employment
Feldman and Audretsch (1999)	4	—	+	++	USA	SMAs	patents or innovations
Paci and Usai (1999)	6	++	n.a.	++	Italy	LMAs	patents or innovations
Partridge and Rickman (1999)	5	+	n.a.	+	USA	States	Productivity
Sjöholm (1999)	6	○	○	++	Indonesia	3× districts, 3× prov.	2× prod., 4× other
Baptista and Swann (1998)	9	–	n.a.	+	UK	CSO regions	patents or innovations
Bradley and Gans (1998)	1	n.a.	n.a.	—	Australia	Cities	Employment
Mody and Wang (1997)	6	—	+	n.a.	China	counties/provinces	productivity
Harrison et al. (1996)	7	○	n.a.	n.a.	USA	Counties	patents or innovations
Henderson et al. (1995)	5	+	n.a.	○	USA	SMAs	employment
Glaeser et al. (1992)	4	—	+	+	USA	SMAs	employment

Notes: the numbers in the second column indicate the number of estimated equations from which estimates for the externalities have been derived. The symbols in the next three columns have the following meaning: — significantly negative in all cases; – negative in all cases, but not always significantly so; ○ inconclusive; + positive in all cases, but not always significantly so; ++ significantly positive in all cases; and n.a. no estimates available.

Table 3. Vote counts

	Specialization		Competition		Diversity	
	count	percent	count	percent	count	Percent
Negative significant	60	37%	16	20%	17	11%
Negative insignificant	33	20%	13	16%	40	26%
Positive insignificant	16	10%	19	24%	37	24%
Positive significant	53	33%	31	39%	58	38%
total	162	100%	79	100%	152	100%

Table 4. Meta-regression analysis

	Specialisation	Competition	Diversity
Characteristics of dependent variable			
Data measure employment	0.54	0.41	1.26***
	(1.55)	(0.72)	(3.22)
Data measure patents or innovations	–0.24	–0.21	0.76*
	(–0.51)	(–0.26)	(1.97)
Data measure productivity	–0.97	–0.97	–0.88
	(–1.43)	(–0.92)	(–1.43)
Data are for high-tech only	–0.11	0.49	0.88***
	(–0.24)	(0.88)	(2.98)
Data include the service sector	0.03	–0.04	–0.06
	(0.23)	(–0.21)	(–0.65)
Specification of key variables			
Specialization included		–1.87**	–0.70
		(–2.57)	(–1.42)
Specialisation as a location quotient	1.87***		
	(3.57)		
More specialisation variables included	0.01		
	(0.03)		
Competition included	–0.69		0.12
	(–1.14)		(0.24)
Competition is measured in est. per employee		0.99	
		(1.54)	
Competition is measured in establishments		1.57	
		(1.32)	
More competition variables included		–2.54**	
		(–2.20)	
Diversity included	0.71**	1.24*	
	(2.60)	(1.69)	
Diversity estimated using largest five			2.58***
			(3.34)
More diversity variables included			3.65***
			(6.23)
Other data characteristics			
Population density (log)	0.43***	–0.07	0.004
	(2.99)	(–0.21)	(0.03)
Standardised mean year to which the data pertains#	0.62**	0.42	0.92***
	(2.57)	(0.95)	(3.43)
Length of period covered by the data (in years)	0.74***	0.29	–0.01
	(3.19)	(0.69)	(–0.04)
Data are from Asia	–2.60***	0.06	1.88**
	(–3.41)	(0.06)	(2.47)
Data are from the USA	0.21	–0.33	–0.51
	(0.51)	(–0.39)	(–1.30)
Presence of additional control variables			
Investments or capital stock also included	2.31***	–0.57	–1.15
	(3.21)	(–0.38)	(–1.32)
Educational variables included	–1.99***	1.33**	2.36***
	(–4.95)	(1.99)	(3.75)

Table 4 - continued

Wages or GDP also included	–0.51	–1.37*	0.001
	(–0.71)	(–1.96)	(0.00)
Geographical variables also included	–1.04**	–1.55	–0.29
	(–2.52)	(–1.63)	(–0.62)
Other study characteristics			
Estimated using panel data or similar	–1.31**	0.29	1.76**
	(–2.47)	(0.26)	(2.53)
Standardised year of publication#	0.32	–0.66	–0.17
	(1.36)	(–1.07)	(–0.72)
Limit point 1	–0.34	–1.03	–0.34
Limit point 2	0.49	–0.29	1.14
Limit point 3	0.89	0.57	2.49
Number of observations	162	79	152
Pseudo-R^2	0.26	0.22	0.40

Notes:

t-statistics are included in parentheses in the line below the estimate. Statistical significance is indicated with stars, where ***, ** and * reflect statistical significance at the 1, 5 and 10% level.

