The combined effects from geography and economic structure on the growth dynamics of neighboring spatial units

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Abstract

This paper extends the work in Kocornik-Mina (2007, 2009) by simultaneously examining and measuring the combined geographical and structural effects of nearest neighbors and higher order neighbors on the growth dynamics of individual spatial units and of the system. For comparison, a model with comparable proximity matrices using simultaneous dynamic least squares is estimated. The patterns that emerged are examined and contrasted. Data from Indian states are used for the empirical application.

Keywords: Multiregional growth; Spatial dynamics; India—Growth dynamics.

JEL Classification: 011, R11

AMS Classification: 91B72, 93E24, 91G70

El efecto conjunto de la geografía y la estructura económica en las dinámicas de crecimiento de unidades espaciales vecinas

Resumen

Este artículo continúa el trabajo de investigación de Kocornik-Mina (2007, 2009) al examinar y medir simultáneamente los efectos geográficos y estructurales de los conjuntos de vecinos cercanos y aquellos más distantes en las dinámicas de crecimiento tanto de unidades espaciales individuales como del sistema. A efectos de comparación, se estima un modelo con matrices de proximidad comparables utilizando el método de mínimos cuadrados dinámicos simultáneos. Los patrones resultantes son examinados y contrastados. La aplicación empírica utiliza datos estadísticos de los estados de la India.

Palabras clave: Crecimiento multi-regional, dinámicas espaciales; India—dinámicas de crecimiento.

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1. Introduction

In Kocornik-Mina (2007, 2009) has been considered and modeled the simultaneous growth of a system of spatial units where India is the case for empirical testing. In the nonlinear Lotka-Volterra framework consistent with spatial theory and spatial econometrics, state-level growth dynamics driving the growth of the system as a whole have been expressed as a function of each state's level of per capita income, the level of per capita income of first order neighbors and the level of per capita income of higher order neighbors. States have been classified as first order or higher order neighbors according to their proximity in space and the equivalence of economic structures[1].

Three different models that incorporate alternative approaches to defining contiguity have been estimated by Kocornik-Mina (2007, 2009) using simultaneous dynamic least squares and data from seventeen states in India. The first approach is based on queen type contiguity (Model G). The second approach is based on average location quotients between 1993-94 and 2000-01 (Model H). Location quotients are a measure of over-concentration in an industry or sector. The purpose of comparing states according to average location quotients between 1993-94 and 2000-01 in 13 industries is two-fold. First, to identify groups of states that have on average location quotients above one in the same industries between 1993-94 and 2000-01 and allow for the simultaneous growth or inter-state growth dynamics that may emerge among mainly complementary or mainly competitive economic structures. Second, to group only those states whose ability to maintain an average location quotient above one suggests a deeper and more tenable comparative or competitive advantage in the post 1991 reform liberalized environment. A third approach conducts a factor analysis using standardized annual shares of total net state domestic product (NSDP) at factor cost by industry of origin between 1980-81 and 1995-96 (Model F). The purpose is to allow variance in the data to define contiguity and avoid adopting an arbitrary cutting point as in the case of the definition of contiguity according to location quotients.

The analysis of estimated coefficients by model in Kocornik-Mina (2007) found that in many but not all cases Indian states are proximate both geographically and structurally. In these cases, the estimated coefficients are stronger in absolute terms than those of states with neighbors who are not both geographically and structurally contiguous.

This paper extends the work in Kocornik-Mina (2007, 2009) by simultaneously examining and measuring the combined geographical and structural effects of nearest neighbors and higher order neighbors (b_G, b_H and b_F and also c_G, c_H and c_F, degrees of freedom permitting) on the growth dynamics of individual spatial units and of the system. For comparison, a model with comparable proximity matrices using

[1] Dynamics associated with structural equivalence are expected if similar levels of urbanization, infrastructure (human and physical), and sectoral composition of the economy, among others, are present.

simultaneous dynamic least squares is estimated. The patterns that emerged are examined and contrasted.

The rationale for simultaneously examining geographical and structural effects is given by (1) the similarities and differences observed in the composition of the contiguity matrices and (2) the finding in Kocornik-Mina (2007, 2009) that the effects from nearest neighbors and higher order neighbors are greater in absolute terms when the proximity matrices of structural equivalent states include neighbors that are also geographically proximate.

The paper is organized as follows: Part 2 presents the model, method of estimation and the composition of the proximity matrices. Part 3 reports on the results of simultaneously examining the geographical and structural growth effects on the behavior of the system according to the two approaches proposed. Concluding remarks follow.

2. Model, Methods and Proximity

2.1 The extended Lotka-Volterra (LV) model

Samuelson (1971) proposed the LV model of dynamic interdependence between predators and prey for use in economic analysis.[2] The LV model was generalized and applied to model the inter-regional dynamics of European Union regions by Arbia and Paelinck (2003a, 2003b) as follows:

The two-equation basic LV model

$$\dot{x}_1 = x_1(a_1 - a_{12}x_2) \quad [1]$$

$$\dot{x}_2 = -x_2(a_2 - a_{21}x_1) \quad [2]$$

where:

$\dot{x}_1$ is the time derivative of the prey species (e.g., the change in the number of deer)

$\dot{x}_2$ is the time derivative of the predator species (e.g., the change in the number of tigers)

x_1 is the number of individuals of the prey species

x_2 is the number of individuals of the predator species

a_1 is the constant rate that the prey species develops at

a_{12} is the rate preyed upon by the predator species

a_2 is the rate the predator species fades in the absence of prey

a_{21} is the rate that predator species encounters (feeds upon) its prey

2 Dendrinos et al. (1985) used a modified LV to model inter-urban dynamics. They noted that changes in technology and/or comparative advantage, among other factors, would transform the inter-urban dynamics.

was generalized to n 'species' (spatial units) by introducing a first order contiguity matrix (nearest neighbors), and a second matrix of higher orders of contiguity (all other spatial units in the system):

$$y_{rt} = y_{r,t-1}\ exp\left[a_r y_{r,t-1} + b_r y^{*}_{r,t-1} + c_r y^{**}_{r,t-1} + d_r\right] \qquad [3]$$

where:

$y^{*}_{r,t-1} = \sum w^{*}_{rs} y_{st-1}$ and $y^{**}_{r,t-1} = \sum w^{**}_{rs} y_{st-1}$, where w^{*}_{rs} is the typical element of a first order contiguity matrix $\mathbf{W}^{*}$, and w^{**}_{rs} is the typical element of a higher order contiguity matrix $\mathbf{W}^{**}$

$y_{r,t-1}$ and y_{rt} = endogenously estimated variables for region r at time $t-1$ and t

a_r = own growth effect

b_r = growth effect from first order neighbors

c_r = growth effect from higher order neighbors

d_r = constant representing each spatial unit's residual rate of growth[3]

$\sum y^{*}_{r,t-1}$ = sum of endogenously estimated values of first order spatial units

$\sum y^{**}_{r,t-1}$ = sum of endogenously estimated values of higher order spatial units

This specification is the LV equation for the multiregional system and reintroduces the non-linearity of the generalized LV, which was partly lost in Arbia's and Paelinck's (2003b) double logarithmic version.

