ISSN 1470-2320

2000

Working Paper Series

LSE Development Studies Institute

London School of Economics and Political Science

No.00-06

Regional Distribution Dynamics of GDPs across Indian States, 1965-1988

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Published: March 2000

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ISSN 1470-2320

Regional Distributional Dynamics of GDP across Indian States, 1965-88

by

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March 2000

ABSTRACT

This paper documents the dynamics of convergence of incomes across Indian states over the period 1965-1988. It departs from the traditional analyses on convergence across the Indian states by tracking the evolution of the entire income distribution, instead of standard regression and time series analyses. Our findings document a decline in disparities in the late sixties, with a subsequent increase in inequality in the seventies and eighties. This is accompanied by the clear emergence of two convergence clubs, one at around 130% of the national average, and at 50% of the national average. The dynamic tendencies revealed in the long run, however, suggest a gradual weakening of the polarising tendencies in the income distribution.

Keywords: convergence, distribution dynamics, income distribution, inequality, convergence clubs, India.

JEL Classification: ***C23, D30, O53***

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*I would like to thank John Harriss, Henry Overman, Danny Quah, Ashwani Saith, and Diana Weinhold for guidance, Sankarshan Basu, Terence Byres, Jean Drèze, Rathin Roy and participants at various seminars for many helpful discussions. Funding from the Economic and Social Research Council (UK) is gratefully acknowledged.

ISSN 1470-2320

Introduction

The fact that regional inequalities of incomes across the Indian states exist has been well documented and studied by many. It is almost common knowledge that the western states are the industrially advanced, while the north-west is agriculturally prosperous. There exist pockets of relative success in agriculture and industry the south and the north, while the north eastern states are yet to excel in either.

Saying that regional inequalities exist is just the starting point - what is of concern is that they continue to persist, particularly so that they persist after five decades of concerted state led planning. The persistence of strong regional differentials in income across states also bears heavily upon the continuing policy reforms. Such persistent differential development, given such widespread inter-state socio-ethnic and political differences risk the unleashing of highly destructive centrifugal political forces. It is therefore vitally important that policies for containing and counteracting regional disparities are implemented in the early rapid phase of development.

This study documents the dynamics of growth and convergence of incomes (real per capita) across Indian states over the period 1965-1988. The framework we will be using addresses a number of specific goals: first, we are interested in the dynamics of equality across incomes across Indian states. In other words, is there any tendency of equality in the cross section income distribution across the Indian states? If not, what distributional pattern do they exhibit?

Second, if cohesive[1] tendencies were not to obtain, we would like to characterise the possibilities for inter-regional mobility – are there any signs of poorer regions overtaking the rich in the future? Are there any signs of initially rich economies falling behind? These facts are important for policy purposes. Characterising the presence of other distributional patterns, e.g. convergence clubs or stratification, will enable the researcher to identify the economic forces governing their formation and their persistence.

[1] By cohesion, we simply mean the tendency towards equality of incomes across the States.

This exercise follows from the new wave of empirical growth analyses, following the empirical studies of Barro and Sala-i-Martin(1992), Desdoigts(1994), Quah(1992-98), Nagaraj et al (1998) to name a few. The new wave of empirical studies of income dynamics have made powerful and controversial claims, which have instigated yet further empirical techniques of analysing cross-country income dynamics. These ensuing stylised facts of growth have telling implications for widely accepted theoretical claims. Also, the questions which are addressed in the new empirical growth literature differ from those in earlier empirical works of Kaldor's stylised facts (1963), or of Solow(1957) in a production function accounting exercise. The primary focus is to understand the cross country patterns of income, rather than explaining only within-country dynamics (i.e. the stability of factor shares - the "great ratios" - within a single economy, or growth exclusively in terms of factor inputs). The new empirical literature also uses auxilliary explanatory factors to explain the stylised facts, opposed to analysing the production function residual, as done earlier.

Here we intend to examine inter-state income inequalities in terms of the behaviour of the entire cross section distribution. When the cross section distribution exhibits tendencies of collapsing to a point mass, one can conclude of tendencies towards convergence. If, on the other hand, it shows tendencies towards limits which have other properties – normality or twin peakedness, or a continual spreading apart - these too will be revealed. What this approach essentially endeavours is to describe a law of motion of the cross section income distribution over the period of study. Appropriately named, the distribution dynamics approach exposes instances of economies overtaking, or falling behind – it reveals the existence of any intra-distributional mobility. Finally, this model will allow the researcher to study not just the likelihood, but also the potential causes, of poorer economies becoming richer than those currently rich, and that of the rich regressing to become relatively poor[2].

The distribution dynamics approach to studying convergence (Bianchi, 1997, Desdoigts, 1994, Jones, 1997, Lamo, 1996 and Quah, 1990-1997) improves on the existing approaches employed so far. Standard (i.e. beta convergence) regression analysis only considers average or representative behaviour, and says

[2] The statistical methodology used in this paper is that conceived by Danny Quah (1990-1997).Details of the methodology are elaborated later in the paper. An exercise investigating potential explanatory factors using this methodology is undertaken by the author in a following paper – "Regional Distribution Dynamics of GDP across Indian States – explaining the stylised facts" (in progress).

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nothing about what happens to the entire distribution (Barro and Sala-i-Martin, 1992, and Bajpai and Sachs, 1996, Cashin and Sahay, 1996, Nagaraj et al., 1998, for the Indian case, among many others). Neither are both beta and sigma convergence analyses able to inform the researcher of any prospects of inter-regional mobility. They are unable to uncover the long run aspects of the evolving distributional pattern. Such is also the case with time series applications to regional analyses (Carlino and Mills, 1995). The methodology employed in this paper, conceived and popularised by Danny Quah (1990-1997), goes beyond point estimates of dispersion and unit root analyses to highlight two vital aspects of how a distribution evolves over time – intra-distributional mobility and the long run prospects of the distribution (ergodicity). It encompasses both time series and cross section properties of the data simultaneously and presents itself as an ideal approach for large data sets.

Starting with the basics, this paper uncovers the relevant stylised facts of Indian inter-state income distribution over the period 1965-88. Our main finding is that while cohesive tendencies were observed in the late sixties, these were considerably weakened over the following years with increasing diverging tendencies. Strong tendencies are found of the existence of two income clubs, particularly over the later years (1970 onwards).

The rest of the paper is organised as follows. In Section 2 we will introduce the new methodology to be used in this paper for the analysis. Section 3 presents preliminary results of the analysis on Indian state level data over the period 1965-88. Section 4 develops further dynamics and Section 5 concludes.

2. The New Approach to Convergence: Distribution Dynamics Approach

The approach of distribution dynamics stems from recent empirical research on patterns of cross country growth. The focus of research in the new empirical growth literature no longer concerns understanding the behaviour of per capita income or per worker output of a single representative economy but asks questions like, why do some countries grow faster than others. From the perspective of economic growth empirics, the work described in this paper relates to this research using convergence predictions to distinguish endogenous and neoclassical growth. This new empirical literature is large and helpfully summarised in Barro and Sala-i-Martin(1992), Durlauf and Quah (1996).

The debate pertaining to which empirical approach is used to test convergence has generated a wide and provoking literature. The popularly known "cross section regression analysis" approach examines the regression of (averaged) growth rates of income for each economy on the initial levels of income. Economies are said to be converging to a “global” steady state when a negative relationship is observed between the growth rate of per capita income and its initial level of income[3]. More elaborate techniques involve panel data techniques or pooled data regression to avoid loss of information because of averaging. Another aspect of this approach is to observe the cross section dispersion of income across the economies, where it is expected that as each economy becomes as rich as the rest, the cross section dispersion will narrow over time[4]. Time series analyses have also been used to study convergence which
entails testing whether inter-regional disparities have neither unit roots or divulging deterministic time trends.

However, both cross section regression and time series approaches have proven to be incomplete in studying convergence. It has been argued by many, that convergence as a notion of “catch-up” is not useful when studied by standard regression analysis as it captures only representative behaviour, and uninformative, in general, for the dynamics of the distribution of income across countries (Friedman, 1992, Leung and Quah, 1996). Again, while time series analyses accounting for the univariate dynamics, does not utilise the cross section information, the evolution of income dispersion, (say, in terms of the standard deviation), also does not tell us anything about the underlying cross section growth dynamics. An invariant standard deviation could be consistent with a number of situations: one where the positions of the regions remain invariant over time, but another, where there could be exchange of positions over time[5].

What each of these techniques fail to inform the researcher is about the *intra-distributional dynamics* of the income distribution and hence, of any other distributional pattern other than convergence. The focus of the new empirics of economic growth research has shifted to understanding the growth dynamics of groups of entire macroeconomies - to understand the patterns of interaction between countries or regions. Such dynamics of cross section income distributions are not revealed by either cross section regression or time series

[3] This is also known as *beta convergence*
[4] This is popularly known as *sigma convergence*.
[5] For a detailed critique, see Quah (1993b, c)

approaches. Convergence regression and sigma convergence cannot reveal the relevant intra-distributional dynamics which would lend insights into any inter-regional patterns of economic interaction. Likewise, time series analyses also fail to shed any light on the cross sectional characteristics of the distribution. These goals have necessitated going beyond the extant technical tools of studying convergence.

In view of the drawbacks presented above, Danny Quah's approach[6] of distribution dynamics to characterising convergence moves away from a singular treatment of cross section regression or a time series approach. The main motivation behind this approach is to expose other distributional patterns of income, if convergence were not to obtain. This involves tracking the evolution of the entire income distribution itself over time. Markov chains are used to approximate and estimate the laws of motion of the evolving distribution. The intradistribution dynamics information is encoded in a transition probability matrix, and the ergodic distribution associated with this matrix describes the long term behaviour of the income distribution. Such an approach has revealed empirical regularities such as convergence clubs, or polarisation, or stratification – of cross economy interaction that endogenously generates groups of economies; of countries catching up with one another but only within sub-groups (Bernaud and Durlauf, 1996, Bianchi, 1997, Quah, 1997a).

Random Fields and the Random Element

The distribution dynamics approach is based on treating a single income distribution as a *random element* in a field of income distributions. Figure 1 presents the entire distribution of State income (relative per capita) in India for the period 1965-88. Such structures where both time series and cross section dimensions are large and of equal magnitude are called *random fields* in probability theory. At each point in time, the income distribution is a *random element* in the space of distributions. This approach involves estimating the density function of the income distribution at each point in time and then observing how it evolves over time. These dynamics account for the change in the shape of the distribution and for intra-distributional dynamics which are notable

[6] See Quah (1996a, b-1997a, b, c). Similar studies which have focused on the behaviour of the entire distribution have been of Bianchi(1997) where he uses the bootstrap test to detect multimodality and that of Bernaud and Durlauf(1995), where they identify "multiple regimes" across the economies.

characteristics of convergence. Another aspect we will be interested in is the dynamics of each state's relative position.

There are two approaches to density estimation, parametric and non-parametric. The former assumes the data to be drawn on one of the known parametric distributions. The task is then to estimate the underlying distribution by estimating the parameters from the data. The non-parametric approach is based on weaker assumptions and does not "fit" a known distribution onto the data – the data itself determines the estimator of the density function. In our analysis, we shall non-parametrically estimate a density function of the given data set as it does not impose a known structure on the distribution, allowing us to detect structures different from parametric forms. Nor does it impose any assumptions about the moments of the density function from which the data are drawn.

There are a number of different methods of non-parametric estimation, of which an excellent account is obtained in Silverman (1986). To study the distribution dynamics of the Indian income distribution, we shall be using transition probability matrices and stochastic kernels to estimate the density function and observe its evolution.

2.1 Models of Intra-distribution Churning/ Mixing

Two other models which highlight the distribution dynamics of an income distribution are stochastic kernels and transition probability matrices. Here the cross section income distribution is seen as a realisation of a random element in the space of distributions. Of the two models, the transition probability matrix is the discrete version, while the stochastic kernel is the continuous version. We present the underlying formal structure of these models as a law of motion of the cross section distribution of income in the technical appendix.

