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The spatial and temporal dynamics of US regional income inequality, 1950–1989

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Abstract. The inverted-U hypothesis which so influenced research on regional income inequality is obsolete and does not predict or explain the recent rise in regional inequality. We argue that the regional dynamics literature on polarization, polarization reversal and spatial restructuring offers more powerful explanations to changes in regional income inequality. In addition to the conventional approach of measuring systemic inequality, the empirical analysis in this paper emphasizes inequality variations, which put into focus the interplay between regional dynamics and regional income inequality. The findings highlight the impact of sectoral shifts and global spatial restructuring on the US regional economy, where new cores of growth and renewed growth are emerging.

Introduction

Kuznets' seminal work in 1955 introduced the inverted-U hypothesis which states that income inequality between individuals tends to first increase and then decline as a nation progresses during the course of economic development. The hypothesis has since been extended to explain changes in regional income inequality. Based on international cross-sectional data and national time-series data, Williamson (1965) showed that regional inequality within nations also follows the path of an inverted-U, increasing in early stages of economic development and decreasing in later stages. The initial increase in regional inequality is explained by concentration of income and income-generating factors in selected regions of a nation; and the subsequent decrease in regional inequality is explained by diffusion of income and income-generating factors. The increase and decrease in regional inequality are also referred to as regional divergence and regional convergence respectively, and their occurrences have been verified by empirical studies of many developed countries (Easterlin 1958; Perin and Semple 1976; Robinson 1976; Smolensky 1961; Williamson 1965).

Explanations for the inverted-U in regional income inequality have been strongly influenced by neoclassical logic, which emphasizes the tendency toward equilibrium as the factor market adjustment mechanism evens out regional differentials in income (Alonso 1980; Easterlin 1958). Using the US as an illustration, Williamson (1965) argued that the initial directions of labor and capital migration favored the more developed North; later as the nation's interregional linkages improved, labor and capital migration became less selective and would slow down or reverse to benefit the South.

Recent evidence however suggests that changes in income inequality and changes in regional income inequality continue after the last stages of the inverted-U model. In the US once again personal income inequality has increased (Danziger and Gottschalk 1993). Interestingly, regional income inequality in the US has also increased during the late 1970s and the 1980s (Amos 1988; Braun 1991; Coughlin and Mandelbaum 1988; Rowley et al. 1991). The neoclassical logic, on which the inverted-U is theoretically based, does not predict increases in inequality after regional convergence at advanced stages of development. These new trends raise doubts about the predictive and explanatory power of the inverted-U hypothesis.

Until recently, the attention in the literature has been on testing the validity of the inverted-U rather than on formulating a theory of regional income inequality (Fisch 1984). There have been some attempts of broad theorization (e.g. Lipshitz 1986 and Semple 1977), but they tend to be confined to the issue of equilibrium versus disequilibrium and are not concerned with what may occur following regional convergence in the last stages of the inverted-U. In this sense the highly acclaimed inverted-U hypothesis is more a hindrance than a catalyst to development of theory. While this paper does not attempt to formulate a full-fledged theory of regional income inequality, we wish to elaborate an approach which may be instrumental in future theory development. Rather than focusing on regional divergence and convergence, we choose to look at inequality dynamics and variations, that is, where and when inequality increases and decreases. Instead of specific positions in the economic development continuum, we highlight the flows of factors of production which underlie changes in inequality. The regional dynamics literature provides a ready pool of knowledge and is the most appropriate building block for explaining regional income inequality – the selective growth and decline of regions underlie changes in regional income inequality. We start with a discussion of salient strands in the regional dynamics literature which have important bearing on regional income inequality. Then we explain the importance of focusing on both an overall level of inequality, which we refer to as systemic inequality, as well as the variations of inequality. The purpose of the empirical analysis is to demonstrate our suggested approach, and to illustrate using the US as an example that regional dynamics is a more powerful and meaningful predictor of regional income inequality than level of economic development.

Regional dynamics and regional income inequality

In this section we attempt to explain regional income inequality in the context of regional growth and decline. The discussion involves three phases – regional divergence and regional convergence as predicted by the inverted-U; and the recent increase in regional income inequality. In all three phases the emphasis is on flows of factors of production, especially capital and labor.

Polarization as an explanation for regional divergence

During the course of development in advanced industrial economies, initial advantages and agglomeration of activities associated with a "leading sector" result in the formation of a core region (Pred 1973). In the core, self-sustaining growth is made possible by the shift of labor and resources into the leading sector which accounts for rise of income (Clark 1940; Fisher 1939). In most developed countries this leading sector is manufacturing. The formation of the core is accelerated by the movement of labor and capital from the periphery, referred to as "backwash" effects. The notion of circular cumulative causation and the core-periphery model, among others, explain and portray the growth and prosperity of the core at the expense of peripheral areas[1] (Friedmann 1966; Kaldor 1970; Mera 1973; Myrdal 1957). These studies, together with the Marxist views[2], were reactions to the apparent failure of neoclassical regional growth models in explaining the perpetuation of the core and of regional income inequality (Richardson 1978).

