Convergence in Space

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Abstract

The study of regional income convergence continues to attract enormous attention. Recent emphasis has been placed on the underlying spatial dimensions of regional growth processes both from theoretical and empirical perspectives, as well as from exploratory and confirmatory methodological stances. This paper provides a survey of these efforts. It focuses on a comprehensive overview of empirical studies of regional convergence and divergence, summarizing the existing body of substantive results. The paper also provides a critical review of empirical approaches and methodological advances with an emphasis on the treatment of spatial effects, namely spatial dependence, spatial heterogeneity and spatial scale. A number of areas that have been overlooked are highlighted, and the paper suggests a research agenda on regional growth empirics.

1 Introduction

There is a growing recognition of the importance of space to many socioeconomic processes (Goodchild et al., 2000). Perhaps nowhere has this been more evident than in the interest in spatial patterns of inequality and the dynamics of geographical income differentials. This interest spans multiple social sciences. Within economics the question of economic convergence,[1] which is broadly concerned with whether poor economies catch-up to wealthier economies, has generated an explosion of empirical studies[2] at the inter-

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[1]A recent bibliometric analysis of regional science journals found that the topics of regional growth, convergence and agglomeration have the highest citation indices of all themes published over the last decade (Rey and Anselin, 2000).

[2]Recent surveys of this literature can be found in De la Fuente (1997); Durlauf and Quah (1999); Temple (1999); Florax et al. (2002); Fingleton (2003); Magrini (2004).

national (Pritchett, 1997), national (Barro and Sala-i-Martin, 1992), state (Bukenya et al., 2002), and urban (Drennan and Lobo, 1999) scales. Within criminology (Morenoff et al., 2001), geography (Gaile, 1984; Harvey, 1996; Fan and Casetti, 1994; Glasmeier and Fuelhart, 1999), history (O'Connor et al., 2001), sociology (Sassen, 1993, 1994), political science (Gruber and Gaines, 2001) as well as economics (Krugman, 1999), there have been long standing concerns with levels of spatial income inequality, their persistence and the underlying processes giving rise to them. Here again, these issues have been explored across a spectrum of spatial scales from that of the global economy (Theil, 1989; Krugman and Venables, 1995; Jones, 1997b; Galbraith and Berner, 2001) down to the level of the neighborhood (Durlauf, 1994; Ioannides and Selsen, 2001).

This interest has been reflected in theoretical, policy and empirical developments. From a theoretical perspective, the importance of spatial externalities in fueling economic growth, and potentially contributing to increased regional income differentials are central themes in the models of new economic geography (Puga, 1999; Fujita et al., 2001) as well as endogenous growth theories (Aghion and Howitt, 1997). From a policy perspective, the adjustment of local and state economies to the spatial impacts of globalization (Glasmeier and Conroy, 1994), the design of geographically targeted aid programs to alleviate poverty and the appropriate delineation of target boundaries as well as the geographic unit chosen to evaluate the effectiveness of these programs are central concerns (Baker and Grosh, 1994). On the empirical front, there has been a "rediscovery" of the region as a useful unit of observation for the purposes of testing competing economic growth theories (Blanchard and Katz, 1992) as well as a host of regional economic issues (Quigley, 2001).

Despite this resurgence of interest in regional economic growth and inequality, the geographical dimensions of the data underlying empirical analyses have received much less attention. Instead, methods developed in the mainstream social science disciplines have been applied with little regard for the potential challenges posed by spatially referenced data. This ignores the findings of the literature in spatial econometrics (Anselin and Florax, 1995; Anselin, 2001; Anselin et al., 2004) and spatial statistics (Getis et al., 2002) that highlights the importance of taking the spatial dimensions to heart in any analysis using georeferenced data.

Empirically, the treatment of space in the analysis of regional income growth, spatial income inequality, and regional income distributions has only recently begun to attract attention. With respect to growth empirics, there is some evidence suggesting that physical location and geographical spillovers can matter more than traditional macroeconomic factors (Quah, 1996a; Moreno and Trehan, 1997). Moreover, recent applications of formal spatial econometric methods to the question of regional income convergence have yielded new insights about the nature of spatial economic change (Chua, 1993; Moreno and Trehan, 1997; López-Bazo et al., 1998; Rey and Montouri, 1999; Fingleton, 2002). These findings are promising, yet much remains to be done regarding the development of spatially explicit methods for analyzing regional economic convergence and inequality.