For each spatial unit's equation, first order neighbors and higher order neighbors have the same estimated b_r and c_r, respectively. This imposition to keep the number of parameters to be estimated manageable "controls for the presence of spillover effects" albeit with the risk of bias in the estimates of these spillovers and "other coefficients" (Piras et al., 2006: 7) but here the results will be used in line with the possible uses appropriate to the particular estimator (simultaneous dynamic least square) chosen here (more below).

The theory behind equation [3] is that of the principles of spatial econometrics: interdependence of endogenous variables, asymmetry, non-locality effects of exogenous variables, non-linearity, and presence of topological variables. Accordingly, the generalized LV model in equation [3] is used to keep track of the structure of spatial

[3] Conceptually, this constant captures all influences on a spatial unit's growth not accounted for by the specific LV variables (own growth, growth from first order neighbors and growth from higher order neighbors). For example, it captures the growth effects from spatial units not included in the sample and the regional policies that influence regional and multiregional growth autonomously.

dependence[4] among spatial units and of the collective behavior that results from their micro-level interactions.[5] By removing the cyclicality of the standard predator-prey model, the generalized LV model is no longer a non-convergent model assuming constant predator-preying rates[6] and thus should not be interpreted in terms of predator-prey behavior although some regions may fall prey to other regions. Rather, the generalized LV model describes "a different convergence path and a different steady-state level for each region, as well as the conditions for the long-term equilibrium for the entire area" (Arbia and Paelinck, 2003b: 359). Moreover, as coefficients are region-specific, spatial heterogeneity is well taken into account. To note, Paelinck (2004) has proposed a more sophisticated specification which, if the model converges mathematically, avoids negative equilibrium values (see also Griffith and Paelinck, 2011, chapter 11).

Arbia and Paelinck (2003b) note that the generalized LV model can be considered a semi-reduced form of the larger multiregional model of Sakashita and Kamoike (1973) as states income per capita are related to each other directly. The Sakashita-Kamoike model is embedded in the neoclassical framework. Limiting assumptions regarding labor and capital mobility ensure that the Sakashita-Kamoike model converges. The generalized LV model is similarly consistent with the classical convergence model of Barro and Sala-i-Martin (1992) when instead of differentials finite differences are considered and there are no growth effects from first and higher order neighbors ($b = c = 0$) (Arbia and Paelinck, 2003b). Thus while in the classical convergence model a single economic convergence parameter is estimated for all observations in the sample, in the generalized LV model the richness of the parameters is reflected *inter alia* in that each spatial unit can converge to a different per capita income level as a function of the eigenvalues of the system.[7]

2.2 Method of Estimation

The examination and simultaneous measurement of b_G, b_H and b_F and also c_G, c_H and c_F, degrees of freedom permitting can be done as shown in the following simple example: $y=b_Gx_G + b_Hx_H + b_Fx_F + \ldots$, which can be rewritten as $y= b\,(w_Gx_G + w_Fx_F + w_Hx_H) + \ldots$, all coefficients being spatial unit-specific (Indian states, in the application), and the w's being (algebraic) weights ($\sum w_i=1$, $i=G, F$ and H). That is, the three estimates are being introduced simultaneously and the result expressed as in the second equation, which is derived from the first one. The premise of this approach, heretofore referred as Model G+H+F, is that, once captured, dynamics emerging from geographical proximity and structural equivalence are independent. That is, growth effects among economic

4 Spatial dependence means that "the probability of a specific value occurring in a specific location depends on the value of neighboring locations" (Florax and Nijkamp, 2004: 3). Anselin (1988) defines it as "the existence of a functional relationship between what happens at one point in space and what happens elsewhere" (p. 11).

5 Beinhocker (2006) includes in his definition of a complex system the notion that the micro-level interactions "lead to the emergence of macro-level patterns of behavior" (p. 18).

6 The predator prey model is only one example of a two-equation LV model.

7 To note, in the neoclassical growth model spatial units can converge to differentially determined steady-state levels of capital and output per worker, but not to different rates of growth.

structures that are competitive or complementary are not cancelled out by growth effects that emerge from geographical neighbors, even if a spatial unit is a first order neighbor according to both definitions of proximity. Albeit a strong assumption, it is one worth exploring alongside the alternative view, which allows for the potential substitution between growth effects from structural equivalence and geographical proximity in a system of interacting spatial units. Here, one or another type of growth effect may no longer emerge if the interactions between first order neighbors in Models G, H and F are simultaneously measured and the long run behavior of the system examined.

In this context, the proposed second approach to simultaneously measure dynamics emerging from geographical proximity and structural equivalence is to estimate the extended Lotka-Volterra model using simultaneous dynamic least squares (labeled Model SDLS GHF). Simultaneous dynamic least squares (SDLS) is an estimator method appropriate for projections, policy simulations and mathematical programming, among others (Griffith and Paelinck, 2007, 2011, Paelinck, 1990, 2004). It may be used to capture linkages between endogenous variables as well as the effects of exogenous shocks (Griffith and Paelinck, 2007, 2011, Paelinck, 1990). This estimation technique minimizes the sum of squared deviations between the observed and the endogenously generated values of the endogenous variable (Paelinck, 2004, Griffith and Paelinck, 2011, chapter 11). It offers the additional advantage that an optimal starting point for the endogenous simulation can be set so that "the tendency for SDLS values is to 'close in' on the observed values slightly more than the OLS values" (Arbia and Paelinck, 2003b: 353).

It is expected for estimated coefficients according to the two approaches to indicate the same overall direction of dynamic growth effects from nearest neighbors and higher order neighbors. Variations in own growth effects a as a result of changes in the composition of first and higher order neighbors should in all instances exhibit positive correlations per findings in Kocornik-Mina (2007) that a_H, a_F and a_G are positively correlated (r=.704 for a_H/a_F; r=.809 for a_G/a_F; and r=.940 for a_H/a_G). The p-values respectively are .001, .000 and .000. Similarly, a positive correlation is expected between b and c.[8] In addition, differences in magnitude are expected at least in part given the decision to include states as nearest neighbors in Model SDLS GHF only once. As indicated below, Model G+H+F has several instances in which states that are nearest neighbors according to geography are also nearest neighbors according to one or both definitions of structural equivalence.

2.3 Proximity

Table 1 lists first order neighbors by state for each approach in Kocornik-Mina (2007, 2009), as well as first order neighbors to be used in Model SDLS GHF. First order neighbors in Model G+H+F are simply the sum of the neighbors in Models G, H, and F.

[8] Kocornik-Mina (2007, 2009) found significant positive correlation of r=.825 for b_G/b_H (p=.000) and r=.578 for c_G/c_H (p=.015).The corresponding correlations with F are not significant.