In the US, polarization began to take place as early as the 19th century. The most significant indicator of polarization was the emergence, consolidation and widening of the Manufacturing Belt in Northeast and Midwest states, which until the late 1960s was the nation's main economic core. The agglomeration of manufacturing attracted capital, and large cities with ample employment opportunities became magnets for labor migration especially from the South. Secondary cores in the West also grew due to labor migration during the Western expansion. The result of polarization was regional divergence or large income inequality between regions.

Polarization reversal as an explanation for regional convergence

The second phase of regional dynamics in the US was characterized by slower growth, stagnation, and decline of states within the main core and new growth in the former periphery which began in the 1960s and early 1970s (Casetti 1984; Peet 1983; Richardson 1980). The agglomeration advantages which had contributed to polarization earlier were counteracted by a new set of forces that favored new locations of growth and agglomeration in the periphery. The

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1 Although the core-periphery model originated by Friedmann (1966) was first used to explain regional uneven development in developing countries, the phenomenon of resources flowing from the periphery to the core and of the core's economic and political dominance is not necessarily confined to today's developing countries. It is also descriptive of the polarization process that many developed countries have experienced in the past.

2 The Marxist views of regional uneven development were most elaborate when applied to the context of developing countries. Ede (1982) identified two major variants: according to the Neo-Marxist view, external dependency relations are the most important explanation for regional inequality within a nation; the orthodox approach, on the other hand, focuses on relations of production.

periphery's emerging advantages included less unionization, lower labor and land costs and attractive climate and amenities (Bluestone and Harrison 1982; Bourne 1980). The maturing of manufacturing product cycles in conjunction with post-Fordist techniques of vertical disintegration also facilitated the diffusion of industrial production from the traditional core to "new industrial spaces" in the periphery (Hall 1987; Norton and Rees 1979; Scott 1988; Storper and Walker 1989). In the US polarization reversal coincided with the well known Snowbelt-Sunbelt shifts, which describes the migration of firms, capital and population from the Northeast and Midwest toward the South and West.

It is important to point out that polarization reversal is not the same as the equilibrium predicted by neoclassical regional growth models. The former is primarily a result of capital seeking out locations which promise lower costs and higher profits, and is by no means indicative of uniform factor returns across regions. Although the net effect of polarization reversal is decline in regional income inequality due to elevated incomes in the periphery, the departure of capital from the Northeast and Midwest has indeed contributed to poverty-stricken pockets in many manufacturing-based cities and states. Instead of an underlying equilibrating force, it is the movement of factors of production that determines who is the winner and who is the loser.

Spatial restructuring as an explanation for increase in regional income inequality

Recent trends of increase in income inequality in the US, United Kingdom, Sweden and Germany are evidence that the inverted-U model is inadequate (Danziger and Gottschalk 1993; Fritzell 1993). One of the reasons for increase in income inequality is sectoral shifts. As manufacturing employment declines and services employment increases, the former's high paying jobs are replaced by low paying and non-unionized jobs in the service sector (Grubb and Wilson 1989). The bi-polar structure in the service sector which consists of high-skilled and high-salaried professionals and executives as well as low-skilled and low-salaried workers also strengthens the bi-polarization of income. Fritzell (1993), for example, showed that the shrinkage of the middle class and increases in the upper and lower ends of income distribution have led to increase in income inequality.

The increase in regional income inequality is less well understood. We suggest that it is due to spatial restructuring both within and outside of the national boundary, which triggers new directions of capital flows. In the US this new scenario is characterized by the selective growth of some regions, especially the renewed growth of New England states. The literature suggests that the New England "turnaround" is due to a combination of high technology industries, education and training systems, and producer services (Barff and Knight 1988; Lampe 1988; Norton 1987). In addition to sectoral shifts (to high technology industries and producer services), the New England growth reflects deeper spatial restructuring as a result of international competition. Facing stiff competition from newly industrialized economies (NIEs) and other industrial nations, the US manufacturing sector has responded by relocating some of its production from the traditional core to new sites both within and outside the nation, where greater profits may be realized due to lower costs and less taxing environmental regulations. High technology industries and producer services have since become new leading sectors, which favor locations in large metropolitan centers, many in the traditional core, that have the necessary infrastructure and are well connected in international communications. For example, the "world cities" along the Pacific and Atlantic coasts have skilled human resources and access to information which attract international business operations (Coffey and Bailly 1991; Daniels et al. 1991; Harrington et al. 1991). These cities are well connected internationally, produce goods and services which are of demand in national and international markets and which can maintain aggregate income levels (Kassab 1992). Therefore, capital moves back to selective locations within the traditional core where the new leading sectors thrive, which once again leads to increase in regional income inequality.

The above discussion illustrates that regional dynamics is intricately related to regional income inequality. The growth and decline of regions are immediately translated into changes in regional income inequality. When income inequality in a society increases the logical question is who are the people that have become richer than others, and why; likewise the key question concerning regional income inequality is why some regions have grown more or less than other regions. The answer to the latter is in regional dynamics. Unfortunately past attempts in theorizing regional income inequality have been unduly constrained by the inverted-U hypothesis, which is essentially an abstract, static and deterministic model that does not specify where and why regional income changes. In the following empirical analysis we will show how changes in regional income inequality reflect the several phases of regional dynamics discussed above. By focusing on inequality variations rather than systemic inequality, we use an approach that is different from conventional work, and which allows clear and strong connections to be made between regional income inequality and regional dynamics.