While providing rich conceptual frameworks for thinking about the dynamics of regional evolutions, the abstract nature of modern growth theories has led to a growing gap between the empirical and theoretical growth literatures (Durlauf, 2001, p. 65). The implementation of growth theories in estimable econometric specifications has been fraught with a number of problems, some of which have been overlooked to date. Chief among these is the representation of spatial spillover effects which are often central to recent theoretical arguments (Moreno and Trehan, 1997). These spillovers introduce a form of simultaneity into model specification reflecting spatial interaction across the observational units. This type of simultaneity is not accounted for appropriately by traditional econometric estimators (Rey and Boarnet, 2004). In order to close the gap between theory and practice, new methods of dynamic spatial analysis are required that can translate fascinating theoretical constructs such as convergence clusters (Quah, 1996a), poverty traps (Esteban and Ray, 1994) and convergence clubs (Chatterji and Dewhurst, 1996) into empirically testable specifications. More broadly, there is a need for further advances in empirical methodology in the growth and agglomeration literatures (Brülhart, 1998).

Although related, the questions of convergence, inequality and distributional dynamics have largely been treated in separate literatures. This is beginning to change, however, with several recent calls for integration of the inequality and convergence literatures (Sala-i-Martin, 2002; Howlett et al., 2002; Quah, 2002), as well as a reconsideration of the relationship between growth and inequality (Benabou, 1996). This integration is currently focused at the international scale, while the articulation of the relationship between growth, inequality and convergence at the subnational and regional scales remains unexamined.

In this paper we revisit the literatures on regional convergence and inequality with a critical eye towards the role of spatial effects in empirical analysis. We focus on both confirmatory approaches as well as exploratory modes of analysis. Highlighted are a number of areas where geographical perspectives have yeilded improved understanding of regional growth dynamics as well as areas that remain relatively unexplored from a spatial perspective.

The paper is organized as follows. In section 2 we review the empirical literatures on convergence and inequality, highlighting key research themes. Attention is first focused on confirmatory analyses of convergence, followed by the literature on exploratory data analysis of growth dynamics. The final theme in this section focuses on the regional inequality literature. Following the review component of the paper we then present a research agenda for empirical research on regional growth and inequality in section 3. The paper closes with some summary comments.

2 Space, Convergence and Inequality

As is discussed more fully below, the convergence literature is concerned with the question of whether poor economies catch-up to wealthier economies over time, while the inequality literature has tended to focus on a more detailed analysis of the nature of income differentials across economies at one point in time. The role of space has only recently begun to attract attention in the regional convergence literature, while the older literature on regional inequality has been virtually silent on the complications that spatial data pose.

Over the past 15 years the number of empirical studies of regional convergence has exploded.[3] Different notions of regional convergence abound in the literature (Quah, 1993b; Sala-i-Martin, 1996) and much controversy exists surrounding the connections between alternative definitions of convergence and the empirical strategies used to examine regional growth patterns (Jones, 1997a), and the evaluation of competing growth theories in light of existing evidence (Bernard and Durlauf, 1996; Galor, 1996; Esteban, 2000). Additionally, the empirical evidence is not robust to the underlying research design as the conclusions from cross-sectional studies (Barro and Sala-i-Martin, 1992; Sala-i-Martin, 1997; Tsionas, 2000a) differ from those generated by time-series (Bernard and Jones, 1996a,b) and panel data approaches (Islam, 1995; Evans and Karras, 1996; Lee et al., 1998).

The empirical literature on growth can be split into two sets of studies. The first is confirmatory in orientation where formal growth theories are used to specify an econometric equation that is estimated using observations on national or regional economies. The second group of studies is more exploratory in nature and has generated a number of novel techniques for

[3]Overviews are provided in the references listed in footnote 2.

uncovering empirical patterns in the same growth data sets used in the confirmatory studies. In large part, the findings of these two sets of studies tend to be conflicting (Bernard and Durlauf, 1996), although some have stressed their complementarities (Sala-i-Martin, 1996).

These controversies noted above and the conflicts between the two empirical literatures have given rise to several calls for focused attention on the underlying empirical strategies used in the econometric analysis of growth patterns (Maddala and Wu, 2000; Durlauf, 2001). The main concerns in these calls have been with traditional econometric issues of endogeneity of regressors, collinearity between regressors and the modeling of parameter heterogeneity. Omitted from this list are the issues associated with spatial effects.

Spatial effects can be profoundly important in the analysis of growth patterns, both for the confirmatory and exploratory approaches. Spatial dependence (i.e., autocorrelation) can invalidate the inferential basis of traditional econometric methods since a key assumption of observational independence no longer holds. Moreover, as is explored in more detail in section 2.2, the exploratory methods used in growth analysis also rest on notions of random sampling. The same difficulty holds for methods used in regional inequality analysis.

