Endogenous regional growth: a critical survey

Mark Roberts (*Centre for Economic and Public Policy*, University of Cambridge, UK)
and **Mark Setterfield,** (Trinity College, Hartford, USA)

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Abstract: This paper provides a critical survey of the now burgeoning literature on the spatial application of endogenous growth theory. Attention is paid both to the (mainly North American) "new economics of urban and regional growth" literature, and to European literature that has focused on questions of convergence and the estimation of the Verdoorn law. The paper then identifies potentially fruitful new directions for research for those interested in the nature of spatial growth processes.

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JEL codes: O18, O30, R11

Introduction

An important stylised fact of capitalist growth and development is large and persistent differences in per capita income growth between regions. Theoretical and empirical analysis of the regional growth process has a history stretching back over more than fifty years, with neoclassical approaches dating back to Borts and Stein (1964) and an emphasis on increasing returns at the regional level going back to Kaldor (1970) and even Marshall (1890). However, traditionally, the subject has been rather marginal to the mainstream of economics. This has begun to change in the last 15 years though, with the mid-1980s renaissance of interest in growth theory sparking a related rise of interest in regional and urban growth processes. In this context, Glaeser (2000) identifies the emergence of a "new economics of urban and regional growth", which has been especially influenced by the work of Romer (1986, 1990) and the realisation that cities provide the most natural environment in which to look for evidence of the knowledge spillovers so emphasised by endogenous growth theory (Lucas, 1988).[1]

The "new economics" literature has mainly been a North American literature, having primarily involved North American academics and/or focused on US regional growth. By contrast, rising interest amongst European researchers in regional growth processes has come from a different angle. In particular, aided by the development of *Eurostat*'s REGIO database[2] and stimulated by deepening European integration, European researchers have been quick to apply advances in spatial econometrics to the analysis of regional growth disparities in the EU. However, the focus has typically been at a higher level of spatial aggregation than in the US-based "new economics" literature. Hence, the focus has been less on cities or metropolitan areas and more on broadly defined administrative regions. Nevertheless, both the North American and European literatures share the feature of being mainly empirically

[1] Endogenous growth theory is associated here with neoclassical endogenous growth theory in the sense that the emphasis is on the supply-side determinants of growth. However, association of the concept of endogenous growth with supply-side macroeconomics does not automatically follow. Hence the origins of the concept of endogenous growth can be contested (Roberts and Setterfield, 2007) whilst, more importantly, there exist Keynesian as well as neoclassical endogenous growth models. The penultimate section of this paper returns to the issue of the existence of both Keynesian and neoclassical endogenous growth models.
[2] Also important in this context has been *Cambridge Econometrics'* extension of the REGIO database, which has been used as the basis for much empirical work (see http://www.camecon.com/services/europe/research2.htm).

driven. Only more recently have there been explicit theoretical attempts to incorporate geographic space into growth models to create *geographical or spatial models of endogenous growth* (Martin and Ottaviano, 1999).

Despite the paucity of explicit spatial models, endogenous growth theory as applied to the urban and regional levels is already having a substantial policy influence. This is exemplified by the UK's "new regional policy" which, partly inspired by endogenous growth theory, has identified five key drivers of local productivity growth- skills, investment, innovation, enterprise and competition (HM Treasury, 2001). Moreover, there is an (often implicit) presumption in regional development circles that Universities and other research institutions can act as catalysts for localised growth. This proposition is consistent with the "new economics" argument that knowledge spillovers are geographically bounded and that, by driving productivity growth, they also drive regional growth.

Given the above, this paper provides a critical survey of literature relating to the spatial application of endogenous growth theory. Both the North American and European literatures that have come into being over the last 15 years are discussed.[3] By necessity, the paper abstracts from much of the research on regional growth that has been done by geographers and other social scientists.[4] Furthermore, even within the domain of the economics literature, the survey is necessarily selective, focusing on work and issues that the authors consider to be of greatest importance.

The paper is organised as follows. First, important issues of measurement and definition are briefly discussed. Second, data for the EU is used to provide an indication as to the existing scale of regional disparities in prosperity and growth. Third, the theoretical literature on endogenous growth is examined, with particular attention paid to arguments that have been used to link endogenous growth theory to the urban and regional levels. Fourth, consideration is given to empirical work on regional growth disparities. This includes a critical examination of both the North American "new economics" literature and the

[3] In so doing, the paper leaves to one side a number of interesting contributions focusing on developing countries (see, for example, Deichmann *et al*, 2005).
[4] For a survey of work by geographers see Sheppard (2000).

European spatial econometrics literature. Fifth, the paper identifies remaining theoretical and empirical shortcomings with the spatial application of endogenous growth theory. In so doing, it suggests gaps in the literature which, in the opinion of the authors, future work should address. Finally, the paper is brought to an end with some concluding remarks.

On the Metric of Regional Growth and Definition of the Region

Before endogenous growth theory can be considered, an obvious and fundamental question that must be addressed is that of the relevant metric of regional growth. At the regional level, where factor mobility is high, it has been traditional since Alonso (1964) to argue that capital and labour will move until a spatial equilibrium is reached. In this equilibrium, utility levels across homogenous agents will be equalised. *Ceteris paribus*, this will tend to make for the spatial equality of wages and profits, not to mention the spatial equality of productivity levels at the margin. In light of this, it has been argued that the relevant metric of growth at the regional or urban level is provided by *employment* or *population* growth rather than income/output per capita or productivity growth. In particular, this argument has been characteristic of the North American "new economics" literature (see, in particular, Glaeser *et al*, 1992; Glaeser, 2000).

But traditionally, levels of labour mobility have been much lower in Europe than in the United States (Cheshire and Magrini, 2005, p 1). Consequently, empirical research on EU regional growth has overwhelmingly focused on output, income and productivity based measures of growth (see, *inter alia*, Cheshire and Magrini, 2005; Fingleton and McCombie, 1998; Le Gallo and Dall'erba, 2005). Even in the US context, it has been acknowledged that output, income and productivity based measures of growth might, under certain circumstances, provide information on localised sources of productivity – for example, if workers need to buy land to live or, if congestion effects make crowded locations less pleasant (Glaeser, 2000, p 86).[5, 6]

[5] The argument that congestion will lead to the bidding-up of factor prices has been used as the basis for a notable test by Rauch (1993) for human capital knowledge spillovers in US metropolitan area data. This study is examined in more detail later in the paper.

Having considered the question of the relevant metric of regional growth, the next question is that of how to define the region. Obviously, the answer partly depends upon the precise research question that is being addressed. Thus it might seem more obvious to look for evidence of the knowledge spillovers emphasised by endogenous growth theory in more tightly defined regional areas that correspond to individual cities.[7] This has been the practice of much of the "new economics" literature, which has made extensive use of plentiful data at the Standard Metropolitan Statistical Area (SMSA) level (see, for example, Beardsell and Henderson, 1999; Glaeser *et al*, 1992; Jaffe *et al*, 1993; Rauch, 1993). These regions have the advantage of corresponding to an analytical/functional definition of the region, representing relatively self-contained zones of economic activity.

By contrast, studies of European regional growth have typically utilised NUTS definitions of regions.[8] This is hardly surprising given that the NUTS classification was constructed by *Eurostat* to provide harmonised social and economic indicators across European regions. However, unlike US SMSAs, NUTS regions are defined according to *normative* rather than analytical criteria (corresponding to institutional/administrative boundaries) and therefore represent a less satisfactory definition of the region for the purposes of analysing regional growth.[9] Given the problems with the NUTS classification, a small number of studies on European regional growth have preferred to make use of data on functionally defined economic regions (Cheshire and Carbonaro, 1995, 1996; Cheshire and Magrini, 2005; Magrini, 1998, 1999). However, data on such regions is not publicly available, so it is likely that the majority of future European regional growth studies will continue to make use of the

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[6] More fundamentally, it might be argued that, even for the US, the argument that the appropriate metric of regional growth is provided by employment or population growth is theoretically contestable on the grounds that it presupposes a neoclassical (supply-side) view of the world. Thus, the argument that the choice of metric is influenced by the degree of spatial mobility of factors of production implies acceptance of the notion that the availability and productivity of factors are the key drivers of growth. However, what of the possibility that growth is instead driven by aggregate demand under circumstances in which geographical confinement of such growth is possible? Again, we return to this issue of "Keynesian" versus "neoclassical" regional growth in the penultimate section.

[7] This is so for theoretical reasons that will be elaborated on in the section on the "The regional application of endogenous growth theory."

[8] NUTS is an acronym for Nomenclature of Units of Territorial Statistics. For details of the definition of the NUTS regions see http://europa.eu.int/comm/eurostat/ramon/nuts/basicnuts_regions_en.html.

[9] See Magrini (1998, chapter 3) for discussion of the difficulties posed by NUTS regions for the empirical analysis of regional growth.

NUTS classification. This being the case, there needs to be awareness of the problems associated with the classification, and attempts should be made to test and control for problems of measurement error.[10]

The scale of regional disparities in growth and prosperity[11]

Whilst being cognisant of the problems with the NUTS classification mentioned above, it is nevertheless useful to examine data from the REGIO database to form a broad impression of the scale of regional disparities in both growth rates and levels of prosperity. In particular, starting with the latter, Table A1 in the appendix makes use of data from *Cambridge Econometrics*' European Regional Database, which builds upon the REGIO database, to rank 210 NUTS2 regions according to their levels of Gross Value Added (GVA) per capita in 2002.[12, 13] The table is split-up according to which quartile of the distribution a region belongs to, with Table 1 providing some useful summary statistics. Thus, from this table, it is clear that the disparity between the richest NUTS2 region in 2002 and the poorest was extremely large, with Inner London in the UK having a level of GVA per capita 4.7 times as great as Ipeiros in Greece. Furthermore, more generally, it can be seen that the average level of GVA per capita for the regions belonging to the first quartile of the distribution was 37% above the overall NUTS2 average, whilst the average level for the regions belonging to the fourth quartile was 30% below.

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[10] Roberts (2004), for example, attempts to control for similar problems in the context of data on the UK counties. This he does by employing instrumental variable techniques such as Durbin's ranking method and paying careful attention to outliers. Additionally, where appropriate, researchers might consider orthogonal regression methods (on which, see Malinvaud, 1980).

[11] The focus in this section is on NUTS2 regions within Europe. However, focusing upon either regions within Europe at a different level of spatial aggregation (for example, NUTS1 or NUTS3) or regions within the United States would have provided similar impressions of large disparities.

