Slow Convergence? The New Endogenous Growth Theory and Regional Development*

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Abstract: In economics, interest has revived in economic growth, especially in long-term convergence in per capita incomes and output between countries. This mainly empirical debate has promoted the development of endogenous growth theory, which seeks to move beyond conventional neoclassical theory by treating as endogenous those factors—particularly technological change and human capital—relegated as exogenous by neoclassical growth models. The economists at the forefront of the formulation of endogenous growth theory and the new growth empirics have begun to use long-term regional growth patterns to test and develop their ideas. Their analyses suggest that regional convergence is a slow and discontinuous process. In this paper we consider whether endogenous growth theory can help to explain this finding. We argue that endogenous growth theory has important regional implications, but also major limitations when applied to a regional context.

Key words: endogenous growth, regional convergence, human capital, technology, externalities.

The study of the capitalist space economy traditionally has been dominated by two opposing views about the expected long-term trajectories of regional development. The first, rooted in neoclassical equilibrium economics, holds that, provided there are no major barriers to the operation of market forces, in an integrated national space economy there are strong pressures leading to the general *convergence* of regional incomes over time. Regional disparities are unlikely to be persistent, since such inequalities will set in motion self-correcting movements in prices, wages, capital, and labor, which impart a strong tendency toward regional convergence. Two of the earliest and most influential statements of this view are Borts and Stein's (1964) classic study of regional development in the United States and Williamson's (1965) analysis of the evolution of regional income differences in advanced industrial countries.

According to the second scenario, there are no necessary reasons why regional growth and incomes should converge, even over the long run. To the contrary, regional *divergence* is more likely. The models of regional growth advanced by writers such as Perroux (1950, 1955), Myrdal (1957), and Kaldor (1970, 1981) predict that regional incomes will tend to diverge, because market forces, if left to their own devices, are spatially disequilibrating. Economies of scale and agglomeration lead to the cumulative concentration of capital, labor, and output in certain regions at the expense of others: uneven regional development is self-reinforcing rather than self-correcting. Various countervailing forces (congestion diseconomies, "trickle-down"

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effects, and governmental fiscal transfers) may keep regional divergence in check, but are considered unlikely to be sufficient to promote regional convergence.

The Marxist accounts of uneven regional development that became popular among geographers during the 1970s and early 1980s challenged both of these views. Epitomized, for example, by the writings of Harvey (1982), Massey (1984), and Smith (1984), these Marxist theories viewed regional economic evolution as neither convergent nor divergent, but as essentially *episodic*: the accumulation crises that from time to time punctuate the course of capitalist development promote the search for new spatial, technological, and social "fixes" and lead to new configurations of regional relative growth and decline. Thus, in theory, it would be possible to observe regional convergence during one historical phase of regional development but divergence in another phase. Although there were some attempts to link Marxist models of uneven regional development and regional cumulative causation models of the Myrdal-Kaldor type (for example, Holland 1976), the focus of Marxist regional theory was more on the dynamics of periodic "spatial restructuring" than on the long-term trajectories of regional growth.

Since the mid-1980s, this shift away from a concern with the long-term evolution of the space economy within geographic studies of regional development has continued. Marxist approaches have given way to neo-Marshallian and transactions cost theories of regional economic agglomeration and growth. While these studies have certainly shed some interesting light on the technological, institutional, and social foundations of regional economic development, understanding and charting the trajectory of a nation's regional system *as a whole* has in effect been subordinated to the analysis of a particular sort of region—the exemplar "industrial districts" of post-Fordist "flexible specialization"—regardless of where these are found (Markusen 1996). Although this biased focus on "new" regions to the neglect of "old" regions has recently begun to be addressed (see, for example, Gertler 1992; Cooke 1995; Florida 1996), thereby highlighting the diversity of change evident across different types of regional economy, the emphasis remains firmly on the contingent conditions of growth in *particular* regions, rather than on the long-term evolution of the *entire* regional economic system.

It is perhaps ironic, therefore, that while geographers' interest in the measurement of the long-term evolution of regional systems has waned, economists have been busy reviving their interest in long-term economic growth. After languishing in the early 1960s, since the mid-1980s long-term growth has reappeared back on the economists' research agenda. An important stimulus for this revival has been renewed interest in the empirics of growth, and especially in the evidence for long-term convergence in per capita incomes and output between nations. This empirical debate has in turn promoted the reexamination and reorientation of growth theory. The thrust of this new endeavor has been to escape the straightjacket of conventional neoclassical theory by treating as *endogenous* to the growth process those factors that the neoclassical growth model relegates as *exogenous*, in particular technological change and human capital. Hence the label *endogenous growth theory* is commonly used to refer to this new approach. These empirical and theoretical developments have important implications for the study of long-term regional growth trajectories. Indeed, some of the economists who have been at the forefront of the formulation of endogenous growth theory and the new growth empirics have begun to use regional growth patterns to evaluate and develop their ideas. A reexamination of regional growth patterns and an assessment of the usefulness and applicability of the new endogenous growth theory to the analysis and explanation of long-term regional development would thus seem apposite. At the same time, recent

advances in, and evidence from, economic geography provide a valuable means of interrogating the claims and predictions of endogenous growth theory. These twin motivations form the rationale for this paper.

The New Empirics of Regional Convergence

Over the past decade, empirical work by economists on cross-national and cross-regional convergence has proliferated (for useful reviews see, for example, Chatterji 1992; Barro and Sala-i Martin 1995a; Canova and Marcet 1995; de la Fuente 1995; Galor 1996; Sala-i-Martin 1996a). Essentially, attention has focused on two concepts or measures of convergence. So-called *β-convergence* among a group of economies (countries or regions) is said to exist if the regression coefficient, β, of the growth rate of regional relative per capita income (usually measured by per capita gross domestic product (GDP)) over a given period on the level of regional relative per capita income at the beginning of the period is negative (see Appendix 1). A negative value of β implies that there is a tendency for per capita incomes to equalize across economies; the value of β measures the speed of convergence. A group of economies (countries or regions) is said to be characterized by so-called *σ-convergence* if the dispersion (variance) of their relative per capita income levels tends to decrease over time. The concept of σ-convergence can easily be shown to be closely related to that of absolute convergence (see Appendix 1). The existence of β-convergence will tend to generate declining dispersion or σ-convergence. However, since the latter also depends on the variance of the error terms or "shocks" in the growth regression, although the long-term (steady-state) dispersion falls with β (the strength of the convergence effect) it rises with the variance of the disturbance term. Thus the existence of β-convergence is a necessary but not sufficient condition for σ-convergence.