Spatial dependence can arise in a number of ways. From a substantive viewpoint, technology spillovers, labor and nonlabor migration, commodity flows and a host of other types of spatial interaction can tie the fortunes of neighboring economies together. At the same time, an implicit assumption in most empirical growth research is that the administrative boundaries used to organize data series coincide perfectly with the actual market boundaries over which economic processes operate. If this is not the case then a form of measurement error will induce spatial autocorrelation into the data series (Anselin and Rey, 1991).

A key limitation of the majority of empirical analyses of cross-sectional regional growth has been the assumption that a single growth model holds for all the economies in the sample (Durlauf, 2001). The spatial econometric literature (Anselin, 1988) offers a number of specifications that can be employed to represent alternative forms of spatial heterogeneity (i.e., model instability of a spatial nature), yet the application of these specifications to the question of parameter heterogeneity in regional convergence analysis remains unexplored.

The role of spatial externalities and spillovers in shaping economic growth and income mobility has been highlighted as an important issue (Ravallion and Jalan, 1996). Together with the geographical targeting of programs aimed at alleviating poverty (Baker and Grosh, 1994; Jalan and Ravallion, 1998) and the evaluation of federal government efforts to reduce regional income disparities (Shankar and Shah, 2001), there is a clear need to develop spatially explicit analytical measures for policy analysis and formulation.

The inherent dynamic aspect of the convergence question poses numerous challenges for the application of spatially explicit methods given that these methods are designed for cross-sectional analysis. As such, there is a pressing need to extend spatial analytical techniques to include dynamic components. At the same time, there is a wealth of sophisticated time-series methods that have been brought to bear on the convergence question. However, these tend to provide only limited insights as to the geographical properties of the underlying income series. From this perspective there is a parallel need to extend time-series methods to more fully incorporate space.

2.1 Confirmatory Analysis of Regional Convergence and Divergence

Initial work on the convergence hypothesis (i.e., Barro and Sala-i-Martin (1991)) was most often based on neoclassical growth theory (Solow, 1956; Ramsey, 1928). This work emphasizes the principle of transition dynamics as a mechanism to account for growth rate differentials. The principle posits that the growth rate of an economy is proportional to the distance between its current position in the income distribution and its steady state position. The speed of convergence, which is often taken to be homogeneous across economies, is the rate at which the gap separating a country's current position and its steady state position is closed:

$$\frac{d \log y_{i,t}}{dt} = \alpha \left(\log y_i^* - \log y_{i,t} \right) \tag{1}$$

where $y_{i,t}$ is per capita income of economy i at time period t, y_i^* is the steady state income for economy i, and α is the speed of convergence.

This notion of convergence does not imply that all countries are converging to the same position in the income distribution. Instead, this principle attributes differences in growth rates to countries having different steady state income positions *and/or* different gaps between their current incomes and these steady state positions. This reasoning has given rise to an extensive literature of empirical studies using so-called growth regressions:

$$1/T \log(y_{i,t_0+T}/y_{i,t_0}) = \theta_0 + (1-\beta_T)\log\left(y_{i,t_0}\right) + \sum_{j=1}^{k} Z_{i,t_0,j}\theta_j + \epsilon_i \tag{2}$$

which relate the growth rate in per capita income over the period t_0 to t_0+T to an initial level of income and a set of steady state determinants (Z). As the speed of convergence is a function of the β_T parameter, this form of convergence is referred to as β-*convergence*.

Recently, the growth regression approach has been extended to consider the role of spatial effects in the econometric analysis (López-Bazo et al., 1998; Rey and Montouri, 1999; Azzoni, 2000; Lall and Yilmaz, 2001; Fingleton, 2000, 2002; Carrington, 2002; Bivand and Brunstad, 2003; Lim, 2003). This research is yielding growing evidence that spatial dependence, when present and accounted for, can affect the quantitative and qualitative inferences made about regional growth processes. For example, taking spatial dependence into account, Rey and Montouri (1999) find a slower rate of convergence in incomes for the US states over the 20th Century. They also show that a previous finding of a structural break in the convergence process for the same system is not robust to the presence of spatial dependence. In addition to spatial dependence, however, there is also a need to extend growth regressions to account for various sources of spatial heterogeneity. Indeed, the assumption of a single steady state existing for all regions in a national system is largely at odds with empirical evidence of spatial variation in production technologies as revealed by Rigby and Essletzbichler (1997). Incorporation of such heterogeneity is crucial to an improved understanding of regional dynamics.

Technology transfer and spillovers are of central importance to endogenous growth theories of regional change. Despite this, the literature in this area has been slow to develop spatially explicit models of technology change and diffusion, and has instead posited that the speed of technology adoption by lagging regions is proportionate to the gap separating their current level of technology with that of the leading technology regions (Nijkamp and Poot, 1998).[4] Much work is required to move beyond these a-spatial models of technology diffusion to consider the complex spatial and institutional structures that mediate technology diffusion (Essletzbichler et al., 1998). Here again, the spatial econometric literature offers a rich menu of specifications, only a fraction of which have been applied to the convergence question.