The variables are standardized in such a way that their mean is 0 and a value of +1 represents a value one standard deviation above the mean. For the mean year to which the data pertains, one standard deviation is 6.96; for the year of publication, it is 3.29.

Table 5a. Marginal effects Specialisation

	neg. sign.	neg. insign.	pos. insign.	pos. sign.
Data measure employment	–0.183*	–0.021	0.035*	0.169
	(–1.70)	(–0.65)	(1.75)	(1.43)
Data measure patents or innovations	0.090	–0.004	–0.020	–0.066
	(0.50)	(–0.22)	(–0.49)	(–0.54)
Data measure productivity	0.369	–0.070	–0.083	–0.215*
	(1.49)	(–0.77)	(–1.46)	(–1.94)
Data are for high-tech only	0.039	–0.001	–0.009	–0.029
	(0.24)	(–0.11)	(–0.24)	(–0.25)
Data include the service sector	–0.010	0.000	0.002	0.008
	(–0.23)	(0.02)	(0.23)	(0.23)
Competition included	0.256	–0.017	–0.056	–0.183
	(1.15)	(–0.47)	(–1.09)	(–1.26)
Diversity included	–0.272**	0.038	0.062**	0.172***
	(–2.57)	(1.05)	(2.11)	(3.10)
Specialisation as a location quotient	–0.510***	–0.141**	0.042	0.609***
	(–5.26)	(–2.25)	(1.38)	(3.91)
More specialisation variables included	–0.004	0.000	0.001	0.003
	(–0.03)	(0.00)	(0.03)	(0.03)
Population density (log)	–0.156***	0.000	0.034**	0.122***
	(–2.89)	(0.02)	(2.14)	(3.07)
Standardised mean year to which the data pertains	–0.225***	0.000	0.049**	0.176**
	(–2.65)	(0.02)	(2.05)	(2.45)
Length of period covered by the data (in years)	–0.271***	0.001	0.059**	0.212***
	(–3.24)	(0.02)	(2.35)	(2.96)
Data are from Asia	0.792***	–0.219***	–0.152***	–0.421***
	(7.16)	(–4.25)	(–4.10)	(–4.89)
Data are from the USA	–0.075	–0.002	0.016	0.061
	(–0.52)	(–0.21)	(0.52)	(0.5)
Investments or capital stock also included	–0.515***	–0.223***	–0.009	0.747***
	(–5.58)	(–3.50)	(–0.23)	(4.64)
Educational variables included	0.680***	–0.171***	–0.138***	–0.370***
	(7.18)	(–3.22)	(–3.73)	(–5.91)
Wages or GDP also included	0.198	–0.033	–0.046	–0.119
	(0.69)	(–0.36)	(–0.67)	(–0.93)
Geographical variables also included	0.391***	–0.064	–0.087**	–0.240***
	(2.62)	(–1.16)	(–2.36)	(–3.07)
Estimated using panel data or similar	0.485***	–0.157	–0.108***	–0.221***
	(3.02)	(–1.74)	(–2.76)	(–3.82)
Standardised year of publication	–0.117	0.000	0.025	0.091
	(–1.34)	(0.02)	(1.22)	(1.39)

Note: *t*-statistics are included in parentheses in the line below the estimate.

