

Spatial clustering of fertility decline in India

Debasish Nandy & Suddhasil Siddhanta

Abstract: India's fertility is declining and at present the country is experiencing significant demographic transition. The fertility pattern at the district level shows robust spatial clustering of low fertility values and its spatial propagation with time. While the role of the socio-economic characteristics in explaining fertility variations have been analysed in details, limited attention has been given to understand the role of space behind the rapid change in reproductive behavior. The present paper, thus, tries to highlight the importance of spatial factors in describing fertility transition in India. Employing geo – statistical tools the paper brings out the regionality in fertility pattern and also points out the contours of fertility decline in India. To judge the role of space in fertility transition, the study employs a comparative framework considering the structural factors along with the spatial factors. The result of an error analysis endorses that fertility diffusion seems to be well entrenched in Indian population though the nature of the diffusion may be anisotropic, resulting in striking regional patterning in fertility decline which is supposed to be associated with cultural factors, land inheritance system, cropping patterns, historical influences and socio-political institutions. Our findings taken together, indicates that space plays a crucial role in Indian fertility transition points to believe that individuals' location in the broad spectrum of individual, society, nation is more important rather than individual capacity building factors in order to describe the ongoing fertility transition in the country.

Key words: Fertility transition, Spatial contiguity, Contour map, Structural factors, Error analysis, Kernel distribution, LISA, Regional variation, Fertility diffusion etc.

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1. Introduction

India's fertility is declining and at present the country is experiencing significant demographic transition with substantial mortality decline and corresponding rapid pace of fertility decline. From a stage of weak or no sign of fertility decline, total fertility rate in India is now well below three children per women and have achieved replacement level fertility at least in the urban segment of the country. Even then the regional variation in fertility levels as well as its decline seems to be substantial. More interestingly, fertility rates are declining at the district level using particular regional roots, thus indicating that space has significant role in the process dynamics behind the ongoing fertility transition in the country.

Even then, the literature on Indian demography has repeatedly drawn policy makers' attention regarding the crucial role of structural factors to achieve replacement level fertility every where within the country (Murthi et al. 1995, Drèze et al. 2001). Considerable ink has been spoiled to prove the relationship between female literacy and fertility but limited attention has been given to understand the role of space in fertility variations as well as its decline (though some original attempts has been made by Guilmoto et al. 2001, Bhat et al. 1999). The present paper is an attempt to shade some light on the role of space in explaining the pattern of fertility decline in Indian population. Using geo-statistical tool, the paper indicates robust spatial clustering of districts with low fertility levels on one hand and highlights the spatial trend of fertility decline during 1981-2001 on the other. Using a Multi-linear framework, next the study tries to model the fertility levels of 1980s on the basis of contemporary socio-economic characteristics and predict 2001 fertility rates on the basis of the result of that model. Calculating the difference between estimated fertility and the predicted fertility of 2001, the study analyses the spatial properties of the residuals employing global as well as local indices of spatial autocorrelation. The result of the error analysis clearly endorses that spatial diffusion in fertility is well entrenched in Indian population but the nature of diffusion might be anisotropic, leading to striking regionalites in its pattern. Such regionality might

be associated with difference in cultural factors (i.e., mainly unequal manifestation of patriarchy), cropping pattern, land inheritance system, historical influence and the nature of the socio-political institution. The findings of this analysis may be found to be useful for policy planners and researchers.

The paper is organized as follows. Section I describes the data sources and the motivation for this study. In the next section we try to identify the spatial patterns of district level fertility and its decline in India during 1981 to 2001. Section III tries to model the district level fertility of 1981 on the basis of structural factors and predict the possible fertility rates for 2001, and pursues an error analysis to cater the importance of space in fertility decline in India. Next section discusses some of the salient features of this analysis and brings up a number of research agenda so important to understand the dynamics of fertility transition in India.