Table 1

First Order Neighbors in Models G, H, F, and SDLS GHF

(Continues)

State	First Order Neighbors in Model G	First Order Neighbors in Model H	First Order Neighbors in Model F	First Order Neighbors in Model SDLS GHF
Andhra Pradesh	Karnataka, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu	Assam, Bihar	Haryana, Himachal Pradesh	Assam, Bihar, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu
Assam	West Bengal	Andhra Pradesh, **Bihar**, Kerala, Rajasthan	**Bihar**, Karnataka, Orissa	Andhra Pradesh, Bihar, Karnataka, Kerala, Orissa, Rajasthan, West Bengal
Bihar	Madhya Pradesh, **Orissa**, Uttar Pradesh, West Bengal	Andhra Pradesh, **Assam**, Jammu and Kashmir, **Orissa**	**Assam**, Karnataka, **Orissa**	Andhra Pradesh, Assam, Jammu and Kashmir, Karnataka, Madhya Pradesh, Orissa, Uttar Pradesh, West Bengal
Gujarat	Madhya Pradesh, **Maharashtra**, Rajasthan	**Maharashtra**	Jammu and Kashmir, **Maharashtra**, Tamil Nadu, Uttar Pradesh	Jammu and Kashmir, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Uttar Pradesh
Haryana	**Himachal Pradesh**, **Punjab**, Rajasthan, Uttar Pradesh	**Punjab**, Tamil Nadu	Andhra Pradesh, **Himachal Pradesh**	Andhra Pradesh, Himachal Pradesh, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh
Himachal Pradesh	**Haryana**, **Jammu and Kashmir**, Punjab, Uttar Pradesh	**Jammu and Kashmir**, Karnataka, Kerala, Rajasthan	Andhra Pradesh, **Haryana**	Andhra Pradesh, Haryana, Jammu and Kashmir, Karnataka, Kerala, Punjab, Rajasthan, Uttar Pradesh
Jammu and Kashmir	**Himachal Pradesh**, Punjab	Bihar, **Himachal Pradesh**, Karnataka, Madhya Pradesh, Orissa, **Uttar Pradesh**	Gujarat, Maharashtra, Tamil Nadu, **Uttar Pradesh**	Bihar, Gujarat, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Punjab, Tamil Nadu, Uttar Pradesh
Karnataka	Andhra Pradesh, Kerala, Maharashtra, Tamil Nadu	Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Punjab, Rajasthan, Uttar Pradesh	Assam, Bihar, Orissa	Andhra Pradesh, Assam, Bihar, Himachal Pradesh, Jammu and Kashmir, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh
Kerala	Karnataka, Tamil Nadu	Assam, Himachal Pradesh	Madhya Pradesh, Punjab, Rajasthan, West Bengal	Assam, Himachal Pradesh, Karnataka, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu, West Bengal
Madhya Pradesh	Andhra Pradesh, Bihar, Gujarat, Maharashtra, **Orissa**, **Rajasthan**, Uttar Pradesh	Jammu and Kashmir, Karnataka, **Orissa**, **Rajasthan**	Kerala, Punjab, **Rajasthan**, West Bengal	Andhra Pradesh, Bihar, Gujarat, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Orissa, Punjab, Rajasthan, Uttar Pradesh, West Bengal

Table 1

First Order Neighbors in Models G, H, F, and SDLS GHF

(Conclusion)

State	First Order Neighbors in Model G	First Order Neighbors in Model H	First Order Neighbors in Model F	First Order Neighbors in Model SDLS GHF
Maharashtra	Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh	Gujarat, Tamil Nadu	Gujarat, Jammu and Kashmir, Tamil Nadu, Uttar Pradesh	Andhra Pradesh, Gujarat, Jammu and Kashmir, Karnataka, Madhya Pradesh, Tamil Nadu, Uttar Pradesh
Orissa	Andhra Pradesh, Bihar, Madhya Pradesh, West Bengal	Bihar, Jammu and Kashmir, Madhya Pradesh	Assam, Bihar, Karnataka	Andhra Pradesh, Assam, Bihar, Jammu and Kashmir, Karnataka, Madhya Pradesh, West Bengal
Punjab	Haryana, Himachal Pradesh, Jammu and Kashmir, Rajasthan	Haryana, Karnataka, Uttar Pradesh	Kerala, Madhya Pradesh, Rajasthan, West Bengal	Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Rajasthan, Uttar Pradesh, West Bengal
Rajasthan	Gujarat, Haryana, Madhya Pradesh, Punjab, Uttar Pradesh	Assam, Himachal Pradesh, Karnataka, Madhya Pradesh	Kerala, Madhya Pradesh, Punjab, West Bengal	Assam, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Punjab, Uttar Pradesh, West Bengal
Tamil Nadu	Andhra Pradesh, Karnataka, Kerala	Haryana, Maharashtra	Gujarat, Jammu and Kashmir, Maharashtra, Uttar Pradesh	Andhra Pradesh, Gujarat, Haryana, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Uttar Pradesh
Uttar Pradesh	Bihar, Haryana, Himachal Pradesh, Madhya Pradesh, Rajasthan	Jammu and Kashmir, Karnataka, Punjab, West Bengal	Gujarat, Jammu and Kashmir, Maharashtra, Tamil Nadu	Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, West Bengal
West Bengal	Assam, Bihar, Orissa	Uttar Pradesh	Kerala, Madhya Pradesh, Punjab, Rajasthan	Assam, Bihar, Kerala, Madhya Pradesh, Orissa, Punjab, Rajasthan, Uttar Pradesh

Note*:* States in bold are those that are nearest neighbors according to at least two definitions of contiguity

Model G+H+F can only be meaningful if there are important differences in the composition of first order neighbor matrices in Models G, H and F. Accordingly, Table 2 lists normalized and non-normalized Hamming distance[9] for every pair of first order neighbors matrices to highlight differences or similarities in composition.[10] These measures of Hamming distance suggest some degree of similarity in the composition of first order neighbors matrices in Models G and H for Gujarat, Orissa, Haryana, Kerala,

[9] Hamming (1950) introduced the Hamming metric for error detecting and error correcting codes explaining that "the distance D(x, y) between two points x and y [can be defined] as the number of coordinates for which x and y are different" (p. 155).

[10] The normalized and non-normalized Hamming distance between pairs of matrices of higher order neighbors do not differ from those in Table 2.

Maharashtra and West Bengal. In Models H and F the Hamming distance is least, thus suggesting similarities in the two sets of first order neighbors matrices, for Maharashtra, Gujarat, Bihar, Orissa, Haryana, Tamil Nadu and Andhra Pradesh. Between Models F and G the matrices are the most similar for Assam, Haryana and Himachal Pradesh.