In addition to the issues that spatial heterogeneity and dependence present to empirical investigations of regional economic change, the challenges that changes in spatial scale pose for our understanding of economic

[4]Two important exceptions are Paci and Pigliaru (2002) and Caniëls and Verspagen (2003).

growth and change are equally deserving of attention. While a number of studies have examined the robustness of growth regressions to various aspects of research design (Levine and Renelt, 1992; Sala-i-Martin, 1997; Fernández et al., 2001), changes in spatial scale have yet to be incorporated in this important line of research.

2.2 Exploratory Analysis of Growth Dynamics

An alternative set of empirical strategies takes the distribution of regional incomes as the unit of analysis rather than the individual economies themselves. Proponents argue that these empirical methodologies allow for the analysis of economic growth without having to impose prior assumptions on the growth processes (Quah, 1993a; Fingleton, 1999; Magrini, 1999).

Regional income distributions have been analyzed using a variety of methodologies. The earliest work examined the concept of σ-convergence in which the focus was on how the level of dispersion/variance changed over time (Easterlin, 1960; Williamson, 1965). This form of convergence has continued to attract much attention (Coughlin and Mandelbaum, 1988; Fan and Casetti, 1994; Carlino and Mills, 1996; Bernard and Jones, 1996c; Azzoni, 2001).

Despite their popularity, measures of σ-convergence suffer from a number of limitations. From a geographical perspective their focus on dispersion will mask nontrivial geographical patterns that may themselves also be fluctuating over time (Rey and Montouri, 1999). At the same time, changes in this measure over time present an aggregate view of the transitional dynamics in the regional distribution. No information is provided on the movement of individual economies within the distribution. Finally, other characteristics of the distribution (skewness, modality etc.) are ignored.

More sophisticated distributional approaches have recently appeared. One active area is the estimation of regional income densities using a variety of parametric and nonparametric methods. Quah (1993a,b, 1994, 1996b) has pioneered the use of stochastic kernels to estimate the underlying regional income distribution and to analyze its evolutions over time. An example can be seen in Figure 1 which plots the kernel density estimates for the 48 lower US states at 10 year intervals demonstrating a general trend towards $\sigma-$convergence over the last 70 years. Stochastic kernels have been used to study a number of characteristics of spatial income distributions including changes in modality (Bianchi, 1997; Magrini, 1999, 2004), distributional mixing (Canova, 1999; Tsionas, 2000b; Webber, 2002), stochastic dominance (Carrington, 2003), as well as the long run steady state income distribution

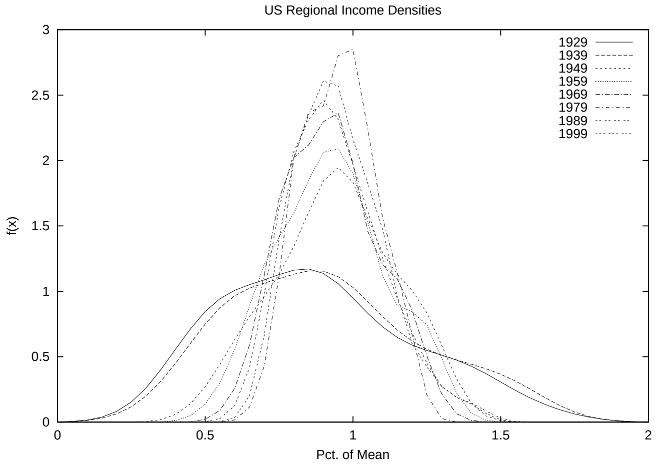

Figure 1: Kernel Densities for Lower 48 US states

(Johnson, 2000).

Closely related to the work on stochastic kernels has been the use of Markov chain modeling to represent the dynamics of regional income distributions, again pioneered by Quah (1993a). This can be viewed as a discretization of the income distribution into non-overlapping and exhaustive income intervals. This discretization is then used to estimate the probability that an economy that was in one interval in one time period transitions into another interval (or remains in the same interval) in a future time period. Estimation of the full set of transition probabilities allows for the analysis of a number of important characteristics of the distributional dynamics including: the ergodic steady state income distribution (Magrini, 1999), the transitional speed to the steady state distribution (Fingleton, 1997) convergence and/or polarization tendencies (Quah, 1996b) and a number of measures of intra-distributional rank and class mobility (Hammond and Thompson, 2002).