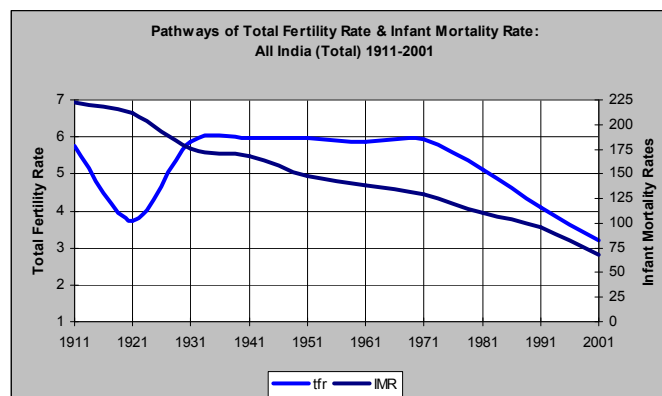
2. Background

2.1. Motivation of the study

Alike other developing countries, fertility decline in India seems to be very impressive and secular at least since mid eighties. The following figure 1 indicates the pathways of total fertility rates and infant mortality rates over the time period 1911 to 2001. The infant mortality figures are scaled according to the right vertical axis; the total fertility rate is scaled as shown on the left axis. The study employs fertility estimates as done by Bhat (1989), and the infant mortality data is taken from K. Srinivasan edited book, ‘Population Policy and Reproductive Health’.

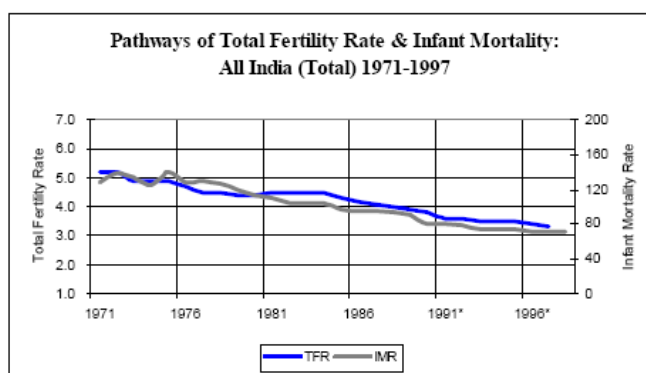
Figure 1: Pathways of Total Fertility Rate & Infant Mortality Rate:

All India (Total) 1911-2001



As can be seen from the above bi-variate graph, the country has obeyed text book transition scheme with mortality declining first and fertility falling after a lag. The time lag might be more than sixty years, much longer than what happens in many other developing countries like Brazil, Colombia, Mexico etc. The fertility starts declining only after 70s, a slight increase during mid 80s and a secular decline since then. The next figure indicates the pathways of total fertility and infant mortality during 1971 and 1997 using the time series data available from ‘Sample Registration System’.

**Figure 2: Pathways of Total Fertility Rate & Infant Mortality Rate:
All India (Total) 1971-1997**



But India is not a monolith. Each of the indicators shows a considerable regional variation across the length and breadth of the country. Demographic regionality seems to be substantial within the country. However such variation is rarely scattered mostly reveals itself in clusters providing new if not rare insights into the spread of different trends in different regions of the country. These clusters often do not conform to the commonly understood administrative boundaries and cut across these in many insightful ways.

The literature on Indian demography already establishes such regional patterning in fertility as well as in many other demographic characteristics and endorses that for better understanding of contemporary fertility transition in India, one has to take disaggregated unit of analysis to unmask the regional intricacies and to produce more intriguing and nuanced pattern (Bhat et al. 1999, Guilmoto et al. 2001, Guilmoto et al. 2005, 2007, 2008). Interestingly the state level data regarding fertility also hides the within state

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variability, thus found to be inadequate to understand the spatial pattern of fertility rates¹. The district level distribution of fertility rates for 1981, 1991 & 2001 are given in Appendix 1 which amplifies 'within' as well as 'between' state diversities in fertility pattern. Thus the literature as well as the representation in Appendix I together endorse that contemporary pattern of fertility can best be analyzed within the local context using disaggregated unit of analysis.