[12] Included in the table are all regions for which *Cambridge Econometrics* provides data for both 1980 and 2002. These regions belong to the EU-15 countries and, therefore, exclude regions from the latest wave of member countries. Also included are the regions of Switzerland, although Switzerland is only a member of the European Economic Area and not the EU. Note, finally, that a limited number of NUTS1 regions have also been included in the table. In particular, NUTS1 regions which have no constituent NUTS2 regions have been included.

[13] All levels of GVA per capita reported have been normalised by dividing through by the mean level of GVA per capita for the sample. Levels have been calculated using 1995 Purchasing Power Standard (PPS) exchange rates.

Table 1: levels of GVA per capita (1995 PPS) for the European NUTS2 regions, 1980 and 2002		
	2002	**1980**
Highest Lowest	Inner London, UK (249) Ipeiros, GR (53)	Bruxelles-Brussels, BE (239) Acores, PT (36)
1st quartile mean	137	132
2nd quartile mean	103	103
3rd quartile mean	89	92
4th quartile mean	70	74
Interquartile ratio	1.37	1.41
Coefficient of variation	0.28	0.32

Important to note is that these large disparities in prosperity were not confined to regions belonging to different countries. Hence, large disparities also existed *within* many individual EU countries. From Table A1 it can therefore be seen that the least prosperous region in the UK (the Highlands and Islands of Scotland) had a level of GVA per capita that was 34% below the overall average, implying that the ratio of GVA per capita in the richest region in the country (Inner London) to the poorest was 3.78. Although not quite so marked, large disparities between the richest and poorest regions also existed for Belgium (ratio of richest to poorest = 2.86), Germany (2.35), Norway (2.16), France (2.14), Italy (2.11), Austria (2.10) and Spain (2.02). For the remaining countries, the disparities were smaller (ratio of richest to poorest < 2), but, with the possible exception of Denmark, still significant.[14] Moreover, with the exceptions of Denmark and Switzerland on the one hand and Greece and Portugal on the other, all countries in the sample had regions in both the top *and* bottom halves of the distribution of GVA per capita levels.[15]

As can be seen from Table 1, the large disparities in prosperity that existed in 2002, were also evident in 1980. In fact, in terms of the gap between the richest and the poorest regions, the disparity increased. However, more generally, there seems to have been a small decline in dispersion between 1980 and 2002 as measured by both the interquartile ratio and the coefficient of variation. From Table 2, this was caused by regions in lower quartiles of the 1980 distribution growing, on average, faster over the full sample-period. Nevertheless, it remains the case that, overall, large interregional disparities in levels of prosperity have been

[14] The ratios for these remaining countries were as follows: Switzerland (1.79), Sweden (1.69), Portugal (1.68), Greece (1.64), Finland (1.62), Netherlands (1.58), Ireland (1.57), Denmark (1.31).

[15] In the cases of Denmark and Switzerland, all regions had levels of GVA per capita in the top half of the distribution, whilst, in the cases of Greece and Portugal, all regions had levels in the bottom half.

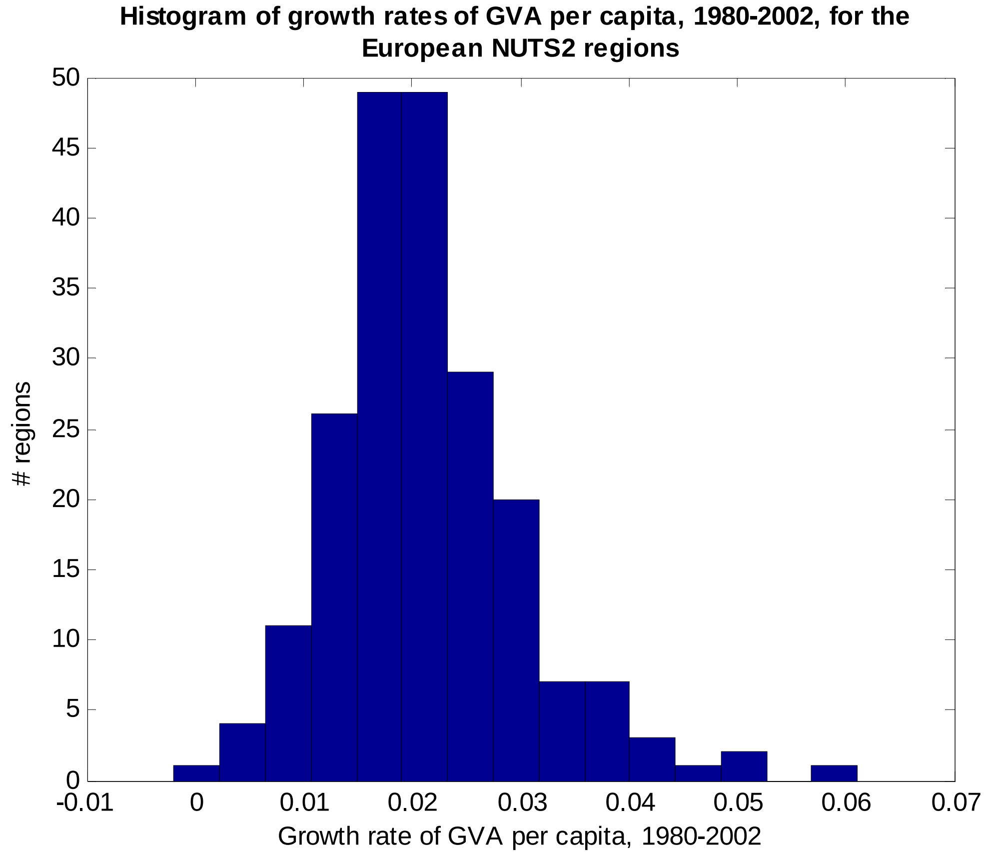
a notable and persistent feature of Europe's economic landscape over the last quarter of a century.

Table 2: growth rates of GVA per capita (1995 PPS) for the European NUTS2 regions, 1980-2002 and 1980-1990			
	1980 mean GVA per capita	Growth rate	
		1980-2002	1980-1990
1st quartile	132	1.75%	1.75%
2nd quartile	103	1.99%	1.96%
3rd quartile	92	2.14%	2.18%
4th quartile	74	2.62%	2.39%

Turning to the scale of interregional growth rate disparities, Figure 1 provides a histogram of average growth rates of GVA per capita between 1980 and 2002. From this, it can be seen that, although a large number of the NUTS2 regions grew at a rate close to the overall average of 2.13% per annum, there were large discrepancies between the fastest and slowest growing regions. Thus, at the top of the distribution, a total of 14 regions recorded growth rates in excess of 3.5% per anuum with the fastest growing region (Southern and Eastern Ireland) displaying an average annualised growth rate of 6.11%. By contrast, at the bottom of the distribution, 14 regions grew at less than 1% per annum with three of these regions (Sterea Ellada in Greece, the Highlands and Islands of Scotland, and Groningen in the Netherlands) exhibiting negligible growth.[16]

To bring home just how large the above disparities are, it is worth remarking, that whilst a growth rate of 6.11% per annum will cause GVA per capita to double in just over 11 years and a growth rate of 3.5% per annum will cause it to double in just under 20 years, a growth rate of 1% implies that it will take almost 70 years for GVA per capita to double. It is also worth remarking that, just as with levels of prosperity, large variations in growth rates also existed between regions within individual EU countries. As an example, whilst Stockholm in Sweden grew at an average annual rate of 3.84%, the region of Mellersta Norrland in the same country grew at an average annual rate of just 0.63% per annum.

[16] The finding of negligible growth for Groningen, however, needs to be treated with caution. This is because, in the NUTS classification, all income created by the Dutch North Sea oil industry is attributed to this region (Magrini, 1998, chapter 3).



Endogenous growth theory and its regional application

Endogenous growth theory

Although the *idea* of endogenous growth is not new (Roberts and Setterfield, 2007), endogenous growth as a mainstream theoretical concept dates back only to the mid-1980s. In particular, modern endogenous growth theory has its origins in the work of Paul Romer (Romer, 1983, 1986, 1990). Since then, important contributions to the literature have been made by, *inter alia*, Aghion and Howitt (1998), Grossman and Helpman (1991), and Lucas (1988).

The endogenous growth literature departs from traditional neoclassical growth theory (Solow, 1956; Swan, 1956) through its emphasis on the modelling of the creation and accumulation of *knowledge*. This is not to say that knowledge is not present in the Solow-Swan model; just that there is no explicit theory of the knowledge accumulation process. Knowledge is implicitly treated as a pure public good in Solow-Swan. Consequently, in contrast to endogenous growth theory, there can be no localised knowledge accumulation.

It is the endogenisation of knowledge creation and accumulation that, in part, explains the label "endogenous growth theory". However, there is also another, related, reason for this label. The endogenisation of knowledge creation and accumulation generates (either directly or indirectly) increasing returns to scale that render the equilibrium (steady-state) growth rate dependent on technological and preference parameters. Hence, growth is endogenous in the sense that it is not pre-determined by an exogenous driving force.[17]

Endogenous growth models differ from one other in the precise mechanisms for knowledge creation and accumulation they describe. In the original model of Romer (1986), the mechanism is indirect: knowledge accumulation is an *accidental byproduct* of the investment decisions of individual firms. Capital accumulation indirectly generates intra-firm knowledge accumulation through learning-by-doing, and the knowledge so-acquired *spills over* to other firms (so that, in the aggregate, knowledge remains a public good). Increasing returns thus arise from knowledge spillovers, which constitute a type of positive externality. The spillover mechanism reconciles endogenous growth with perfect competition, although the resulting equilibrium growth rate is suboptimal. This, in turn, justifies government intervention to encourage capital accumulation.[18]

In contrast, later endogenous growth models posit more direct mechanisms of knowledge creation and accumulation (Aghion and Howitt, 1998; Grossman and Helpman, 1991; Romer, 1990). Although these models differ in their details, they all portray knowledge accumulation as the *intentional* outcome of decisions to invest in research and development (R&D). Thus knowledge ceases to be a pure public good because, in order for firms to have the incentive to

[17] More recently, this second sense in which growth is endogenous in mainstream endogenous growth models has been challenged (Jones, 1995, 2002; Mankiw *et al.*, 1992). In particular, it has been claimed that such growth is crucially dependent on a knife-edge assumption and predictions of "scale effects" that are not observed internationally. This has led to the emergence of "semi-endogenous" growth models. Crucially from the current viewpoint however, these models share the same basic mechanisms for endogenous knowledge creation and accumulation as their "fully endogenous" counterparts.