A final approach to distributional modeling is based on regression trees (Durlauf and Johnson, 1995; Johnson and Takeyama, 2001). A form of classification analysis, regression trees allow for the identification of convergence clubs and permits parameter heterogeneity in the underlying growth models. While the confirmatory approaches to convergence analysis can be extended to search for the existence of convergence clubs, the regression tree approach offers a less ad-hoc method for detecting this form of spatial heterogeneity (Johnson and Takeyama, 2001).

Kernel densities, σ-convergence analysis, Markov chains and regression trees provide important complementarities to the confirmatory approaches to convergence analysis, particularly in regards to the study of heterogeneity within growth processes. However, all of these approaches rest on the implicit assumption that each economy represents an independent observation providing unique information that can be used to estimate the income distribution or its growth path. In essence the cross-sectional observations at one point in time are viewed as a random sample from a univariate distribution. This stands in stark contrast to the empirical reality of strongly spatially autocorrelated income series (Rey and Montouri, 1999; Le Gallo and Ertur, 2003). Unlike the case of the classical approaches to convergence, where the issue of spatial dependence has begun to attract attention, the implications of spatial autocorrelation for the exploratory approaches to convergence analysis have been virtually ignored.

2.3 Regional Income Inequality

Closely related to the topic of regional income convergence is the question of regional inequality. A large literature[5] has examined the question of regional inequality relying on methods that are distinct from those used in the convergence literature. One of the more popular approaches to regional inequality is the decomposition of a global measure of inequality (i.e., variance) into inequality "between" or "within" regional groupings. By partitioning a group of n spatial observations into ω mutually exclusive and exhaustive groups, a global inequality measure such as Theil's T (Theil, 1996) can be decomposed as follows:

$$T = \sum_{g=1}^{\omega} s_g \log(n/n_g s_g) + \sum_{g=1}^{\omega} s_g \sum_{i \in g} s_{i,g} \log(n_g s_{i,g}) \tag{3}$$

where n_g is the number of observations in group g (and $\sum_g n_g = n$), $s_g = \sum_{i \in g} y_{i,g} / \sum_i^n y_i$ is the share of total income accounted for by group g, and $s_{i,g} = y_{i,g} / \sum_{i=1}^{n_g} y_{i,g}$ is region i's share of group g's income.

The first term on the right hand side of (3) is the "between-group" component of inequality, while the second term is the "within-group" component of inequality. In other words:

$$T = T_B + T_W. \tag{4}$$

[5]Examples include Alonso (1980); Amos (1983); Maxwell and Peter (1988); Tsui (1993); Fan and Casetti (1994); Kanbur and Zhang (1999); Nissan and Carter (1999); Azzoni (2001); Zhang and Kanbur (2001).

The first term measures the distance between the mean incomes of the aggregate groups. The second term measures distances between the incomes of regions belonging to the same group.

The decomposition allows the analysis to move beyond a simple σ-convergence study to consider the amount of spatial polarization (i.e., T_B/T) for a given level of inequality. This is important, as it is entirely possible for a general decline in $\sigma-$convergence to coexist with increasing polarization within the income distribution. The relative importance of the inter- and intra-group components has been the subject of a number of regional studies. At present, however, these studies have three specific limitations:

- The sensitivity of the polarization measures to choice of spatial scale is unknown;
- No formal inferential framework exists for testing hypotheses about the level of spatial polarization;
- The relationship between overall inequality and spatial autocorrelation has been unexamined.

The importance of the first limitation stems from a lack of consensus in the literature on the relative importance of the inter and intra-regional components of inequality. It is currently unknown how much of the variation in the empirical evidence is due to changes in spatial scale across existing studies and/or other aspects of research design. The lack of an inferential framework for regional inequality analysis has restricted existing work to a descriptive stage. This is in contrast to the richer body of confirmatory work in the regional convergence literature, and hampers attempts to integrate the convergence and inequality literatures.

The relationship between spatial autocorrelation and inequality is important for a number of reasons. First, the spatial dependence poses challenges for the development of methods of inference in regional inequality analysis. Second, when viewed in a dynamic context, as in Figure 2, the covariation of inequality measures and spatial autocorrelation measures may reveal deeper insights about spatial economic change than would be possible by using either measure in isolation. Finally, there is a need to explore the relationships between convergence, inequality and spatial clustering. Here again, because the methods used in inequality analysis are distinct from those of convergence analysis, the combined application of these alternative approaches holds the potential for a more comprehensive study. In this regard, several interesting questions can be examined:

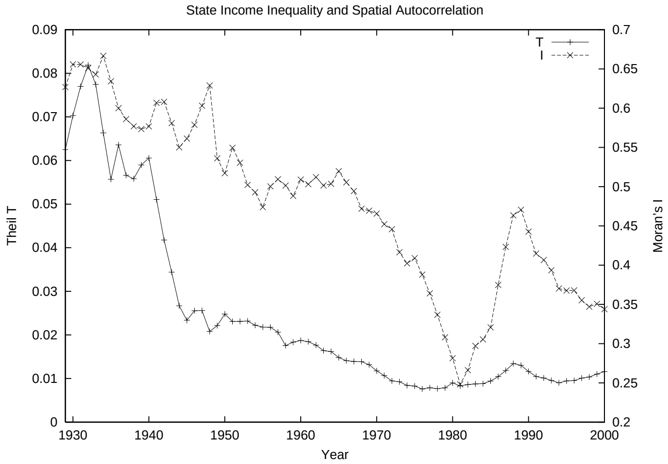

Figure 2: Inequality (T) and Spatial Autocorrelation (I) in the 48 lower US States.

- Do systems with high levels of regional inequality display different growth patterns from those with low levels of inequality?
- Is the relationship between growth and inequality influenced by the spatial distribution of inequality?
- Does the relative importance of the inter-regional and intra-regional components of inequality vary: [a] at different stages in a country's economic development; [b] over phases of macroeconomic business cycles; [c] with different levels of spatial aggregation of the observational units?

3 A Research Agenda for Regional Convergence and Inequality

From our review of the empirical literature, we can see three areas that offer potentially fruitful avenues for future research: [1] spatial effects in regional inequality and convergence analysis; [2] new measures for space-time analysis; [3] comparative regional dynamics; The specific issues within each of these areas are outlined below.

3.1 Spatial Effects in Regional Convergence and Income Mobility

While the number of empirical studies of regional economic convergence continues to expand, the explicit modeling of the spatial dimensions and the attenuating effects of spatial dependence, spatial heterogeneity, and spatial scale have attracted attention in only a minority of these studies. Although few in number, the latter studies have produced results pointing to potentially important consequences for inferences that ignore spatial effects when present. Future research in this area should examine the impacts that spatial effects have on both confirmatory and exploratory methods of convergence and inequality analysis. Specifically, the following questions are of interest:

- *How fragile are existing inferences about regional income convergence processes to the presence of spatial dependence and/or heterogeneity?*
- *Do spatial dependence and spatial heterogeneity affect the econometric analysis of convergence in distinct ways?*

  These two questions could be examined by revisiting a select number of prominent analyses of the convergence hypothesis, such as Mankiw et al. (1992); Barro and Sala-i-Martin (1992). These studies could be replicated as closely as possible using traditional econometric methods. Spatial effects should then be tested for, and if found, incorporated into the analysis using recently developed spatial econometric specification procedures (Anselin et al., 1996; Florax et al., 2003).

  An important methodological issue related to this approach will be the need for extending specification search procedures to be able to distinguish between spatial dependence and spatial heterogeneity, as both effects appear throughout the growth literature. While recent attention in the spatial econometrics literature has focused on developing approaches for spatial dependence models that are robust to alternative forms of dependence, the robustness of these approaches towards spatial heterogeneity is largely unknown. At the same time, formal specification search strategies for spatial heterogeneity have yet to be suggested.

The questions raised above relate to the confirmatory analysis of regional convergence. The role of spatial effects in the application of exploratory methods for regional income dynamics generates a second set of research questions that require attention.

- *What are the properties of exploratory methods for measuring income dynamics in the presence of spatial heterogeneity and dependence?*

  This could be addressed by viewing income mobility within the context of nuisance spatial dependence. More specifically, the effects of boundary mismatch could be explored using Monte Carlo simulation techniques. Cross-sectional income distributions with a given level of income mobility can be simulated for a regular lattice structure. A second boundary structure could be imposed on the lattice and used to generate an "observed" cross-sectional distribution. The latter data can be used to estimate the amount of income mobility. A similar approach can be taken to examine the properties of the following statistics in the presence of spatial dependence: [a] Income mobility/stability indices [b] Markov transition matrices [c] Ergodic income distributions.

- *What are the properties of kernel density and other nonparametric distribution estimators in the presence of spatial dependence?*

  While the use of kernel density estimators to analyze regional income distributions has attracted a great deal of attention, the properties of these estimators in the presence of spatial dependence are unknown. At a minimum, the empirical standard deviation, which forms a central parameter in many kernel density estimators, will be a biased estimate for the population standard deviation if the series is spatially autocorrelated. When spatial interactions across observational units are permitted the situation becomes even more complex. Models of data generating processes that allow for spatial interaction require a multivariate distribution. Existing density work assumes a univariate data generating process which rules out the incorporation of spatial interaction. Therefore, the properties of the classic kernel density estimators in the presence of spatial dependence should be evaluated using Monte Carlo simulation techniques. Some initial work along these lines is reported in Gustafsson (2003) and Rey and Dev (2003).