2.2.Data to Study fertility variations

The data used in this study are based on Census and National Sample Survey Organisation based statistics. To account for regional heterogeneity, which can be more useful to understand the role of space, the lowest administrative units (i.e. district) at which fertility data are available have been used. From administrative point of view, use of smaller units facilitate planning and evaluation of public policies and helps to identify the very local patterns distinctively different from the global trend. Census of India provides different socio-cultural, economic and demographic information from where it is possible to estimate district level fertility rates. We use the estimated district level fertility rates by Prof. Mari Bhat published in Martine et al. (1998) and in Bhat (2004)². We have taken 1981, 1991 and 2001 data to make comparative judgment. Total fertility rate data at the district level are not available prior to 1981.

Fertility is measured by the total fertility rate which represents the number of children that would be born to a woman if she were to live to the end of our child bearing years and bear children at each age in accordance with the prevailing age specific fertility rates. We think the total fertility rate is a more useful measure of fertility levels since it is independent of the age structure of the population.

District is the lowest administrative unit for which reliable fertility data is available.

¹ The state level variability in fertility is clearly depicted in Guilmoto (2000) in the Blot Plot represented in Guilmoto 2005. However in order to sensitize reader's attention regarding this issue we have given the distribution of district fertility estimates for some large states in the form of Box Plot in Appendix I. The graphs given in Appendix I reconfirms the between state and within state diversity in fertility and seem to be indicative to understand the importance of local context in analyzing reproductive behaviour in India.

² However there are other sources from where reliable fertility estimates are available. We stick to the estimates made by P N Mari Bhat to have data for three successive census years from a single source.

3. The geography of fertility transition in India

3.1. Spatial pattern of fertility levels during the last three census years

Using district level fertility rates, in first step we plot the fertility estimates in Indian administrative maps using the geographical coordinates to analyse the spatial pattern of fertility during 1981 to 2001 using geo-statistical technique. In particular we use thematic maps to display the geography of fertility transition in order to grasp the regional variability which seems to be substantial as envisaged from literature and also from the figures presented in Appendix I.

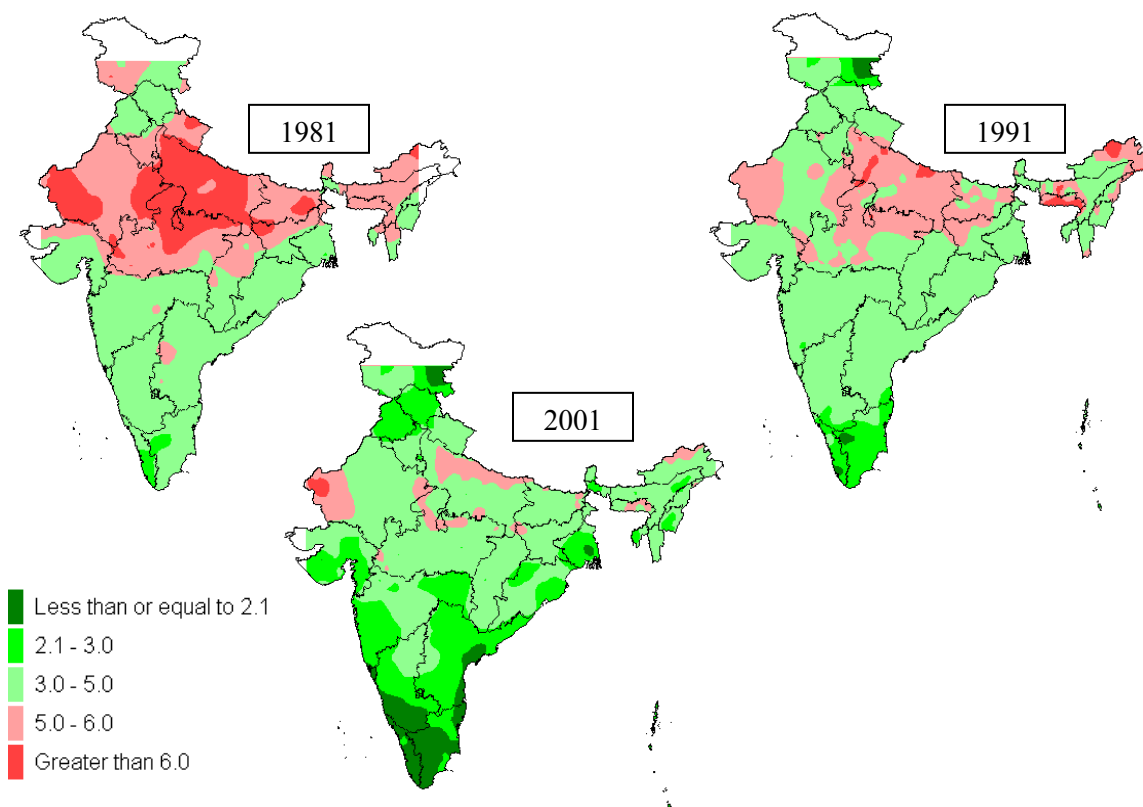
Use of mapping technique is common in literature. The most popular method often used in social science is Choropleth, where geographical areas are shaded on the basis of proportion of values of statistical variables to be depicted in map. This map is based on administrative units and depends on administrative boundaries and thus more appropriate for those analyses where administrative unit is the main focus of analysis. But in social science, particularly in demography, administrative unit, if not always, is not the prime concern; rather understanding of spatial pattern on the basis of data may be more important. In this section, we employ isarithmic mapping technique that depicts smooth continuous spatial phenomena. After mapping the district level fertility estimates, we then prepare surface/grid map on the basis of spatial interpolation techniques (Kriging³). Performing kriging we then estimate the continuous values from all locations on the maps and contour them to form the geographical regions on the basis of homogenous values of total fertility rates. We then trim the regions of homogenous values along the international boundary of India to visualize the several contours of different fertility levels.