[18] Important aspects of the Romer (1986) model were anticipated by Arrow (1962).

invest in R&D in the first place, knowledge must be, at least partially, *excludable*. The resulting monopoly control enables firms to earn abnormal profits which justify the cost (Romer, 1990) and risk (Aghion and Howitt, 1998) of their R&D. Clearly, in these models, endogenous growth presupposes imperfect competition.[19]

However, although firms in these later models can exclude others from directly copying their ideas, knowledge spillovers still occur. Thus, spillovers are posited in research activities: whilst intellectual property rights deter the outright theft of ideas, nothing prevents a firm from building on ideas implicit in existing goods or the accumulated stock of public knowledge. This gives rise to either *horizontal innovation*, whereby the existing stock of knowledge acts as an input into entirely new product varieties (as in Romer, 1990), or *vertical innovation*, whereby rival firms compete to improve the quality of existing product lines (as in Aghion and Howitt, 1998; Grossman and Helpman, 1991).[20] In the former case, knowledge spillovers are predominantly *cross-industry* in nature[21], whilst, in the latter case, they are mainly *within-industry* in character. Note also the Schumpeterian nature of growth in the latter case, where monopoly profits earned by the incumbent firm stimulate market entry and hence the introduction of improved versions of the same product. The knowledge creation process is therefore characterised by "creative destruction", resulting in a business stealing effect.[22]

By focusing on intentional, profit motivated, knowledge creation and accumulation, later models of endogenous growth highlight the importance of *human capital* in the growth process. Specifically, these models treat human capital as a key input into the knowledge creation process – a pre-requisite for transforming a society's existing stock of knowledge into a continuous flow of new knowledge. Furthermore, the higher is the level of human capital, the more effective will the transformation process be, the faster will be the rate of new knowledge creation and the higher will be the equilibrium growth rate. Note that by

[19] In particular, competition in the intermediate goods sector is assumed to be monopolistic, typically being modelled in the Dixit-Stiglitz (1977) manner.
[20] There also exist endogenous growth models that combine vertical and horizontal innovation (see, for example, Young, 1998; Won-Li, 2000).
[21] This is reminiscent of Jacobs (1969)-style knowledge spillovers.
[22] This business stealing effect acts as a negative externality, offsetting the positive externality resulting from within-industry knowledge spillovers.

focusing on individuals involved in the knowledge creation process, the emphasis is not so much on an economy's *average* level of human capital, but on the availability of highly trained specialists.

Notice also that the treatment of human capital described above means that knowledge is embodied in the existing stock of goods and services that incorporate ideas arising from previous knowledge creation activities (see also Magrini, 1998, p 44).[23] By contrast, the earlier Lucas (1988) model sees knowledge as being embodied within human capital itself, so that knowledge spillovers are dependent on *direct human interaction*. This being the case, encouraging human capital accumulation provides not just an indirect spur to growth (as in R&D-based models), but also a much more direct stimulus. Knowledge creation goes hand-in-hand with human capital accumulation (in fact, the two are basically indistinguishable), so facilitating the latter directly facilitates the former.

The regional application of endogenous growth theory

Given his treatment of the knowledge creation and accumulation processes, it is hardly surprising that the link from mainstream endogenous growth theory to the "new economics of urban and regional growth" starts with Lucas (1988) and his emphasis on the importance of direct human interaction. Simply put, direct human interaction requires proximity, meaning that knowledge spillovers are most likely to occur at a local level. This leads to the contention that cities provide the most obvious locus of such spillovers (Lucas, 1988, pp 38-39). Since Lucas, authors working in the "new economics" have elaborated upon the point that proximity facilitates knowledge spillovers by emphasising that knowledge is conceptually distinct from information (Feldman and Audretsch, 1999, p 411). Thus, whilst *information* can be transmitted at a cost which is invariant to distance, *knowledge* can adopt a "sticky" character that prevents its easy codification and renders it largely tacit in nature. This is particularly the case when knowledge is of a highly contextual and uncertain nature, as is likely to be the case at the forefront of any knowledge creation process. Citing Von Hipple

[23] Strictly speaking, in the Romer (1990) model, the stock of knowledge is embodied in a set of blueprints for the production of intermediate goods. These blueprints subsequently act as inputs to the production of new final goods.

(1994), Feldman and Audretsch (1999, p 411) state that such knowledge "is best transmitted via face-to-face interaction and through frequent contact." Consequently, it is "talk" and, in particular, the "quality of talk" (i.e. its relevance to productive knowledge creation) that matters.[24, 25] In this context, individuals can be imagined as supplementing their knowledge and human capital through "chance" pairwise meetings at which ideas are exchanged (Jovanovic and Rob, 1989). Obviously, the higher is the average level of human capital, the greater is the expected probability that a "chance" meeting results in an improvement in an individual's knowledge and human capital (Rauch, 1993, p 381). Furthermore, it might be imagined that, in meeting and discussing, individuals not only transmit knowledge (thereby leading to a spillover), but also *alter*, and, therefore, *create*, knowledge.

Whilst the above discussion fits most neatly with Lucas's treatment of knowledge, it has also been argued within the "new economics" that proximity "enables workers to acquire human capital by imitating a rich array of role models and learning by seeing" (Glaeser, 2000, p 85). This implies that, even if the link from human capital to economic growth is only indirect, in the sense that human capital is merely an input into the creation of either embodied (e.g. in the quality of final goods) or disembodied knowledge, the local (urban and regional) dimension remains important in the knowledge creation and accumulation processes.[26]

[24] Not all "new economics" authors have been so careful in making the distinction between knowledge and information (see, most notably, Glaeser, 1994).

[25] This is consistent with work by the economic historians Simon and Nardinelli (1996) on the growth of English and Welsh cities over the late 19th and 20th centuries. Thus, drawing inspiration from endogenous growth theory, they state that "People in cities talk; the talk leads to the creation of knowledge. Cities where the "talk is good, "meaning that it carries useful information, grow more rapidly than cities where the talk is mostly noise." (p 385, footnote excluded). In this context, Simon and Nardinelli associate high-quality talk with information-oriented professionals such as brokers, accountants and lawyers. Regressing city population growth on the initial share of employment accounted for by such professions and various control variables, they find a strong positive relationship that is consistent with the "talk is good" hypothesis.

[26] Not only might imitation by individuals be important, but so, too, might imitation by firms. Thus, there is an interesting related literature on general-purpose technologies (GPTs) where a GPT is a new technological paradigm that has the potential to affect the entire economic and social system (Aghion and Williamson, 1999). When a new GPT is introduced to an economy, however, it is unclear what the best application of the GPT is. This being the case, firms look for examples of other firms that have successfully implemented the technology. In other words, they look for a "role model" firm from which they might be able to acquire a knowledge spillover by observation. It is easy to imagine this process having a local dimension, so that successful adoption of the GPT takes-off in a single or small number of regions in the first instance, leading to a temporary period of very fast growth in these regions.

Of course, imitation works both ways and can represent a double-edged sword for urban regions. Thus, "a rich array of role models" may include not only individuals with high levels of human capital who contribute to localised knowledge accumulation, but also individuals with little in the way of formal qualifications who engage in activity (e.g. crime) that only serves to redistribute and/or destroy existing economic activity. As such, history is likely to matter in the determination of regional growth processes and it is easy to imagine the operation of processes of "circular and cumulative causation" akin to those discussed by Myrdal (1957).

In sum, endogenous growth theory's potential role in explaining urban and regional growth disparities comes from the hypothesis that knowledge spillovers are geographically bounded because of their embodiment in human capital and/or because human capital accumulation itself has a regional dynamic (the role model effect). Thus, fast growing regions are predicted to be those in which the conditions for knowledge creation, accumulation and transmission are ripe. This means that the local entry cost into knowledge creating activities will be important, and variations in such costs will lead to interregional growth rate differences.[27] Likewise, variations in the local supply of inputs into knowledge production – such as the availability of human capital, and activities and institutions (universities and colleges, for example) that promote its acquisition – will be important in explaining interregional growth differences. The internal spatial structure of a region will also affect growth. Thus, to the extent that the spatial configuration of a city or region impedes human interactions that facilitate good-quality talk, growth will suffer. Consequently, the nature of a city's built environment will matter for growth, as will the degree of segregation between groups characterised by high and low levels of human capital.[28] Meanwhile, in a more broadly defined region that consists of multiple cities, it is possible that the distance between cities

[27] In the Romer (1990) model, for example, a reduced fixed cost of R&D stimulates entry into research activities, which, in turn, increases the equilibrium growth rate.

[28] The effect of the degree of segregation on knowledge spillovers and human capital accumulation could potentially be negative or positive. Thus, imagine increased segregation between a group possessing high levels of human capital and a group possessing low levels. On the one hand, the individuals in the low human capital group would get less chance to interact with individuals in the high human capital group, thereby providing a potential absence of access to positive role models. On the other, individuals in the high human capital group would have a greater tendency to interact with each other, which might better promote good quality talk and thus facilitate knowledge spillovers.

and the quality of transportation links between them will be important,[29] since these factors will impinge upon the ability of individuals in different cities to engage in face-to-face interaction.

It is important to note, however, that the links between endogenous growth theory and regional analysis discussed above are not links that have typically been explicitly modelled.[30] Thus, although “new economics” authors have been quick to draw such links, this is typically done in a discursive rather than analytical manner. As discussed below, this has led to a rather loose correspondence between ideas in endogenous growth theory and their representation in empirical work on urban and regional growth. It is also clear that there is some inconsistency between the “new economics” and the theoretical endogenous growth models on which it purports to build. For example, consider the way in which the geographical bounding of knowledge spillovers is invariably explained by the need for direct human contact. This is consistent with the Lucas (1988) treatment of knowledge, but not with that found in the R&D-based models of endogenous growth of Romer *et al*. The literature would therefore benefit from more theoretical work – in particular, theoretical work focusing on the explicit incorporation of space into endogenous growth models and which pays attention to the geographical mechanisms by which knowledge spillovers occur.[31, 32]

The regional application of endogenous growth theory: empirics

Empirical work associated with the "new economics of urban and regional growth"

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[29] In this context, it may be hypothesised that significant non-linearities exist in terms of the impact of infrastructure projects to improve transportation links. Thus, for example, whilst initial improvements from a low base might yield increasing returns, improvements to an already highly developed transport system might only result in decreasing returns.