Both stochastic kernels and transition matrices provide an estimate of intradistributional mobility taking place. In both cases, it is assumed that an economy (in our case, a state) over a given time period (say, one year or five years) either remains in the same position, or changes its position in the income distribution. Such a change in position of an economy in the income distribution is called a transition. Our task is to observe how many such transitions take place in the given time period.

First, what needs to be identified is the position of the economy in the income distribution in the starting period. This is done by dividing the income distribution into "income states". Income states are a range of income levels, say between a fifth and a half of the weighted average of the country. Then we observe how many of the economies which are in an income state say, (0.2, 0.5) in the initial period land up in that very state, or elsewhere. If they do end up in another income state, (for example, in the income range of a half to three quarters of the weighted average income) there is said to mobility. If they end up in the same, there is persistence. We will be interested in the former possibility i.e. of intra-distributional mobility.

In our exercise on India, we have measured these transitions and the results are tabulated in Tables 1 and 2 as *transition probability matrices*. Interpreting the transition matrix is as follows: First, we discretise the space of possible values of income, in *r* states. For instance, we define the state *i* = (0.2 , 0.5) as one which has regions with an income which lying between 0.2 and 0.5 times the average income of the country. The probabilities obtained, give us the percentages of economies (in our case, Indian states) which given a starting state, have moved on to a different state. So, our row probabilities all add up to 1. Of these, the diagonal of the transition probability matrix is of interest to us. A diagonal with high values indicates higher probabilities of persistence - the likelihood of remaining in a particular state when one starts there. Thus, the smaller the diagonal, the greater intra-distributional mobility there exists.

The transition probability matrix also allows us to take a long run view of the evolution of the income distribution. This is tabulated in the row called the "Ergodic Distribution"

There is, however, a drawback in this measure as the selection of income states is arbitrary - different sets of discretisations may lead to different results. The *stochastic kernel* improves on the transition probability matrix by replacing the discrete income states by a continuum of states. This means that we no longer have a grid of fixed income states, like (0.2 0.5), (0.5 0.75) etc. but allow the states to be all possible intervals of income. By this we remove the arbitrariness in the discretisation of the states. We now have an infinite number of rows and columns replacing the transition probability matrix. In our exercise on India, such stochastic kernels are presented in Figures 5a*i* –h*i*.

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Interpreting the stochastic kernels is as follows. Any slice running parallel to the horizontal axis (i.e. t + k axis) describes a probability density function which describes the transitions from one part of the income distribution to another over k periods. The location of the probability mass will provide us information about the distribution dynamics, and thus about any tendencies of convergence. Concentration of the probability mass along the positive slope indicates persistence in the economies' relative position and therefore low mobility. The opposite, i.e. concentration along the negative slope, would imply overtaking of the economies in their rankings. Concentration of the probability mass parallel to the t + k axis indicates that the probability of being in any state at period t + k is independent of their position in period t – i.e. evidence for low persistence. Finally, convergence is indicated when the probability mass runs parallel to the t axis.

3. What has been happening to the inter-state income distribution in India?

3.1 A Preliminary Look

Let us now take a look at the inter-state income distribution of India over the period 1965-1988. The data which has been used for this analysis has been obtained from the World Bank web-site http//www.worldbank.org, compiled by Özler. B, G Dutt and M Ravallion(1996). The income variable we shall be working with in this paper is that of real GDP per capita for each individual state.

Fig.2[7] tracks the real GDP per capita (relative to the all India average) of each Indian state over different time periods. Each of these diagrams emphasise the physical spatial dimension, by plotting each states' income on its physical grid, for each of the years - 1965, 1970, 1980, and 1988. The base of each diagram is formed of the latitude and longitude measurements. The vertical axis graphs per capita GDP (real and relative to the Indian average).

These pictures give us a first hand idea of the dynamic spatial patterns of regional growth across Indian states. Fig.2 reveals the persistent dominance of Punjab and Haryana in the north west, Gujarat and Maharashtra in the west. Punjab already had a per capita income of 270 (in 1990 dollars) in 1965 which increased to 370, increasing by a factor of 34% by 1988. Gujarat's and Maharashtra's per capita

[7] All graphs and calculations were done using Danny Quah's econometric shell *tSrF*

income had increased from 183 and 196 (in 1990 dollars) to 233 and 303 by a factor of 20% and 27 %, respectively. By comparison, the Indian average per capita GDP (in 1990 dollars) was 153 in 1965 and 195 in 1988 (increasing by 27 %). Hence, Punjab was already almost twice as rich as the Indian average in 1965 and remained so at the end of the period. Maharashtra, Gujarat and Haryana's income per capita have also maintained a per capita of almost twice the Indian average all throughout the period. Averaging, states of Punjab, Haryana, Gujarat, Maharashtra were at 123%, in 1965 and over 152%, in 1988 of the Indian average[8].

The poorest regions are also evident - Bihar, Orissa in the east, Rajasthan in the west, and Uttar Pradesh in the north have consistently been lying around the lowest per capita GDPs. Bihar, Orissa and Uttar Pradesh and Rajasthan have been at 85% in 1965 and 80% in 1988 of the Indian average. Bihar and Orissa had per capita GDPs of 122 and 121 in 1965 and 122 and 145 in 1988 (in 1990 dollars). Thus over the entire period of study, the income of the richer states has been almost three times that of the poor. Interestingly, while the growth rates of Madhya Pradesh, Assam, Andhra Pradesh, Uttar Pradesh, Orissa, and Bihar, the six poorest states, were all significantly below the national growth rate, they account for more than half of the Indian population.

However, not all that were rich remained rich, and those poor remained poor. West Bengal, notably, with a GDP per capita of 196 in 1965 and 205 (in 1990 dollars) in 1988 fell steeply in its ranking from second to eighth by 1988. Thus, West Bengal teamed with Punjab, Haryana and Maharashtra in the 1960s, but experienced dismal growth over the following years. Again, while the surge of growth in the 1980s benefited the four richest states, it also pushed up Karnataka and Tamil Nadu, whose 1988 per capita income had increased by 21% and 36% over 1980-88.

Summarising - these diagrams reveal information on the dynamic spatial patterns of regional growth in the Indian states. It reveals both persistence and mobility. Some of rich states have remained rich (the richest, Punjab, has retained the highest position all throughout) while a number of poor states have remained poor- Bihar, Uttar Pradesh and Orissa have consistently been the worst performers. There are also high performers who have declined in their performance over the period – West Bengal, others who were poor have picked

[8] Author's own calculation.

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up over the period, for example, Karnataka. Thus, apart from those consistent performers, there is plenty of evidence of relative successes and failures all across India. Such relative successes and failures are interesting as they have important dynamic dimensions. But, what is more than apparent is that there exists a group of high income states and a group of low income states - there are indications of polarisation of the income distribution.

Looking at the same details, one also observes, over 1965 to 1988 the standard deviation (SD) of per capita income has increased by 192%, while the interquartile range (IQR) has increased by 137%. A significant increase in spread manifests clearly. However, the difference in the extent of increase of the standard deviation and the inter-quartile range has an interesting implication. With an increase in the SD almost double that of the increase in IQR, one can say that much of the spread has been due to some high performers out-performing the rest of the intermediate states (and some low performers remaining relatively stagnant). Cases of Punjab, Haryana and Maharashtra as high performers and Bihar and Orissa as low performers seem to fit into this story. Punjab's and Haryana have had their growth rates almost double over this period, while Bihar and Orissa's growth can be considered as imperceptible. Here, once again, one could take such dynamics as evidence of polarising tendencies.

A useful way of interpreting the dynamic behaviour of the interquartile range and the standard deviation are Tukey boxplots[9]. In Figure 3, each boxplot represents the income distribution of a single year - starting at the top quartile(i.e. 3rd quartile) and ending at the first, with the height representing the inter-quartile range. The middle 50% of the distribution thus lies in the box. The horizontal bar in the box is the median of the income distribution and thus provides us with a measure of location. If the median is located in the middle of the box, the distribution is symmetrical, otherwise skewed. Other observations lying outside the interquartile range lie on the thin lines extending from the boxes on either sides the two ends known as the upper and lower adjacent values - if the inter-quartile range is r, then the upper adjacent value is the largest income value observed that is no larger than the 3rd quartile plus 1.5 x r, while the lower value is the lowest income observed no smaller than the 1st quartile. Observations which lie beyond this range are located as isolated points outside the thin lines.

[9]The Tukey Box-plot has been extensively used in Quah (1997b) to study income distribution dynamics

Fig.3 shows that though the Indian relative income distribution has fluctuated about its central value, with a particular deterioration in the early seventies, there does not appear to be a great change in the inter-quartile spread, except for 1970, when there was significant spreading out in the middle. Also, what is noticeable in later years is the appearance of upper outside values, beyond the upper adjacent value. The median of the 1985 distribution lies lower than that in 1965, and skewed towards the bottom tail of the distribution. With little change in the inter-quartile range, the growth in standard deviation thus accounts for most of the spreading taking place in the tails, particularly the upper, as is observed in the box-plots.

Thus, our initial look at the income distribution across the Indian States, so far, suggests that the mean and the standard deviation are insufficient in describing the behaviour of the distribution. A preliminary analysis not only reveals that income inequality has increased, but there appears to be some polarising tendencies.

3.2 Intra-distributional dynamics

So far we have discussed "snap-shots" of how the income distribution has evolved over time. We will now consider the intra-distribution dynamics. Cross profile graphs are an informative way of looking at our data before any modelling - they describe when economies overtake, fall behind or pull ahead. These graphs rank the regions (in our case, states) according to their relative income per capita in the first year of the sample (1965) and describe how this ranking evolves over time. Figure 4 describes the evolution of the rankings of the Indian states over different years: each line refers to a single year and describes the relative income of the states ordered according to the initial ranking. The larger the income inequality, the steeper they are. Any intra-distributional change in the ranking is manifested as an increase in the choppiness, or the jaggedness of the lines. Such choppiness is referred to as intra-distributional “mixing” or “churning”(Quah, 1997a, b, c) Such “churning” reveals intradistributional aspects which remain totally obscured when one deals with only the first and second moments.

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Fig. 4 presents the cross profiles plots of the Indian (inter-State relative per capita) income distribution over periods 1965, 1975 and 1985. What is immediately apparent is the change in choppiness through time in the cross profile plots. We note that the 1965 line is evidently monotonically increasing; it is steeper for the richer states. The following lines are however slightly flatter, with the 1985 line looking slightly more steeper than 1975. The increasing choppiness indicates high mobility with regard to the changes in the states' relative positions - the number of peaks in each line indicates that. Not much seems to have changed between 1975 and 1985. Inequality thus appears to be highly persistent between periods 1975-1985.

The cross-profile plots, hence, reveal characteristics of the intra-distributional mobility which are otherwise obscured in traditional approaches. They have given us a first-hand look at the importance of the intradistributional characteristics and the dynamic behaviour of the distribution. We are yet, though, not in a position to show any deep underlying regularities of the data. For that we turn to more formal structures to identify signs of intra-distributional mobility.

4. Further Dynamics

Looking at such random elements is intuitive and informative for a first hand insight into the dynamics of the distribution. We will now turn to the other two representations of intradistribution churning - stochastic kernels and transition probability matrices. Modelling the distributions dynamics, both in continuous (stochastic kernels) and discrete (transition probability matrix) versions, lends a detailed insight into the evolution of the income distribution across the Indian states. Figures 5 a-h represent the non-parametric stochastic kernels and their contour plots for relative per capita income of k-year transitions (k = 1, 5).

Figures of 5a.i and 5a.ii over the period 1965-1988 reveal a probability mass running off the positive diagonal, almost parallel to the t-axis with two sharp peaks - this implies that the Indian states have shown a strong tendency of changing their relative position in one year. The peaks at the “head” and the "tail" of the mass suggests tendencies of the low and middle income economies income states experiencing mobility over the period. The contour of the above in Figure 5a.ii reveals these tendencies more clearly - the peaks pertain to two groups of

states; one changing positions from less than 50% of the all India average to around 75% of the all India average, while another group at nearly 125% of the all India average to about the average all India level. The contour also reveals the formation of some middle income group States, some of which have remained in their same positions, and some which have improved their relative position.