There have been numerous attempts to measure the speed of cross-country β-convergence (see Baumol 1986; Romer 1986; Baumol and Wolff 1988; DeLong 1988; Dowrick and Nguyen 1989; Barro 1991; Dowrick and Gemmell 1991; Barro and Sala-i-Martin 1992a, 1992b, 1995a; Chatterji 1992; Mankiw, Romer, and Weil 1992; Canova and Marcet 1995; Sala-i-Martin 1996a). The general conclusion from these studies is that only when attention is restricted to the set of richer Organisation for Economic Cooperation and Development (OECD) countries is there some support for absolute convergence.[1] This has prompted two main developments in the basic convergence regression. The first is the idea of *club convergence*—that is, the hypothesis that only countries that are similar in their structural characteristics and that have similar initial conditions will converge to one another. Thus the richer OECD countries may form one "convergence club," the developing countries another, and the underdeveloped yet another. There need be no convergence among these clubs, and hence the broad inequalities among the different club sets may persist or even increase, so that the cross-country income

[1] The earlier studies used Maddison's (1982) historical series on GDP for 13 advanced countries for 1870–1979 and found strong evidence of convergence in the post–World War II period. However, this finding can be criticized on the grounds that it referred only to a set of similar countries, all of which were rich ex post and hence biased toward convergence, whereas the analysis should have included an ex ante sample of countries that in 1870 were likely to have industrialized. When the sample of countries is expanded to include developing and undeveloped nations, the evidence for convergence disappears. There is no consistent tendency for the poorer countries to grow faster than, and hence to catch up with, the richer, and no tendency for the cross-national dispersion of per capita GDP to decline over time.

distribution becomes polarized (see, for example, Chatterji 1992; Canova and Marcet 1995; Galor 1996; Quah 1996a).[2]

The second reformulation of the standard β-convergence model has been to test whether economies converge, not to a common steady state (equalization of incomes) but to their own long-term steady-state (equilibrium) income relativities. This concept is known as *conditional convergence* (Sala-i-Martin 1991; Barro and Sala-i-Martin 1992a; Mankiw, Romer, and Weil 1992), because convergence is conditional on the different structural characteristics or "fundamentals" of each economy, such as its societal preferences, technologies, rate of population growth, and government policy. Different structural characteristics imply that different countries will have different steady-state relative per capita incomes. To test for conditional convergence, therefore, it is necessary to hold constant the steady state of each economy. One method is to introduce into the basic "growth regression" additional structural-type variables that proxy for the steady state. If β is negative once these other regressor variables are included, then the economies in question are said to display *conditional* β-convergence. Using this approach, Barro (1991), Mankiw, Romer, and Weil (1992), and Barro and Sala-i-Martin (1995a) find strong cross-country support for the conditional convergence hypothesis.

An alternative method is to restrict the analysis of convergence to sets of economies for which the assumption of similar technology, institutions, tastes, and so forth is not unrealistic. Hence similar economies should display absolute β-convergence. It is in this context that economists have begun to show considerable interest in the question of regional convergence within countries. They argue that regions within a nation are much more likely to share similar structural characteristics than are different nations, so that *regional systems may be expected to show much greater evidence of long-term absolute convergence.* In the view of Barro and Sala-i-Martin, for example,

> Although differences in technology, preferences and institutions do exist across regions, these differences are likely to be smaller than those across countries. Firms and households of different regions within a single country tend to have access to similar technologies and have roughly similar tastes and cultures. Furthermore, the regions share a common central government and therefore have similar institutional set-ups and legal systems. This relative homogeneity means that absolute convergence is more likely to apply across regions within countries than across countries. (Barro and Sala-i-Martin 1995a, 382)

They add that factor mobility is also likely to be higher across regions than between countries, and that legal, cultural, linguistic, and institutional barriers are smaller between regions within countries than between countries.

Barro and Sala-i-Martin (1991, 1992a, 1992b, 1995a) have tested for absolute convergence of regional per capita incomes across the U.S. states, the Japanese prefectures, the NUTS1 regions in eight European countries (Germany, France, the United Kingdom, Italy, the Netherlands, Belgium, Denmark, and Spain), and the Canadian provinces. In all cases they find evidence of long-term regional convergence. The dispersion (variance) of regional per capita incomes declines steadily over time. Moreover, the speed with which regions of different countries converge to their respective national means (absolute β-convergence) is remarkably similar, about 2 percent per annum (that is, a value of about –0.02; see Table 1). In the case of the United States, Europe, and Japan, they also find that the

[2] The existence of convergence clubs can be explored statistically by adding successive powers of $\log(y_{it})$ as additional variables in the basic "growth regression" to test for the existence of multiple steady states to which different groups of countries are converging.

Table 1

The Empirics of Regional Convergence: Summary of Some Major Studies

Study	U.S. States	Japanese Prefectures	European Regions (NUTS1)	European Regions (NUTS2)	Canadian Provinces	Australian States
Barro and Sala-i-Martin (1995a)	*1870–1990* β= 0.027	*1930–90* β= 0.027	*1950–60* β= 0.018			
	1920–1930 β= –0.014	*1930–55* β= 0.035	*1960–70* β= 0.023			
	1940–50 β= 0.043	*1955–90* β= 0.019	*1970–80* β= 0.020			
	1960–70 β= 0.024	*1980–85* β= –0.001	*1980–90* β= 0.010			
	1980–90 β= 0.001					
Sala-i-Martin (1996b)	*1870–1990* β= 0.017	*1955–90* β= 0.019	*1950–90* β= 0.015		*1961–91* β= 0.024	
Armstrong (1995)	*1963–86* β= 0.023		*1950–60* β= 0.012	*1950–60* β= 0.016		*1953–91* β= 0.009
			1960–70 β= 0.025	*1960–70* β= 0.027		*1977–93* β= –0.017
			1975–93 β= 0.006	*1975–81* β= 0.008		
				1981–93 β= 0.002		
				1975–93 β= 0.003		

Note: The rate of β-convergence is estimated from growth regressions for the periods shown. All of the studies use a non-linear version of the basic growth regression, namely

$$(1/T)\log(y_{it+T}/y_{it}) = \alpha - [(1-e^{-\beta T})/T]\log(y_{it}) + \epsilon_{it,t+T},$$

where $\epsilon_{it,t+T}$ is the average of the error terms between t and $t+T$. This is preferred to the straightforward linear growth regression because it allows convergence to be asymptotic and for the speed of β-convergence to be compared directly across historical periods of different length without having to use transformations. In the table a positive value of β (but less than unity) implies regional convergence. A negative value implies divergence.

speed of regional convergence has varied over time, and that there have been periods when β has been positive—that is, regional per capita incomes have diverged, as has happened since the mid to late 1970s. Similar estimates of convergence of around 2 percent per annum have been produced by other authors for Japan (Shioji

1993), Canada (Coulombe and Lee 1993), Australia (Cashin 1995), Sweden (Perrson 1994), and Germany (Keller 1994).

Armstrong (1995) has also carried out extensive analyses of regional convergence for Europe, the United States, and Australia. His results, like those of Barro and Sala-i-Martin, suggest that there has been considerable variability in the speed of convergence over different periods of time (Table 1). For the United States, he found regional incomes converged at an overall rate of just over 2 percent between 1963 and 1986. There was also substantial variation between different subperiods, however, from a convergence rate of 3.6 percent over 1963–71 and 1971–75 to regional divergence of 0.40 percent per annum between 1975 and 1981. In the case of Australia, he found regional income convergence of about 1 percent per annum for the whole 1953–91 period, but divergence since the late 1970s. The European results follow a somewhat similar pattern, with absolute convergence of about 1 percent per annum between 1975 and 1991 at the NUTS1 level, but only 0.4 percent per annum for NUTS2 regions. At both geographic scales, there is evidence that convergence fluctuates with the economic cycle, being greater in boom periods than during recessionary phases, and that the speed of convergence slowed down considerably after 1981.[3] Although there is little indication of regional convergence clubs, even in the European case, where a major division between the dynamic northern growth regions and the economically peripheral Mediterranean area might have been expected,[4] there is clear evidence of *geographic clustering* of regional growth rates in both Europe and the United States. Fast-growth regions tend to be spatially clustered with other fast-growth regions, and similarly, slow-growth regions tend to be geographically grouped in close proximity.[5]

It should be noted, however, that these estimates of regional convergence, and the methods by which they have been obtained, can be questioned (Bernard and Durlauf 1995). One problem is that the "growth regression" approach only relates a region's growth to its *own* history, and then only by *averaging* across the trends for all regions. By pooling data for all the geographic areas in the system being studied, the growth regression approach thus assumes that the underlying convergence-generating process is identical across space, when in reality it is likely that the rate of convergence will vary from region to region (see Quah 1993; Canova and Marcet 1995).[6] In other words, different regions may converge to different long-

[3] This result is supported by Dunford's (1993) more descriptive study of regional disparities in the European Union. Dunford finds that the regional dispersion of GDP per capita increased in most of the European Union member states during the 1980s. Unfortunately, however, Dunford does not estimate growth regressions of the sort used in the regional growth empirics literature. Instead, he regresses regional growth rates (over 1977–89) on the *end of period*, rather than initial, levels of regional per capita GDP. It is difficult, therefore, to reconcile his results with the work being discussed here.