Table 2

Normalized and Non-normalized Hamming Distance between Pairs of Matrices of First Order Neighbors

State	Model G versus Model H		Model H versus Model F		Model F versus Model G	
	H dist	H_N dist	*H* dist	H_N dist	*H* dist	H_N dist
AP	7	0.41	4	0.24	7	0.41
AS	5	0.29	5	0.29	4	0.24
BH	6	0.35	3	0.18	5	0.29
GJ	2	0.12	3	0.18	5	0.29
HY	4	0.24	4	0.24	4	0.24
HP	6	0.35	6	0.35	4	0.24
J&K	6	0.35	8	0.47	6	0.35
KN	10	0.59	9	0.53	7	0.41
KR	4	0.24	6	0.35	6	0.35
MP	7	0.41	6	0.35	9	0.53
MH	4	0.24	2	0.12	6	0.35
OR	3	0.18	4	0.24	5	0.29
PJ	5	0.29	7	0.41	6	0.35
RJ	7	0.41	6	0.35	5	0.29
TN	5	0.29	4	0.24	7	0.41
UP	9	0.53	6	0.35	9	0.53
WB	4	0.24	5	0.29	7	0.41

Note: H_N dist refers to normalized Hamming distance and H dist to non-normalized

Notwithstanding the commonalities in the composition of first order neighbors of some states, a sample average Hamming distance of at least 5 ($H_N >= 0.30$) indicate that the different criteria to define contiguity (geographically and structurally) do yield some diversity and that interesting variations are observed irrespective of definition of contiguity. In terms of normalized Hamming distance, the differences in the composition of first order neighbors matrices in Models G and F are small for Himachal Pradesh (H_N=0.24), Orissa (H_N=0.29), and Bihar (H_N=0.29). The H_N is not as short for Maharashtra and Punjab (0.35 in both cases). The Hamming distance is 4 for Haryana (H_N=0.24); 6 for Jammu and Kashmir and Kerala (H_N=0.35); 7 for Tamil Nadu, Andhra Pradesh and West Bengal (H_N=0.41); and 9 for Uttar Pradesh (H_N=0.53).

Another way to think about what the implications of the degree of similarity and difference of the original first order neighbor matrices in Models G, H and F are for the current analysis is in terms of the diversity of the sample. India is a federation consisting of 28 states and 7 union territories (UTs). Table 3 presents data on area, population and net state domestic product (NSDP) per capita in constant (1993-94) prices of all 35 administrative divisions in India. The point to note is the range of variation in magnitudes across states and UTs. In area terms the biggest state (Rajasthan) is 92 times the smallest state (Goa). In terms of population size the difference between the largest and smallest state is similarly noteworthy: The population in Uttar Pradesh in 2001 is at least 300 times bigger than the population in Sikkim. In terms of NSDP per capita in constant 1993-94 prices, the difference in magnitude between the state with the highest NSDP per capita (Goa) and the state with the lowest (Bihar) is equally important. In 2000-01, Goa's NSDP per capita was at least 6 times that of Bihar's.

Table 3

Population, Area and NSDP Per Capita for States and UTs in India in 1981, 1991 and 2001

(Continues)

State/Union Territories	Area in sq km	Population ('000s)			NSDP per capita in constant (1993-94) prices, Rupees		
States		1981	1991	2001	1980-81	1990-91	2000-01
Andhra Pradesh	276,754	53,551	66,508	75,728	4,604	6,873	10,195
Arunachal Pradesh	83,743	632	865	1,091	4,017	6,927	9,135
Assam	78,438	18,041	22,414	26,638	4,636	5,574	5,943
Bihar	94,163	69,915	86,374	82,879	3,427	4,474	3,879
Jharkhand	79,714	BH	BH	26,909	BH	BH	7,212
Goa	3,702	1,087	1,170	1,344	9,473	14,709	26,730
Gujarat	196,024	34,086	41,310	50,597	6,455	8,788	12,489
Haryana	44,212	12,922	16,464	21,083	7,514	11,125	13,822
Himachal Pradesh	55,673	4,281	5,171	6,077	5,793	7,618	11,029
Jammu and Kashmir	222,236	5,987	7,719	10,070	6,244	6,272	7,385
Karnataka	191,791	37,136	44,977	52,734	4,943	6,631	11,900
Kerala	38,863	25,454	29,099	31,839	5,692	6,851	10,510
Madhya Pradesh	308,014	52,179	66,181	60,385	5,084	6,350	7,195
Chhattisgarh	135,191	MP	17,615	20,834	MP	MP	6,423
Maharashtra	307,713	62,783	78,937	96,752	7,102	10,159	14,211
Manipur	22,327	1,421	1,837	2,389	4,400	5,393	6,845
Meghalaya	22,429	1,336	1,775	2,306	5,441	6,928	9,427
Mizoram	21,081	494	690	891	n/a	n/a	n/a
Nagaland	16,579	775	1,210	1,989	5,726	8,313	11,473
Orissa	155,707	26,370	31,660	36,707	4,085	4,300	5,562
Punjab	50,362	16,789	20,282	24,289	8,442	11,776	15,048
Rajasthan	342,239	34,262	44,006	56,473	4,254	6,760	8,104
Sikkim	7,096	316	406	540	n/a	n/a	10,703
Tamil Nadu	130,058	48,408	55,859	62,111	5,266	7,864	13,017
Tripura	10,486	2,053	2,757	3,191	4,001	5,026	9,397

Notes: Indiastat.com notes that population data for Assam in 1981 has been interpolated and for Jammu and Kashmir in 1991 projected.

n/a = data are not available in constant (1993-94) prices.

BH stands for Bihar, MP stands for Madhya Pradesh and UP stands for Uttar Pradesh.

Sources: Indiastat.com and Census of India (1981, 1991 and 2001). Area data from state websites and *Census of India: Map Profile 2001*. NSDP per capita from EPW Research Foundation (2003), *Domestic Product of States of India, 1960-61 to 2000-01*, Mumbai: EPW Research Foundation.

Table 3

Population, Area and NSDP Per Capita for States and UTs in India in 1981, 1991 and 2001

(Conclusion)

State/Union Territories	Area in sq km	Population ('000s)			NSDP per capita in constant (1993-94) prices, Rupees		
Uttar Pradesh	240,928	110,863	139,112	166,053	4,133	5,342	5,570
Uttaranchal	53,483	UP	7,113	8,480	UP	UP	7,720
West Bengal	88,752	54,581	68,078	80,221	4,952	5,991	9,796
Union Territories							
Andaman & Nicobar	8,249	189	281	356	12,830	12,668	15,822
Chandigarh	114	452	642	901	-	-	27,764
Dadra & Nagar Haveli	491	104	138	220	-	-	-
Daman & Diu	112	79	102	158	-	-	-
Delhi	1,483	6,220	9,421	13,783	11,642	15,736	26,390
Lakshadweep	32	40	52	61	-	-	-
Pondicherry	479	604	808	974	9,880	11,256	22,252

Notes: Indiastat.com notes that population data for Assam in 1981 has been interpolated and for Jammu and Kashmir in 1991 projected.
n/a = data are not available in constant (1993-94) prices.
BH stands for Bihar, MP stands for Madhya Pradesh and UP stands for Uttar Pradesh.