Following are the isarithmic maps of fertility rates for three successive census years - 1981, 1991 and 2001. To make the analysis comparable we use same class-width of TFR values on the basis of United Nations categorization i.e., category I (districts with fertility

³ Kriging is a geo-statistical method for spatial interpolation. This technique assumes that spatial variation of an attribute is neither totally random nor deterministic. Instead, the spatial variations may consist of three components: spatially correlated component, representing the variations of the regionlised variable; a drift or structure representing a trend; and a random error term. We use ordinary Kriging method to focus on the spatially correlated component.

rates less than 2.1), Category II (districts with fertility rates 2.1 to 3.0), Category III(districts with fertility rates 3.0 to 5.0) and category IV (districts with fertility rates 5.0 & above)⁴.

Figure 3: Spatial Patterns of fertility levels in India, 1981-2001



The district level fertility data show exciting pattern that need to be flagged. While the district of Mokukchung records the highest TFR of 9.1 in 1981, the number of districts with TFR > 6.5 (about 23) is not just confined to the north eastern part of the country but small cluster of high TFR can be observed in the states of Rajasthan and Madhya Pradesh⁵. Similarly according to 1991 Census, the district of Karimganj has the highest TFR of 7.08 but such high level of TFR is not limited to the north eastern part of the country, small cluster of high fertility can be located in Madhya Pradesh & Uttar Pradesh. In 2001, the district of Jaisalmir, shows the highest TFR values. The number of districts

⁴ Use of normal bandwidth on the basis of average will result in loss of comparability and can understate the regional clustering which is the main purpose of this study.

⁵ and even in Goa, Daman & Diu.

with TFR > 5 is no longer confined to the periphery of Jaisalmir. Significant cluster of high TFR can be observed in the states of Uttar Pradesh, Madhya Pradesh and Bihar.