To obtain a detailed look of the intervening years, we divide the sample period into three sub-sample periods - 1965-70, 1971-80, and 1981-88. The first period was one which reaped the benefits of the successful implementation of the first two Five Year Plans and an agricultural boom, which led to a hike in the overall growth rate. However, to add to the onslaught of a number of droughts (1966-7), the oil shock in the early seventies and following balance of payments problems, the 1970s was plagued by what is commonly termed as the "industrial stagnation phase". This led to a severe set back in economic growth all through the seventies. The early eighties, however, brought an end to that phase and thereafter the Indian growth rate gradually was on the pick up.

Observation of the stochastic kernels and the contour plots reveal that the later years provide increasing evidence of persistence and low probabilities of changing their relative position. Over the periods 1965-70, 1971-80, and 1981-88, we observe in Fig. 5c-e the probability mass lengthening and shifting totally in line with the positive diagonal, the two peaks still at the two ends of the mass. The contours in Figures 5c.ii., 5d.ii and 5e.ii reveal the cluster of States at the two peaks to consist of some low income economies at around 50% of the all India average and another at 150% of the average. Thus, though an overall view of the entire sample period 1965-88 shows some signs of cohesion, the sub-sample periods, particularly during the later years, have shown the cohesive forces substantially dissipating in influence. The result has been more of that of the rich states forging ahead, with the poor making little progress and a dispersing middle income group

The longer horizons, over 5 year transitions reinforce these conclusions, in Figures 5f - h, reveal the probability mass running on, or very close to, the positive diagonal, with the distinctive peaks at both ends. However, as the contours in Figures 5f.ii, 5g.ii, 5h.ii are relatively less condensed (though slight), there is some tendency of intra-distributional mobility. The contour for 1965-70 reveals two distinct clusters of states at around 50% of the all India average and another at around 130% of the average. Persistence seems to be more strong at

the low income cluster. What appears interesting in this plot is the clear emergence of another middle-income cluster at around the all India average. This disappears in the following plot for 1970-81, where the probability mass is roughly along the main diagonal. Still along the diagonal, the probability mass in the 1981-88 plot reveals the same income clusters, less concentrated and relatively dispersed, showing the early signs of the formation of a middle income group. The overall view holds - persistence of two distinct groups of low and high income groups and a dissipating middle income group.

The long run view of whether the economies will converge over the long run is addressed by calculating the transition probability matrices. The results are tabulated in the appendix (Tables 1 and 2). Interpretation of the tables is as follows. Each of the defined states for each table is different, such that each distribution is uniform at the beginning year of the sample. The first column of the table accounts for the number of transitions over the time period beginning at each state. The following columns present the calculated probabilities of transition from one specified state to another. Like the stochastic kernel, a "heavy" main diagonal is bad news - i.e. indicating persistence.

Table 1 reports results quite similar to those obtained for the stochastic kernel - the values in the main diagonal are around 50%, which indicates that the probability that an economy remains in its own income state is around 50%. The off-diagonal values are those which are indicative of mobility, albeit little. Mobility is evident and obvious for the above average income group. The states with incomes in the first two states reveal some low income states which have forged ahead. We also have an estimator of the long run tendencies, named the ergodic distribution, accounted in the last row of the table. This will give us the long run tendency of an economy to land up in a given income range. The results suggest that over the long run, the probability that an economy lands up in the 4th state is the highest, a little over 40%. What is encouraging is that the lower income groups vanish in the ergodic distribution.

Following tables give us estimates of the transition matrix for the sub-periods. The second period again reveals tendencies of both persistence and mobility, with tendencies of persistence in the lower income group and the high income groups. The probability that the first two income states and last two income states shift anywhere other than their own is zero. Though there are signs of persistence,

ISSN 1470-2320

there is evidence of some inter-state (income state) movement, again in the high income clusters. This trend continues in the next period.

It is important to remember that as these estimates are based on time stationary transition matrices, it may not be reliable for long time periods for economic structural changes. Hence, the 1965-88 results do not conform with the those of the sub-sample periods.

5. Conclusion

This paper ventured to investigate regional distributional dynamics of Indian inter-state income using an alternative methodology. We have used the approach of distribution dynamics in characterising convergence and analyse the inter-State (relative per capita) income distribution of India over the period 1965-1988. Our main result is that over the entire period, though there do appear signs of some narrowing in the first period, 1965-70, the periods of 1971-80 and 1980-88 shows strong signs of persistence and formation of a rich income group and a poor income group at around 50% and 125% of the Indian average. The long run view, however, is encouraging in that the polarising tendencies are to weaken over time, with the lower income group vanishing.

ISSN 1470-2320

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Appendix

States used in the study:
Andhra Pradesh
Assam
Bihar
Delhi
Gujarat
Haryana
Jammu and Kashmir
Karnataka
Kerala
Madhya Pradesh
Maharashtra
Orissa
Punjab
Rajasthan
Tamil Nadu
Uttar Pradesh
West Bengal

Other states were excluded from the study due to the incomplete data available over the given period.

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Technical Appendix

Here we will present the formal underlying structure for both models highlighting distribution dynamics Let us first consider the continuous version. The model is one for a stochastic process that takes values which are probability measures associated with the cross section distribution.

Let F_t be the probability measure associated with the cross section distribution. The following probability model holds:

$$F_{t+1} = T^*(F_t, u_t). \qquad (1)$$

Here T* is a mapping operator which maps probability measures in one period (with a disturbance term) to those of another. It encodes information of the intra-distribution dynamics: how income levels grow closer together or further away over successive time periods. Our task is to estimate T* from the observed data set.

For simplicity in calculations, iterating the above equation one can write, (and leaving out the error term)

$$F_{t+s} = T^{*s} . F_t. \qquad (2)$$

As s tends to infinity it is possible to characterise the long run distribution - this is called the *ergodic* distribution and it predicts the long term behaviour of the underlying distribution.

Handling equation (2) is difficult; hence, the concept of the stochastic kernel was introduced to estimate the long run behaviour of the cross-section distribution[10]. This concept has been used by Quah (1996, 1997) Lamo (1996)

Let us consider the measurable space (**R**, *R*). R is the real line where the realisations of the income fall and *R* is its Borel sigma algebra. B (**R**, *R*) is the Banach space of finitely additive functions. Let F_{t+1} and F_t be the elements of B that are probability measures in (**R**, *R*). A stochastic kernel is a mapping M : **R** x *R* -> [0, 1], satisfying the following :

[10]See Stokey, Lucas and Prescott (1989) and Silverman (1986)

(i) $\forall$ a $\in$ **R**, M (a, .) is a probability measure.

(ii) $\forall$ A in *R*, M (., A) is a sigma measurable function.

Then M(a, A) is the probability that the next state period lies in the set A, given that the state now is a.

For any probability measure F on (**R**, *R*) $\forall$ A in R:

$$F_{t+1} = \int M(x, A)\, dFt(x) \qquad (3)$$

, where M (., .) is a stochastic kernel, and $F_{t+1}(A) = (T^*F_t)A$. T^* is an operator associated with the stochastic kernel that maps the space of probabilities in itself, (adjoin of the Markov operator associated to M). The above equation (3) measures the probability that the next period state lies in the set A, when the current state is drawn according to the probability measure F_t. F_{t+1} i.e. T^*F_t is the probability measure over the next period state, when Ft is the probability measure over this period. Hence we can consider the T* in the previous equations as being generated by the above differential equation. Our empirical estimation will involve in estimating a stochastic kernel as described above.

Such stochastic kernels though satisfactory as a complete description of transitions, are however, simply point estimates and we are yet to have a fitted model. It is thus not possible to draw inferences and derive long run estimates. However, it is possible for us to infer whether income levels have been converging and diverging. For these computations, we turn to the discrete formulation of the above.

Transition probability matrices

Now let us consider the discrete version. Given that using the stochastic kernel it is not possible for us to draw any inferences about the long run tendencies of the distribution of income, we now turn to a discrete version of the above calculation. Here we calculate T* from the above equation 3 and to compute the values using equation 2. T* is calculated assuming a countable state-space for income levels $Y_t = \{ y_{1t}, y_{2t}, ..., y_{rt}\}$. Thus T* is a transition probability matrix Q_t , where

$$F_t = Q_t (F_{t-1}, u_t)$$

Q_t encodes information of the short run distribution dynamics and the long run information is summarised by the ergodic distribution - it gives the distribution across states that would be achieved in the long run. Here, convergence is takes place when the ergodic distribution

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degenerates towards a mass point. The transition matrix and the stochastic kernel together expose the deep underlying short run and long run regularities in the data.

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Table1: Inter-State (per capita) income dynamics, 1965-88
First Order transition matrix, Time stationary

(Number)	**Upper end point**				
	0.640	**0.761**	**0.852**	**1.019**	**1.393**
5	**0.40**	**0.00**	**0.40**	**0.00**	**0.20**
5	**0.00**	**0.40**	**0.20**	**0.20**	**0.20**
2	**0.00**	**0.00**	**0.50**	**0.00**	**0.50**
4	**0.00**	**0.00**	**0.25**	**0.25**	**0.50**
1	**0.00**	**0.00**	**0.00**	**1.00**	**0.00**
Ergodic	**0.00**	**0.00**	**0.22**	**0.44**	**0.33**

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Table2a: Inter-State (per capita) income dynamics, 1965-70
First Order transition matrix, Time stationary

(Number)	**Upper end point**				
	0.640	**0.761**	**0.852**	**1.019**	**1.393**
5	**0.40**	**0.00**	**0.40**	**0.00**	**0.20**
5	**0.00**	**0.40**	**0.20**	**0.20**	**0.20**
2	**0.00**	**0.00**	**0.50**	**0.00**	**0.50**
4	**0.00**	**0.00**	**0.25**	**0.25**	**0.50**
1	**0.00**	**0.00**	**0.00**	**1.00**	**0.00**
Ergodic	**0.00**	**0.00**	**0.22**	**0.44**	**0.33**

Table2b: Inter-State relative (per capita) income dynamics, 1971-80
First Order transition matrix, Time stationary

(Number)	**Upper end point**				
	0.680	**0.730**	**0.795**	**1.010**	**1.489**
5	**0.40**	**0.60**	**0.00**	**0.00**	**0.00**
1	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**
3	**0.00**	**0.67**	**0.33**	**0.00**	**0.00**
4	**0.00**	**0.00**	**0.75**	**0.25**	**0.00**
4	**0.00**	**0.00**	**0.00**	**0.50**	**0.50**
Ergodic	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**

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Table2c: Inter-State relative (per capita) income dynamics, 1981-87
First Order transition matrix, Time stationary

(Number)	**Upper end point**				
	0.533	**0.628**	**0.795**	**1.010**	**1.489**
6	**0.17**	**0.50**	**0.33**	**0.00**	**0.00**
4	**0.00**	**0.00**	**0.25**	**0.75**	**0.00**
3	**0.00**	**0.67**	**0.33**	**0.67**	**0.00**
2	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
2	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
Ergodic	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

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Fig.1: Relative GDP per capita of Indian States 1965-1988