[30] An exception is provided by Magrini (1998, chapters 5 and 6).

[31] Further reasons for the need for more theoretical work are highlighted later in the paper.

[32] As mentioned previously, there has been some theoretical work in this direction in the form of the explicit development of geographical or spatial models of endogenous growth (Martin and Ottaviano, 1999). In particular, these models look to combine the treatment of space provided by the "new economic geography" literature of, *inter alia*, Fujita, Krugman and Venables (1999) with endogenous growth mechanisms. However, the treatment of space in these models is very simple, whilst the geographical bounding of knowledge spillovers is assumed rather than explicitly modelled.

The "new economics of urban and regional growth" claims endogenous growth theory as its inspiration, but is primarily an empirical literature led by North American researchers. The first seminal article in this literature is Glaeser *et al* (1992). Three different "theories" of endogenous regional growth are identified and tested for a sample of 1016 city-industries using SMSA data, with regional growth measured by employment growth.[33] Given that all three theories concern different types of knowledge spillovers and emphasise human interaction as the mechanism for knowledge spillovers, the use of such data seems entirely appropriate. Thus, not only are SMSAs analytically/functionally defined regions, but they constitute a meaningful level of spatial aggregation at which to look for knowledge spillovers. The three "theories" tested are characterised by Glaeser *et al* as: (1) the Marshall-Arrow-Romer (MAR) theory, (2) the Porter theory, and (3) the Jacobs theory. In the MAR theory, knowledge spillovers are assumed to occur *within* industries through several different mechanisms. These include employees in different firms talking with each other, inter-firm labour mobility, and employees leaving established firms and using their acquired expertise to start-up independently. Consequently, a high degree of specialisation is predicted to be good for a region's growth, while competition is predicted to be bad. This is because increased competition reduces the ability of firms to appropriate knowledge spillovers, therefore reducing the incentive to invest in activities that are, directly or indirectly, related to knowledge creation.

The Porter theory, like the MAR theory, predicts that specialisation is good for regional growth, because of within-industry knowledge spillovers. But unlike the MAR theory, competition is also predicted to be good. Hence although competition reduces the returns to knowledge creation, "it also increases pressure to innovate: firms that do not advance technologically are bankrupted by their innovating competitors" (Glaeser *et al*, 1992, p 1131). This positive ‘stick’ effect of increased competition is taken to outweigh the negative ‘carrot’ effect.[34]

[33] This is for reasons discussed earlier.
[34] The Porter theory is attributed by Glaeser *et al* to Michael Porter (in particular, Porter, 1990).

Finally, the Jacobs theory is associated by Glaeser *et al* with the work of Jane Jacobs (in particular, Jacobs, 1969). It differs from both the MAR and Porter theories by assuming that knowledge spillovers are of the *cross*-industry variety. Particularly important is the cross-fertilisation of ideas between different industries, meaning that diversification of industry within a region is predicted to be good for growth. The Jacobs theory also shares with the Porter theory the notion that local competition is good for growth.

The link between formal endogenous growth theory and the three stylised theories of growth presented by Glaeser *et al* (1992) is loose, which is in keeping with the empirical orientation of the "new economics" literature. Thus, whilst the MAR theory is clearly meant to apply Romer's (1986) model to the regions, there are no formal equivalents of the Porter and Jacobs theories in endogenous growth theory – although elements of both can be found. Hence Jacobs's idea that spillovers are of the cross-industry variety seems consistent with the notion of horizontal innovation found in some R&D-based models (notably, Romer, 1990). Meanwhile, the Jacobs-Porter idea that competition is good for regional growth is consistent with the modelling of the competition-growth nexus in neo-Schumpeterian models (see, for example, Aghion and Howitt, 1998, chapter 7).

Moreover, the questions asked by Glaeser *et al* are clearly important for improving our understanding of the regional growth process. In particular, whether it is specialisation or diversification that enhances regional growth, and whether or not competition boosts regional growth clearly matters for both the theoretical modelling of knowledge spillovers and for policymaking. Given this, it is interesting that Glaeser *et al*'s results come out decisively in favour of the Jacobs theory. Thus, conditional upon a number of control variables[35], both Glaeser *et al*'s diversity and competition measures are found to have a significant positive influence on SMSA employment growth, whilst their specialisation measure is found to have a significant negative effect. However, it is important to beware Glaeser *et al*'s warning that their results should not be taken out of context. Thus, given their sample period of 1956-1987, they state that "we are looking at a particular period of US history in which traditional

[35] Namely, the 1956 log city-industry wage, the 1956 log city-industry employment level, national employment growth in an industry and a dummy variable for Southern city-industries.

manufacturing industries have fared poorly because of import competition." (Glaeser *et al*, 1992, p 1151). They further note that their sample is limited to "very mature cities" in the US (p 1151), meaning that the authors have little to say about the growth of small city-industries (Glaeser, 1994, p 16). We might add that Glaeser *et al*'s study focuses on industries that were highly concentrated in the 1950s: for any given city, they only include an industry in their sample if it was one of the six largest (see also Henderson *et al*, 1995, fn. 3, p 1076).

The nature of their sample might explain why subsequent literature on the importance of diversification versus specialisation for regional growth has produced mixed support for Glaeser *et al*'s findings.[36, 37] Thus, whilst both Feldman and Audretsch's (1999) and Van Stel and Nieuwenhuijsen's (2004) results are similar to those of Glaeser *et al*, Beardsell and Henderson (1999) and Henderson *et al* (1995) find that it is specialisation rather than diversity that is good for regional growth.[38] However, the sole focus of Beardsell and Henderson (1999) is the spatial evolution of the computer industry at the MSA level between 1977 and 1992. Hence, whilst their findings are clearly relevant to thinking about the future of regional growth and, in particular, to policymakers looking to base growth around the computer industry, they are not comparable with those of Glaeser *et al* (1992). If anything, their focus on such different industries means the Beardsell and Henderson (1999) and Glaeser *et al* (1992) studies should be thought of as complimentary.   Meanwhile, whilst Henderson *et al*'s (1995) study seems more directly comparable to Glaeser *et al* (1992), the differences in samples alone can plausibly explain the differences in results. Thus, for the shorter period 1970-1987, Henderson *et al*'s results again relate to *individual* industries rather than to a pool of industries. Indeed, Henderson *et al* restrict themselves to consideration of

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[36] Differences in empirical methodology also likely contribute to differences in results. For example, of the studies discussed below, Henderson *et al* (1995) differs from Glaeser *et al* (1992) by not controlling for competition. Meanwhile, Beardsell and Henderson (1999) make use of conditional Markov chain analysis as well as regression methods.

[37] Glaeser *et al*'s finding that competition is associated with fast regional growth has been subject to little subsequent controversy. Reflecting on this, Glaeser (2000, p 93) states that "Every piece of research in this area that I am aware of finds a positive effect of competition on later growth." However, as Glaeser acknowledges, there are problems interpreting this relationship between competition and growth. Hence, one interpretation is that competition encourages innovation, whilst an alternative is that fast growing cities have a lot of new plants and firms that are also small, in which case reverse causation from growth to competition exists.

[38] The study by Feldman and Audretsch (1999) is interesting because it uses a direct measure of the innovative output of a city-industry as its dependent variable. Consequently, this study relates more directly to the object of interest- knowledge creation, accumulation and spillovers.

eight individual industries, three of which are newer "high-tech" industries (computers, electronic components, and instruments). These industries were marketing products in 1987 that did not even exist in 1970. Furthermore, they did not have a significant presence in every city in Henderson *et al*'s sample, in either the initial or the terminal year of the study. Still, the fact that the results for the five traditional manufacturing industries that Henderson *et al* consider are decisively against the idea that diversity is good and specialisation bad for local growth, does raise some concern. In particular, they call attention to the danger of relying on the "average" picture obtained from pooled estimation for implementing policy at a local level. This is especially important when local policy relates to a particular set of industries that are very different from the average. Furthermore, it leaves one to wonder whether, because of ignored heterogeneity, pooling itself results in bias in even the estimated "average" picture.[39] Finally, at the theoretical level, it suggests that endogenous growth theory is too aggregated to provide anything more than broad insight into the fact that knowledge creation and accumulation matters for regional growth. Thus, given that different regions are characterised by different industry-mixes, simple endogenous growth models are incapable of furnishing a proper understanding of the likely mosaic of regional growth patterns.

Given the above, it is hard to draw firm conclusions about the predominant nature of knowledge spillovers and thus decide upon a single "flavour" of endogenous growth theory. However, within the "new economics" literature, there is much more agreement on the empirical importance of human capital for regional growth. Hence, even in some of the studies mentioned above, there is support for the importance of human capital. Henderson *et al* (1995), for example, find that, for the computer and medical equipment industries, the presence of a local pool of highly qualified workers increases the probability that a region is a significant player. More generally, the importance of human capital has been borne out by both Rauch (1993) and Glaeser *et al* (1995). Using data from the 1980 US Census for individuals and households in 237 SMSAs, Rauch (1993) estimates the average level of

[39] One possibility is that there may be an ecological inference problem. Alternatively, something akin to Simpson's paradox might be in operation. The latter arises when, for example, the probability of an event *A* occurring in a population *X* and in a population *Y* is in both cases greater than it not occurring. However, when the two populations are combined, the opposite is found (see McCombie and Roberts, 2007).

human capital within a city to have a highly significant positive impact upon both wage and rent levels. This is consistent with the presence of human capital knowledge spillovers, and, therefore, with the regional application of endogenous growth theory.[40] Indeed, the fact that it is the *average* level (rather than the total stock) of human capital that appears important is consistent with Lucas's (1988) treatment of human capital and knowledge. From a practical viewpoint, this suggests that, *ceteris paribus*, rapid growth is more likely in a small city that is populated by highly educated people (e.g., Boulder, Colorado, in the US or Cambridge in the UK) than a large city that is mainly populated by the relatively uneducated.

Rauch's (1993) finding that it is years of schooling rather than years of experience that matters is also consistent with Lucas (1988). A major part of formal education is concerned with communication skills (Rauch 1993, p 391), and as seen in the previous section, the link from endogenous growth theory to the regions comes from the need for direct human communication for knowledge spillovers to occur.