[4] This lack of convergence clubs contrasts somewhat with the study of trends in per capita GDP among U.K. counties by Chatterji and Dewhurst (1996). They provide evidence of three convergence clubs among the U.K. counties over the period 1977–91, and while like Armstrong they also find that the speed of regional convergence varies with the economic cycle, the relationship is in the opposite direction: convergence appears to be fastest during periods of slow national growth rather than during national booms.

[5] Armstrong deploys a range of spatial autocorrelation procedures to test for the presence of geographic clustering of the unexplained residual regional growth rates from his growth regressions.

[6] Canova and Marcet (1995) argue that by assuming a common rate of convergence for all regions and ignoring the heterogeneity of the space economy, the growth regression model seriously underestimates the rate of regional

term relative income levels that reflect persistent local differences in structural characteristics (see Durlauf and Johnson 1995; Evans and Karras 1996). Furthermore, the approach fails to take into account how different regions *relate to one another,* whereas the growth trend of a region may actually depend crucially (either positively or negatively) on the growth trajectories of others (see Quah (1993) for a discussion of this issue of the interrelatedness of regions within the cross-regional income distribution).

A second problem concerns the theoretical underpinnings of the β-convergence model. In one sense the approach is merely descriptive and says nothing about the mechanisms at work. However, as Barro and Sala-i-Martin (1995a) show, it does provide a direct test of the standard (Solow-Swan) neoclassical growth model (with its assumption of diminishing returns to capital) (see Solow 1956). As Barro and Sala-i-Martin admit, the slow rates of regional convergence given by the growth regression model are much less than would be expected from a standard neoclassical view of the regional growth process. The rate of 2 percent per annum that seems to typify the United States implies that it takes 35 years for an initial regional disparity in relative per capita income to be halved, while the rate of 1 percent found in Europe implies a "half-life" of about 70 years.[7] These results thus raise fundamental questions about the validity of neoclassical growth theory. In this context, the significant spatial clustering of regions with similar growth rates found by Armstrong (1995) and Quah (1996b) suggests that spillover effects (of labor, capital, technology, and other influences on growth) are geographically localized, which also runs counter to neoclassical growth theory. Likewise, the fact that regional convergence does not appear to be a simple monotonic process, but seems to vary over time, requires explanation. In particular, most of the advanced countries show a similar sharp slowdown in the speed of regional convergence and even a trend toward increased regional income dispersion since the mid-1970s. Most authors invoke "exogenous shocks" to account for these "deviations." Thus Barro and Sala-i-Martin (1995a) attribute the recent convergence slowdown in Europe to the uneven regional impact of the early 1970s oil price hike, that in the United States to the impact of Reagan's economic policies, and that in Japan to the exceptional growth of Tokyo during the 1980s. The growth regression approach is unable to tell us whether this appeal to ad hoc, "exceptional" events is sufficient, or whether the reversal of convergence over the past two decades signals a more fundamental structural or systemic change to the process of regional growth.

New Endogenous Growth Theory

During the mid-1980s, several problems with the canonical neoclassical growth model were "rediscovered." A basic limitation is that because of the assumption of diminishing returns to capital in the production function (see Appendix 2), the model predicts that per capita output growth declines in the long run. To remedy this defect, *exogenous* technological progress is added to the model, so that long-term growth also becomes exogenous, determined by technological factors

convergence. By giving much greater attention to the initial starting position of each region they find that, instead of very slow absolute convergence, European regions show quite rapid *conditional* convergence. They therefore reject the contention that regions are converging to an identical steady state and insist that the main determinant of a region's steady-state position is in fact its position in the initial interregional income distribution.

[7] The half-life, or time required for one-half of the initial deviation of relative regional per capita income from its steady-state value to be eliminated, is given by $H = \ln 2 / -\ln(1-\beta)$.

autonomous to the model. When the model was tested empirically, however, it was found that the proportion of observed growth that had to be attributed to unexplained "exogenous" technological progress was substantial. Then, in addition, as we have already noted, the neoclassical model's prediction of converging per capita incomes appeared increasingly at odds with the lack of evidence for international convergence and the fluctuating strength of the convergence process even within the industrialized club of countries (Abramovitz 1986; Boltho and Holtham 1992).[8] One response to some of these problems was to *augment* the neoclassical production function with a measure of human capital (Appendix 2), as proxied by some form of educational variable (see, for example, Mankiw, Romer, and Weil 1992). Yet while the inclusion of human capital reduces the predicted speed of convergence, the returns to capital nevertheless still diminish in the long run. Furthermore, even with the inclusion of a human capital term, the augmented model predicts conditional rather than absolute convergence. Only when national differences in such variables as savings and population are controlled for can convergence be identified (see Table 2).

The recent development of endogenous growth theory represents a more radical response to the shortcomings of the conventional neoclassical approach.[9] Endogenous growth theory is a radical response in the sense that it introduces increasing returns into the production function in order to determine the long-term growth rate *within* the model—that is, *endogenously*.[10] There are two different types of endogenous growth theory, however, which envisage different sorts of increasing returns (Table 2): *endogenous broad capital* models and *endogenous innovation* models (Crafts 1996a). Endogenous "broad capital" models can be further separated into two sets: those that simply show capital investment as generating externalities, and those that emphasize human capital and relate technological change to "learning by doing" and "knowledge spillovers." The second type, endogenous innovation growth theory, has been labeled Schumpeterian because it emphasizes the returns to technological improvements arising from deliberate and intentional innovation by producers.[11] In the remainder of this section we review these three different classes of models.

The endogenous broad capital model modifies the conventional neoclassical production function to include externalities to investment (Appendix 2). For example, Romer (1986) argues that investment in

[8] It is clear that the "Golden Age of Capitalism" between 1950 and 1973 was the era of most rapid convergence in per capita incomes, and it is difficult to explain this using only the basic neoclassical model (see Crafts and Toniolo 1995).

[9] Buchanan and Yoon (1994) provide a useful collection of articles showing the origins of thinking on increasing returns and their current return to popularity. There are, of course, even more fundamental critiques of the neoclassical production function. Scott (1992), for example, dismisses the concept of the production function on the grounds that capital inputs fail to take account of the rate of obsolescence, and in this respect Scott's dismissal echoes that of Kaldor (1985).

[10] The centrality of increasing returns to the new growth theories is reminiscent of the development theory of Myrdal (1957), Hirschman (1958), and others, which envisaged a tendency toward cumulative causation and divergence, and of the demand-led models of cumulative growth and increasing returns described by Kaldor (1985). However, this earlier work tended to be less abstract and mathematical and to be more descriptive than the endogenous theories. According to Romer (1993) and Krugman (1995b), recent advances in the formal modeling of imperfect competition have facilitated a rescue of some of the insights of the earlier tradition.

[11] See Van de Klundert and Smulders (1992), Gould and Ruffin (1993), and Boltho and Holtham (1992) and Crafts (1996a) for useful surveys of the new growth models.