Several salient features are forthcoming from the above three figures. Gradual increase in green belt indicates considerable increase in districts in the advanced stage of fertility transition. The first map, i.e., the district level fertility pattern during 1981, clearly divides Indian landscape into two distinguished clusters. The districts of the northern and north western part of the country are showing very little or no sign of fertility transition, whereas the districts of the southern-eastern parts are in the incipient stage with few pockets of Tamil Nadu and Kerala where TFR are in the advanced stage of transition. Close inspection of the fertility pattern in the 1981 map clearly points out the link between traditional cultural division and spatial pattern of fertility transition. This division is reflected in the kinship system, language, land inheritance system and cropping pattern. The major ingredient of the North South divide is the kinship system with Indo-Aryan in north and Dravidian in south (Karvee 1965, Trautmann 1993, Basu 1992, Kishore 1993). Indo Aryan kinship is characterized by strong subordination of women. The relevant features of this kinship system are spatially exogenous marriage rule and exclusion of women from property inheritance claim. In this Indo-Aryan system, the blood relation is strictly separated from the in-laws, i.e., a clear cut distinction between the family of birth and the family of marriage. In this Northern system, the bride is an outsider and has to shift loyalties from the family of births to the family of marriage. The bride gets assimilated into one at the cost of other. Such a conservative social norm naturalizes excessive female subordination and restricts female autonomy or female agency. On the other hand, southern kinship system is characterized by spatially endogenous marriage⁶, equal importance of affinity⁷, and decent in social co-operation among males and inclusion of women in the property inheritance process. The marriage rule is completely different from that of Indo-Aryan kinship. In the Dravidian system, there is no distinction between 'family of birth' and the 'family of marriage'. In the southern system a bride does not enter a household as a stranger and her communication

⁶ By spatially endogenous marriage we mean to say that marriages are performed within nearer places say for example a near by village. Endogamy can be defined as the rule enjoying marriage within a specified group.

⁷ The social relationship between individuals and groups resulting from marriage.

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with her natal kin after marriage remains considerable and so does her frequency of visit to her parent's house. Such a system brings in greater female autonomy or female empowerment and improves the capacity for agency.

Kinship provides a major avenue of access to social resources and interaction and hence determines the freedom or autonomy women can enjoy. Women's autonomy helps to create women's agency. Women's ability to exercise agency can strengthen their ability to express their differential preferences and priorities (Kabeer 2005). Received literature already indicates a strong impact of women's agency on fertility behavior. In addition to this, the mapping exercise emphasizes the role of kinship and thus female autonomy on India's fertility transition. While 1981 data clearly indicates the impact of kinship in the *autonomy-fertility* relationship, the 1991 & 2001 maps further indicate that low TFRs are no longer confined to the female friendly southern and eastern part of the country, it spreads across the Vindya Parbat, crosses the Narmada-Shone line and moves towards the north western region particularly in the districts of Punjab, Haryana and Eastern Rajasthan.

The role of kinship structure on fertility transition can also be analyzed with the help of two way contingency table as well as degree of association test. To construct the two way contingency table, first we transfer the district level fertility data into four categories. The first category indicates the number of districts with fertility less than or equal to the 'replacement level fertility' i.e., number of districts which are in the post transitional stage. The second category consists of districts with $2.1 > \text{TFR} \leq 3$ that describes the characteristics of advanced stage of fertility transition. The third category i.e., districts with $3 > \text{TFR} \leq 5$ can be termed as 'early or incipient stage of fertility transition' and finally the fourth category encompasses the districts with $\text{TFR} > 5$. On the other hand following Agnihotri (2000), we use modified kinship classification. The dichotomous kinship variable used in this study represents the core Indo-Aryan kinship system and the rest. The rest includes different systems like the peripheral Indo-Aryan, the Dravidian and the tribal. This can be termed 'female friendly' while the Indo-Aryan system can be termed 'male centered'. The dichotomous kinship variable takes the value 1 for core Indo-Aryan region and zero for all other. The core Indo-Aryan region consists of

contiguous tract of around 160 districts in the north and north-west part of the country. The list of district falling in the Indo-Aryan region is taken from Agnihotri (2000).

Following are the contingency tables for the respective last 3 census years, which present a joint frequency distribution of two categorical variables. Such contingency table is used to examine whether or not two categorical variables are stochastically independent⁸. The 4*2 contingency tables are presented below, where 4 columns represent four categories of fertility transition and two rows represent the ‘dichotomous’ kinship classification.