A final question regarding space in the analysis of regional income distributions focuses on the comparative performance of the confirmatory (i.e., econometric) and exploratory (Markov and kernel density) approaches in a predictive context. As Jones (1997b) has noted, the cross-country growth literature has not examined the shape of the steady state income distributions that would follow from growth regressions. This raises the following question:

- *How different are the predictive distributions generated by Markov methods from those produced by augmented spatial econometric models?*

  The predicted income series from the spatial econometric specifications of a growth equation could form the basis for the application of a kernel density estimator to produce a predictive density. This density can then be discretized using the same class intervals as those employed in a Markov chain analysis of the observed regional income data. The estimated Markov transition matrix can then be used to generate the future discretized density to compare against that from the spatial econometric approach. The comparison of formal spatial econometric approaches and spatially adjusted nonparametric models for income distributions could be based on simulation designs similar to those used by Fingleton (2001).

3.2 New Empirical Measures for Space-time Dynamics

A second major direction for future research should focus on the development of new spatially explicit exploratory measures for inequality and convergence analysis. Two research tasks seem appropriate here:

- *Exploratory spatial empirics: method development and extensions*
  Several new metrics for spatial cohesion, spatial flux, intra and interregional mixing in the study of income distributions and their dynamics have been recently suggested (Rey, 2001, 2003b,a). While initial applications of these methods have yielded promising results (Bickenbach and Bode, 2001, 2003; Le Gallo, 2004), these methods can likely benefit from further analysis and refinement (Magrini, 2004). For example, the approach used in the spatial decomposition of a rank correlation measure suggested in Rey (2003b) may offer a path for extending a related static rank statistic for spatial association (Ekwaru and Walter, 2001a,b) to a dynamic context. Additionally, the spatial Markov approach suggested by (Rey, 2001) appears to offer some complementarities to recent work by Dezzani and Al-Dousari (2001) extending a Markov random field approach (Cressie, 1991, p. 407) to a dynamic context.

  Two new sets of measures are also possible. The first concerns alternative spatial decompositions of global inequality measures. Currently, the decompositions rest on mutually exclusive and exhaustive partitioning of regional economies, yet it may be fruitful to develop contiguity and distance based decompositions by drawing on related research in spatial econometrics (Florax and Rey, 1995). At the same time, hybrid decompositions based on the union of the traditional and contiguity based rules are also possible.

A second set of new measures derives from the integration of the concept of a spatial multiplier with regional inequality measures. A variety of spatial multipliers follow from alternative specifications of spatial econometric models (Anselin, 2003). A spatial multiplier provides a measure of how a particular spatial unit directly and indirectly impacts the entire set of spatial observations. By exploiting this structure and coupling spatial econometric models to the case of regional inequality it may be possible to develop a mechanism to identify key economies in a spatial system; key in the sense that changes in these economies have disproportionate effects on the system. This offers the potential for aiding in the design of geographically targeted programs for poverty eradication.

- *Evaluation of the formal sampling properties of new measures*

  Developing new empirics is clearly an important task. However, to fully realize the potential of these new measures, it is critical that their formal sampling properties be understood. This is particularly challenging given the complications arising for inference with spatially referenced data. Two sets of approaches to studying these sampling distributions are possible. The first can employ asymptotic techniques as in Maasoumi (1997). The second track could utilize computationally based approaches suggested by Mills and Zandvakili (1997). These two sets of approaches provide alternative inferential frameworks for these new spatially explicit measures of convergence and inequality analysis. These approaches could be compared in a set of Monte Carlo simulations as well as in case studies using data sets from different regional systems.

3.3 Comparative Regional Income Dynamics

The final area where we see much promise is comparative regional growth dynamics. There is a large and growing literature of empirical analyses of regional growth and inequality within specific national and continental systems. Table 1 provides a representative selection of such studies.