Table 2

A Typology of "New" Growth Theories

Type of Growth Theory	"Engine of Growth" Convergence?
Augmented neoclassical	Physical and human capital, exogenous technical progress universally available. Slow and conditional convergence within clubs of countries with similar socioeconomic structures.
Endogenous broad capital	Capital investment, constant returns through knowledge spillovers. Cumulative divergence, but shaped by government spending and taxation.
Intentional human capital	Spillovers from education and training investments by individual agents. Convergence dependent on returns to investment, public policy, and patterns of industrial and trade specialization.
Schumpeterian endogenous innovation	Technological innovation by oligopolistic producers, with technological diffusion, transfer, and imitation. Multiple steady states and persistent divergence likely. Possible club convergence and catch-up.

capital stock generates "learning by doing" (see Arrow 1962) and "spillovers" of knowledge and that, through these externalities, technology becomes a "public good." In this way, technological progress is made *endogenous* to the growth process. One implication of this approach is that investment in physical capital equipment is strongly correlated with, and causally related to, growth (DeLong and Summers 1991). However, several criticisms of these models have been influential. High rates of fixed capital accumulation appear to *follow*, rather than precede, periods of rapid growth (Blomstrom, Lipsey, and Zejan 1996). Moreover, one of the major problems of this type of capital model is that, unrealistically, technological change is pictured as the "side effect" of other activities rather than the result of deliberate choices and actions by economic agents (Romer 1994; Crafts 1995).

Thus a second series of endogenous models portrays technological progress as the result of intentional research and education (R&E) and introduces human capital into the production function.[12] In these versions, investment in human capital generates spillover effects which increase the productivity of both physical capital and the wider labor force (Lucas 1988). It is assumed that human capital is acquired intentionally by individuals because it leads to higher real wages and that each generation of workers assimilates ideas passed on by the preceding generation so that there are no diminishing returns. Another variant asserts that external increasing returns from human capital arise from on-the-job training or "learning by doing" in employment (Lucas 1988). The model thus implies that because of national differences in investment in R&E income differentials between countries may be persistent (see Stokey 1991; Lucas 1993). Nevertheless, these human capital models continue to face the key question that besets all the broad capital models, namely whether it is convincing to show returns to capital as constant or increasing rather than diminishing. A series of studies has produced evidence that returns to even broad capital are in fact diminishing in the long run (Mankiw, Romer, and Weil 1992; Levine and Renelt 1992; Islam 1995). This problem is one of the reasons why attention has shifted to explicitly technological models.

In Schumpeterian endogenous growth theory, purposive and profit-seeking

[12] This also led to Rebelo's (1991) endogenous growth model, where A is a constant and represents a composite of K and H.

improvements in technology are the main force behind rising standards of living. Rather than assuming technological progress to be exogenous or simply a side effect, Schumpeterian models seek to explain it. Typically, the incentive for firms to undertake research and development is the possibility that new products may earn temporary monopoly profits (Romer 1990; Grossman and Helpman 1991; Aghion and Howitt 1993). According to this approach, imperfect competition allows firms to capture sufficient profits to cover the costs of R&D; by developing a new product which is slightly higher up the "quality ladder" firms can capture the rents hitherto enjoyed by the producers of previous generations of the product. These innovations subsequently become the intermediate inputs to other firms, so that they determine the overall rate of growth. In general, growth depends on the balance of costs and benefits of research and is therefore influenced by the allocation of resources to innovation, by the size of markets, the productivity of labor involved in research, and the degree of market power enjoyed and expected by innovators. As we will see, there are numerous points of contention in this analysis.

The implication of these endogenous innovation models is once again possible divergence in growth patterns. But, this prediction is complicated by the need to take account of processes of *technology transfer* and *diffusion*. Recent technological approaches have argued that rapid growth is a function of both access to new technological ideas and the diffusion of those ideas through the productive structure (Romer 1993). It may well be that different countries exhibit different "social capabilities" to absorb, apply, and adapt to new technologies (Abramovitz 1986). If imitation is cheaper than innovation, however, then a process of club convergence will occur between interdependent economies as discoveries occur in the "leading edge" economy and then are imitated, relatively quickly, in "follower" economies (Barro and Sala-i-Martin 1995b). Thus, assuming technology transfer, endogenous innovation models, like augmented neoclassical models, can also generate patterns of club and conditional convergence (Gould and Ruffin 1993; Barro and Sala-i-Martin 1995b). There is, therefore, increasing interest in whether and in what ways trade, by disseminating new ideas and increasing the incentive for innovation, increases the rate of technological progress and hence growth (Grossman and Helpman 1991; Rivera-Batiz and Romer 1991; Ben David 1995).[13] The consequences of trade depend on whether it causes countries to specialize in industries and sectors where there is scope for technology spillovers, or whether it encourages specialization in labor-intensive, low-technology industries (this is also an issue in "strategic trade theory"; see, for example, Krugman 1995a).

The growing interest in how trade shapes the distribution of economic growth is not the only reason why these endogenous models are of potential relevance to economic geography. The emphasis placed upon increasing returns raises the issue of whether and to what extent these returns are geographically based or localized. Furthermore, by highlighting the increasing returns stemming from different types of investment the new growth economics implies that institutions and policy may have stronger effects on the growth rate than would be predicted using the traditional neoclassical model (Crafts 1996a).

[13] Young (1991), for example, argues that the effects of trade depend on the patterns of specialization that they create. He suggests that the development of new products exhibits a cyclical pattern. Innovations are gradually assimilated and made profitable through processes of learning by doing, and while this continues increasing returns exist. There is a limit to the improvements yielded by learning, however, and once these limits are reached diminishing returns set in. None of these processes are inevitable, as domestic producers may, of course, be unable to survive foreign competition.

Two main areas of policy debate have been stimulated by the new growth theories. The first focuses on the impact of fiscal policies and public infrastructure on national growth (see, for example, Barro 1991; Rebelo 1991; Sala-i-Martin 1996b; Levine and Renelt 1992; Easterly and Rebelo 1993) and the second on the scale of the resources and incentives available to technologically innovative sectors. Both of these are also relevant for the regional growth issue, especially since economic geographers have directed attention to the role of local institutional "thickness" and (central and local) state intervention in shaping regional development trajectories. The spatial implications and dimensions of endogenous growth theory thus warrant closer discussion.

Endogenous Regional Development

A recent review of regional convergence concludes that "Perhaps the greatest methodological challenge of all . . . is to adapt the concepts and techniques of new growth theory to a regional context" (Armstrong and Vickerman 1995, 19). As yet, there have been few explicit attempts to make this adaptation and to formulate regional endogenous growth models, although there are signs that this may be changing (see Benabou 1993, 1994; Bertola 1993; Cheshire and Carbonaro 1995; Sala-i-Martin 1996b). Without doubt, the development of endogenous growth theory reopens, and extends, the debate on processes of cumulative causation in regional development.[14] The slow rate of regional convergence identified earlier, and the tendency to find spatial clusters of high- and slow-growth regions, suggest that the key growth processes highlighted by the new growth theories either operate differentially over space or produce uneven development as part of their routine operation. In this section we start to consider the spatial dimension of these processes by addressing three overlapping themes: the significance and possible spatial consequences of increasing returns and externalities; the role played by endogenous human capital development in regional economies; and the importance of both technology innovation and technology transfer.