Sources: Indiastat.com and Census of India (1981, 1991 and 2001). Area data from state websites and *Census of India: Map Profile 2001*. NSDP per capita from EPW Research Foundation (2003), *Domestic Product of States of India, 1960-61 to 2000-01*, Mumbai: EPW Research Foundation.

In particular, the relevance of the diversity of the sample is that states with high levels of income per capita in 1980-81 are not always the states with high growth rates between 1980-81 and 2000-01. This diversity directly influences estimated coefficients. To recall, in the LV model the growth effects from first order neighbors and higher order neighbors are estimated using the sums of endogenously estimated values ($y^{*}_{r,t-1}$ and $y^{**}_{r,t-1}$, respectively). This means that each state has a different sum of NSDP per capita at the beginning of the period, that is, in 1980-81. Then there is also the matter of different growth rates. Thus in addition to different sums of NSDP per capita in 1980-81 states are subject to different aggregate growth rates between 1980-81 and 2000-01. Table 4 lists the sums according to each of the models by state. The differences between Models G+H+F and SDLS GHF can be observed.

Table 4

Sums for First Order Neighbors

State	Sum of NSDP per Capita 1980-81 (in Rs)				Sum of Rates of Growth 1980-81 – 2000-01 (in %)			
	First Order		Higher Order		First Order		Higher Order	
	SDLS GHF	G+H+F	SDLS GHF	G+H+F	SDLS GHF	G+H+F	SDLS GHF	G+H+F
Andhra Pradesh	47,815	47,815	40,233	40,233	25.8	25.8	20.5	20.5
Assam	31,894	35,257	56,123	56,123	21.8	22.6	27.4	27.4
Bihar	38,772	51,577	50,517	50,517	19.0	23.3	30.3	30.3
Gujarat	32,173	46,377	54,024	54,024	17.6	26.4	28.5	28.5
Haryana	32,553	46,788	52,585	52,585	20.3	26.7	26.6	26.6
Himachal Pradesh	45,888	59,646	40,972	40,972	24.2	28.3	22.3	22.3
Jammu and Kashmir	54,757	64,744	31,651	31,651	30.1	35.3	19.1	19.1
Karnataka	68,788	68,788	18,921	18,921	35.0	35.0	10.8	10.8
Kerala	43,398	43,398	43,562	43,562	25.9	25.9	20.4	20.4
Madhya Pradesh	64,331	76,924	23,208	23,208	35.5	44.8	12.4	12.4
Maharashtra	36,820	54,997	48,730	48,730	21.5	34.2	24.2	24.2
Orissa	33,855	45,694	54,712	54,712	16.5	20.3	31.9	31.9
Punjab	48,699	60,466	35,511	35,511	27.0	34.0	20.3	20.3
Rajasthan	57,734	76,401	30,665	30,665	30.0	37.2	16.3	16.3
Tamil Nadu	46,750	53,852	40,637	40,637	26.0	30.4	19.4	19.4
Uttar Pradesh	69,441	75,685	19,017	19,017	38.3	39.2	10.2	10.2
West Bengal	39,778	39,778	47,922	47,922	17.6	17.6	28.9	28.9

3. Estimation and Results

3.1 Sample and Data

To control as much as possible for differences in collection methods and data availability the study by Kocornik-Mina (2007, 2009) was restricted to a sample of 17 states.[11] The choice of Indian states rather than districts as the unit of analysis introduces certain limitations; the most obvious is that states in India suffer from important internal disparities that are subsumed when looking only at the state level. However, quality and availability of state level data provide a strong argument in favor of this decision (Lall, et al., 2003, Lall, et al., 2004).

[11] The seventeen states in the sample in alphabetical order are Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. In 2000-01, total NSDP of all 17 states represented 94.2 percent of all-India net domestic product (NDP) and 97.3 percent of the population. In 1980-81 the proportion was 96.6 percent and 97.8 percent, respectively, and 96.0 percent and 97.5 percent in 1990-91. In 2000-01 average NSDP per capita in constant (1993-94) prices for the 17 states in the sample was 9,078 rupees compared to an all-India net domestic product (NDP) per capita in constant (1993-94) prices of 10,427 rupees.

The data used to estimate the model coefficients *a*, *b*, *c* and *d* are NSDP per capita published by the EPW Research Foundation[12] (2003) and supplemented with data from the Government of India's Central Statistical Organization. The period of analysis is from fiscal year 1980-81 to fiscal year 2000-01. As the 1993-94 series is more comprehensive and methodologically sound than earlier series it was chosen by Kocornik-Mina (2007, 2009) for estimating model coefficients. Indeed, the 1993-94 series is expected to incorporate methodological improvements consistent with the recommendations of the 1993 United Nations System of National Accounts guidelines. In addition, estimates are expected to include new products in agriculture and allied activities, mining, banking and finance, public services and other services. The NSDP per capita data are in constant 1993-94 prices. By eliminating the price effect it is possible to focus on changes in quantities over time. Per capita income is a proxy for a spatial unit's location-specific factors.

3.2 Results

Descriptive statistics in Table 5 for the observed and endogenously generated values of annual NSDP per capita between 1980-81 and 2000-01 indicate a good fit. The standard deviation is for the most part larger for the observed values of NSDP per capita but not that different from the NSDP per capita in Models G+H+F and SDLS GHF.

Table 5

Descriptive Statistics of Observed and Estimated NSDP Per Capita for Models GHF and G+H+F (in Rs)

State	Observed		Estimated			
			SDLS GHF		G+H+F	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Andhra Pradesh	6,846	1,647	6,845	1,622	6,845	1,620
Assam	5,482	321	5,479	299	5,484	292
Bihar	3,938	322	3,940	237	3,939	242
Gujarat	9,551	2,527	9,557	2,445	9,552	2,425
Haryana	10,402	2,008	10,401	1,974	10,402	1,973
Himachal Pradesh	7,676	1,763	7,678	1,740	7,675	1,745
Jammu and Kashmir	6,523	477	6,524	426	6,524	457
Karnataka	7,333	2,051	7,332	2,055	7,335	2,045
Kerala	7,277	1,824	7,278	1,814	7,276	1,815
Madhya Pradesh	6,080	888	6,078	850	6,082	846
Maharashtra	10,420	2,825	10,419	2,810	10,421	2,798
Orissa	4,738	571	4,738	503	4,738	504
Punjab	11,734	2,002	11,734	1,997	11,734	1,996
Rajasthan	6,278	1,524	6,273	1,475	6,277	1,464
Tamil Nadu	8,242	2,435	8,238	2,430	8,244	2,430
Uttar Pradesh	5,028	518	5,028	493	5,026	485
West Bengal	6,543	1,531	6,544	1,533	6,543	1,529

[12] The EPW Research Foundation has extended the 1993-94 series back to include estimates of SDP from 1980-81 on.