Glaeser *et al*'s (1995) results, meanwhile, are consistent with those of Rauch (1993). For a sample of 203 US cities, the authors find the initial level of human capital to have a significant (conditional) positive effect on city growth (as measured by both population and income per capita growth) between 1960 and 1990. Furthermore, it is again the *average* level of education that is important (p 138).[41, 42] However, some care is required with Glaeser *et al*'s (1995) study because it employs the same type of Barro-style regression that has been subject to much criticism in cross-country convergence studies (see, for example, Temple, 1999). Hence Glaeser *et al*'s simple cross-sectional regressions ignore the possibility of omitted city effects that could be correlated with both the initial level of human capital and

[40] Rauch (1993) calculates that the size of the human capital knowledge externality is such that an additional year of average city level education will increase local TFP by 2.8% (with a standard error of 0.8%).
[41] Glaeser *et al* (1995) find that a one standard deviation increase in the median years of schooling in 1960 is associated with a 2.78% increase in income over the sample-period.
[42] Glaeser *et al* (1995) also find a significant negative impact of the initial unemployment rate on city growth. They interpret this as reinforcing the importance of human capital, because they view unemployment as proxying unobserved deficiencies in human capital. The alternative interpretation is that high initial unemployment indicates deficient aggregate demand for locally produced commodities, which, in turn, impacts negatively upon city growth. This alternative interpretation is more consistent with Keynesian endogenous growth models.

subsequent city growth.[43] This could bias their results in favour of the human capital externality story.[44] Alternatively, as Glaeser (1994) admits, results indicating the importance of human capital could be attributable to an increasing skill-bias in technological progress over time rather than significant knowledge spillovers. Indeed, this alternative link between human capital and regional growth seems highly plausible in view of recent literature relating increases in income inequality in the US and UK to skill-biased technological progress (see, for example, Aghion and Williamson, 1999; Bresnahan, 1999). Of course, this alternative story does not imply that human capital is unimportant for city growth. After all, it implies that those US cities which have benefited most from the occurrence of skill-biased technological progress are precisely those with high average levels of education. However, it does mean that, whilst important in *distributing* growth between cities, human capital does not *drive* city growth.

The study by Glaeser *et al* (1995) is also important for its focus on a number of potential social and political determinants of US city growth. These include measures of the degree of racial segregation within a city, which, as previously discussed, could be important from an endogenous growth perspective thanks to both role model effects and the nature of spatial knowledge flows. The authors find racial segregation has an important positive impact on city growth for cities with large non-white populations (p 146). Whether or not this reflects role model and other endogenous growth theory type effects or econometric misspecification, however, is clearly something that requires further research. This is also the case for their finding of a significant positive relationship between government debt per capita in 1960 and subsequent city growth.

Empirical work on European regions

Whilst North American research explicitly derives from the (imperfect) spatial interpretation of endogenous growth theory, it was noted earlier that research on EU regional growth

[43] To overcome such problems, a panel data approach to estimation allowing for city specific fixed effects is recommended.
[44] A second important econometric problem that could bias Glaeser *et al*'s results is spatial autocorrelation. We return to this theme in the next subsection.

disparities emerged from a different starting point. In particular, against the backdrop of increasing European integration, it arose from the increased availability of data for the EU regions stemming from the development of the REGIO database. Furthermore, unlike the "new economics" literature, it is distinguished by the widespread application of spatial econometric techniques. According to Abreu *et al* (2005, p.21), 68% of all spatial econometric studies on growth published since 1995 make use of European regional data.[45]

Before examining this use of spatial econometric techniques, however, it is worth dividing studies of European regional growth into two different categories. The first category consists of studies concerned with the question of cross-regional convergence (see, *inter alia*, Armstrong (1995a, b) and Le Gallo and Dall'erba (2005)). In the second category, exemplified by Fingleton and McCombie (1998) and Pons-Novell and Viladecans-Marsal (1999), are studies that test for localised increasing returns using the Verdoorn law.[46]

The studies in these categories originate from very different theoretical paradigms. Hence whilst the convergence literature is rooted in traditional neoclassical growth theory, the Verdoorn law literature is embedded within a Kaldorian vision of regional growth. Both approaches pose, in different ways, challenges to endogenous growth theory. Traditional neoclassical theory poses a challenge because it relies upon the assumption of constant returns to scale. It, therefore, views the knowledge spillovers that are central to endogenous growth theory as being of little empirical importance. Kaldorian growth theory concurs with endogenous growth theory as to the importance of localised increasing returns, but takes a demand-oriented view of regional growth. Thus, in its simplest form, the Verdoorn law is specified as a positive causal relationship running from the growth of aggregate demand for regional output (as proxied by regional output growth) to regional labour productivity growth.

[45] The widespread application of spatial econometric techniques by European researchers and their neglect in the "new economics" literature is somewhat ironic. This is because many of the major contributions to spatial econometric methodology have been made by North American based academics (see, most notably, Anselin, 1988).

[46] This contrast between North American and European research is, of course, an oversimplification. Thus, the most notable early contributions to the regional convergence literature were made by Barro and Sala-i-Martin (for an overview see Barro and Sala-i-Martin, 2004, chapter 11). Meanwhile, the first regional estimation of the Verdoorn law was for the US states (McCombie and de Ridder, 1984). However, clearly, in recent years, interest in both regional convergence and the Verdoorn law has mainly been a European interest with a European focus.

In essence, therefore, and in contrast to endogenous growth theory, aggregate demand growth for local output is a prerequisite for the realisation of localised increasing returns to scale. The Verdoorn law is then seen as providing the linchpin of theoretical models of "circular and cumulative causation" (Dixon and Thirlwall, 1975) in which localised increasing returns help regions to maintain initial growth advantages, whilst, at the same time, making it difficult for lagging regions to catch-up. Originally, the Verdoorn law was understood to operate only in manufacturing industries (Kaldor, 1966), but this position is difficult to maintain in the present day.[47]

Turning to the results of these literatures, convergence analyses find that, at the aggregate level, convergence between NUTS regions has slowed – indeed, virtually ceased – since the mid-to late-1970s. This is the case regardless of whether the focus is absolute β-convergence (the tendency for poorer regions to grow faster than richer regions) or σ-convergence (a declining dispersion of per capita income levels).[48] Underlying this aggregate pattern, however, exists a heterogeneity of experience across sectors (Le Gallo and Dall'erba, 2005) with, for example, the market and non-market service sectors experiencing σ-convergence whilst other sectors have experienced no such convergence or even, in the case of agriculture, divergence. Differences between core and peripheral regions have also been discovered (Le Gallo and Dall'erba, 2005).[49, 50] These results concerning a lack of both absolute β- and σ-convergence at the aggregate level seem more consistent with an endogenous growth view of the world than with a traditional neoclassical view. Indeed, if knowledge spillovers in capital accumulation *à la* Romer (1986) are incorporated into the Solow-Swan model, the predicted speed of convergence in the model slows with divergence predicted if the knowledge

[47] For an extensive general overview of the Kaldorian growth literature and issues involved in the specification of the Verdoorn law see McCombie *et al* (2002).

[48] These findings with respect to convergence are broadly consistent with the NUTS2 data considered in the third section of the paper. Thus, although note was made of a decline in the dispersion of GVA per capita levels between 1980 and 2002, it was pointed out that this decline was small. Furthermore, although regions in lower quartiles of the distribution of 1980 GVA per capita levels tended to grow faster over the period 1980-1990, the implied rate of absolute β convergence was a very slow 1.3% per annum. Considering the full-sample period of 1980-2002, however, gives a slightly higher estimated rate of absolute β convergence of 2.1% per annum. This indicates stronger convergence in the 1990s.

[49] Le Gallo and Dall'erba (2005) make use of data for 145 NUTS2 regions for 1975-2000. The data covers five different sectors- agriculture, energy and manufacturing, construction, market services and non-market services.

[50] Similar results to those of Le Gallo and Dall'erba (2005) hold within individual EU countries (see, for example, Roberts, 2004, in the case of the UK).

spillovers are sufficiently strong.[51] However, the results concerning a diversity of experience across sectors seem more difficult to reconcile with simple spatial applications of endogenous growth theory. This is because of the highly aggregated nature of endogenous growth models. Once again, this suggests that such models are insufficient to furnish a proper understanding of the mosaic of regional growth experiences.

In the Verdoorn law literature, meanwhile, both Fingleton and McCombie (1998) and Pons-Novell and Viladecans-Marsal (1999) find evidence of substantial localised increasing returns to scale in EU manufacturing at the NUTS2 and NUTS1 levels, respectively.[52] These findings again provide support for endogenous growth theory, even though simple studies of the Verdoorn law are incapable of testing the specific emphasis of such theory on dynamic knowledge spillovers. However, the support found for the Verdoorn law also challenges the supply-side emphasis of endogenous growth theory.

Turning now to the use of spatial econometric techniques, this is predicated upon the realisation that the assumption of an independently distributed error term is unlikely to hold in a cross-sectional regional setting. This is for two reasons: (a) the fact that NUTS regions in the EU are not defined on analytical/functional grounds and so do not delineate meaningful areas of economic activity; and (b) recognition that significant spillovers of the sort emphasised by endogenous growth theory may occur not only between agents *within* regions, but also between agents in *different* regions. Spatial autocorrelation arising for the first reason is considered to be a "nuisance", whilst that arising for the second reason is considered to be "substantive" on the grounds that it has a meaningful economic interpretation. To test for, and subsequently deal with, spatial autocorrelation, studies of European regional growth have typically adopted a "testing-up" strategy (see, for example, Fingleton and McCombie, 1998, and Pons-Novell and Viladecans-Marsal, 1999). This begins with standard OLS estimation of the growth equation under consideration. Spatial autocorrelation in the residuals

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[51] The predicted speed of convergence in the Solow-Swan model is given by $\beta \approx (1 - \alpha)(n + g + d)$ where α is the elasticity of real output with respect to capital, n is the rate of population growth, g is the rate of technological progress and d is the rate of capital depreciation. Under constant returns to scale, α is equal to the capital share (i.e. $\alpha \approx 0.30$), but with the inclusion of knowledge spillovers, α increases above this value, implying that $\beta \rightarrow 0$.