As we argued in the last section, endogenous growth theory is based on the existence of positive externalities and increasing returns. There is, of course, a long tradition of using externalities and increasing returns in urban and regional analysis, a tradition that has been revived in recent years (see Phelps 1992). Economic geographers have used neo-Marshallian external economies to explain the rise and success of new industrial districts, and the spatial clustering of firms has been used to explain national competitive advantage (Scott 1988; Porter 1990).[15] In addition, there has also been a resurgence of interest in the pecuniary economies which are produced by the agglomeration of firms from different industries in urban locations (Krugman 1991). Together, these types of increasing returns imply that regional development is highly path dependent; temporary conditions and shocks, as well as historical "accidents," may have permanent effects as patterns of specialization, of economic success or economic backwardness, become "locked in" through external and self-reinforcing effects. The implication of endogenous growth is that there are other types of externality, particularly in human capital development and technological leadership, which also act to "lock in" regional patterns

[14] While the idea of cumulative causation has long been familiar in economic geography, many would argue that it has never been fully incorporated into regional models (Armstrong and Taylor 1993). Endogenous growth theory may well provide the stimulus to do just this, as well as shedding light on the endogenous limits of cumulative processes.

[15] While much of this literature has focused on manufacturing, it has recently been argued that increasing returns are becoming more important to service industries.

of industrial specialization. To date, however, the new growth theory has given inadequate attention to the spatial dimensions of these types of externalities. Usually it is assumed that externalities and spillovers are perfectly mobile within national industries and sectors, even between different nations. However, we need to know much more about the specific geographies of such externalities and spillovers, particularly in the realms of human capital and technological development.

While the study of regional human capital development remains underdeveloped, there is an emerging interest within economics in the relationships between human capital and local economic performance. The focus of this is typically on the local skill base and the importance of local work force training, as human resources are far less mobile than capital and are a key constituent of the *indigenous* potential and competitiveness of localities and regions.[16] One set of human capital models emphasizes that human capital formation is group activity involving externalities which reinforce the persistence of socioeconomic inequalities and within urban areas. These externalities include the ability of local communities to provide financial resources for education and the series of rules, norms, and peer effects described as "social capital" (Benabou 1993, 1994). In this view, investment in human capital is a local public good. Durlauf (1994) also argues that neighborhood spillover effects, combined with income-based segregation, transmit economic status from one generation to the next. Most of these arguments have been developed on the basis of U.S. urban neighborhood experience, but similar cumulative effects may be apparent at regional scales and in other settings.

Another set of models highlights the possible connections between spatial variations in human capital and differences in productivity levels and growth. Analysts argue that the educational profile of the work force is one of the factors underlying interurban and regional differences in productivity growth (Lucas 1988; Mullen and Williams 1990; Ke and Bergman 1995). If groups of highly skilled and educated workers are concentrated in an area they will be more likely to exchange ideas, which in turn will boost the rate of technological improvements in local industries (Rauch 1993). According to Bradley and Taylor (1996), localities with a poor socioeconomic infrastructure and poor economic performance also tend to be marked by a poor educational performance.[17] In their view, the interaction between the local educational system and local economic performance produces a process in which spatial patterns of wealth creation and deprivation are self-perpetuating. Regional differences in real wage returns to investment in education and training would play an important role in this interaction (for the case of the United Kingdom see Bennett, Glennerster, and Nevison 1995). Once again, path dependence is important here, as regions which have traditionally specialized in sectors where returns to education are low would suffer cumulative disadvantage in comparison with high-skill, economically dynamic regions.

These analyses suggest that the migration of better-educated, highly skilled, and more enterprising workers is regionally disequilibrating, in that it benefits destination regions at the expense of the areas of ori-

[16] In fact, the terms endogenous growth and indigenous growth have often been taken as synonymous in recent regional studies. We argue later that this is mistaken and that confusing the terms can lead to misleading policy implications.

[17] This, in turn, has adverse long-term effects on economic development and on the socio-occupational mix of localities. Bradley and Taylor's conclusion is based on a statistical analysis of the interactions among educational provision, socioeconomic profile, and economic performance in the English local education authority areas.

gin. In many of the models, the migration of educated and skilled labor into areas which already have a high proportion of such workers in their socio-occupational mix is a key mechanism reinforcing differential regional growth and prosperity (Bradley and Taylor 1996). In contrast to the benefits to the destination areas, the origin regions tend to be left with less-skilled, less-enterprising, and more poorly educated workers, so that their relative human capital disadvantages are intensified. In Bertola's (1993) endogenous model of localized growth, for example, capital and labor tend to migrate to prosperous regions and to create increasing returns in these areas, which leads to permanent interregional income inequalities. These studies also imply that geographic spillovers of externalities and increasing returns are largely spatially confined to neighboring areas; this could possibly explain the spatial clustering of growth regions discussed earlier.

Another possible explanation for this geographic clustering lies in technological transfer and spillovers, and here too it is important to add a spatial dimension to the endogenous technology models. First, there is copious evidence that R&D activities themselves tend to cluster spatially in key regions, and there is a substantial literature on the underlying causes of the localization of high-technology industry (see, for example, Malecki 1991; Hall and Markusen 1985; Storper 1992; Thwaites and Oakey 1985; Todtling 1991).[18] Many of the explanations focus on factors which relate to human capital, such as the presence of pools of skilled and technical personnel and the propinquity of universities and government research establishments, but they rarely adopt an explicitly human capital perspective. Second, a smaller but highly significant literature suggests that technology transfers and spillovers are to some extent spatially localized. Acs, Audretsch, and Feldman (1993) find that more than 80 percent of new innovations in U.S. manufacturing in the early 1980s occurred in just 11 states and was highly correlated with R&D expenditure by private industry and universities in those areas.[19] Further, Audretsch and Feldman (1994) find that industries where technological spillovers are most important (i.e., where R&D and skilled labor are most important) are more spatially clustered than industries where spillovers are less significant. Likewise, Jaffe, Trajtenberg, and Henderson (1993) find that citations to domestic patents within the United States are more likely to come from the states and metropolitan areas where the cited patents are located. Others have identified a regional pattern to the diffusion of product innovations and a tendency for regional externalities to shape the adoption of innovations, whereby firms use other firms in a region to learn about and to utilize new technology (see Antonelli 1990; Thwaites 1982; Alderman and Davies 1990).

Endogenous innovation growth theories thus reopen the debate on whether regional technological differences play a causal role in regional patterns of growth. Earlier studies that found little evidence of technological progress and diffusion as causes of regional differences in productivity growth within the United States may well have been premature in their dismissal of the impact of technology. These studies were typically based on fairly crude statistical measures of "technology" (see, for example, McCombie 1982; Hulten and Schwab 1984). More recently, it has been

[18] The situation may well be different in smaller countries such as the Netherlands, where Kleinknecht and Poot (1992) find that technological innovation is fairly evenly distributed across regions.

[19] Acs, Audretsch, and Feldman (1993) use the U.S. Small Business Administration database. They suggest that small firms are able to access and exploit knowledge created by R&D in university laboratories and large corporations.

argued that, in some cases, regional spillovers of technology do raise regional productivity levels (Antonelli 1994). Thus, while endogenous growth theorists have begun to explore the explicit role of technology in determining economic growth trajectories and have started to appreciate that technological progress may have important localized origins and effects, the fact that this recognition remains constrained within a "production function" framework seriously limits the potential insights it offers into the regional growth process. In the next section we highlight some of these limitations by comparing endogenous modeling with other types of approach more familiar in recent economic geography.