Table 6 presents the results of the two estimations. It lists the average estimated coefficients by grouping. The level of NSDP per capita in 1980-81 and the annual rate of growth (ARG) between 1980-81 and 2000-01 are also given by state and by grouping. The latter data highlight the diversity in the sample of Indian states and are used to indicate whether states are high or low income, high or low growth and/or, more broadly, whether they fall in advancing or lagging groupings.

Table 6

Estimated Coefficients *a, b, c* for All Models, by State and Grouping

(Continues)

	a'					*b'*				
	G	F	H	SDLS GHF	G+H+F	G	F	H	SDLS GHF	G+H+F
First tier Advancing										
Gujarat	-0.2331	0.1588	-0.3958	-0.1604	-0.4702	0.5398	-0.0837	0.9947	0.3924	1.4508
Haryana	-0.0203	-0.0502	-0.1263	-0.0552	-0.1968	-0.0332	0.1340	0.0984	-0.0183	0.1992
Maharashtra	0.1699	0.1832	0.3280	0.1942	0.6810	-0.2347	-0.1278	-0.2535	-0.1595	-0.6160
Punjab	-0.0868	-0.2089	-0.0833	-0.1117	-0.3790	-0.0330	-0.1471	-0.0180	0.0397	-0.1980
Tamil Nadu	-0.0105	-0.2649	-0.1448	-0.0085	-0.4202	-0.0928	0.0870	0.1148	-0.0307	0.1089
Average	**-0.0362**	**-0.0364**	**-0.0844**	**-0.0283**	**-0.1570**	**0.0292**	**-0.0275**	**0.1873**	**0.0447**	**0.1890**
Second tier Advancing										
Himachal Pradesh	-0.0354	-0.0279	-0.0200	-0.0552	-0.0833	0.0459	0.0741	-0.0348	-0.0064	0.0852
Kerala	-0.2922	-0.2459	-0.6635	-0.4690	-1.2016	-0.1880	0.5522	-0.2393	-0.0422	0.1249
West Bengal	-0.0464	-0.0339	-0.0840	-0.0701	-0.1643	-0.0228	0.0086	-0.0348	-0.0161	-0.0490
Average	**-0.1247**	**-0.1025**	**-0.2559**	**-0.1981**	**-0.4831**	**-0.0550**	**0.2116**	**-0.1029**	**-0.0216**	**0.0537**
Intermediate										
Andhra Pradesh	0.0286	0.0285	0.0575	-0.1100	0.1146	-0.0205	0.0319	0.0485	0.0607	0.0599
Karnataka	-0.0329	0.0482	0.0739	-0.0406	0.0892	0.0208	-0.0124	-0.0038	0.0024	0.0046
Rajasthan	0.1095	0.3138	0.1226	0.3141	0.5459	0.0995	-0.0561	-0.1351	-0.0297	-0.0917
Average	**0.0351**	**0.1302**	**0.0847**	**0.0545**	**0.2499**	**0.0332**	**-0.0122**	**-0.0301**	**0.0111**	**-0.0091**
Lagging										
Assam	-0.0248	-0.4236	-0.0577	-0.0771	-0.5061	0.0739	-0.1909	0.0148	0.0499	-0.1021
Bihar	-0.7703	-1.4517	-0.9279	-0.6082	-3.1499	0.0714	1.5005	0.3070	0.2258	1.8789
Jammu and Kashmir	-0.0625	-0.0630	-0.0520	-0.1705	-0.1775	-0.0222	0.0610	-0.0641	0.0158	-0.0254
Madhya Pradesh	0.0327	0.2088	0.0044	0.0339	0.2459	0.0821	-0.0265	-0.1421	-0.0242	-0.0864
Orissa	-0.1453	-0.8400	-0.1659	-0.1147	-1.1511	0.0649	0.2776	0.0787	0.0650	0.4212
Uttar Pradesh	-0.0196	-0.0615	-0.1608	0.0117	-0.2419	-0.0974	0.0221	0.1018	-0.0036	0.0265
Average	**-0.1650**	**-0.4385**	**-0.2266**	**-0.1542**	**-0.8301**	**0.0288**	**0.2740**	**0.0494**	**0.0548**	**0.3521**

Note: *a'*, *b'* and *c'* are *a*/10,000, *b*/10,000 and *c*/10,000 respectively

Table 6

Estimated Coefficients *a, b, c* for All Models, by State and Grouping

(Conclusion)

	c’					NSDP per Capita	
	G	F	H	SDLS GHF	G+H+F	Level 1980-81	Growth rate 1980-81 to 2000-01
First tier Advancing	-0.1390	0.0069	-0.1004	-0.2247	-0.2326	6,455	4.0
Gujarat	0.0100	-0.0212	-0.0135	0.0176	-0.0247	7,514	3.2
Haryana	0.0740	0.0096	0.0157	0.0894	0.0994	7,102	4.4
Maharashtra	0.0182	0.0731	0.0108	-0.0281	0.1022	8,442	2.8
Punjab	0.0358	0.0147	-0.0079	0.0595	0.0426	5,266	4.7
Tamil Nadu	**-0.0002**	**0.0166**	**-0.0191**	**-0.0173**	**-0.0026**	**6,956**	**3.8**
Average							
Second tier Advancing							
Himachal Pradesh	-0.0021	-0.0055	0.0204	0.0249	0.0128	5,793	3.6
Kerala	0.0817	-0.1551	0.0885	0.1437	0.0152	5,692	3.8
West Bengal	0.0119	0.0098	0.0128	0.0261	0.0345	4,952	3.6
Average	**0.0305**	**-0.0503**	**0.0406**	**0.0649**	**0.0208**	**5,479**	**3.7**
Intermediate							
Andhra Pradesh	0.0143	-0.0054	-0.0022	-0.0490	0.0066	4,604	3.8
Karnataka	0.0045	0.0032	0.0034	0.0384	0.0111	4,943	4.3
Rajasthan	-0.0672	-0.0104	0.0235	-0.0148	-0.0541	4,254	3.8
Average	**-0.0161**	**-0.0042**	**0.0082**	**-0.0085**	**-0.0121**	**4,600**	**4.0**
Lagging							
Assam	-0.0058	0.0251	-0.0040	-0.0287	0.0152	4,636	0.9
Bihar	-0.0092	-0.1815	-0.0352	-0.0960	-0.2259	3,363	0.8
Jammu and Kashmir	0.0116	-0.0185	0.0276	-0.0075	0.0207	6,244	0.9
Madhya Pradesh	-0.0597	0.0018	0.0334	0.0660	-0.0245	5,113	2.2
Orissa	-0.0094	-0.0107	-0.0001	-0.0198	-0.0202	4,085	1.7
Uttar Pradesh	0.0309	-0.0084	-0.0307	-0.0034	-0.0082	4,194	1.6
Average	**-0.0069**	**-0.0320**	**-0.0015**	**-0.0149**	**-0.0405**	**4,606**	**1.3**