Data and methodology

The purpose of the empirical analysis is to show the relations between regional dynamics and regional income inequality. We employ state-level per capita income data published by the US Bureau of Census (1966; 1978; 1987; 1992) for the 49 contiguous states and at five-year intervals from 1950 to 1985, plus 1989. The data are adjusted for inflation and are expressed in 1989 constant dollars, using consumer price indices published by the US Bureau of Census (1987; 1991). The empirical analysis is mainly concerned with between-state (or inter-state) income inequality, which is the most appropriate scale of analysis that reflects differentials of income due to processes of regional growth and decline such as polarization, polarization reversal and the recent spatial restructuring. Although recent literature has emphasized intra-state inequality (Amos 1988; Bishop et al. 1992; Braun 1991), it tends to reflect urban-rural differentials rather than regional and long-distance flows of resources and is therefore less appropriate for our purpose.

In the following we discuss two approaches to measuring income inequality: systemic inequality and inequality variations. The former is the conventional approach but the latter is a better tool in demonstrating the relations between regional dynamics and regional income inequality.

Systemic inequality

Systemic inequality evaluates an overall level of inequality within a system. For example, regional divergence would be associated with a high level of systemic inequality, and regional convergence a low level of systemic inequality. It ignores possible inequality variations that exist between regions, that is, greater inequality between some regions and smaller inequality between others. If one is concerned only with systemic inequality, the processes and the regional dynamics that led to regional convergence or divergence would not be readily revealed. For example, a decrease in systemic inequality may be a consequence of low-income regions growing faster, slow growth in high-income regions, or a combination of both; likewise, an increase in systemic inequality may be a consequence of faster growth of high-income regions, slower growth of low-income regions, or a combination of both.

Most conventional measures of inequality are designed to evaluate systemic inequality. Among commonly used measures are: (i) dispersion indices such as standard deviation and coefficient of variation; (ii) Lorenz Curve indices such as the Gini coefficient and the dissimilarity index; and (iii) information theoretic measures such as the Shannon entropy measure. Columns (2) through (5) in Table 1 report the systemic inequality between states based on coefficient of variation, dissimilarity index and the Shannon entropy measure (see Appendices A and B). They show that income inequality between states declines from 1950 to 1975 and then increases again after 1975.

Table 1. Systemic inequalities

Year (1)	C.V. (2)	D (3)	I (4)	% of max. Ineq. (5)	b (6)	R^2 (7)
1950	0.2394	0.0890	0.0408	0.73	−0.2480	0.7873
1955	0.2218	0.0845	0.0346	0.62	−0.2296	0.8297
1960	0.2040	0.0785	0.0295	0.53	−0.2100	0.7960
1965	0.1873	0.0715	0.0248	0.44	−0.1935	0.8195
1970	0.1532	0.0580	0.0165	0.29	−0.1583	0.8474
1975	0.1275	0.0455	0.0115	0.20	−0.1314	0.8257
1980	0.1369	0.0465	0.0132	0.24	−0.1415	0.8348
1985	0.1593	0.0550	0.0176	0.31	−0.1661	0.8877
1989	0.1865	0.0640	0.0238	0.42	−0.1941	0.9211

(2) Coefficient of variation
(3) Dissimilarity index (see Appendix A)
(4) Total inequality (see Appendix B)
(5) Total inequality (4) as a percentage of maximum inequality; where maximum inequality = $\log N$ = 5.6147 bits
(6) b estimate of rank-size function (see Eq. (1))
(7) R^2 is the coefficient of determination for estimating rank-size function

A fourth approach, which has rarely been used in connection with inequality, is the rank-size function. The rank-size function describes the relation between the size and rank of observations when they are arranged in descending order according to size (Zipf 1949). Its logarithmic form is:

$$\ln y = a + b \ln r \tag{1}$$

where y is size, r is rank ($r = 1$ for the largest size), a is the intercept and b is the slope of the rank-size curve on a doubly-logarithmic scale. The coefficient b evaluates the percentage change in size associated with 1% change in rank.

The rank-size function has been most widely applied to investigate urban systems (Berry 1961; Carroll 1982; Sheppard 1982), in which case y is population size of cities and r is rank according to population size. The estimated value of b evaluates the degree of population concentration in an urban system (Danta 1987; Fan 1988; Malecki 1975; 1980).

It is not difficult to see that the level of concentration in a system corresponds to the level of systemic inequality. Suppose a certain amount of resources is distributed between the individuals in a system, the pattern of distribution determines the level of concentration from the "point of view" of the resources, and the level of systemic inequality from the point of view of the individuals. Specifically, high/low level of concentration corresponds to high/low level of systemic inequality. The parameter b, therefore, is also a measure of systemic inequality: a more negative b indicates greater systemic inequality, and a less negative b smaller systemic inequality.

In our empirical analysis the rank (r) of a state is determined by its per capita income (y), for example, $r = 1$ for the highest income state, $r = 2$ for the second highest income state, etc. Column (6) in Table 1 reports the b values that were estimated from regression, and column (7) reports the associated R^2 values. Supporting the systemic measures reported earlier, the estimated b values indicate that between-state income inequality declines from 1950 to 1975 and increases thereafter.