Endogenous Growth, Institutions, and Indigenous Development

There are clearly significant differences, in terms of theory, method, and style, between endogenous growth models and the approaches to regional and local growth issues that prevail within contemporary economic geography. In the regulation theory approach that has influenced so much of economic geography in recent years, with the assumption of a transition from Fordism toward a more flexible post-Fordist regime of accumulation, national and regional growth rates are interpreted as depending fundamentally on the degree of correspondence between the organization of production and the regulatory institutional and social structures which support and regulate the economy. Commentators have argued that the correspondence between Fordist mass production and the institutional structures based on the "Keynesian Welfare State" have unraveled since the mid-1970s and that this breakdown has produced a growing divergence of regional growth rates as old Fordist industrial regions spiral into decline and economic growth shifts into regions of post-Fordist flexible production (Scott 1988). Although the notion of a strict dichotomy between Fordism and post-Fordism has rightly been questioned, post-Fordist strategies involving the flexible use of labor, machinery, and flexible interfirm relations continue to be seen as fundamental to rapid growth. Moreover, the significance which regulation theory accounts accord to the social and institutional contexts of the national economy have been transferred to smaller geographic scales, and especially to the "new industrial districts." Thus economic geographers have begun to show how the "thickness" and form of institutions are not uniform across a country but vary between regions and localities, with direct consequences for the growth performance of different areas (Amin and Thrift 1994; Storper 1993, 1995).

The contrast between the formal, equilibrium-type models of endogenous growth theory and the more descriptive and political-economic orientation of much post-Fordist and institutionalist work in economic geography is immediately apparent. Indeed, while post-Fordism was initially defined fairly rigidly in functionalist and organizational terms, in recent years it has been treated as a looser, stylized tendency and a broad chronological scheme (Amin 1994). Despite their fundamental differences, of course, both post-Fordist "theory" and endogenous models are types of abstraction and generalization. In our view, this does not mean that they necessarily deny the importance of geographic contingency. More specifically, the fact that the relationships proposed by endogenous growth models are often expressed mathematically need not imply that they inevitably conflict with an appreciation of geographic diversity and specificity. Rather, models of increasing returns summarize plausible, middle-level types of connections which are likely to vary over space and to work out differently in different places. While regional specificities and geographic contingencies clearly cannot be readily incorporated into formal growth models, these models can be used to sup-

ply a series of propositions which act as the starting points, and return destinations, of empirical research. Mathematical conceptualizations should not be understood as representations, but as metaphors or heuristic devices, whose value has to be tested in empirically grounded research (Sheppard and Barnes 1990). This is not to argue that these mathematical growth models should be treated uncritically. So far, their progress has been assessed mainly on the basis of mathematical criteria, and if such criteria are the only, or most important, basis of assessment then the danger is that the models will rely on chaotic conceptions rather than on theoretically valid causal relationships and be unable to reveal much about regional growth processes (cf. Sayer 1984). Thus while endogenous growth models represent a conceptual advance over orthodox growth theory, they are nevertheless constrained by their adherence to an equilibrium framework which results in several key limitations.

First, the main type of evidence used by endogenous growth theory has been the extensive statistical exercises reviewed earlier, and there have been few intensive studies of how increasing returns actually operate in specific industries and places. The proposed relationships may be mathematically plausible but their empirical significance has yet to be established. In contrast, recent analyses of regional growth in economic geography have tended to rely much more on intensive studies of particular regions and industrial districts rather than extensive statistical analyses. Until very recently, however, such studies in economic geography have been preoccupied with the most successful and dynamic districts, which in many ways are untypical of the majority of regions (see Gertler 1992). The recent widening of focus to include less-successful industrial regions may herald a better understanding of the more mundane mechanics of regional economic growth (Grabher 1993; Cooke 1995; Florida 1996). Those extensive studies that have been carried out by post-Fordist theorists have, not surprisingly, emphasized the change from regional convergence to divergence which has occurred in many industrial countries since the mid-1970s (Dunford 1993; Dunford and Perrons 1994). However, unlike the endogenous growth models, this reversal of regional convergence is atributed not to the impress of ad hoc "shocks," but to a major systemic discontinuity in production and accumulation.

Largely as a result of their dependence on types of increasing returns, endogenous growth models have difficulty accounting for shifts and reversals in rates of regional convergence; most have little to say about the slowness or nonexistence of regional convergence in Western countries in recent years.[20] Those forces which limit cumulative divergence, such as technological diffusion, have been much weaker but why this might be so is unexplained. Crafts (1996b) suggests that it may be possible to link endogenous models to Schumpeterian long-wave ideas and that the transition from one long wave to another results in a period of divergence. It might be that while major innovations tend to "bunch" in waves, the productivity advantages these innovation waves generate through "learning-by-doing" may differ and decay differentially across regions. Specifying and elaborating such ideas is not straightforward. In recent years many long-wave approaches have been broadened to take account of political conditions, institutional frameworks, and changes in the prevailing means of organizing and coordinating production. Although some endogenous growth models are sensitive to political variables and conditions, including the distribution of income, this sensitivity has been defined in terms of statistical regressions at national aggregate scales so that it provides little guide to how these variables relate to per-

[20] For example, Rigby (1991) documents the persistence of profit rate differences across Canadian regions between 1961 and 1984.

ods of regional convergence and divergence.

Furthermore, the rigidity of some of the models' assumptions tends to make them inappropriate for understanding historical change. For example, the association of innovation with oligopoly is problematic, as some studies have found that in some high-technology districts small firms, often formed by "breakaway" personnel, are significant innovators (Smith et al. 1993). Monopoly may also result in the disappearance of the stimulating effect of interfirm competition (Geroski 1994). Moreover, the association of innovation with oligopoly obscures the fact that spillovers across a *diversity* of firms in different sectors may be more important to technological and productivity growth than the spatial specialization of single industries or sectors (Jacobs 1969; Glaeser et al. 1992). Some of the existing perspectives on regional technological change attempt to construct a more historically dynamic approach to this issue. For example, in Markusen's (1985) profit cycle theory, technologically dynamic regions start with a fairly competitive stage, in which externalities are important, but then progress to a more oligopolistic stage as their products mature and technology diffuses to other areas. Similarly, some long-wave approaches argue that the innovation sector is competitive at the beginning of a "technological long wave," but gradually becomes oligopolistic, or that returns from innovation move from increasing to diminishing as a technological-economic paradigm matures. Such possible changes are missed by the endogenous innovation models, which fail to historicize the relationship between corporate context and innovation. Moreover, the Schumpeterian endogenous models are partial in the sense that while they stress innovation, and to a lesser extent imitation, they tend to overlook other processes of technological and productivity change. Webber and Rigby (1996), for instance, argue that productivity change, or unit cost reduction, in postwar U.S. manufacturing has been dominated by market selection effects, whereby some firms gain a larger share of the market, and by the entry and exit of marginal firms. Thus, they argue that the effects of innovation and imitation on productivity change and production costs are often exaggerated at the expense of changes in market structure.

The fact that high-growth regions on occasion lose their momentum and suffer problems of relative economic decline poses major problems for endogenous growth approaches in general. The models convey an inadequate sense of the obstacles and barriers to further growth which frequently arise.[21] One reason for this is that the models treat externalities in a general and abstract manner and, in relating them to the *rate* of technological progress or economic growth, they do not consider the actual *direction* or trajectory of these processes. But by obstructing changes of direction in a region's technological or growth trajectory, certain types of increasing returns may in fact engender the onset of relative regional decline. As Arthur (1989, 1994) argues, once a user has opted for a particular technology then increasing returns may encourage other users to replicate this choice, so that accidental initial events may have long-term consequences. However, this may result in these users being "locked in" to an inefficient technology so that the region's production structures gradually rigidify. As Frankel (1955) once argued, the "interrelatedness" of the different parts of an economic system (be it a firm, region, or nation) will increase the costs of changing any one part of that system. Thus increasing returns may in some senses become a force for *inertia*. Such effects are ignored by the endogenous

[21] A similar problem besets Kaldor's approach to regional growth, which also emphasized increasing returns in the form of economies of scale and the Verdoorn effect. Kaldor's model generates "too much cumulation" and does not give due weight to the barriers to continued accumulation which can emerge (Gordon 1991; Setterfield 1997).

growth models. If there are limits to the advantages to be gained from learning-by-doing with an individual product (Young 1993), then regional prosperity will in part depend on the ability of regions to absorb new classes of innovations.