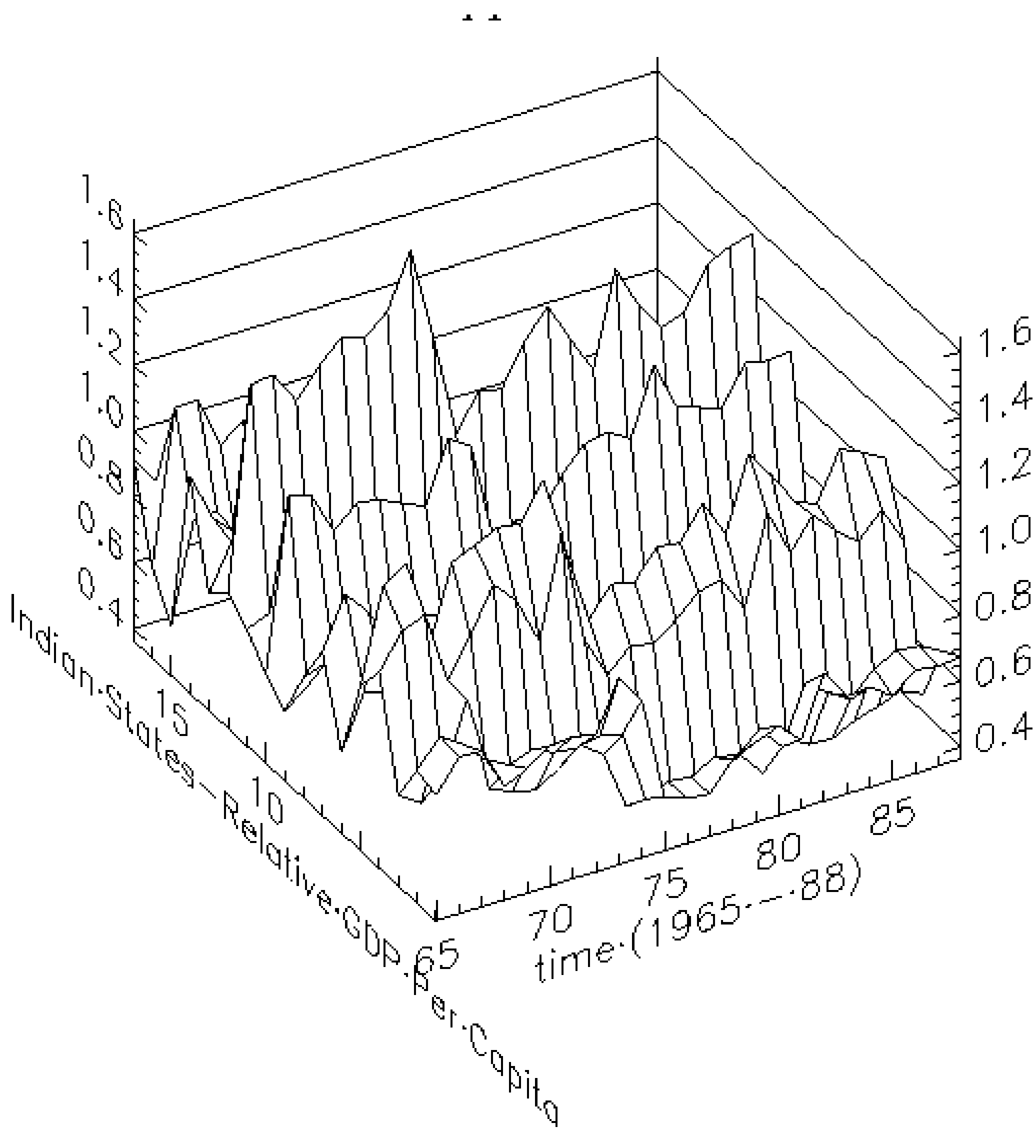

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Fig.2 Indian inter-state spatial dynamics of GDP per capita
1965, 1970, 1977,1988

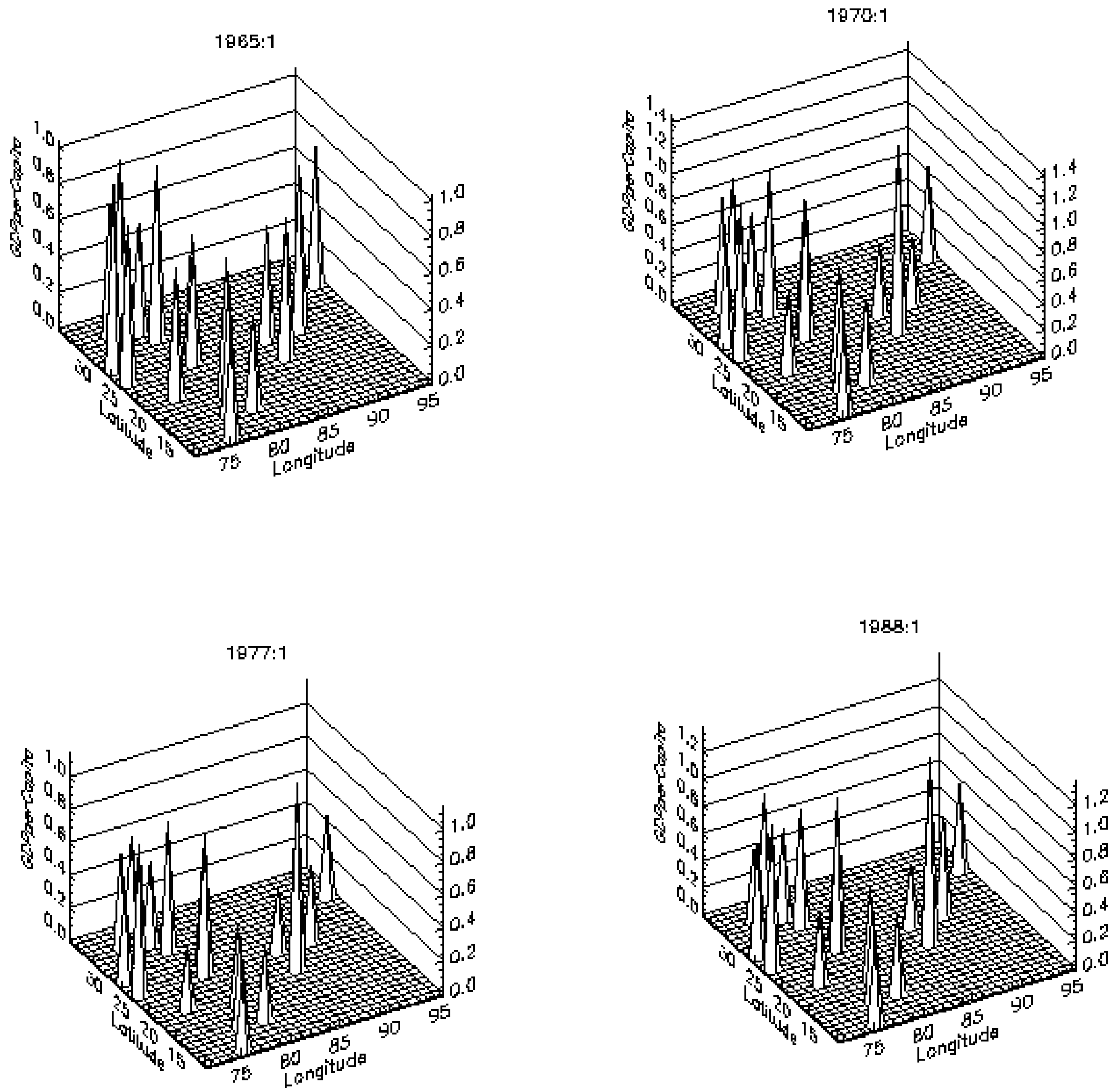
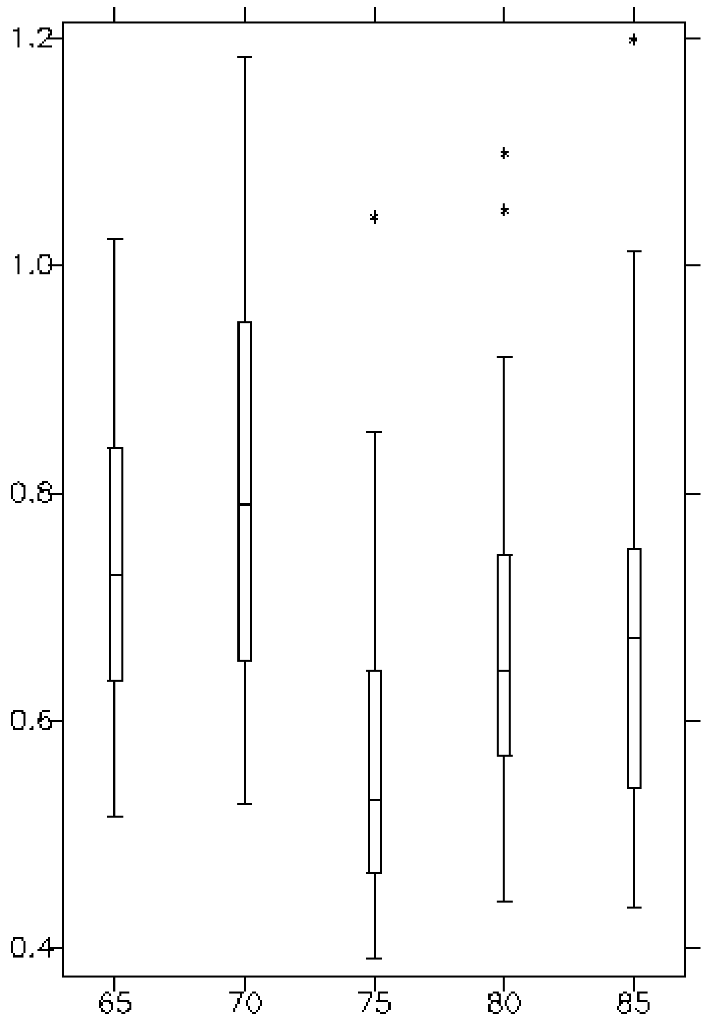


Fig.3: Tukey Boxplots, relative per capita incomes across Indian states



1965, 1970, 1975, 1980, 1985

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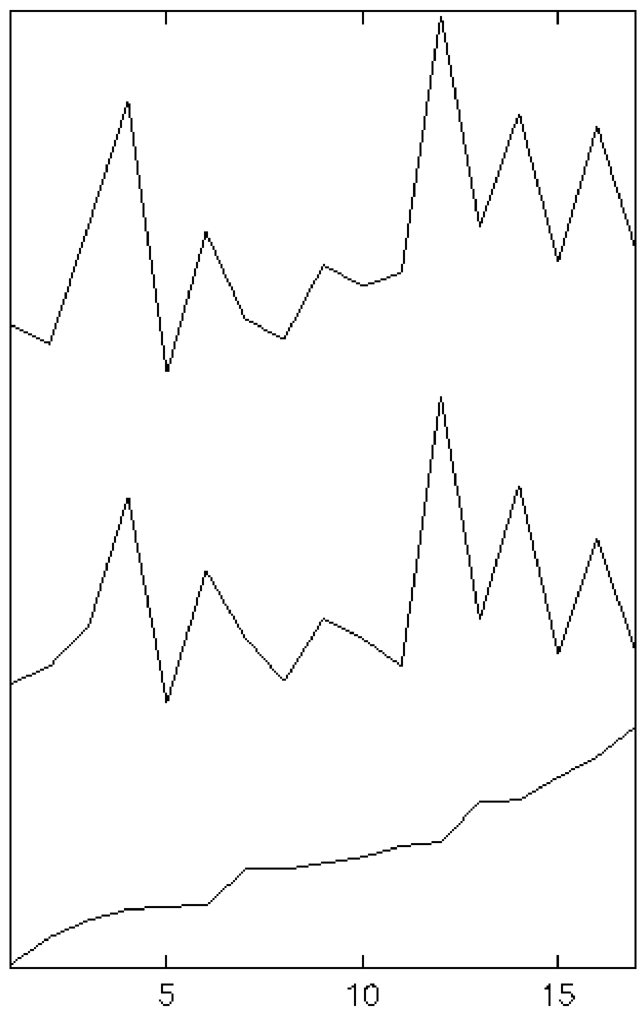
Fig.4: Cross profile dynamics across Indian States