Table 5b. Marginal effects Competition

	neg. sign.	neg. insign.	pos. insign.	pos. sign.
Data measure employment	–0.075	–0.068	–0.012	0.155
	(–0.77)	(–0.71)	(–0.36)	(0.71)
Data measure patents or innovations	0.045	0.034	–0.002	–0.076
	(0.24)	(0.27)	(–0.08)	(–0.27)
Data measure productivity	0.275	0.096^{***}	–0.092	–0.280
	(0.72)	(2.76)	(–0.51)	(–1.32)
Data are for high-tech only	–0.079	–0.081	–0.027	0.187
	(–1.04)	(–0.88)	(–0.47)	(0.87)
Data include the service sector	0.008	0.007	0.000	–0.016
	(0.21)	(0.21)	(0.15)	(–0.21)
Specialisation included	0.223^{***}	0.242^{***}	0.184^{*}	-0.650^{***}
	(2.68)	(3.53)	(1.99)	(–3.64)
Diversity included	–0.337	-0.126^{***}	0.096	0.366^{**}
	(–1.32)	(–3.01)	(0.92)	(2.25)
Competition is measured in est. per empl.	–0.235	-0.129^{*}	0.041	0.323^{*}
	(–1.28)	(–1.98)	(0.56)	(1.85)
Competition is measured in establishments	-0.141^{**}	-0.203^{**}	–0.211	0.555^{*}
	(–2.48)	(–2.28)	(–1.14)	(1.88)
More competition variables included	0.718^{**}	0.074	-0.195^{***}	-0.597^{***}
	(2.42)	(0.65)	(–2.78)	(–3.76)
Population density (log)	0.014	0.012	0.001	–0.026
	(0.21)	(0.22)	(0.15)	(–0.21)
Standardised mean year to which the data pertains	–0.083	–0.069	–0.004	0.156
	(–0.95)	(–0.92)	(–0.22)	(0.97)
Length of period covered by the data (in years)	–0.057	–0.048	–0.003	0.108
	(–0.7)	(–0.67)	(–0.22)	(0.71)
Data are from Asia	–0.011	–0.009	–0.001	0.020
	(–0.06)	(–0.06)	(–0.04)	(0.06)
Data are from the USA	0.066	0.052	0.000	–0.118
	(0.37)	(0.41)	(0.03)	(–0.4)
Investments or capital stock also included	0.133	0.081	–0.022	–0.192
	(0.32)	(0.48)	(–0.17)	(–0.42)
Educational variables included	-0.161^{**}	-0.194^{**}	–0.140	0.495^{**}
	(–2.39)	(–2.44)	(–1.34)	(2.33)
Wages or GDP also included	0.402	0.105^{**}	–0.137	-0.370^{***}
	(1.61)	(2.01)	(–1.22)	(–2.92)
Geographical variables also included	0.481	0.078	–0.179	-0.380^{***}
	(1.39)	(0.82)	(–1.13)	(–3.12)
Estimated using panel data or similar	–0.049	–0.049	–0.014	0.112
	(–0.31)	(–0.25)	(–0.14)	(0.25)
Standardised year of publication	0.128	0.108	0.007	–0.243
	(1.02)	(1.06)	(0.21)	(–1.08)

Note: *t*-statistics are included in parentheses in the line below the estimate.

Table 5c. Marginal effects Diversity

	neg. sign.	neg. insign.	pos. insign.	pos. sign.
Data measure employment	–0.013	–0.192***	–0.267***	0.471***
	(–1.61)	(–3.54)	(–2.83)	(3.72)
Data measure patents or innovations	–0.009	–0.134**	–0.153	0.295**
	(–1.42)	(–2.45)	(–1.55)	(2.01)
Data measure productivity	0.031	0.226	0.037	–0.293
	(0.74)	(1.27)	(0.54)	(–1.79)
Data are for high-tech only	–0.007	–0.133***	–0.120**	0.338***
	(–1.60)	(–3.37)	(–2.39)	(3.18)
Data include the service sector	0.001	0.012	0.009	–0.023
	(0.62)	(0.65)	(0.63)	(–0.65)
Specialisation included	0.007	0.117**	0.149	–0.273
	(1.54)	(2.03)	(1.10)	(–1.44)
Competition included	–0.002	–0.026	–0.020	0.048
	(–0.24)	(–0.24)	(–0.23)	(0.23)
Diversity estimated using largest five	–0.009	–0.184***	–0.476***	0.670***
	(–1.58)	(–4.42)	(–6.50)	(9.47)
More diversity variables included	–0.078**	–0.447***	–0.385***	0.909***
	(–2.19)	(–7.04)	(–6.51)	(19.87)
Population density (log)	–0.000	–0.001	–0.001	0.001
	(–0.03)	(–0.03)	(–0.03)	(0.03)
Standardised mean year to which the data pertains	–0.014*	–0.193***	–0.145**	0.352***
	(–1.71)	(–2.92)	(–2.53)	(3.55)
Length of period covered by the data (in years)	0.000	0.003	0.002	–0.005
	(0.04)	(0.04)	(0.04)	(–0.04)
Data are from Asia	–0.016*	–0.234***	–0.390***	0.639***
	(–1.86)	(–3.59)	(–2.97)	(3.65)
Data are from the USA	0.011	0.117	0.059	–0.186
	(0.87)	(1.22)	(1.47)	(–1.37)
Investments or capital stock also included	0.061	0.308	–0.031	–0.338**
	(0.64)	(1.32)	(–0.19)	(–1.98)
Educational variables included	–0.036*	–0.335***	–0.387***	0.757***
	(–1.66)	(–4.54)	(–4.97)	(6.33)
Wages or GDP also included	–0.000	–0.000	–0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Geographical variables also included	0.005	0.064	0.037	–0.106
	(0.52)	(0.58)	(0.80)	(–0.65)
Estimated using panel data or similar	–0.008	–0.162***	–0.401***	0.571***
	(–1.57)	(–4.21)	(–3.52)	(5.06)
Standardised year of publication	0.003	0.037	0.027	–0.067
	(0.76)	(0.72)	(0.71)	(–0.73)

Note: *t*-statistics are included in parentheses in the line below the estimate.