In these debates it is apparent that endogenous growth approaches to regional development have to meet and respond to certain fundamental criticisms of the underlying endogenous growth models. There are at least three important critiques inherent within alternative approaches to regional development. First, the neo-Keynesian or Kaldorian critique argues that the endogenous models remain preoccupied with the supply side and that they rule out the key effects of the growth in demand for exports, and balance of payments constraints, on employment and productivity trends (McCombie and Thirlwall 1997). As a consequence, it is argued that endogenous growth models miss the main source of increasing returns, namely Verdoorn's Law, whereby rising output generates economies of scale and raises productivity (Kaldor 1981). This contentious effect is clearly distinct from the supply-side productivity effects envisaged in the endogenous growth approaches and may exist even if returns to capital are diminishing in the long run. The neo-Keynesian viewpoint emphasizes that endogenous growth approaches began with closed national economy models, which may have been applicable to some national economies in the past but are increasingly less so, and which are especially difficult to apply to regional economies, which are far less self-contained. Neo-Keynesians are, therefore, skeptical of the increasing number of attempts to link trade and technological diffusion to endogenous growth models because of their neglect of possible demand-side increasing returns.

While the debate about the significance and sources of increasing returns remains open, a second type of critique denies that increasing returns of any sort are necessary to explain uneven regional development. Sheppard and Barnes (1990), for example, offer an alternative neo-Ricardian approach which dismisses single-commodity models and simplified notions of capital. In this radically different view the marginal productivities of capital and labor do not determine profits and wage rates, and capital is better understood in terms of a Marxian and Sraffian circulation of commodities. As capital intensity is no guide to profit rates, capital may flow from capital-poor to capital-rich regions and thus accentuate regional imbalances. Rather than increasing returns, this approach explains the concentration of industrial activity in core regions in terms of the balance of class forces, and hence the distribution of income, and the lower transport costs and higher accessibility of these regions. The latter is crucial, because it facilitates a quicker turnover time for capital and therefore a higher profit rate in any given time period. In this view increasing returns may be incidental. Despite its being based on a radically different type of model, however, the neo-Ricardian view also emphasizes the importance of investment and productive techniques to regional development. Nevertheless, whether the approach necessarily denies that agglomeration can generate increasing returns within these spheres remains unclear.

Third, another fundamental critique of endogenous models is their reliance on static formal equilibrium frameworks which pay no heed to the (historical) social and institutional contexts which shape the operation of the growth processes (Skott and Auerbach 1995). This means that the models continue to represent economic actors as perfectly rational and fully knowledgeable of alternative choices and the consequences of their decisions (Boyer 1993). One problem here is that the importance of the effects of actors' expectations of economic growth on the level and type of investment is thereby neglected. Gertler (1986), for example, found that regional capital investment in the United States is an unpredictable and discontinuous process. It may well be that investors' expectations and confidence levels, labeled

"animal spirits" in Keynesian literature, partly explain this unpredictability (Clark, Gertler, and Whiteman 1986). These expectations may also play an important role in connecting institutional frameworks and social climates to the long-term dynamics of economic growth (Kotz, McDonough, and Reich 1994).

As we have seen, endogenous innovation models themselves highlight the diffusion and absorption of product and process innovations as being central to growth. The notion of the social capability of firms to generate, absorb, apply, and learn from innovations occupies a key place in these models. However, this capability itself appears to be exogenous, and very little is said about how such capability is determined and how it evolves through time. It is clear that this capability partly reflects the content of national technology regimes—that is, the social, institutional, and regulatory structures which shape the incentives and opportunities for R&D (Lundvall 1992; Archibugi and Michie 1995). It may also be that "social capability" is an integral part of varied "regional technological regimes" which may shape the adoption of new technological practices (Gertler 1993). In the United States, for example, it has been found that within given industrial sectors, different regions occupy different positions in production technology (capital/output and labor/output) space, and further that these differences are relatively stable through time (Rigby and Essletzbicher 1996). At present we know very little about the causes of these regimes; about how and in what ways they are related to local capital vintages, sunk costs, social externalities, foreign direct investment, and public sector activities.

On these issues endogenous growth models clearly raise more questions than they can answer. They continue to treat firms as "black-box" representative agents. But, as post-Fordist approaches in geography have emphasized, technological innovation is deeply embedded in organizational features and corporate systems so it would be a mistake to expect regional technological and growth trajectories to be reducible to formal models. A wide range of studies in economic geography have stressed that organizational and social divisions of labor and firm strategies are the bases of economic growth. In particular, it has been argued that interfirm and social networks which allow cooperative, reciprocal, and high-trust relationships and facilitate the sharing of risks and information are crucial to regional growth and high-technology districts. If these networks disintegrate for any reason, then the evidence suggests that local technological districts may decline precipitously (Glasmeier 1991; Saxenian 1991; Storper and Harrison 1991). While geographers are a long way from fully understanding these processes, their recognition of the importance of the social and institutional contexts of growth is a distinct advance on much of the economics literature.

This does not mean that economic geographers have nothing at all to learn from endogenous growth theory. The theory is based on the contention that the main factors underlying economic development should be understood as internal to an economic model of the growth process. This is clearly different from the way in which the term *endogenous development* has recently been used in economic geography and regional studies. Here it has been argued that the shift from "Fordism" to "post-Fordism" is creating scope for the rebirth and promotion of localized "endogenous" economic development. Thus Garofoli (1992), for example, argues that flexible production has allowed some regions to benefit from "development from below," a self-centered style of diffuse industrialization which is mainly controlled by actors within the local area. He calls this "endogenous development" and, in his view, this involves the local capacity to promote social learning, entrepreneurship, and innovation and to develop local productive interdependencies (see also Cooke and Morgan 1998). Although this is not a closed regional strategy, nevertheless it is

premised on a high degree of local autonomy (see Hilpert 1991). A similar theme of endogenous development weaves its way through much of the literature on the so-called "new industrial districts," which are seen as archetypal exemplars of endogenous development based on agglomerations of (typically small) locally originating businesses and locally based networks of trust, cooperation, and competition, all held together by locally based institutions, customs, and conventions (Harrison 1992; Storper 1995).

In these accounts, therefore, the term endogenous development is used in a manner which is synonymous with "locally based." Indeed, the term is very close to the idea of *indigenous development,* which has come to dominate local economic and regional policy thinking (see, for example, Campbell 1990; Chisholm 1990; Stohr 1990; Bennett, Krebs, and Zimmerman 1990). Almost invariably this concept is used to refer to policies aimed at stimulating local enterprise, small-firm growth, and technological innovation, although it has recently been widened to include the development of a "flexible" and highly trained local labor force.[22] In many of these discussions, the terms endogenous and indigenous development are used interchangeably. Yet, while endogenous growth theory supports an emphasis on increasing returns, human capital, and technology, it also implies that indigenous and endogenous are not synonymous. Endogenous growth theory makes the key factors to growth, including human capital, technology, and externalities, internal to the production function, not to local or even national economies. On the contrary, the theory underlines the importance of national and international (global) flows of goods and knowledge. Trade and the national system of education, for instance, are shown to be fundamental to a receptiveness to foreign innovations and new ideas. The implication is that those who advocate indigenous development should be wary of neglecting the larger scale and extralocal connections and flows highlighted by endogenous growth theory. In this respect, endogenous growth economics reinforces the criticism that indigenous local economic development policy of itself is unlikely to be sufficient for the regeneration of economically lagging areas (Armstrong and Taylor 1993).