Inequality variations

The systemic inequality approach reviewed above depicts overall levels of regional inequality but does not reveal the processes by which selective growth of regions took place, and therefore is not adequate if one is concerned with the regional dynamics that underlie changes in regional income inequality. Among the four types of measures introduced, information theoretic measures and the rank-size function can be modified to also address inequality variations.

Decomposed information theoretic measures

Information theoretic measures can be decomposed into additive terms which measure the inequality between and within groups of elements in a system. We group the 49 contiguous states into four regions, based on the geographic scheme

Table 2. Between-region and within-region inequalities

Year	BRQ		WRQ		Shares (%) in WRQ			
	level	%TQ	level	%TQ	Northeast	Midwest	South	West
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1950	0.0088	21.60	0.0320	78.40	13.89	6.43	65.84	13.85
1955	0.0071	20.56	0.0275	79.44	13.85	16.49	53.35	16.31
1960	0.0073	24.84	0.0222	75.16	14.86	10.00	60.47	14.67
1965	0.0051	20.54	0.0197	79.46	14.02	11.34	60.04	14.61
1970	0.0031	18.94	0.0133	81.06	19.37	12.22	48.91	19.53
1975	0.0014	12.47	0.0101	87.53	20.19	8.00	53.09	18.72
1980	0.0019	14.29	0.0113	85.71	17.89	8.09	48.21	25.81
1985	0.0031	17.52	0.0145	82.48	20.36	7.05	52.77	19.82
1989	0.0064	27.00	0.0174	73.00	20.65	8.05	52.59	18.72

(2) Between-region inequality (see Appendix C)
(3) Between-region inequality as a percentage of total inequality
(4) Within-region inequality (between-state inequality within regions) (see Appendix C)
(5) Within-region inequality as a percentage of total inequality
(6) – (9) Shares of each region in within-region inequality

traditionally used by the US Bureau of Census (see Appendix C). Table 2 gives a summary of the results. An interesting trend of between-region inequality (BRQ) is that its level and proportion (columns (2) and (3)) decline to the lowest point in 1975 and then rise again after 1975, a trend similar to total inequality reported in Table 1. This suggests that the inequality between the Northeast, Midwest, South and West is an important reason for the recent increase in regional inequality.

On the other hand, throughout the study period the level and proportion of within-region inequality (WRQ) (columns (4) and (5)) are significantly higher than that of BRQ, which indicates that the majority of inequality is found within rather than between the four census regions. Columns (6) through (9) report their shares of WRQ. In every year the South has the largest share, which has generally declined from 1950 to 1970 and subsequently hovers at about half of total WRQ. The Northeast's share has remained stable and low until after the late 1960s. These trends are consistent with the regional dynamics literature: polarization led to stable and low inequality between Northeast and Midwest states in the traditional core; the inequality between peripheral states in the South was high to begin with, which later declined during polarization reversal when the Southern states experienced rise in income. However the trends in the 1970s and 1980s are not as clear.

Expanded rank-size functions

The decomposed information theoretic approach reviewed above is based on existing schemes of grouping and aggregation, which very often are functions of established social, political, or geographical conventions and may be too rigid for uncovering the most important inequality variations. For example, grouping 49

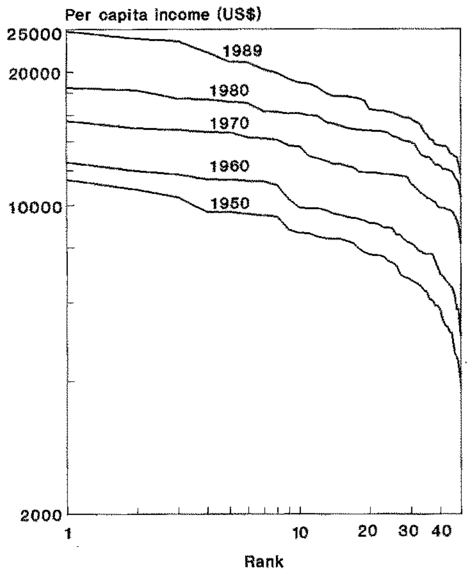

Fig. 1. Rank-size curves

states into four census regions is arbitrary.[3] The expanded rank-size functions, on the other hand, are capable of highlighting where in the system large inequalities occur and where the level of inequality is low (Fan 1992). This approach allows the data to generate "natural" groupings of observations according to income level and level of inequality.

1. Expansions with respect to rank. The rank-size function (1) presupposes that inequality between all elements in a system follows the same law, which is represented by the measure of systemic inequality b. Using the expansion method (Casetti 1972; 1982), the possibilities open that this law is contextually variant, and that inequality can be different for different elements in the system. The rank-size curves in Fig. 1 show that the slopes tend to be steeper at lower ranks, which indicates that inequality is lower between high-income states and higher between low-income states. On the other hand, Eq. (1) assumes that the slope, estimated by b, is linear. Instead of abandoning the rank-size function for other possible functions,[4] Eq. (1) can be expanded easily to account for changes in the slope with rank. For example, b may be defined as a linear function of rank (r) or of the square of rank (r^2):

[3] One may argue that grouping individuals into states is also arbitrary. This problem may be solved if one employs data that reveal variations within states. In this paper the state defines the level of resolution in the empirical analysis and therefore the focus is on the variations of inequality between states.