Moving upwards: 1965, 1975, 1985

Fig.5a.i: Relative Income Dynamics across Indian States, 1 year horizon, 1965-87

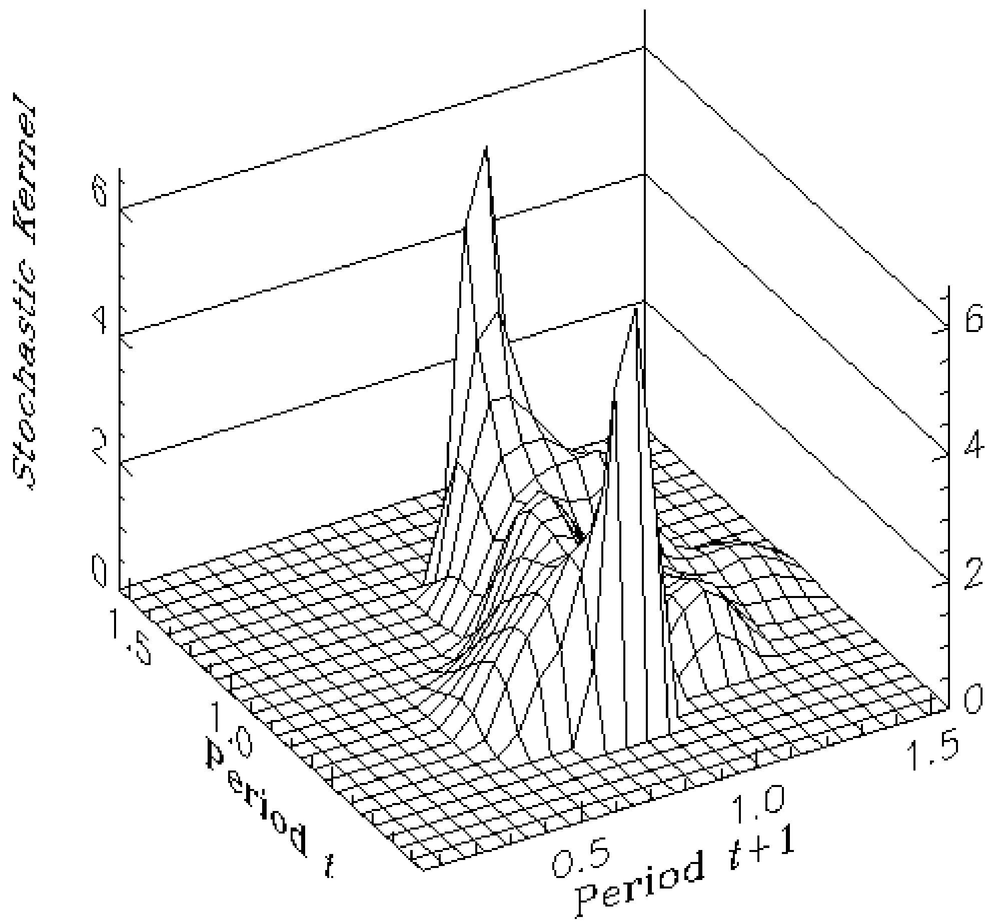


Fig 5a.ii: Relative Income Dynamics Across Indian States, 1 year horizon Contour Plot, 1965-87

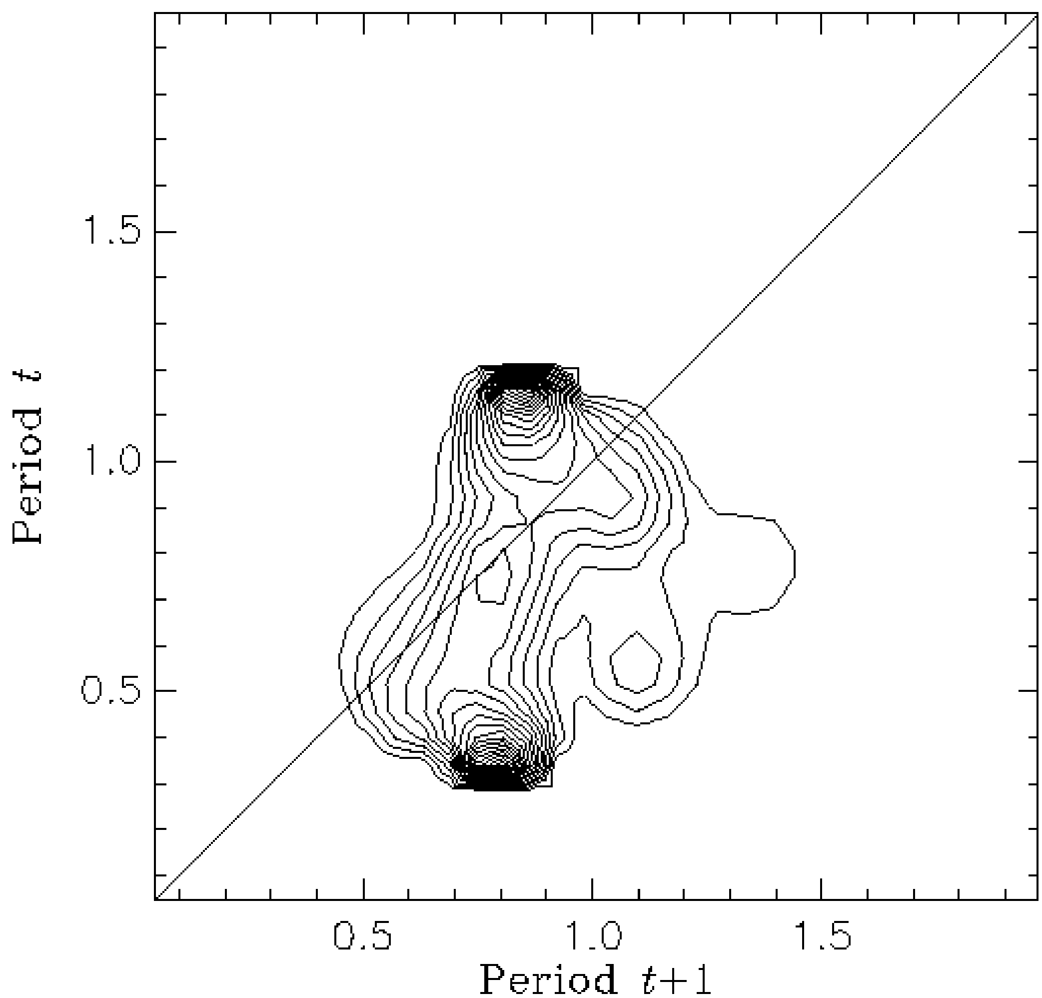


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Fig. 5b.i: Relative Income Dynamics across Indian States, 5 year horizon, 1965-84

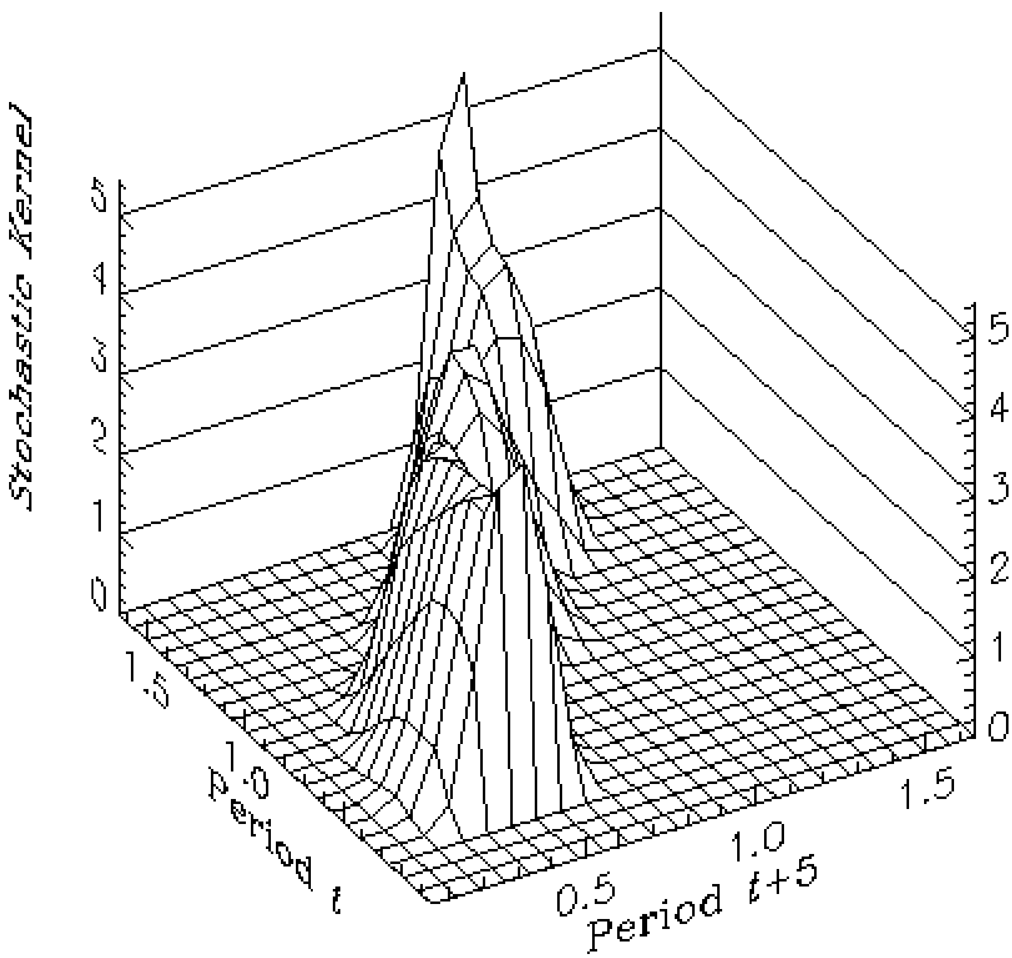

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Fig 5b.ii: Relative Income Dynamics across Indian States, 5 year horizon
Contour Plot, 1965-83

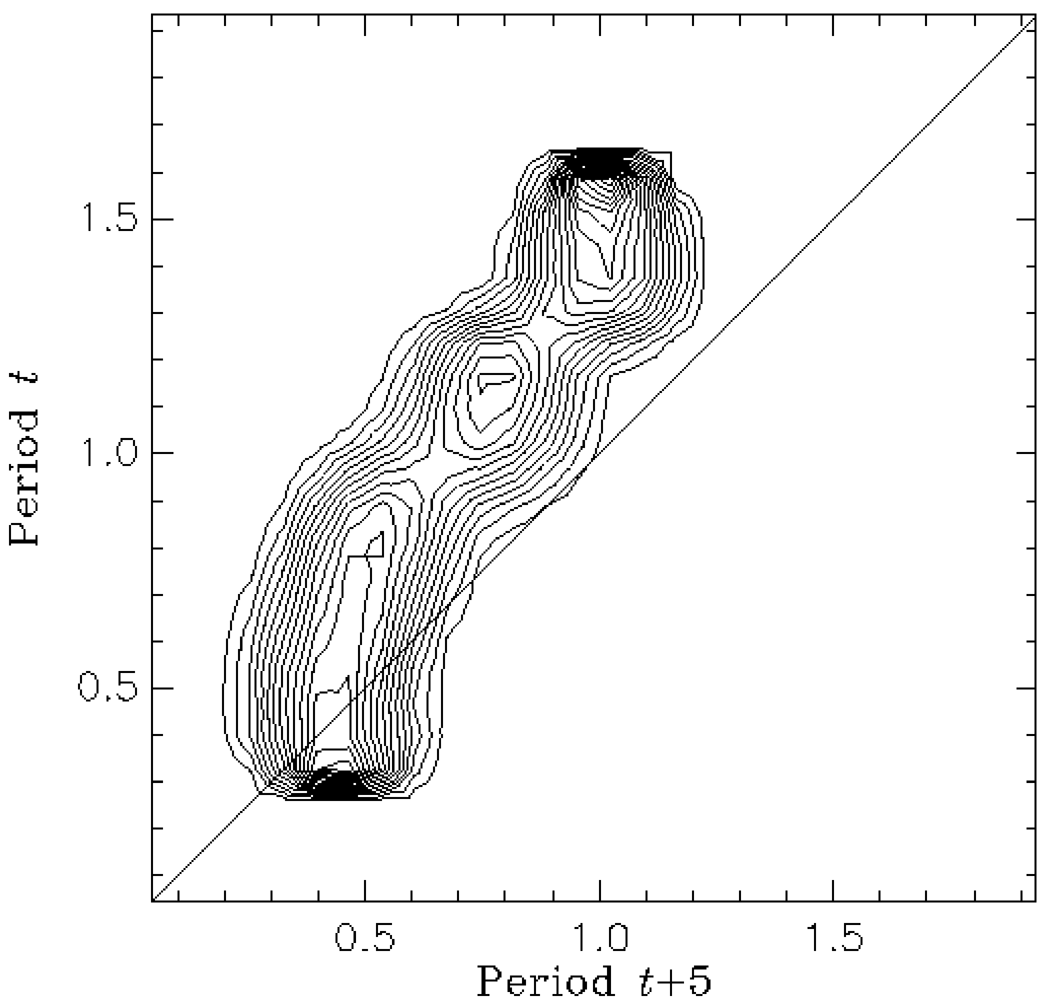

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Fig5c.i: Relative Income Dynamics across Indian States, 1 year horizon 1965-70