But, at the same time, endogenous growth theory could clearly benefit from the idea of indigenous development emphasized by economic geographers. For the evidence does suggest that some of the key elements of growth—increasing returns, human capital formation, and technological progress—have a significant and causal localized dimension. The fact that external economies, skilled labor, and technological innovation all seem to be spatially clustered within nations indicates that geography is fundamental to the growth process. Some economists seem to have appreciated this: for example, both Krugman (1991, 1995b) and Porter (1990, 1994) recognize that the forces of growth and accumulation develop unevenly across the regions of a national economy and that this geographic unevenness in turn has a major influence on national growth, trade, and competitiveness (see Martin and Sunley 1996). Furthermore, the growing focus in economic geography on the role of institutions in shaping regional development also has important potential implications for endogenous growth theory. This perspective recognizes that the institutional structure of the space economy is crucial to the framework of contacts and interfirm networks, the circulation of knowledge, and the administration of markets that underpin a country's technological development. Thus far, although

[22] The underlying logic of such policy prescriptions is that in the same way that successful growth regions and industrial districts appear to owe their dynamism to their indigenous resources and capabilities, so the revival and development of old and declining regions and localities will depend on building and harnessing the indigenous enterprise and resources within these areas.

endogenous growth theory has looked for statistical correlations between growth and policy variables, it has not absorbed much of the new institutionalist economics, let alone geographic perspectives on institutions, yet such ideas would seem to be of central importance for understanding how the growth process is directed, encouraged, or constrained.

Conclusion

To retrace our argument a little, the new empirics of regional convergence in the industrialized world reveal a rate of regional convergence that is much slower than the rate proposed by orthodox neoclassical models. This implies that there continues to be a need for alternative theoretical accounts of regional growth and its underlying dynamics. Endogenous growth theory offers some scope in this direction, as the evidence suggests that the key factors stressed by endogenous growth theory—increasing returns, human capital, and technology—develop unevenly across the space economy and are locally and regionally differentiated. Endogenous growth theory undoubtedly offers some possible explanations of global-local interactions and the dynamics of regional growth, most of which revolve around the proposed connections among these key factors. Endogenous growth theory is also a reminder to economic geographers not to be seduced by an institutional foundationalism which excessively privileges "non-economic" institutional explanations of spatially uneven economic growth.

However, at the same time, as we have also tried to argue, endogenous growth theory is characterized by a series of key limitations, many of which stem from its reliance on formal models which fail to capture the importance of the socio-institutional context and embeddedness of regional economic development. In addition, thus far endogenous growth economics has been overwhelmingly abstractly theoretical and its key contentions have been insufficiently investigated empirically. This problem is particularly acute at the regional level. If future work becomes obsessed purely with the formal derivation of general growth equations and with constructing ever more complex regressions of growth on "conditioning variables" it is likely that growth debates will become entrapped in measuring the statistics of convergence and lose sight of the underlying issues and processes.[23] On the other hand, if the possibilities and questions raised by the endogenous growth models are used to guide more informal and empirical inquiry, then their potential significance for regional research could be more promising. This will depend on the successful combination of different styles of analysis, and in particular the exchange of ideas between the new growth theory and alternative approaches to regional development, including more contextualized, historical studies which are sensitive to the details and specificities of particular places (Crafts 1996b; Romer 1993). As has so often been the case when economists have turned their attention to regional development, the recent interest by the new growth theorists in regional convergence has failed to take *geography* and *place* seriously (see Martin 1999). It is not sufficient for the new growth theorists to analyze regional growth patterns within countries merely because regions offer a more "controlled" test of their models; this of itself provides few insights into the processes of regional development. Rather, endogenous growth theory needs to be properly "spatialized," not only in the sense of recognizing that the growth mechanisms emphasized by the theory operate unevenly across space but also in the sense of recognizing that those mechanisms are themselves spatially differentiated and in part geographically constituted.

[23] Gertler argues that this is precisely what happened to the earlier work on convergence, which flourished and then faded.

Appendix 1: Two Measures of Regional Convergence

Absolute Convergence

The test for regional convergence developed by economists in recent years, based on the so-called "growth regression," has the form:

$$(1/T)\log(y_{it+T}/y_{it}) = \alpha - \beta \log(y_{it}) + \epsilon_{it}, \quad (1)$$

where $y_{it} = Y_{it}/Y_t$ is per capita GDP in the i^{th} region relative to the average for the sample of regional economies under investigation, $(1/T)\log(y_{it+T}/y_{it})$ is the annualized rate of growth of relative per capita GDP in the i^{th} region over the study period between t and $t+T$, and $\log(y_{it})$ is the logarithm of relative per capita GDP in the i^{th} region in the base year t. This growth regression is itself derived from a standard neoclassical production function model (see Barro and Sala-i-Martin 1995a). If $0 < \beta < 1$, the data set is said to exhibit *"absolute" β-convergence*: there is a long-term tendency for per capita GDP to equalize across economies. The value of β measures the speed of the convergence process.

Dispersion

So-called *σ-convergence* exists if the dispersion (variance) of relative per capita GDP levels across regions tends to decrease over time, that is, if

$$\sigma_{yt+T} < \sigma_{yt}, \quad (2)$$

where σ_{yt} is the standard deviation of $\log(y_{it})$ at time t. The concept of σ-convergence can easily be shown to be closely related to that of absolute β-convergence by rewriting the basic growth regression in discrete time, corresponding, for example, to annual data, as

$$\log(y_{it}) = \alpha - (1-\beta)\log(y_{it-1}) + \epsilon_{it} \quad (3)$$

and taking the variance of both sides, so that

$$\sigma^2_{yt+T} = (1-\beta)^2 \sigma^2_{yt} + \sigma^2\epsilon. \quad (4)$$

In other words, the existence of β-convergence will tend to generate declining dispersion or σ-convergence. However, since the latter also depends on the variance of the error terms or "shocks," $\sigma^2\epsilon$, this implies that although the long-term (steady-state) dispersion, given as

$$\sigma^2_y = \sigma^2\epsilon / [1-(1-\beta)^2], \quad (5)$$

falls with β (the strength of the convergence effect), it rises with the variance of the disturbance term. It is in this sense that β-convergence is a necessary but not sufficient condition for σ-convergence.

Appendix 2: Neoclassical and Endogenous Growth Models

The Standard Neoclassical Growth Model

This is given by the production function

$$Y = TK^aL^b \quad (a + b = 1;\ 0 < a < 1),$$

where Y is output; T represents the level of technology, and is often called Total Factor Productivity (TFP); K refers to physical capital; and L to labor. This function has constant returns to scale, and each factor of production shows positive but diminishing marginal productivity.

The Augmented Neoclassical Growth Model

This augments the basic production function with a measure of "human capital" (H), so that

$$Y = TK^aL^bH^c \ (a + c < 1).$$

The Broad Capital Endogenous Growth Model

This modifies the conventional production function to include externalities to investment, in the form

$$Y = K^{a+x}L^b \quad (a + x = 1),$$

where x represents externalities or social returns which result in constant rather than diminishing returns to investment.

The Intentional Human Capital Endogenous Growth Model

This portrays technological progress as a result of research and education via the accumulation of human capital,

$$Y = K^aL^bH^c \quad (a + c = 1),$$

and where the returns to human and physical capital combined are assumed to be constant.

The Schumpeterian or Innovation Endogenous Growth Model

The production function underpinning this model is

$$Y = CK^aL^bD^d \quad (a + b + d = 1),$$

where C is a constant and D is an index of the creation of intermediate goods which embody innovative progress. D increases with the amount of labor allocated to R&D, and it is assumed that this labor is used with constant returns as a result of the spillover effects of increased technological knowledge.

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