[52] Fingleton and McCombie (1988) also find evidence of a significant technological diffusion effect.

of the equation is then tested for using an appropriate test statistic - for example, Moran's *I* statistic. If, using this test, spatial autocorrelation is detected, a decision is made between two different spatial specifications of the growth equation. These specifications are the spatial error model (SEM) and the spatial autoregressive (SAR) or spatial lag model:

SEM specification $g = \boldsymbol{X}\delta_1 + \varepsilon_1$ [1]

where $\varepsilon_1 = \eta \boldsymbol{W}\varepsilon_1 + \mu$

SAR specification $g = \boldsymbol{X}\delta_2 + \rho \boldsymbol{W}g + \varepsilon_2$ [2]

where g is a $N \times 1$ vector of regional growth rates, $\boldsymbol{X}$ is a matrix of exogenous influences on growth, and $\boldsymbol{W}$ is a row-standardised spatial weights matrix that captures the spatial interaction between regions.[53] In the SEM specification it can be seen that the error term adopts a spatial structure with μ being well-behaved. By contrast, in the SAR specification, the spatial autocorrelation is modeled through the use of an extra regressor- namely, the spatially lagged growth rate, which captures the idea that the growth of one region depends directly on the growth of "neighbouring" regions.[54]

The choice between the SEM and SAR specifications is made on the basis of Lagrange Multiplier (LM) statistics. Specifically, following OLS estimation, two such statistics are calculated, one (LM_{SEM}) having greater power against the SEM specification and the other

[53] Normally, the weights matrix takes the form of either a simple contiguity matrix in which only direct interaction between geographically neighbouring regions is allowed for (such a weights matrix is used by, *inter alia*, Armstrong, 1995a, b, and Pons-Novell and Viladecans-Marsal, 1999) or an inverse square distance matrix with or without a critical cutoff distance above which direct interactions between regions are assumed to be negligible (used by, for example, Fingleton and McCombie, 1998). More recently, authors have turned to more sophisticated weights matrices based on, for instance, travel time by road between regions with a penalty for the crossing of a national border (Cheshire and Magrini, 2005). Nevertheless, the selection of the appropriate weights matrix remains a critical issue of specification in spatial econometric models. Although as yet unexploited in the growth context, developments in Bayesian spatial econometrics (see, in particular, Le Sage, 1999) may help tackle this issue.

[54] The standard approach is to estimate both the SEM and SAR models using maximum likelihood (ML) techniques.

(LM_{SAR}) having greater power against the SAR specification. The specification selected is the one with the highest associated LM statistic.[55]

Clearly, the choice between the SEM and SAR specifications in European regional growth studies is of great importance, not least because the former is seen as capturing "nuisance" spatial autocorrelation and the latter "substantive" spatial autocorrelation. Hence the spatial autoregressive parameter ρ in the SAR specification is interpreted as capturing cross-regional knowledge spillovers. This has led to the conclusion that knowledge spillovers between agents in different European regions are substantial. For example, in estimating the Verdoorn law, Pons-Novell and Viladecans-Marsal (1999) find ρ to be 0.201 (table 3, p 448), implying that 20% of growth in one NUTS1 region spills-over into neighbouring NUTS1 regions. This would seem to provide considerable support to the spatial application of endogenous growth theory.

However, the "testing-up" strategy and the interpretation of ρ in equation [2] as capturing endogenous growth theory style spillovers is problematic (Abreu *et al*, 2005, pp32-35; Angeriz *et al*, 2007; Roberts, 2006). Most notably, it is just as (if not more) likely that a significant value of ρ reflects the existence of spatially autocorrelated omitted variables as it does cross-regional spillovers. For example, there is a notable absence of comprehensive data on human capital at the various NUTS levels and so this variable is typically absent from European regional growth studies. However, if human capital levels are spatially autocorrelated, this omitted variable problem will show-up as substantive spatial autocorrelation.[56] Additional problems relate to the difficulty of distinguishing between the SEM and SAR specifications when both the LM_{SEM} and LM_{SAR} statistics are significant (Angeriz *et al*, 2007) and the weakness of the links between the SAR specification and economic theory (Abreu *et al*, 2005, p33; Angeriz *et al*, 2007; Roberts, 2006). With respect

[55] This "testing-up" strategy has its origins in the Monte Carlo study of Anselin and Rey (1991), which investigates the size and power properties of the LM_{SEM} and LM_{SAR} test statistics. A robust version of this strategy also exists in which the two tests are replaced by versions that are robust to local misspecification in the form of the existence of the type of spatial autocorrelation not being tested for. This version of the strategy has, however, been shown to be inferior in the context of Monte Carlo work by Florax *et al* (2003).

[56] Roberts (2004) finds that, for his sample of UK counties, including a proxy for human capital, along with population growth, removes any evidence of spatial autocorrelation in the estimation of convergence equations.

to the latter, if spillovers between regions are thought to operate through a particular variable rather than through income per capita or productivity growth *per se*, it is more appropriate to include a spatial lag of this variable as an extra regressor rather than the spatially lagged growth rate (as in the SAR specification). This approach has recently been adopted by, for example, Angeriz *et al* (2007), who find that interregional spillovers are much smaller than suggested by Pons-Novell and Viladecans-Marsal (1999).

Remaining theoretical and empirical issues in the regional application of endogenous growth theory

It follows from the preceding discussion that both North American and European researchers can learn useful lessons from each other. Researchers working on European regional growth can learn from the "new economics" literature the value of a definition of the region that is appropriate to the issue being studied. They should also heed the lesson that a proper understanding of the causal forces underlying regional growth requires more than studying convergence or the Verdoorn law. In particular, it is important to "get inside" the "black box" of localised increasing returns to unpack the nature of any knowledge spillovers. Whether knowledge spillovers are, for example, within-industry or cross-industry in nature is critical from both theoretical and policy perspectives. But studies of European regional growth are at least aware of the importance that attaches to spatial autocorrelation. In contrast, this phenomenon has largely been ignored in the "new economics" literature. It is therefore possible that the estimating equations in some of this literature are seriously misspecified. Replicating some of the "new economics" research whilst paying explicit attention to the problem of spatial autocorrelation would appear worthwhile, if only to check the robustness of the results so far derived. A second important lesson that the "new economics" literature can learn comes from the European literature on the Verdoorn law. This literature highlights the potential importance of demand growth in driving regional growth processes, a possibility that has been ignored in the "new economics" literature. The importance of this lesson stems from the fact that, even if the knowledge spillovers highlighted by endogenous growth theory exist at the local level, policymakers may never be able to harness them unless they attend to conditions on both the supply- *and* demand-sides of the economy.

This leads to the first of several remaining issues in the spatial application of endogenous growth theory. The overwhelmingly supply-side focus of endogenous growth theory takes the demand-side of regional economies too much for granted. At both a theoretical and policy level, the neglect of the demand-side needs to be re-considered. In the UK, for instance, there is a need to think carefully about the adequacy of a regional policy that relies upon five key supply-side drivers of growth with little or no attention paid to local demand conditions. Meanwhile, at the theoretical level, it should be recognised that endogenous growth models can be either "Keynesian" or "neoclassical" (Roberts and Setterfield, 2007). One example of a "Keynesian" endogenous growth model is the Dixon-Thirlwall model that is part of the Kaldorian tradition discussed in the previous section. Whilst paying due attention to the demand-side, however, the treatment of localised increasing returns in this model is primitive. It does not provide the detailed modelling of increasing returns that is characteristic of "neoclassical" endogenous growth theory. What is needed, then, is the development of "Keynesian" endogenous growth models that combine the strengths of conventional endogenous growth theory with more explicit treatment of the role and evolution of local demand.

Two questions help to highlight the potential importance of demand-side considerations for the analysis of regional growth. First, what does aggregate growth theory indicate about the ultimate *source* of growth? And, second, is this source of growth likely to be geographically confined, giving the growth process an inherently spatial dimension? In “neoclassical” endogenous growth models, the ultimate source of growth is the supply-side expansion of the availability and productivity of factor inputs. Meanwhile, the mechanism that geographically confines this source of growth is the Lucas (1988) theorem that knowledge spillovers require direct human interaction. But from a Keynesian viewpoint, the level and/or growth rate of aggregate demand is the ultimate source of growth. The potential for geographical confinement of demand conditions depends on the precise component of aggregate expenditures that is crucial to the growth process, and/or the growth generating mechanism that characterises the model at hand. In the Dixon-Thirlwall model, for example, the demand for a region's exports is of ultimate importance. Moreover, any historical "accident" in the form of a positive idiosyncratic shock to regional export demand sets in motion cumulative processes that create persistence in the spatial pattern of future aggregate demand growth. Recent contributions to "Keynesian" endogenous growth theory have built upon this, suggesting additional feedback mechanisms so that self-reinforcing growth can breakdown (Setterfield, 1997a, 1997b) or, alternatively, be kick-started where it has previously been absent (Roberts, 2006).[57]

A second remaining issue relates back to the fact that, within the "new economics" literature, the application of endogenous growth theory to a spatial setting is mainly informal. This is problematic not only because the resulting application is sometimes rather loose, but also because the key endogenous growth models upon which the "new economics" literature draws are closed economy models. This is only natural because such models were designed primarily with national economies in mind. However, when translated to a spatial setting, the closed economy assumption encourages a tendency to ignore systemic or "spatial general equilibrium" aspects of the working of regional economies. The danger of this is again highlighted by UK regional policy. Encouraged by a closed economy mentality, UK regional policy effectively assumes that all regions can achieve rapid growth and a high level of prosperity if they push the sorts of policy levers suggested by endogenous growth theory (e.g. skills, investment, innovation, enterprise and competition). But looking at regional economies as a system and acknowledging both the positive and negative linkages between them, is this really possible? Clearly, more theoretical and empirical research is required here. In particular, the development of more explicitly spatial models of endogenous growth would, once again, be useful. In order to facilitate the analysis of models with both multiple regions and sectors, this should draw on modern computer simulation techniques such as those already in use in the “new economic geography” literature.