Note: *a’*, *b’* and *c’* are *a*/10,000, *b*/10,000 and *c*/10,000 respectively

Conceptually, own influence (parameter *a*) is determined by location-specific factors including population growth and location-specific interdependencies given the sectoral composition of a spatial unit’s economy. In addition to the shares of Agriculture, Manufacturing and Services in output, other relevant location-specific factors are physical and human infrastructure that facilitate and enhance economic activity and institutions that reduce uncertainty and transaction costs. From a perspective of economic convergence, if parameter *a* is less than 0 ($a < 0$) it might be an indication that a given spatial unit is converging to a steady state; a different question is to what steady state exactly and anyway the possible steady state results from the interaction of all spatial units. It should be emphasized that all spatial units with $a < 0$ are not converging to the same level of income per capita (Arbia and Paelinck, 2003b). From a perspective of mathematical convergence of a nonlinear Lotka-Volterra model, Paelinck (1992) as discussed by Piras et al. (2006) has demonstrated that a sufficient condition is –as in the case of linear continuous-dynamic models, although for these it is necessary and sufficient – the negativity of the real part of all eigenvalues of the model; a necessary condition for that is that all own coefficients *a* be negative.

In this context, is the pattern exhibited in the simultaneous growth of the system of spatial units, in this case of Indian states one of convergence or divergence?[13] The mathematical convergence of this system of Indian states cannot be asserted because of the positivity of some of the coefficients *a* in Models G+H+F and SDLS GHF. Although being the negative definiteness of the real part of all eigenvalues of the model a *sufficient* condition, even if it is not satisfied Models G+H+F and SDLS GHF could be convergent mathematically. Thus regarding the question of what is the pattern exhibited by this system it can be said that it is one of possible mathematical divergence. To note, estimated coefficients by model for each state indicate for some states possible spatial divergence.

The question of economic convergence, being theoretically informed, is altogether a different one. The results of Models SDLS GHF and G+H+F indicate possible economic divergence of the system as several *a* coefficients are non-negative, and there are important differences in the sign and magnitude of estimated *b* and *c* coefficients. The finding that the dynamics of income per capita exhibit divergent growth paths when the growth effects from first order and higher order neighbors are considered does not preclude the possibility that for some states forecasts of potential equilibrium levels and trends in income per capita exhibit convergence to different levels, that is, spatial convergence to different levels of NSDP per capita.

Regarding parameter *b*, like *c* below, *b* is a spatial interaction term but of first order neighbors. As can be observed, influence of first order neighbors can be positive or negative; the effect will depend on the nature of the interdependencies between locations. These interdependencies will emerge from complementarities in location-specific factors or lack thereof but necessitate channels or avenues of interaction between the locations. As defined by Mishra and Chand (1995), "complementarity is a relationship of being and acting together so as to produce an outcome which neither of the complements can produce all by itself. Complementarity does not stand for a causal relationship. Therefore, fitting a regression equation [does not work]" (p. A78). In the case of empirical studies, Arbia and Paelinck (2003b) expect *b* to be larger than *c*. This is consistent with Tobler's first law of geography: "everything is related to everything else, but near things are more related than distant things" (1970: 236).

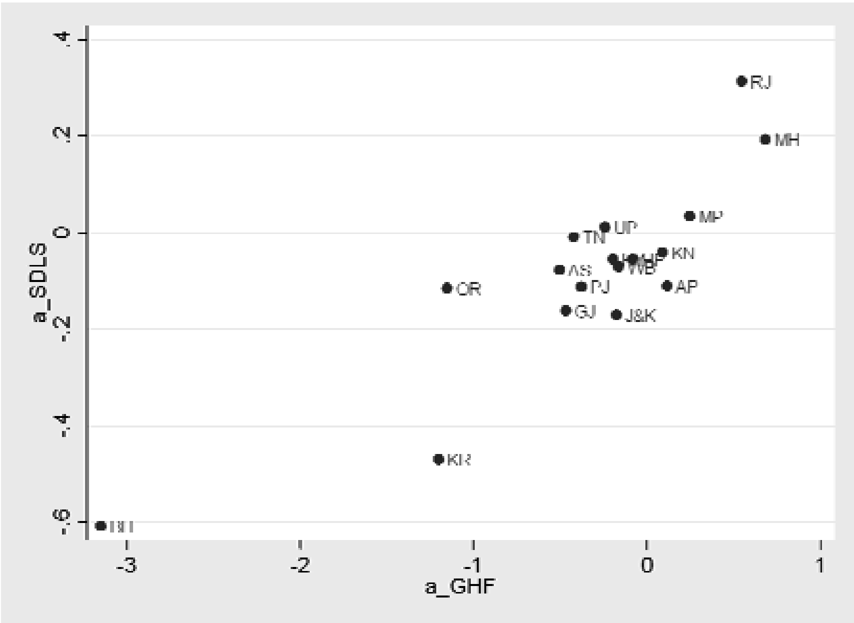
Results in Table 6 above show that with the exception of Karnataka all estimated coefficients $b > c$ for Model G+H+F. In the case of Model SDLS GHF $b > c$ in all cases except for Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Tamil Nadu and West Bengal. It is interesting that all the states in the Second Tier Advancing grouping exhibited larger *c* than *b*. The balance of cumulative spillover effects from higher order neighbors will depend on each state's local conditions and the nature of dynamic interdependencies.

[13] Divergence and convergence have a mathematical meaning and an economic meaning.

As expected there is a positive correlation between estimated coefficients in Models G+H+F and SDLS GHF. The statistically significant correlation for estimates of own effect (*a*), first order neighbors effect (*b*) and higher order neighbors effect (*c*) are .8751, .8713 and .7234, respectively. Andhra Pradesh, Karnataka and Uttar Pradesh are the three states where estimated coefficients for own growth effect (*a*) differed in sign between models (see Figure 1).