[4] Parr (1976) and Parr and Suzuki (1973), for example, suggested lognormal and truncated lognormal functions for city-size distribution because the rank-size representation of an entire urban system is usually not linear but tends to be concave to the origin.

$$b = b_0 + b_1 r \tag{2}$$

$$b = b_0 + b_1 r^2 \ . \tag{3}$$

Expansion equation (2) describes cases where inequality increases or decreases with rank; expansion equation (3) specifies that inequality changes with rank exponentially, and describes cases where inequality increases or decreases more rapidly at lower ranks. Substituting each of these expansion equations into the initial model (1) generates the following terminal models respectively:

$$\ln y = a + b_0 \ln r + b_1 r \ln r \tag{4}$$

$$\ln y = a + b_0 \ln r + b_1 r^2 \ln r \ . \tag{5}$$

Table 3 reports the estimates for models (4) and (5) from regression. The coefficients of determination (R^2) (columns (4) and (7)) are significant improvements over the moderate R^2's associated with the "unexpanded" rank-size function reported in Table 1. In all years the estimates for b_1 are negative and significant for both models, which indicates that as r increases inequality between states tends to become greater (b in Eqs. (2) and (3) becoming more negative). In other words, inequality is smaller between high-income states and greater between low-income states, which is consistent with what is portrayed in Fig. 1. This inherent variation of inequality is crucial for understanding the nature of income inequality between states, and yet would be overlooked if one chose to only investigate systemic inequality.

2. *Expansions with respect to rank and time.* Another major source of inequality variations involves changes in inequality over time. By building upon models (4) and (5) it is possible to pinpoint where along the array of states inequality has increased, and where inequality has decreased, over time. This is much more meaningful than simple statements of regional convergence and regional divergence for understanding the underlying regional dynamics. Changes in inequality over time can be investigated by expanding models (4) and (5) with respect to time. Since the R^2's associated with model (5) are generally higher than those with model (4) (see Table 3), in the following we report only results from expansions based on model (5). Temporal expansions require pooling together cross-sectional data and creating a new variable t, which is assigned the following values: $t = 0$ for 1950, $t = 5$ for 1955, ..., $t = 39$ for 1989.

The coefficient a in model (5) denotes the intercept of the rank-size curve, which also estimates the income level of the richest state ($r = 1$). By defining a as a function of time we investigate how the income level of the richest state has changed over time. Since our interest is on changes in inequality rather than on changes in income, the complexities in the final terminal model can be reduced by converting the income of individual states into an index, expressed as a fraction of the income of the richest state in the corresponding year:

$$y_i' = k(y_i / y_a) \qquad i = 1, \ldots, n \tag{6}$$

Table 3. Estimates for rank-size function expanded in rank

Year	b as a function of r [model (4)]			b as a function of r^2 [model (5)]		
	b_1	t-value	R^2	b_1	t-value	R^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1950	−0.0037	−16.10[a]	0.9679	−6.1E-5	−26.35[a]	0.9868
1955	−0.0031	−20.83[a]	0.9837	−4.9E-5	−23.40[a]	0.9868
1960	−0.0030	−14.31[a]	0.9626	−4.9E-5	−19.12[a]	0.9772
1965	−0.0026	−16.33[a]	0.9734	−4.2E-5	−19.38[a]	0.9803
1970	−0.0019	−14.42[a]	0.9724	−3.0E-5	−15.21[a]	0.9747
1975	−0.0017	−15.51[a]	0.9720	−2.7E-5	−18.08[a]	0.9785
1980	−0.0018	−18.92[a]	0.9812	−2.9E-5	−23.81[a]	0.9876
1985	−0.0017	−14.82[a]	0.9806	−2.7E-5	−19.01[a]	0.9873
1989	−0.0016	−15.39[a]	0.9872	−2.6E-5	−17.13[a]	0.9893

[a] significant at the 5% level

where y_i is the income of the i^{th} state, y_a is the income of the richest state ($r = 1$), and k is a constant, which is arbitrarily assigned a value of 100. By substituting y' for y in model (5), the temporal expansion of a becomes unnecessary since y' for the richest state always equals k which does not change over time. Instead, only b_0 and b_1 in (5) are expanded as functions of time.

The appropriate specifications for the expansion equations are determined by a hypothesis-testing approach,[5] and the results suggest the selection of cubic temporal expansions. Therefore the expansion equations are:

$$b_0 = b_{00} + b_{01}t + b_{02}t^2 + b_{03}t^3 \tag{7}$$

$$b_1 = b_{10} + b_{11}t + b_{12}t^2 + b_{13}t^3 \ . \tag{8}$$

Using the index y' to replace y, and substituting the right-hand-sides of (7) and (8) into model (5) yields the final terminal model:

$$\begin{aligned} \ln y' = {} & a + b_{00}\ln r + b_{01}t\ln r + b_{02}t^2\ln r + b_{03}t^3\ln r \\ & + b_{10}r^2\ln r + b_{11}tr^2\ln r + b_{12}t^2r^2\ln r + b_{13}t^3r^2\ln r \ . \end{aligned} \tag{9}$$