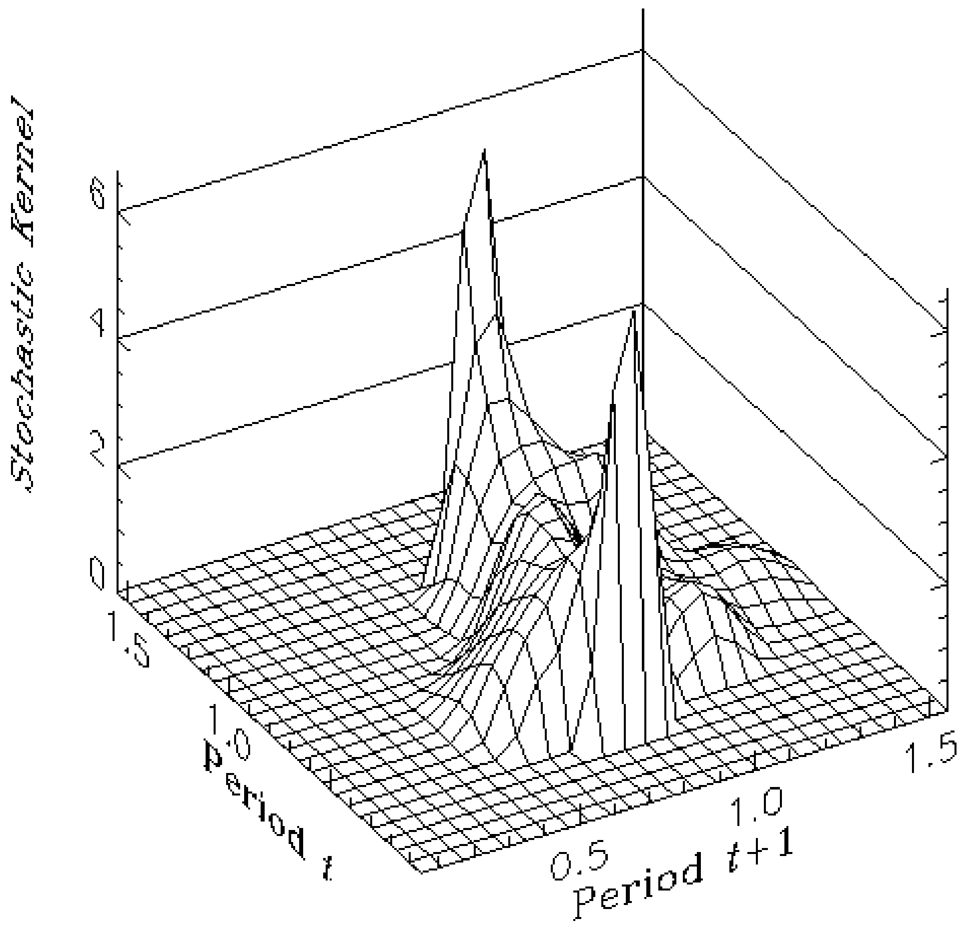

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Fig5c.ii: Relative Income Dynamics across Indian States, 1 year horizon 1965-70, Contour Plot

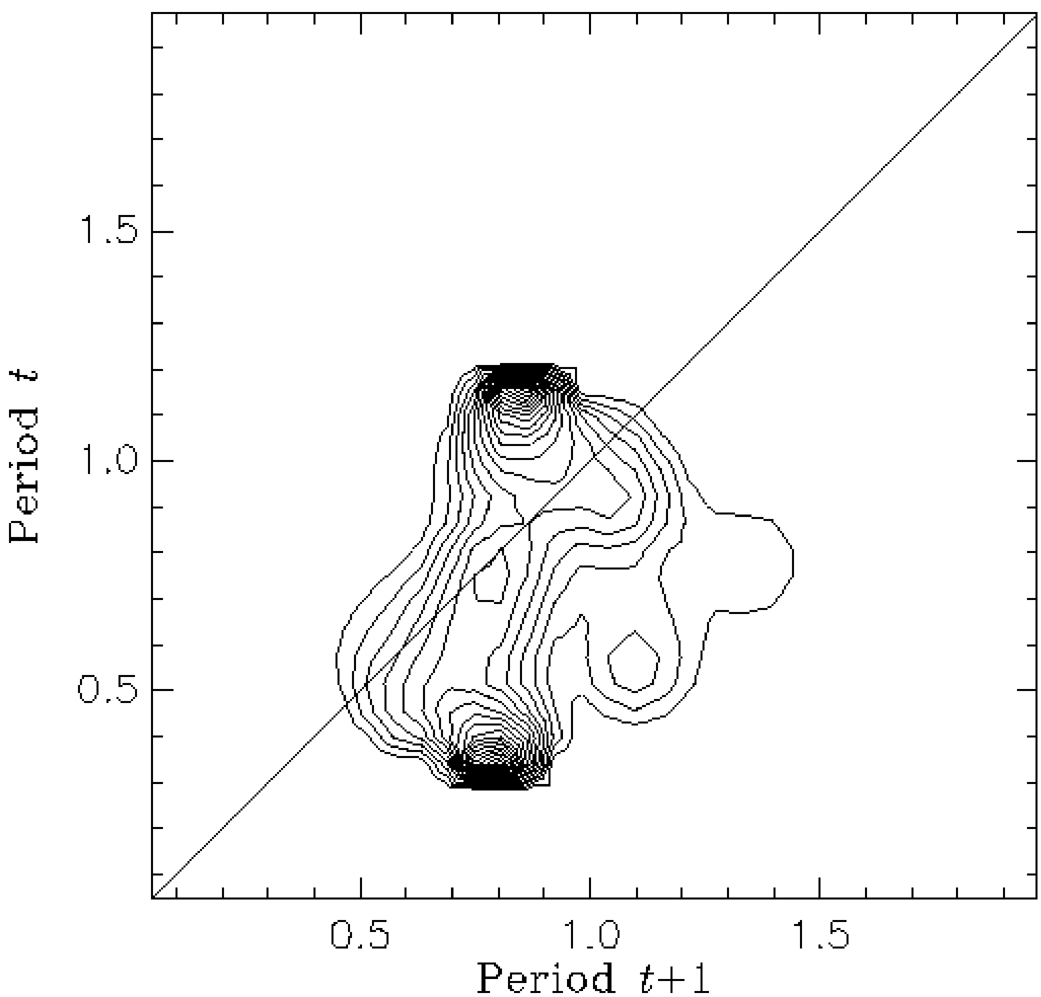

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Fig. 5d.i: Relative Income Dynamics across Indian States, 1year horizon
1971-80

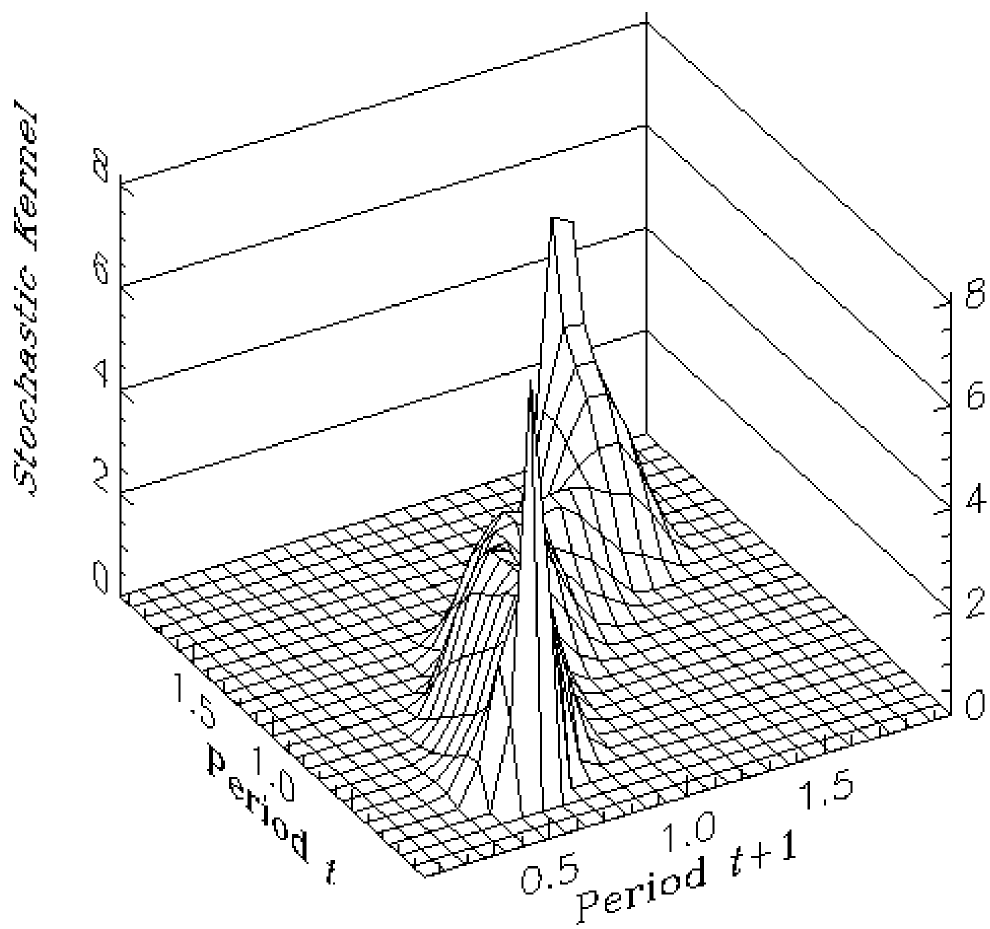

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Fig. 5d.ii: Relative Income Dynamics across Indian States, 1 year horizon 1971-80, Contour Plot

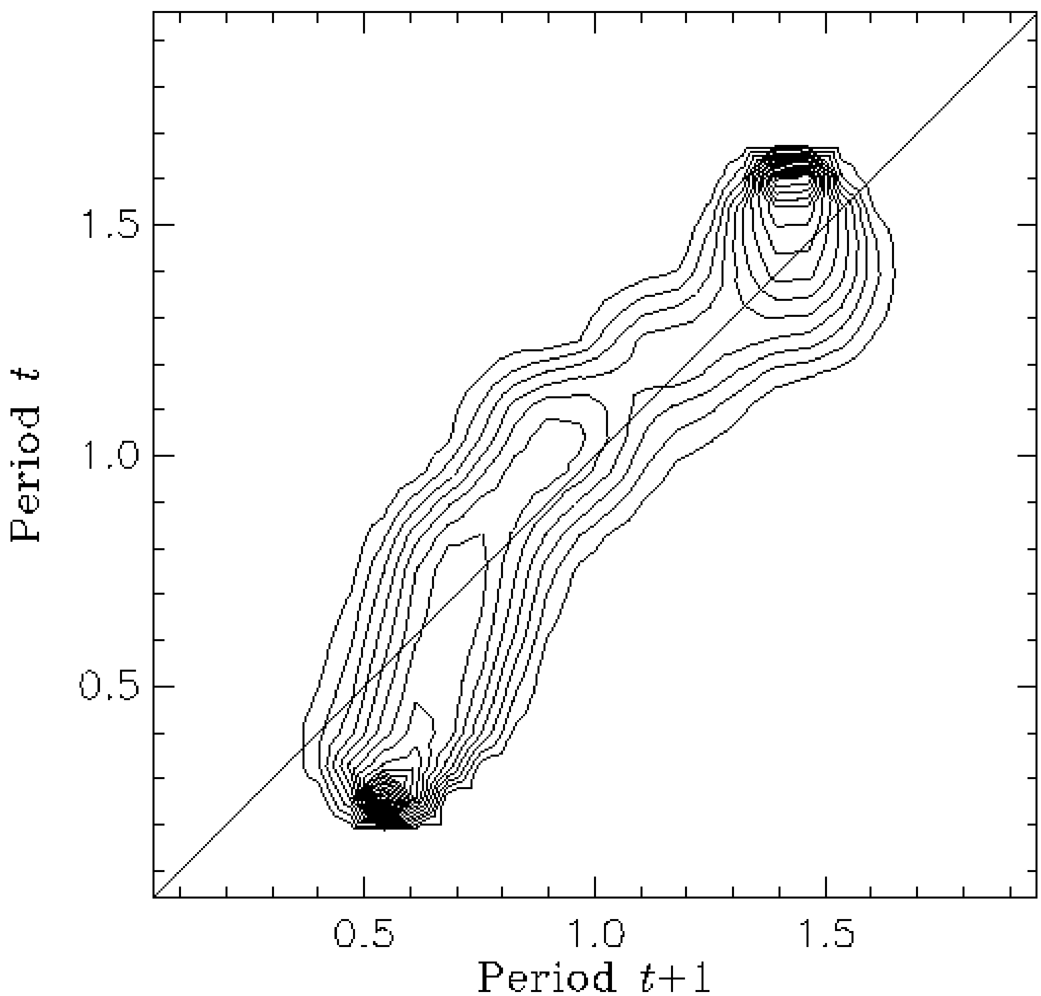

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Fig. 5e.i: Relative Income Dynamics across Indian States, 1 year horizon 1981-87