Figure 1

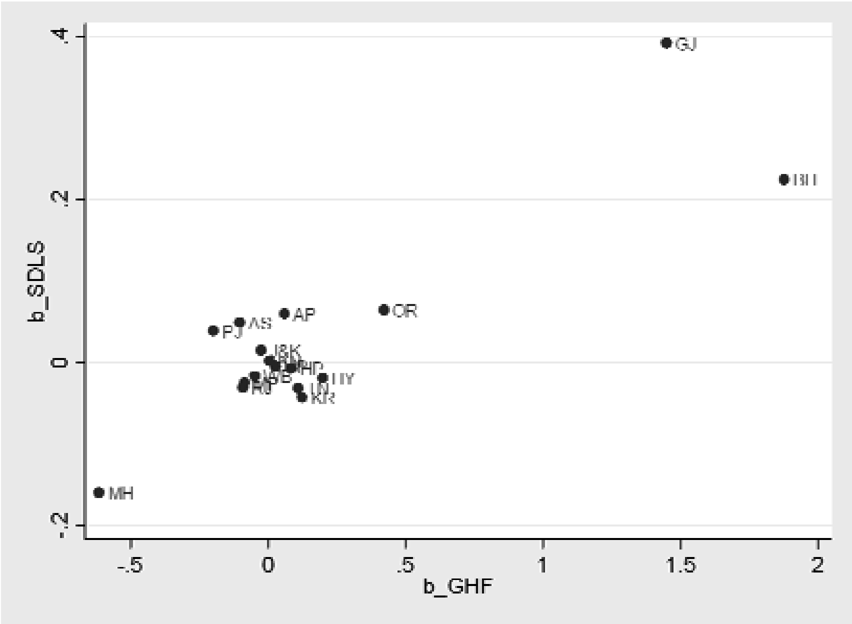
Scatter of Estimated Own Growth Effects (a), by Model



Regarding estimates of growth effects from first order neighbors (*b*), there was a reversal in the direction of the growth effect for Haryana, Punjab, Tamil Nadu, Himachal Pradesh, Kerala, Assam, Jammu and Kashmir and Uttar Pradesh. Figure 2 presents the scatter plot for estimated coefficients according to both models for the growth effects from first order neighbors. The estimates of growth effects according to both models appear as a cluster in the +1 to -1 range, with the exception of Bihar and Gujarat.

Figure 2

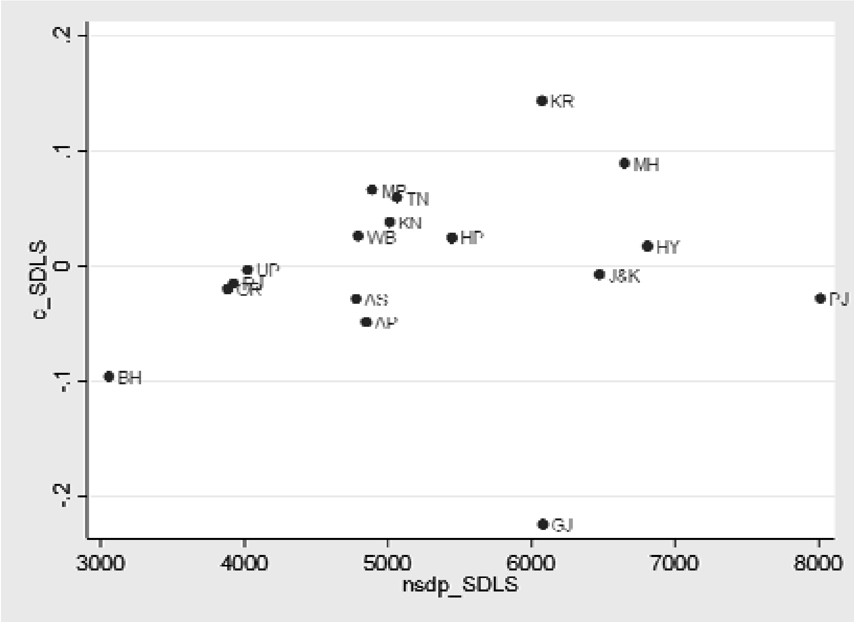
Scatter of Estimated Growth Effects from First Order Neighbors (b), by Model



On average, own growth effects are smaller for First Tier Advancing compared to all the other groupings and this holds true for both Model SDLS GHF and G+H+F. Estimated growth effects *b* and *c* are different for states with different levels of income. Estimated *b* are greater for First Tier Advancing and for Lagging states alike. In the case of Model SDLS GHF this may be at least in part due to the fact that a large number of lagging states had many more first order neighbors than either Intermediate or Second Tier Advancing. On average, growth effects from higher order neighbors *c* tend to be greater for First Tier and Second Tier Advancing states than for lagging states according to Model SDLS GHF only (see Figure 3).

Figure 3

Scatter of Estimated Growth Effects from Higher Order Neighbors (c) and Average NSDP per Capita, Model SDLS GHF



Certain states appear to be characterized by stronger estimated coefficients such as Maharashtra, Gujarat and Bihar according to both models. Other states instead appear to be characterized by weaker estimated coefficients, including Karnataka. In this context it is necessary to gain a better understanding of the underlying factors that enable some states to capture stronger positive growth effects while others have only weak growth effects particularly from first order and higher order neighbors. Kocornik-Mina (2007, 2009) has explored several areas of inquiry pertaining to this issue.

The differences in estimated coefficients between Models SDLS GHF and G+H+F, in particular for *b* are likely to be driven, at one level, by the decision not to introduce in the proximity matrix for Model SDLS GHF a state more than once. The rationale behind this decision is that all forms of growth dynamics (those emerging from geography and those others from structural equivalence) will manifest themselves if the nearest neighbor with whom they are shared is included in the matrix. To illustrate, in the case of Haryana, Model SDLS GHF considered the effect of Himachal Pradesh and Punjab once instead of the two separate times in Model G+H+F. The states with neighbors that are both structurally equivalent and geographically proximate and the particular neighboring states in question are highlighted in bold in Table 1 above.

At another level, more conceptual in nature, the differences between approaches are likely the result of enabling through a more complex proximity matrix in the case of

Model SDLS GHF previously controlled interactions between states that are complementary and/or competitive. Not only will inter-state growth dynamics, no longer differentially filtered by geographical proximity and structural equivalence, but other factors ranging from urbanization rates to cultural affinities are also likely to shape dynamic interdependencies. In the case of Kerala, in which the composition of the matrices does not differ from Model G+H+F to Model SDLS GHF, it would appear that once the growth effects from first order neighbors according to geography and the variance in standardized annual shares of total NSDP at factor cost by industry of origin between 1980-81and 1995-96 are captured the positive combined growth effect from Assam and Himachal Pradesh is overshadowed. Evidently, a wealth of information can be gained through the careful analysis of the overall growth effect as captured by Model SDLS GHF and the individual proximity matrices used in the estimation of Model G+H+F.

4. Concluding Remarks

The simultaneous measurement of geographically and structurally equivalent growth effects through the two separate approaches proposed provides interesting insights into the behavior of both the system and individual spatial units. In doing so, it opens up a number of analytical avenues of inquiry: (1) the long run dynamics of the system may be compared and contrasted and in doing so further confirmed; (2) for individual spatial units it may constitute a step towards identifying not only those relations that are more likely to trigger positive and negative growth effects but also narrow down the set of possible sources of these effects; and (3) highlight the strengths of both model and estimation method to capture more than the two determinants of spatial interdependence.

In terms of the expected relationships between estimates by model, it is reassuring that these delivered the same overall direction of dynamic growth effects from nearest neighbors and higher order neighbors.

Next steps may include studying explicitly mathematical-cum-economic di- or convergence as in Arbia and Paelinck (2003a,b); and/or investigating whether for countries lacking appropriate statistical data, rigorous qualitative methods could be applied (Griffith and Paelinck, 2011, chapter 16).

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