Despite this rich empirical literature, relatively few studies have compared the rates of convergence and inequality across different national sys-

Africa	Piesse et al. (1998); Tsangarides (2000); McCoskey (2002)
Argentina	Utrera and Koroch (1999); Marina (2000)
Australia	Maxwell and Peter (1988),
Bangladesh	Wodon (1999)
Bulgaria	Petrakos (2001),
Bolivia	Andersen et al. (2000),
Brazil	Ferreira (2000); Azzoni (2001),
Canada	Coulombe and Lee (1995); Wakerly (2000),
Chile	Aroca and Bosch (2000),
China	Wei and Ma (1996); Ying (1999, 2000); Yudong and Weeks (2000); Wei et al. (2001),
Colombia	Cárdenas and Pontón (1995); Morón and Rock (1999),
Europe	Armstrong (1995); Rodrigíuez-Pose (1998); Cuadrado-Roura (2001); Carrington (2002),
Finland	Kangasharju (1998); Pekkala (2000),
Great Britain	Gripaios et al. (2000); Roberts (2002)
Greece	Ioannides and Petrakos (2000),
Holland	Van Soest et al. (2001),
Hungary	Petrakos (2001),
India	Cashin and Sahay (1996)
Ireland	O'Leary (1997),
Italy	Paci and Pigliaru (1997); Terrasi (1999),
Japan	Gauthier et al. (1992),
Latin America	Dobson and Ramlogan (2002),
Mexico	Mallick and Carayannis (1994); Gerber (2002); García-Verdú (2002)
Poland	Petrakos (2001),
Romania	Petrakos (2001),
Spain	Suárez-Villa and Cuadrado-Roura (1993); Rodrigíuez-Pose (2000),
Sweden	Persson (1995); Gustavsson (2001),
Turkey	Temel et al. (1999); Gezici and Hewings (2001),
UK	Duranton and Monastiriotis (2001),
US	Carlino and Mills (1993); Crown and Wheat (1995); Loewy and Papell (1996),
West Germany	Niebuhr (2001).

Table 1: Regional and International Convergence/Inequality Studies

tems. Moreover, these comparative studies have tended to concentrate on the more advanced economies such as the European countries and regions (Armstrong and Vickerman, 1995; Tondl, 2001; Cuadrado-Roura and Parellada, 2002), the experiences of the US and the European Community (Boltho, 1989; Greasley and Oxley, 1998a), the cases of Australia and Canada (Greasley and Oxley, 1998b), or the convergence history of Australia relative to that of the US (Oxley and Greasley, 1995). Additionally, the underlying geographical dimensions of regional growth processes have not received attention in these comparative investigations. This situation gives rise to the following research questions:

- *What is the role of space in the internal income dynamics of different continental, national and regional systems?*
- *What is the relationship between convergence, inequality and spatial autocorrelation?*
- *Do spatial spillovers fuel economic growth, convergent growth or divergent growth?*

These questions touch on several important themes related to the role of space in the functioning of regional economic systems. At present, we do not know whether systems with high degrees of spatial autocorrelation in regional incomes display different dynamic properties from those with less spatially clustered income maps. While the relationship between growth (efficiency) and equity (equality) has received some attention, the existing studies have been conducted at different spatial scales. Unknown is how this relationship may be influenced by the spatial distribution of inequality, or whether spatial concentration of inequality strengthens or weakens the speed of convergence. A related issue is how this trivariate relationship between growth-inequality-clustering may manifest itself differently at different spatial scales.

Exploring these questions will likely require the use of the new empirics for inequality, spatial clustering and convergence (from the previous section) in a complementary fashion. Some work on the relationship between inequality measures and spatial clustering has recently appeared (Arbia, 2000, 2001), but this has been limited to a static context. Revisiting this relationship in a dynamic setting and incorporating measures of β and σ convergence appears a promising path to pursue.

4 Conclusion

Our review has revealed that the analysis of regional income convergence and inequality continues to draw much attention over a variety of disciplines within the social sciences. The perspectives vary from those that are theoretical in nature, to others that focus on empirical and policy applications. It is evident that the dynamics of regional incomes have both a temporal and spatial dimension. While the role of space has begun to draw attention in the analysis of economic change, the literature review indicated a variety of gaps where further research is needed.

We outlined a detailed research agenda that identifies a variety of opportunities for the incorporation of spatial effects in the analysis of regional incomes over time. The integration of existing spatial econometric methods could shed light into the effects of spatial dependence and spatial heterogeneity on convergence. It was noted that current exploratory methods of income dynamics could suffer from boundary mismatch, and the implementation of Monte Carlo simulation techniques could offer some interesting insights into the properties of these methods when the spatial dependence is unaccounted for. We also found that there are interesting possibilities regarding the comparisons between the predictive performance of exploratory and confirmatory approaches.

This article identified some promising new empirical measures for space-time dynamics. We find the possibility of using alternative ways to decompose global inequalities based on varying spatial constructs of particular interest. Furthermore, the integration of a spatial multiplier within the analysis of regional inequality measures could identify key economies within a spatial system.

Lastly, it was noted that the incorporation of underlying geographical dimensions when taken in a comparative context may improve our understanding of regional growth processes. It is currently unknown how growth and equality at larger spatial scales are effected by the internal spatial concentration of incomes.

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