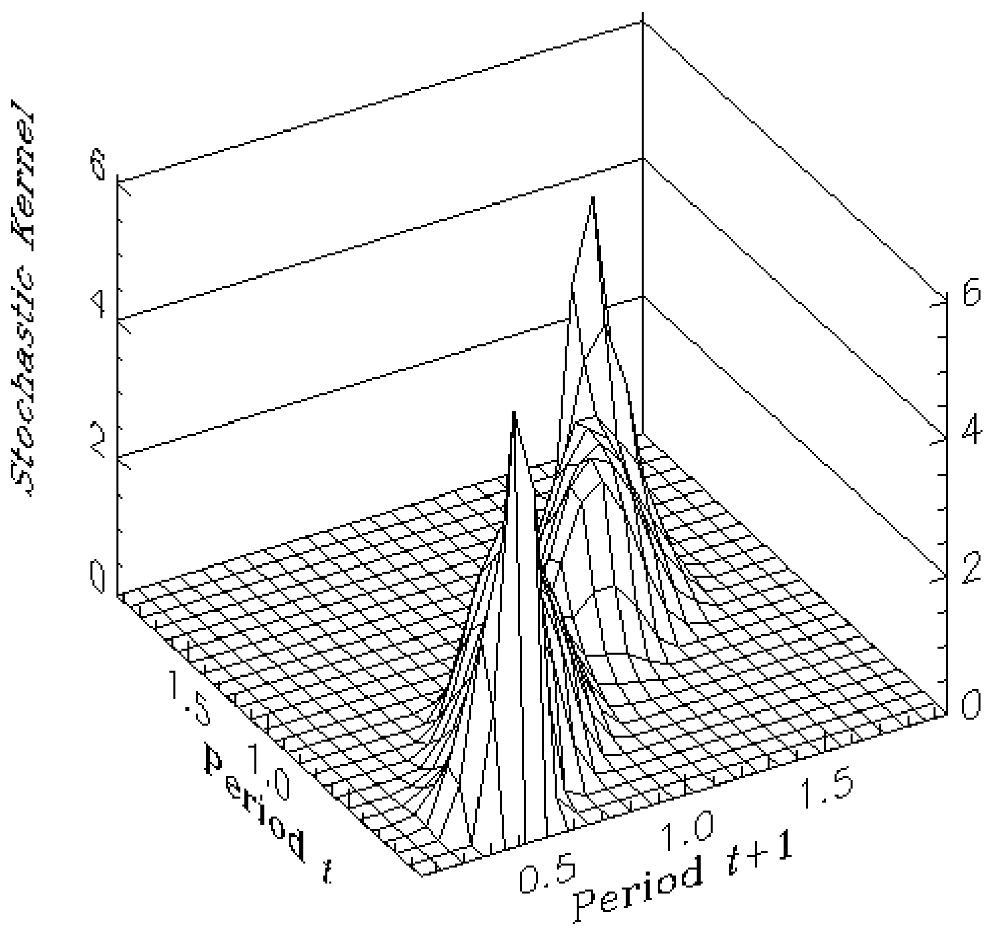

Fig. 5e.ii: Relative Income Dynamics across Indian States, 1 year horizon 1981-87

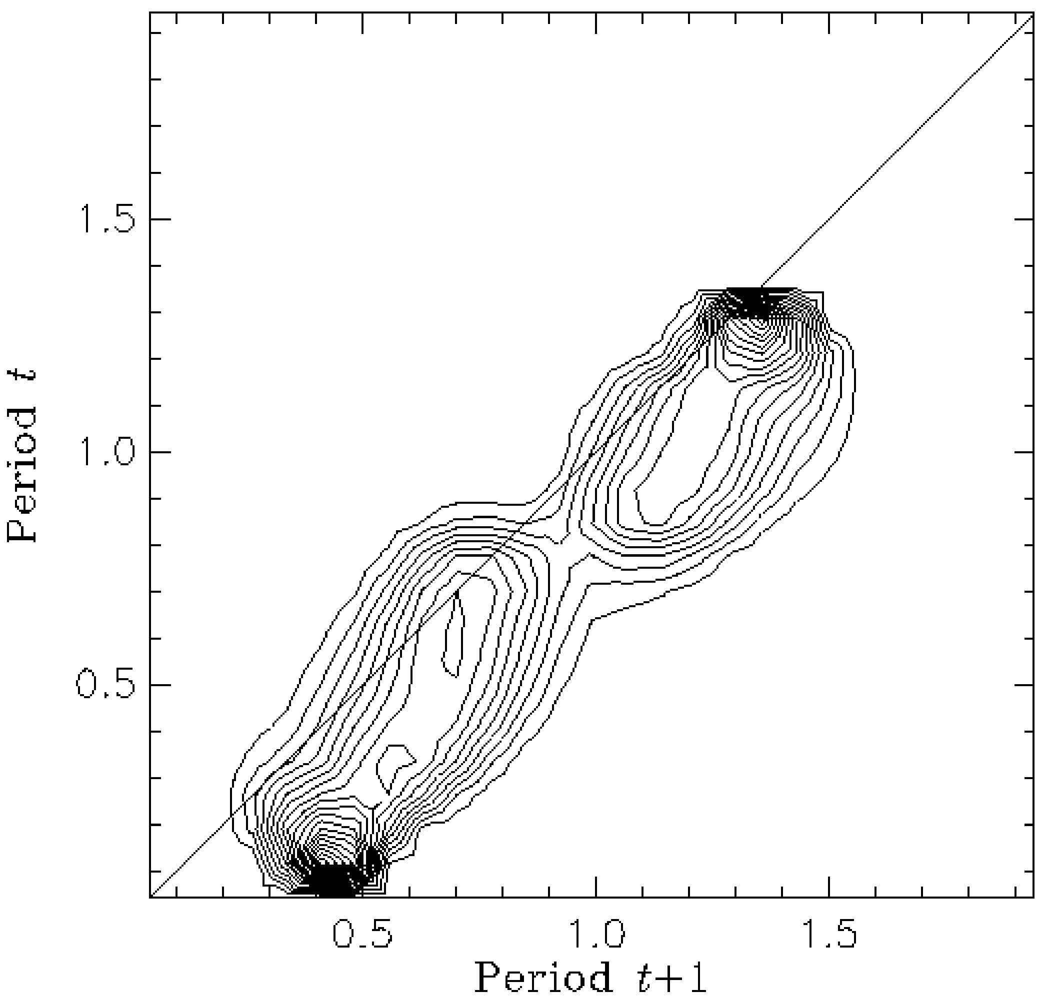

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Fig. 5f.i: Relative Income Dynamics across Indian States, 5 year horizon, 1965-70

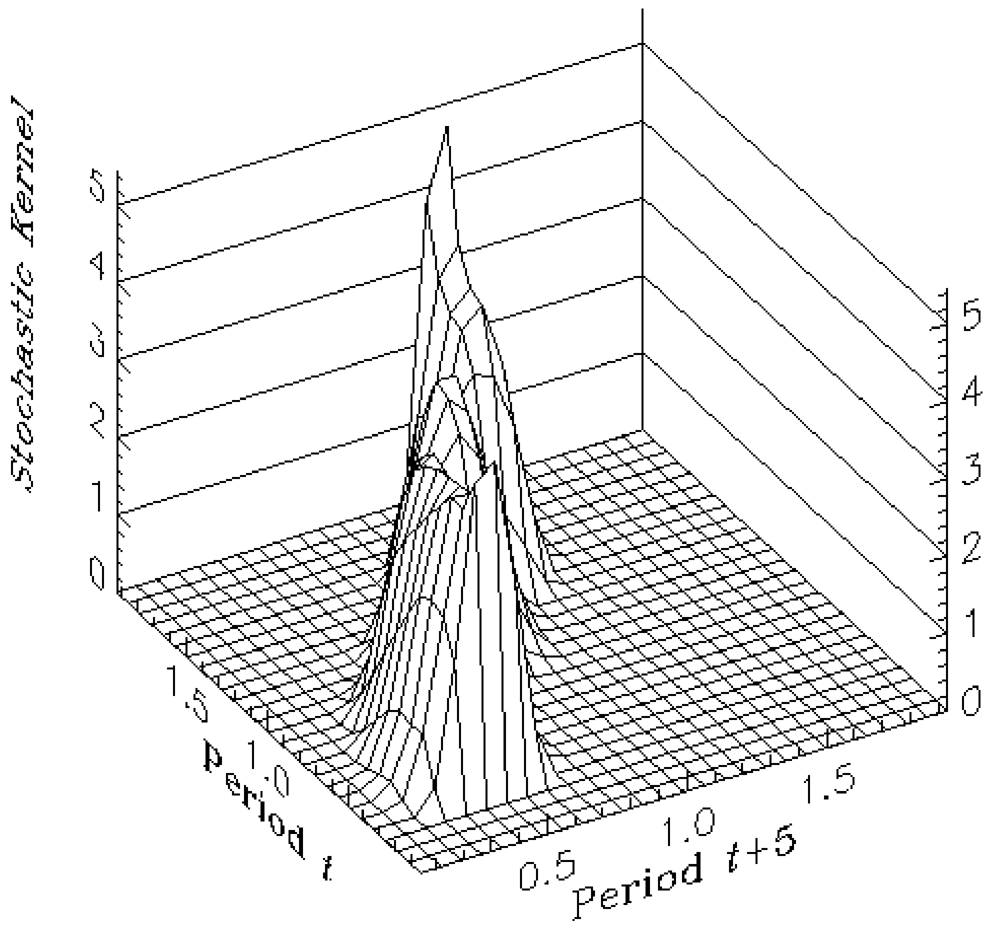

Fig. 5f.ii: Relative Income Dynamics across Indian States, 5 year horizon 1965-1970, Contour Plot