The third outstanding issue concerns the fact that empirical work seems to reveal a considerable diversity of growth patterns and mechanisms in both the spatial and temporal

[57] This relates to the important question of the ability of cities and regions to reinvent themselves, thereby allowing a locality that might have been depressed for decades to escape the seemingly inevitable trap of continuing economic decline. Recent examples of such successful reinvention within the UK include such cities as Manchester, Glasgow, Leeds and Newcastle, as well as parts of London.

dimensions. Thus, in the "new economics" literature, both within- and cross-industry knowledge spillovers have been found, depending on the industries and/or time periods studied. European work, meanwhile, has revealed that different sectors are characterised by different convergence patterns and that, over time, the aggregate speed of convergence has slowed. These results suggest that no single endogenous growth mechanism can explain all spatio-temporal growth rate differences. Instead, it would seem that different mechanisms operate simultaneously, with the exact combination of mechanisms (and their net effect) being context dependent. This being the case, it is useful to view regional growth processes as being characterised by different spatial and temporal growth regimes. Thus, for example, Roberts (2004) has argued that the late 1970s-early 1980s witnessed the emergence of a new growth regime for the system of UK regional economies. This new regime was characterised by a policy-technology mix that favoured certain types of human capital intensive industries. High human capital regions that were well-placed to increase their specialisation in these industries benefited from this regime switch, whilst regions that were not suffered.[58]

A final remaining issue relates to spatial implications of endogenous growth theory that have, as of yet, gone largely unexplored. Some of the most interesting implications of endogenous growth theory concern the impact of the internal spatial organisation of regions on knowledge flows. This is because endogenous growth theory as applied to the regions, relies on human and social interactions for both the occurrence and geographic bounding of knowledge spillovers. The strength of knowledge spillovers can, therefore, be expected to depend on the physical layout of a city or region and the extent to which it encourages human and social interaction were the "talk is good." However, this is something that seems to have gone unnoticed in the "new economics" literature, save for Glaeser *et al*'s (1995) inclusion of a measure of racial segregation in a Barro-style regression. Such regressions are ill-suited to "getting inside" the "black box" of social and human interaction, however. Research drawing on microeconomic data is likely to be much more fruitful in this regard.

[58] Audretsch and Fritsch (2000) have also made use of the analytical device of growth regimes in studying the growth performances of the system of West German planning regions in the 1980s and 1990s. Further applications of the growth regimes device have taken place in the context of international growth disparities (see, most notably, Cornwall and Cornwall, 2001; Cornwall and Setterfield, 2002).

Conclusion

This paper has provided a critical survey of literature relating to the spatial application of endogenous growth theory. In so doing, it has covered both the "new economics of urban and regional growth" literature of Glaeser *et al* and the European literature on convergence and the Verdoorn law. It has been shown that both of these literatures have something to learn from each other. Furthermore, important issues, both theoretical and empirical, remain regarding the spatial application of endogenous growth theory. Prime amongst these is the need to pay more attention to the demand-side of local economies; to beware the pitfalls of drawing conclusions from closed economy models for a system of open regional economies; and to be conscious of the possible existence of different "growth regimes" across both time and space. Overall, we may conclude that whilst endogenous growth theory sheds light on the geographic transmission of knowledge, spatial application of this theory is not, by itself, enough to provide a full understanding of the regional growth process. Further theoretical and empirical work is yet required and one aim of this survey has been to identify areas of research that, in the opinions of the authors, should be given priority.

APPENDIX

TABLE A1: RELATIVE LEVELS AND GROWTH RATES OF GVA PER CAPITA FOR THE EUROPEAN NUTS2 REGIONS								
Region		**GVA per capita relative to sample mean**			**Growth rate of GVA per capita**			
		2002	**1980**	**1980 rank**	**1980-2002**	**rank**	**1980-1990**	**rank**
				1ST QUARTILE				
Inner London (UK)	1	249	210	3	0.0259	51	0.0280	36
Bruxelles-Brussel (BE)	2	212	239	1	0.0102	196	0.0145	172
Zürich (CH)	3	192	197	5	0.0203	105	0.0186	126
Hamburg (DE)	4	188	198	4	0.0163	156	0.0179	135
Ile de France (FR)	5	173	158	10	0.0253	55	0.0271	43
Wien (AT)	6	168	156	12	0.0221	83	0.0278	40
Stockholm (SE)	7	162	123	38	0.0384	8	0.0300	27
Oslo og Akershus (NO)	8	160	94	112	0.0488	3	0.0492	1
Oberbayern (DE)	9	159	156	11	0.0236	69	0.0239	66
Darmstadt (DE)	10	154	144	19	0.0243	63	0.0306	23
Southern and Eastern (IE)	11	153	68	186	0.0611	1	0.0401	9
Åland (FI)	12	151	113	52	0.0367	11	0.0408	8
Bremen (DE)	13	148	167	9	0.0092	198	0.0136	179
North East Scot. (UK)	14	148	112	55	0.0343	16	0.0391	10
Nordwestschweiz (CH)	15	143	177	6	0.0133	176	0.0128	189
Utrecht (NL)	16	141	117	47	0.0364	12	0.0274	41
Stuttgart (DE)	17	140	149	15	0.0202	106	0.0226	76
Salzburg (AT)	18	140	143	20	0.0239	66	0.0178	136
Hovedstadsreg. (DK)	19	138	131	29	0.0189	126	0.0156	157
Trentino-Alto Adige (IT)	20	137	133	27	0.0222	81	0.0199	103
Berkshire et al. (UK)	21	136	92	123	0.0414	7	0.0426	6
Lombardia (IT)	22	135	141	21	0.0164	154	0.0197	109
Groningen (NL)	23	135	211	2	-0.0019	210	-0.0271	210
Espace Mittelland (CH)	24	132	152	14	0.0146	170	0.0131	184
Noord-Holland (NL)	25	132	128	32	0.0231	71	0.0196	111
Emilia-Romagna (IT)	26	131	138	22	0.0156	162	0.0146	170
Karlsruhe (DE)	27	129	136	24	0.0204	104	0.0193	116
Mittelfranken (DE)	28	128	132	28	0.0209	98	0.0208	96
Vorarlberg (AT)	29	127	130	31	0.0229	73	0.0163	151
Etelä-Suomi (FI)	30	127	99	93	0.0349	15	0.0365	11
Antwerpen (BE)	31	126	134	26	0.0166	152	0.0166	148
Dusseldorf (DE)	32	125	146	16	0.0106	195	0.0114	195
Valle d'Aosta (IT)	33	125	145	18	0.0138	173	0.0191	120
Tirol (AT)	34	121	126	36	0.0225	79	0.0181	133
Piemonte (IT)	35	121	127	33	0.0127	182	0.0175	138
Veneto (IT)	36	121	112	54	0.0228	76	0.0245	60
Zentralschweiz (CH)	37	120	145	17	0.0184	131	0.0199	103
Zuid-Holland (NL)	38	120	119	44	0.0223	80	0.0183	131
Oberosterreich (AT)	39	119	117	48	0.0221	84	0.0210	93
Région lémanique (CH)	40	117	171	8	0.0086	201	0.0118	193
Koln (DE)	41	117	135	25	0.0148	169	0.0130	185
Fr.-Venezia Giulia (IT)	42	116	112	53	0.0167	150	0.0219	83
Ticino (CH)	43	116	174	7	0.0058	207	0.0172	141

Region		GVA per capita relative to sample mean			Growth rate of GVA per capita			
		2002	1980	1980 rank	1980-2002	rank	1980-1990	rank
Toscana (IT)	44	116	117	46	0.0162	158	0.0169	144
Madrid (ES)	45	115	92	124	0.0325	19	0.0351	13
Hants. (UK)	46	113	100	91	0.0286	33	0.0197	109
Vlaams Brabant (BE)	47	113	99	97	0.0278	38	0.0218	85
Cheshire (UK)	48	113	101	88	0.0257	53	0.0201	101
Tubingen (DE)	49	113	124	37	0.0207	101	0.0217	87
Lazio (IT)	50	112	110	61	0.0212	93	0.0282	34
Noord-Brabant (NL)	51	112	96	102	0.0309	24	0.0285	30
V. for Storebaelt (DK)	52	111	110	58	0.0209	97	0.0193	116
2ND QUARTILE								
Ostschweiz (CH)	53	111	154	13	0.0088	200	0.0139	177
Navarra (ES)	54	110	103	83	0.0247	59	0.0229	74
Rhone-Alpes (FR)	55	110	113	51	0.023	72	0.0198	105
Liguria (IT)	56	110	106	74	0.0131	177	0.0209	95
East Anglia (UK)	57	109	94	110	0.0321	20	0.0270	44
Alsace (FR)	58	109	117	45	0.0197	114	0.0187	123
Surrey (UK)	59	109	82	152	0.0362	13	0.0312	21
Braunschweig (DE)	60	108	119	43	0.0139	172	0.0136	179
Freiburg (DE)	61	108	121	39	0.019	124	0.0195	114
Oberpfalz (DE)	62	108	97	99	0.0274	42	0.0254	54
Vastsverige (SE)	63	108	107	71	0.0219	86	0.0201	101
Detmold (DE)	64	108	121	40	0.0178	139	0.0185	128
Schwaben (DE)	65	107	115	49	0.0208	99	0.0220	82
Hannover (DE)	66	107	126	35	0.012	188	0.0172	141
Bedfordshire (UK)	67	107	98	98	0.028	35	0.0234	72
Pais Vasco (ES)	68	107	96	104	0.0187	127	0.0237	68
Rheinhessen-Pfalz (DE)	69	105	131	30	0.0123	186	0.0146	170
Sydsverige (SE)	70	105	103	82	0.022	85	0.0205	99
O. for Storebaelt (DK)	71	105	100	89	0.0216	89	0.0151	161
Unterfranken (DE)	72	105	105	76	0.0226	78	0.0245	60
Steiermark (AT)	73	104	99	96	0.0201	107	0.0186	126
Brabant Wallon (BE)	74	104	96	103	0.0306	25	0.0141	174
Oberfranken (DE)	75	104	104	80	0.0199	110	0.0265	50
Gloucester et al. (UK)	76	104	94	113	0.0276	40	0.0278	40
Marche (IT)	77	104	110	60	0.0166	151	0.0157	156
Karnten (AT)	78	104	103	84	0.0195	116	0.0189	121
Cataluna (ES)	79	104	88	135	0.0269	44	0.0318	18
Smaland med oarna (SE)	80	103	108	64	0.0154	165	0.0160	153
Niederosterreich (DE)	81	103	92	125	0.026	50	0.0235	71
Kassel (DE)	82	103	108	66	0.0176	141	0.0150	163
Mellersta Norrland (SE)	83	102	120	42	0.0063	206	0.0131	184
Saarland (DE)	84	102	113	50	0.0123	187	0.0171	143
West-Vlaanderen (BE)	85	101	97	101	0.0215	91	0.0240	64
Arnsberg (DE)	86	101	127	34	0.0083	202	0.0117	194