[5] In a regression, several blocks of variables are entered, consisting of variables associated with b_0 and b_1, then variables associated with the linear temporal expansions of b_0 and b_1, and variables associated with the quadratic temporal expansions of b_0 and b_1, followed by variables generated by subsequent higher degrees of temporal expansions. At every step, the hypothesis that parameters associated with the newly added variables are zero is tested. If the hypothesis is not rejected, one would choose the degree of temporal expansion lower than the one that is being tested. Otherwise, the hypothesis-testing will be repeated for the next higher degree, until a truncation point can be established. For example, if the hypothesis that parameters associated with quadratic temporal expansions of b_0 and b_1 are zero cannot be rejected, one would select linear temporal expansions. If the hypothesis is rejected for the quadratic expansions, the parameters associated with cubic temporal expansions will be tested next.

Table 4. Estimates for rank-size function expanded in rank and in time

Variable	Parameter	Estimate	t-value
Constant	a	4.6298	734.69[a]
$\ln r$	b_{00}	−0.1059	−30.08[a]
$t \ln r$	b_{01}	−2.36E-4	−0.40
$t^2 \ln r$	b_{02}	1.78E-4	4.84[a]
$t^3 \ln r$	b_{03}	−4.66E-6	−7.51[a]
$r^2 \ln r$	b_{10}	−5.83E-5	−30.03[a]
$tr^2 \ln r$	b_{11}	9.93E-7	2.22[a]
$t^2r^2 \ln r$	b_{12}	3.24E-8	1.17
$t^3r^2 \ln r$	b_{13}	−9.86E-10	−2.11[a]

$R^2 = 0.9750$
d.o.f. (reg) = 8
d.o.f. (res) = 432
$F = 2103.03$[a]

[a] significant at the 5% level

Interpretation of individual parameters is not easy with such complex model. Instead, the original inequality measure b can be reconstructed using expansion equation (3) in conjunction with expansion equations (7) and (8):

$$b = b_{00} + b_{01}t + b_{02}t^2 + b_{03}t^3 + b_{10}r^2 + b_{11}tr^2 + b_{12}t^2r^2 + b_{13}t^3r^2 \ . \tag{10}$$

Table 4 reports regression estimates for model (9), from which the estimates for (10) are as follows:

$$\begin{aligned} b = & -0.1059 - 2.36\text{E-}4t + 1.78\text{E-}4t^2 - 4.66\text{E-}6t^3 - 5.83\text{E-}5r^2 + 9.93\text{E-}7tr^2 \\ & + 3.24\text{E-}8t^2r^2 - 9.86\text{E-}10t^3r^2 \ . \end{aligned} \tag{11}$$

Based upon (11) we illustrate inequality variations from three perspectives. In the following we represent inequality by $-b$, so that higher values denote higher inequalities and lower values denote lower inequalities. First, by substituting selected values for t in Eq. (11), the variation of inequality with rank at different points in time can be obtained. Figure 2a and b were generated by substituting for t arbitrarily selected values. In all cases inequality between states is lower at high ranks and becomes higher toward lower ranks. The general positions of the curves indicate that inequality throughout the ranks has declined between 1950 and 1975 (Fig. 2a) and has increased between 1975 and 1989 (Fig. 2b). Most interestingly, changes in position are also accompanied by changes in slope. From 1950 to 1975, inequality at low ranks has declined at a greater rate than that at high ranks; and during 1975–1989, inequality has increased at both low and high ranks, but more so at high ranks.

Figure 3 illustrates the same estimates in Eq. (11) from a second perspective, by plotting the temporal change of inequality for selected ranks. This was done by substituting for r in (11) arbitrarily selected values for rank [5, 25, 45] and plot-