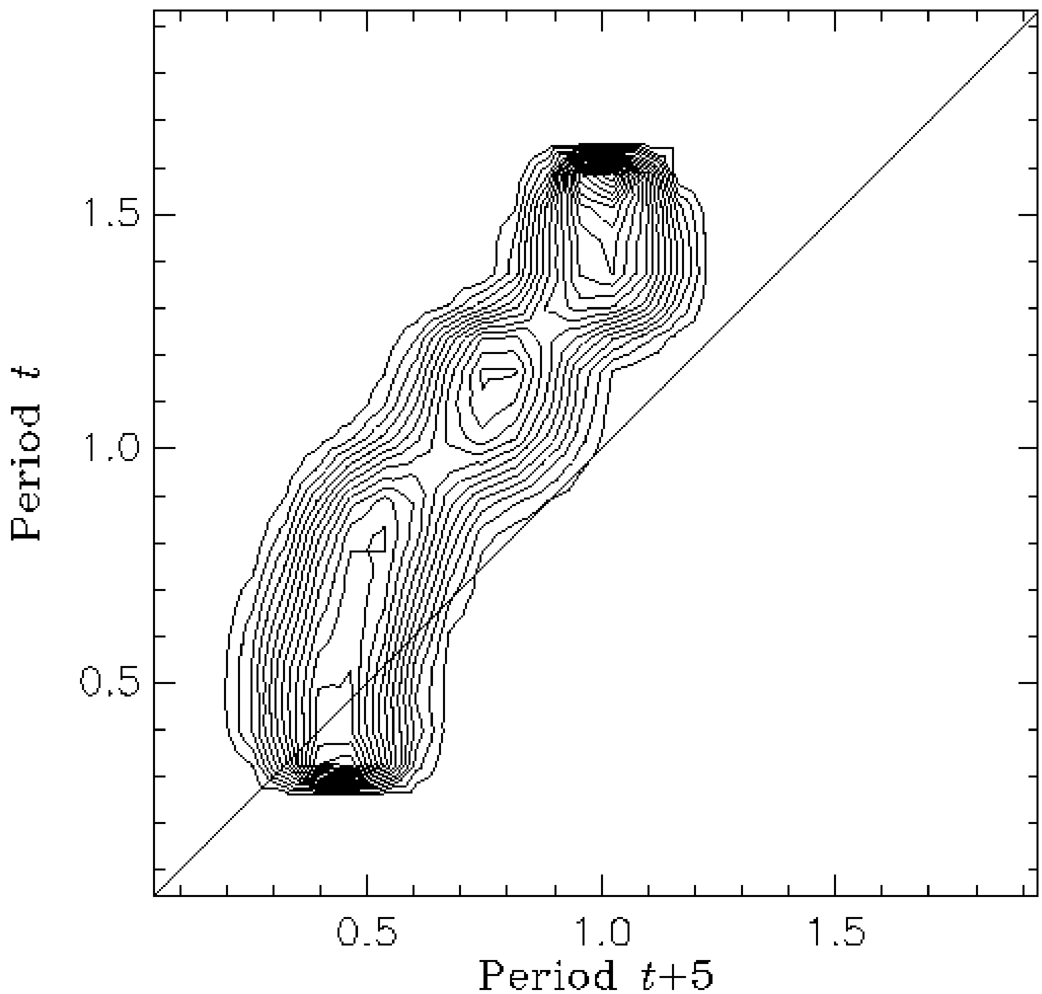

Fig. 5g.i: Relative Income Dynamics across Indian States, 5 year horizon 1970-75

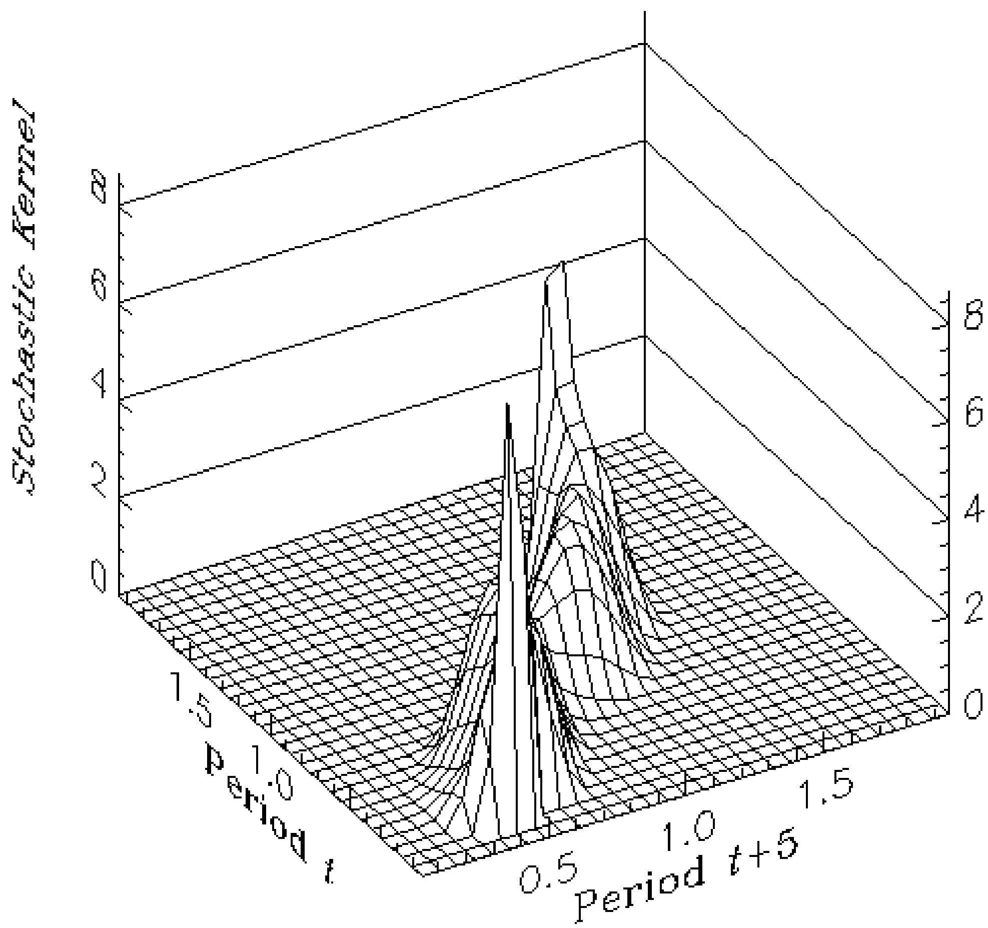

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Fig. 5g.ii: Relative Income Dynamics across Indian States, 5 year horizon 1970-75, Contour Plot

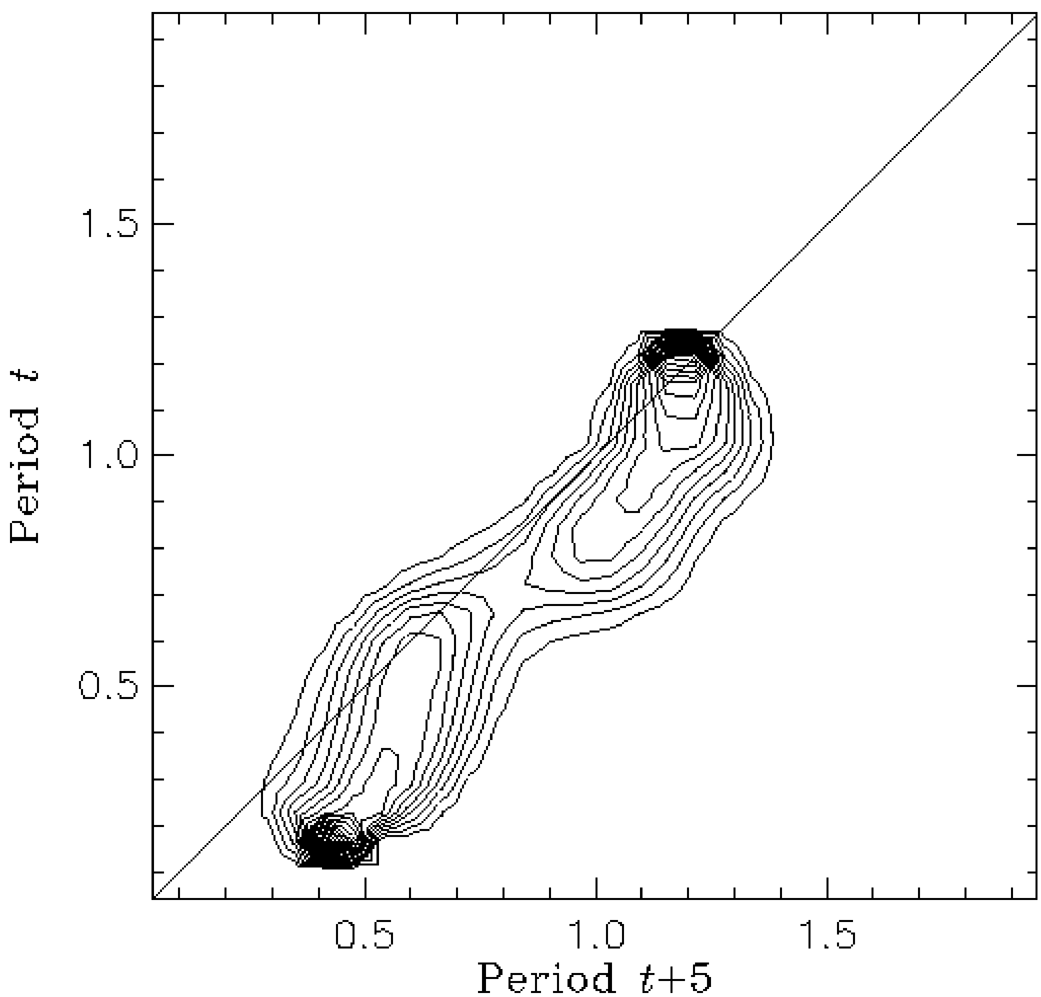

Fig. 5h.i: Relative Income Dynamics across Indian States, 5 year horizon 1978-83

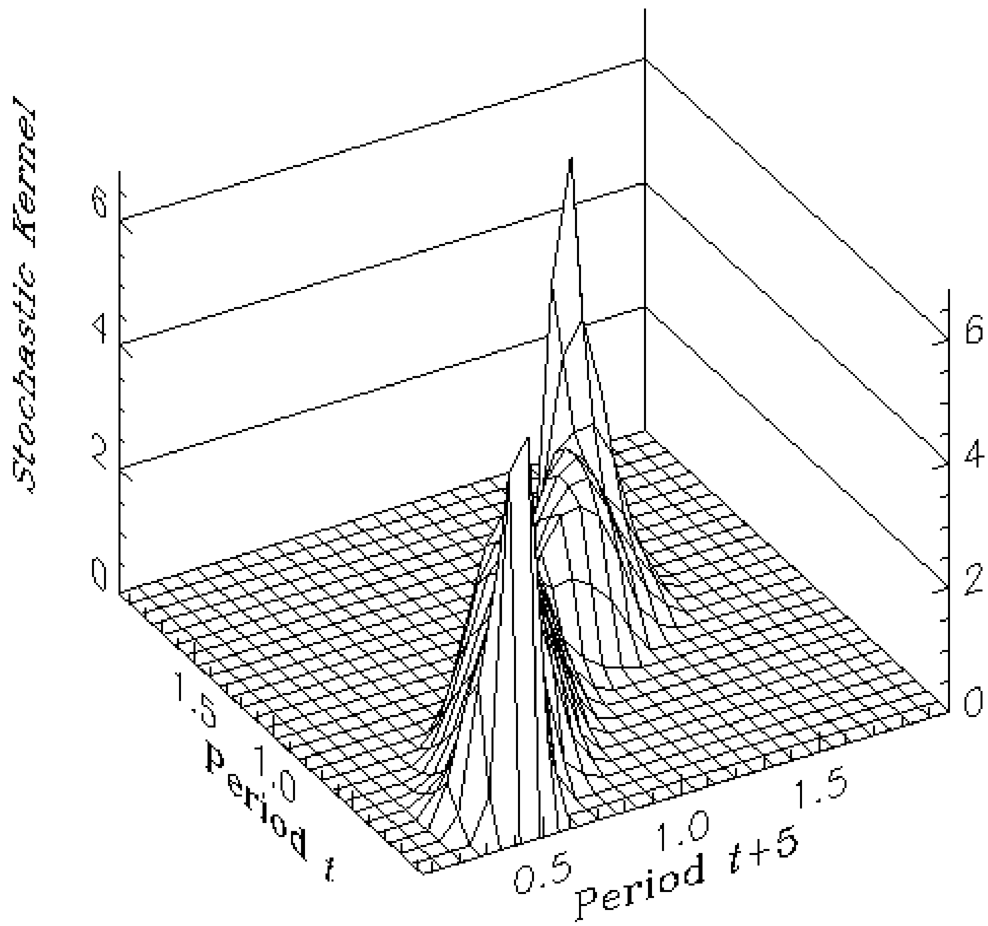

Fig. 5h.ii: Relative Income Dynamics across Indian States, 5 year horizon 1978-83, Contour Plot