Region		GVA per capita relative to sample mean			Growth rate of GVA per capita			
		2002	1980	1980 rank	1980-2002	rank	1980-1990	rank
Umbria (IT)	87	101	109	62	0.0157	161	0.0139	177
Champagne-Ard. (FR)	88	100	111	56	0.0126	184	0.0154	160
Baleares (ES)	89	100	92	122	0.0328	18	0.0282	34
Haute-Normandie (FR)	90	100	105	77	0.0196	115	0.0185	128
Leics. (UK)	91	100	88	132	0.0288	31	0.0304	24
Niederbayern (DE)	92	98	99	95	0.025	58	0.0220	82
Limburg (BE)	93	98	87	138	0.0257	52	0.0278	40
Bourgogne (FR).	94	98	102	86	0.0163	157	0.0197	109
Zeeland (NL)	95	98	104	81	0.0181	135	0.0283	32
Border (IE)	96	98	57	200	0.046	4	0.0284	31
Schleswig-Holstein (DE)	97	98	110	59	0.0153	166	0.0184	129
Overijssel (NL)	98	98	93	117	0.0214	92	0.0216	90
Gelderland (NL)	99	98	95	106	0.0236	70	0.0196	111
Giessen (DE)	100	97	101	87	0.0198	111	0.0144	173
Kent (UK)	101	97	84	145	0.0288	32	0.0266	49
Oost-Vlaanderen (BE)	102	97	95	105	0.0191	120	0.0227	75
Ovre Norrland (SE)	103	97	120	41	0.007	205	0.0122	191
Ostra Mellansverige (SE)	104	97	106	73	0.0152	167	0.0158	155
Centre (FR)	105	97	103	85	0.0191	121	0.0181	133
3RD QUARTILE								
Alpes-Cote d'Azur (FR)	106	96	104	78	0.0215	90	0.0195	114
Norra Mellansverige (SE)	107	96	109	63	0.0094	197	0.0149	164
Rioja (ES)	108	96	99	94	0.0209	96	0.0146	170
Aquitaine (FR)	109	96	99	92	0.0212	94	0.0191	120
Pays de la Loire (FR)	110	96	97	100	0.0227	77	0.0198	105
Midi-Pyrenees (FR)	111	95	93	116	0.0239	65	0.0249	56
East Wales (UK)	112	95	87	139	0.0255	54	0.0295	28
Vestlandet (NO)	113	95	88	133	0.0241	64	0.0247	58
Lisboa e V.do Tejo (PT)	114	94	74	172	0.0306	26	0.0271	43
Friesland (NL)	115	94	90	129	0.0229	75	0.0232	73
Aragon (ES)	116	94	81	155	0.0244	62	0.0306	23
Länsi-Suomi (FI)	117	93	90	131	0.0208	100	0.0260	51
Essex (UK)	118	93	81	154	0.0276	39	0.0222	78
Eastern Scotland (UK)	119	93	90	128	0.0199	109	0.0224	77
Franche-Comte (FR)	120	93	107	72	0.0128	181	0.0135	181
Pohjois-Suomi (FI)	121	93	100	90	0.0173	144	0.0192	117
Weser-Ems (DE)	122	92	108	69	0.0168	149	0.0164	150
Limburg (BE)	123	92	81	153	0.0279	36	0.0327	16
West Midlands (UK)	124	92	93	120	0.0159	159	0.0191	120
Bretagne (FR)	125	92	94	114	0.0207	102	0.0154	160
Auvergne (FR)	126	92	94	115	0.0156	163	0.0171	143
Hereford et al. (UK)	127	91	75	171	0.0317	22	0.0292	29
Basse-Normandie (FR)	128	91	94	111	0.0193	119	0.0155	158
North Yorkshire (UK)	129	90	78	164	0.0284	34	0.0269	46

Region		GVA per capita relative to sample mean			Growth rate of GVA per capita			
		2002	1980	1980 rank	1980-2002	rank	1980-1990	rank
Outer London (UK)	130	90	77	167	0.0247	61	0.0280	36
Koblenz (DE)	131	90	108	65	0.0136	174	0.0187	123
Drenthe (NL)	132	89	106	75	0.0157	160	0.0134	182
Munster (DE)	133	89	111	57	0.0109	194	0.0145	172
Agder og Rogaland (NO)	134	88	108	68	0.0175	143	0.0112	196
East Riding (UK)	135	88	80	157	0.0237	68	0.0314	19
South West Scot. (UK)	136	88	84	144	0.0163	155	0.0216	90
Poitou-Charentes (FR)	137	88	93	118	0.0176	142	0.0186	126
Lorraine (FR)	138	88	108	70	0.0077	203	0.0091	198
Limousin (FR)	139	87	90	130	0.0142	171	0.0175	138
West Yorkshire (UK)	140	87	83	146	0.0206	103	0.0236	69
Trier (DE)	141	87	104	79	0.0128	180	0.0150	163
Sterea Ellada (GR)	142	87	137	23	0.0047	208	-0.0079	209
Cantabria (ES)	143	87	83	149	0.0218	88	0.0140	175
Picardie (FR)	144	87	108	67	0.0111	193	0.0067	201
Greater Manchester (UK)	145	85	88	134	0.0154	164	0.0183	131
Abruzzo (IT)	146	85	87	137	0.0186	128	0.0241	62
Nord-Pas de Calais (FR)	147	85	95	108	0.0134	175	0.0129	187
Trondelag (NO)	148	85	69	183	0.0296	29	0.0303	25
Derbyshire (UK)	149	85	86	140	0.0191	122	0.0218	85
Com. Valenciana (ES)	150	84	77	166	0.0276	41	0.0254	54
Languedoc-Rouss. (FR)	151	83	83	147	0.0279	37	0.0235	71
Shrops. (UK)	152	83	74	174	0.0262	49	0.0266	49
Cumbria (UK)	153	83	95	107	0.013	179	0.0221	79
Liege (BE)	154	83	94	109	0.0119	190	0.0129	187
Dorset (UK)	155	83	79	160	0.0268	45	0.0266	49
Notio Aigaio (GR)	156	82	67	190	0.0379	9	0.0337	14
Lancashire (UK)	157	82	84	143	0.0185	130	0.0220	82
4TH QUARTILE								
Castilla-Leon (ES)	158	81	79	163	0.019	123	0.0148	165
Molise (IT)	159	81	79	161	0.0181	134	0.0217	87
Lincolnshire (UK)	160	81	75	170	0.0272	43	0.0244	61
Attiki (GR)	161	81	91	127	0.0165	153	-0.0003	208
Corse (FR)	162	81	86	141	0.0197	113	0.0168	145
Burgenland (AT)	163	80	69	180	0.0252	56	0.0252	55
Sor-Ostlandet (NO)	164	80	92	121	0.0149	168	0.0147	167
Canarias (ES)	165	80	62	196	0.0376	10	0.0443	4
Luneburg (DE)	166	80	91	126	0.0179	138	0.0180	134
Luxembourg	167	80	73	175	0.0262	48	0.0279	37
Devon (UK)	168	79	73	176	0.0238	67	0.0197	109
Madeira (PT)	169	79	37	209	0.0492	2	0.0475	2
Asturias (ES)	170	77	79	162	0.0131	178	0.0127	190
Sardegna (IT)	171	77	77	165	0.0185	129	0.0207	97
Itä-Suomi (FI)	172	76	87	136	0.0089	199	0.0167	147

Region		GVA per capita relative to sample mean			Growth rate of GVA per capita			
		2002	1980	1980 rank	1980-2002	rank	1980-1990	rank
Namur (BE)	173	76	82	151	0.0184	132	0.0128	189
Nord-Norge (NO)	174	76	85	142	0.0119	189	0.0158	155
Basilicata (IT)	175	76	74	173	0.0171	146	0.0102	197
Northern Ireland (UK)	176	75	69	181	0.0251	57	0.0237	68
Hedmark og Oppland (NO)	177	74	68	185	0.0222	82	0.0240	64
Hainaut (BE)	178	74	80	159	0.0125	185	0.0135	181
South Yorkshire (UK)	179	74	83	148	0.0117	191	0.0078	199
Dytiki Makedonia (GR)	180	73	75	169	0.0189	125	0.0209	95
Kentriki Makedonia (GR)	181	73	76	168	0.0229	74	0.0050	202
Murcia (ES)	182	73	70	179	0.0303	28	0.0269	46
Algarve (PT)	183	72	50	204	0.0429	5	0.0443	4
Northumb. et al. (UK)	184	72	80	158	0.0127	183	0.0160	153
Ceuta y Melilla (ES)	185	71	53	203	0.0421	6	0.0418	7
Tees Vall. & Durham (UK)	186	71	82	150	0.0114	192	0.0147	167
Castilla-la Mancha (ES)	187	71	67	191	0.0247	60	0.0254	54
Merseyside (UK)	188	70	81	156	0.0072	204	0.0047	203
Kriti (GR)	189	69	60	197	0.0319	21	0.0302	26
Galicia (ES)	190	69	68	189	0.0171	147	0.0165	149
Puglia (IT)	191	69	72	177	0.0179	137	0.0167	147
West Wales (UK)	192	69	70	178	0.0176	140	0.0206	98
Sicilia (IT)	193	67	69	182	0.0173	145	0.0215	91
Campania (IT)	194	67	68	187	0.0195	117	0.0247	58
Voreio Aigaio (GR)	195	67	62	195	0.021	95	0.0119	192
Highlands & Islands (UK)	196	66	93	119	0.0028	209	0.0042	205
Andalucia (ES)	197	66	64	192	0.0265	47	0.0212	92
Thessalia (GR)	198	65	68	188	0.0195	118	0.0069	200
Calabria (IT)	199	64	62	194	0.0181	136	0.0174	139
Ionia Nisia (GR)	200	64	56	201	0.0303	27	0.0216	90
Peloponnisos (GR)	201	63	69	184	0.0201	108	0.0045	204
Cornwall (UK)	202	63	57	199	0.0267	46	0.0239	66
Centro (PT)	203	57	40	208	0.0332	17	0.0327	16
Extremadura (ES)	204	57	46	206	0.0294	30	0.0318	18
Anatoliki Makedonia (GR)	205	57	58	198	0.0182	133	0.0195	114
Alentejo (PT)	206	56	48	205	0.0198	112	0.0356	12
Norte (PT)	207	56	44	207	0.0316	23	0.0313	20
Acores (PT)	208	56	36	210	0.036	14	0.0432	5
Dytiki Ellada (GR)	209	55	63	193	0.017	148	0.0028	206
Ipeiros (GR)	210	53	55	202	0.0218	87	0.0016	207

Country abbreviations: AT, Austria; BE, Belgium; CH, Switzerland; DE, Germany; DK, Denmark; ES, Spain; FI, Finland; FR, France; GR, Greece; IE, Ireland; IT, Italy; NL, Netherlands; PT, Portugal; SW Sweden; UK, United Kingdom.

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