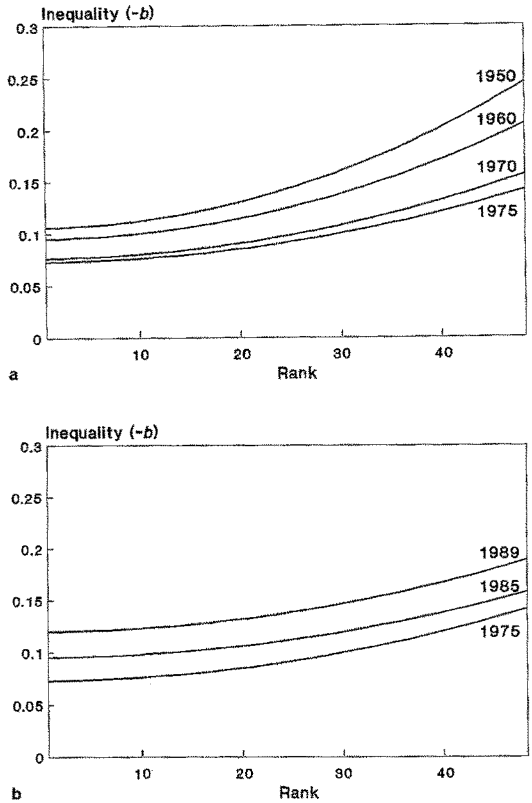

Fig. 2. Changes in inequality with rank **a** 1950–1975; **b** 1975–1989

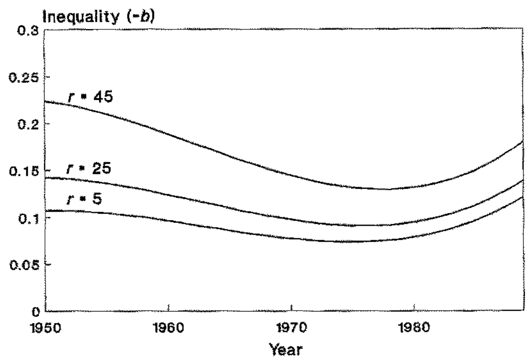

Fig. 3. Changes in inequality with time

ting estimates of $-b$ versus time. For all three ranks, inequality has first declined and then increased. At $r = 45$, the change over time has been most profound, involving high inequality to begin with, followed by a sharp decline until the late 1970s and an increase thereafter. The fluctuations are smaller for $r = 25$ and $r = 5$.

The third perspective involves portraying the spatial variations of inequality, and associating the above findings with individual states. This was done by plot-

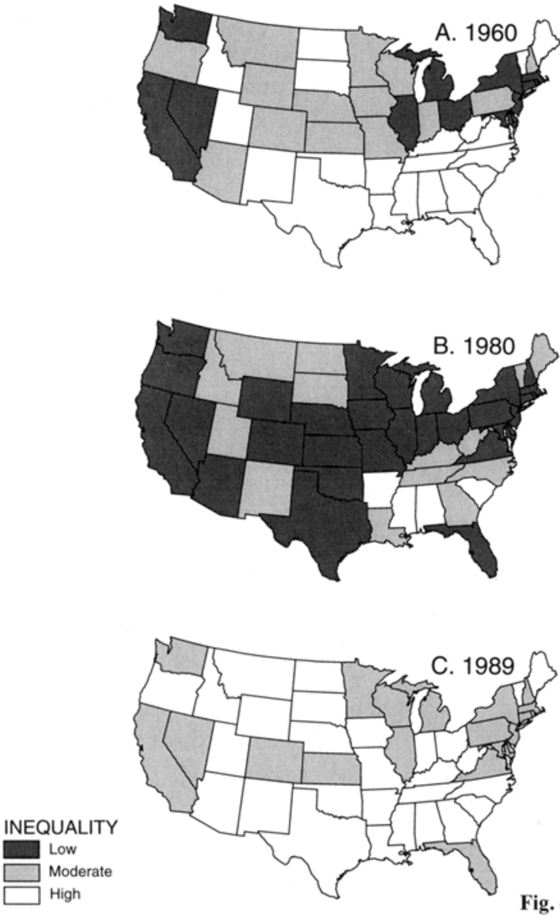

Fig. 4 A–C. Spatial variations of inequality

ting the estimated $-b$ for every state according to their rank at selected points in time. Shading classes were determined by dividing into three equal portions pooled estimates from all years. For the sake of simplicity we refer to these three classes as high (between-state) inequality ($-b>0.131$), moderate inequality ($0.131>-b>0.103$) and low inequality ($-b<0.103$). The maps for 1960, 1980 and 1989 are selected for discussion.

Figure 4 A shows that in 1960 most Manufacturing Belt states were in the low inequality category, including New York, New Jersey, Ohio, Michigan and Illinois, which depicts the consolidation of the main core and the intensification of polarization. There was also a secondary core in the West. The periphery in the South and Southeast, on the other hand, had higher levels of between-state inequality.

The cores identified above were less conspicuous in 1980, shown in Fig. 4 B, as more of the peripheral states were brought into low and moderate inequality categories. They included the Sunbelt states of Florida, Texas, Arizona and their neighbors. Their income growth which signified polarization reversal also reduced the inequality between them as well as the inequality between them and the former cores. Only South Carolina, Alabama, Mississippi and Arkansas remained in the high inequality category. The net effect is one of more even distribution of income between states.

Figure 4C depicts a deviation from further regional convergence. By 1989 between-state inequality had increased in most parts of the country, as the process of spatial restructuring selectively boosted the income of some states. Noticeable among high-income states are those in New England, where five (New Hampshire, Vermont, Connecticut, Rhode Island, Massachusetts) out of six states (except Maine) shifted from low inequality into moderate inequality category. A comparison of 1989 with 1960 suggests renewed growth in some parts of the traditional core, new growth in the Atlantic coast and sustained growth in the West. There was however higher inequality between most of the Great Plains and Central states, and higher inequality between them and the new cores that were emerging.

Discussion and conclusions

The inverted-U hypothesis and the underlying neoclassical logic have greatly influenced the literature on income inequality. We argued in this paper that using level of economic development as an explanation for changes in regional income inequality is static and deterministic, and that it does not explain the recent increase in regional income inequality. Instead, we showed that the regional dynamics literature provides relevant and important materials that conceptually and empirically link changes in regional income inequality with the spatial flows of factors of production that accompany regional growth and decline. Specifically, we suggested three phases of regional dynamics and the associated patterns of regional income inequality: polarization explained early regional divergence, polarization reversal led to regional convergence, and the recent increase in regional income inequality was due to spatial restructuring of the global and US economies and the renewed growth of some traditional core states. In each phase it is the flows of factors of production that contributed to the selective growth of some regions but not others.

The flows of factors of production, especially capital, do not follow the neoclassical disequilibrium-equilibrium model but are a response to regional differentials in competitiveness. In each of the three phases identified, it is the location and specific production requirements of the leading sector(s), be it manufacturing or services, that underlie the spatial shifts of capital and jobs and subsequent changes in regional income inequality. Regional income inequality is therefore not a simple and mechanistic function of a nation's level of economic development. The neoclassical assumption of linearity in development is flawed, because placing a nation in the development continuum as an explanation for regional income inequality ignores the real underlying driving forces of regional change.

The familiar framework of polarization and polarization reversal is also not adequate in accounting for recent changes in regional income inequality. First, systemic inequality has increased. Second, the proportion of between-region inequality has increased, suggesting new shifts of economic growth on a regional basis. Third, for the first time since 1950, inequality between high-income states has increased, depicting the emergence of some states that have performed exceptionally well in the 1980s. A global perspective is necessary for understanding these changes. As the US continues to face strong competition from other industrial nations, its manufacturing production diffuses from the traditional core to low cost sites both within and outside the nation. The domestic economy is concomitantly undergoing sectoral shifts, with services emerging as the new leading sector (Daniels et al. 1991). The New England turnaround and the sustained growth of Atlantic and Pacific states highlight the importance of high technology industries and producer services (Hansen 1990; Perry 1991), and of metropolitan infrastructure and locations that facilitate international communications and business operations. The new cores that emerge are a product of spatial restructuring which accompanied sectoral shifts in the US economy and which also supports the notion of a "bicoastal economy" (Rowley et al. 1991). Old manufacturing sites in the traditional core, Great Plains, Central and Southern states which have little high technology or producer services development begin to assume the new periphery with lower incomes.

The illustration of inequality variations, via decomposed information theoretic measures and expanded rank-size functions, is instrumental in connecting regional dynamics with regional income inequality. In addition to traditional systemic inequality approach, a focus on inequality variations allows one to pinpoint with accuracy where and when in the nation inequality increases or decreases. The findings indicate that during polarization, income inequality between states in the traditional core is low, and income inequality between them and the peripheral states, and between peripheral states, is high. The decline in inequality between low-income states depicts the process of polarization reversal, which brings about rise in income in peripheral states. Finally, the increase in inequality between low-income states and an overall increase in regional inequality in the nation are indicative of new spatial dynamics, comprising new cores in New England and in Atlantic and Pacific states, and a new periphery between the two coasts.

The field of regional income inequality is rich in empirical work but weak in theory. We argued that the inverted-U hypothesis is a constraint to theory development, and that a viable alternative lies in the regional dynamics literature. Although this paper did not attempt to articulate a full-fledged theory of regional income inequality, we have demonstrated the very strong relations between regional dynamics and regional income inequality, which warrant greater attention and further investigation.

Appendices

Appendix A

The dissimilarity index evaluates the maximum vertical deviation between the Lorenz Curve and the diagonal. Using population data from the US Bureau of Census (1975; 1991)

$$D = \frac{1}{2} \sum_{i=1}^{n} \left| \frac{y_i}{Y} - \frac{p_i}{P} \right|$$

where

y_i = per capita income in state i;
p_i = population in state i;
Y = per capita income in the US;
P = population in the US

Appendix B

For each state a value z_i, where $z_i = y_i / \sum y_i$, or the fraction of state i's per capita income with respect to the sum of all states' per capita income, is calculated. The modified Shannon entropy measure (Gaile 1984; Perin and Semple 1976; Shannon 1948; Theil 1967) is:

$$I = \sum_{i=1}^{n} z_i \log n z_i$$

where n is the total number of states. Complete inequality exists when the per capita income of one state is equal to the sum, $z_i = 1$, in which case I would be at its maximum, $\log n$. Conversely, complete equality is achieved when all states have the same per capita income, so that $z_1 = z_2 = \ldots = z_n$, and I is at 0, which is also its minimum. I is also referred to as "total inequality", whose unit is "bit" (binary digit) when the logarithm of base two is used, as in this paper.

Appendix C

Because of its additive property, I can be decomposed into terms with respect to different levels of geographic aggregation so that the sum of all the weighted decomposed terms equals total inequality (Perin and Semple 1976; Theil 1967; Walsh and O'Kelly 1979). By grouping the 49 contiguous states into four regions:

$$I = \sum_{g=1}^{G} Z_g \log \frac{Z_g}{n_g/n} + \sum_{g=1}^{G} Z_g \left[\sum_{i \in s_g} \frac{z_{ig}}{Z_g} \log \frac{z_{ig}/Z_g}{1/n_g} \right]$$

where

n_g $g = 1, \ldots, G$ is the total number of states in region g;
z_{ig} is the fraction of the per capita income of state i in region g with respect to the sum of all per capita incomes in n states;
Z_g is the sum of all z_{ig}'s in the region g.

The first term on the right measures between-region inequality (BRQ); and the second term is a weighted sum of within-region inequalities (WRQ), or between-state inequalities within the four regions.

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