Table 1a: Contingency table showing Distribution of Districts by Kinship classification and Level of Fertility Transition: All India, 1981

		Districts with Total Fertility rate				
		Less than or equal to 2.1	Less than or equal to 3 but greater than 2.1	Less than or equal to 5 but greater than 3	Greater than 5	Total
District	With kinship = 0	1	13	134	55	203
	With kinship = 1	0	0	40	123	163
	Total	1	13	174	178	366

Table 1b: Contingency table showing Distribution of Districts by Kinship classification and Level of Fertility Transition: All India, 1991

		Districts with Total Fertility rate				
		Less than or equal to 2.1	Less than or equal to 3 but greater than 2.1	Less than or equal to 5 but greater than 3	Greater than 5	Total
District	With kinship = 0	9	32	190	43	274
	With kinship = 1	0	1	80	97	178
	Total	9	33	270	140	452

Table 1c: Contingency table showing Distribution of Districts by Kinship classification and Level of Fertility Transition: All India, 2001

		Districts with Total Fertility rate				
		Less than or equal to 2.1	Less than or equal to 3 but greater than 2.1	Less than or equal to 5 but greater than 3	Greater than 5	Total
District	With kinship = 0	65	112	172	12	361
	With kinship = 1	3	48	145	36	232
	Total	68	160	317	48	593

⁸ The reasons for our preferences for such statistical measure are that with categorical variables we cannot compute numerical summaries like covariance or correlation coefficient but we can examine whether or not fertility frequency and kinship are related.

To examine the association between stages of fertility transition and kinship classification we use Cramer's V measure – an index number to compare the degree of association between fertility levels and kinship practices. If there is a strong association between fertility levels and kinship structure, the perception of fertility decline is likely to be reinforced by cultural practices. Following table 2 shows the Cramer's V association for the last 3 census years.

Table 2: Cramer's V association test between fertility transitions and cultural practices

Year	Cramer's V Statistic
1981	0.49
1991	0.44
2001	0.35

All the Cramer's V statistics are highly significant showing the robust connection between cultural practices and fertility outcomes. However the degree of association between fertility and kinship structure decreases with time, indicating that culture is losing its grip over fertility transition. As time goes on, fertility is declining everywhere with different pace / magnitude and is not restricted within any cultural periphery.

1981 map also points out a small cluster comprising some districts of Kerala, indicating advanced stage of fertility decline. The district of Kolkata is the only district, with fertility level less than 'replacement fertility' (i.e. 2.1 children per woman), showing the characteristics of post transitional stage. Significant cluster of high fertility can be found in Auranachal Pradesh, Meghalaya, Tripura and Mizoram. Interestingly some districts of Manipur and Nagaland are showing moderate fertility. The picture becomes more complex during 1990's. The fall in fertility rate is most visible in Southern India particularly in the coastal districts of Kerala and Tamil Nadu. The interior districts in the deccan plateau has less rapid pace of demographic change.

The fall in fertility level is most visible in southern districts particularly in the coastal districts of Tamil Nadu and Kerala. The Coastal patterning of fertility is more visible in 2001 map – where almost all districts of coastal India are either in the advanced stage of

fertility decline or in the post transitional stage⁹. In the north west, fertility decline turn out to be prominent in all districts of Punjab including union territory of Chandigarh. Fertility decline has still not begun in some parts of the Northern Uttar Pradesh along the boundary of Nepal, a contiguous strip of districts along the northern boundary of Madhya Pradesh, a cluster of districts along the western part of Rajasthan and along the eastern border of Bihar. The spatial clustering of districts with fertility level more than 3 in Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Bihar, Chattisgarh, Jharkhand and some contiguous parts of Maharashtra and Karnataka indicate different type of spatial clustering where fertility decline seems not to be substantial. Another cluster of districts with fertility less than 3 can be observed in Punjab and Himachal Pradesh, where decline in fertility seems to be substantial during 1981 to 2001. In the southern districts, rapid fertility decline have been observed in every parts, particularly in Kerala and in Tamil Nadu. Only some parts of the central region of Deccan plateau, particularly some districts of Maharashtra, Karnataka and Andhra Pradesh seem to exhibit partial exception to the southern fertility decline; but the nature of fertility transition in these districts is unlike the northern part and it is expected that a moderate diffusion process is underway in this sub-region.

The fertility pattern of 2001 seems to be not much related with culture, linguistic pattern or any other socio-economic characteristics but seems to relate with spatial diffusion where each unit is supposed to be affected by its neighborhood characteristics. Decline in fertility along the coastal root indicates that the process of reproductive change in India is highly contextual and so intricate details of fertility dynamics can be analysed only at the local context.

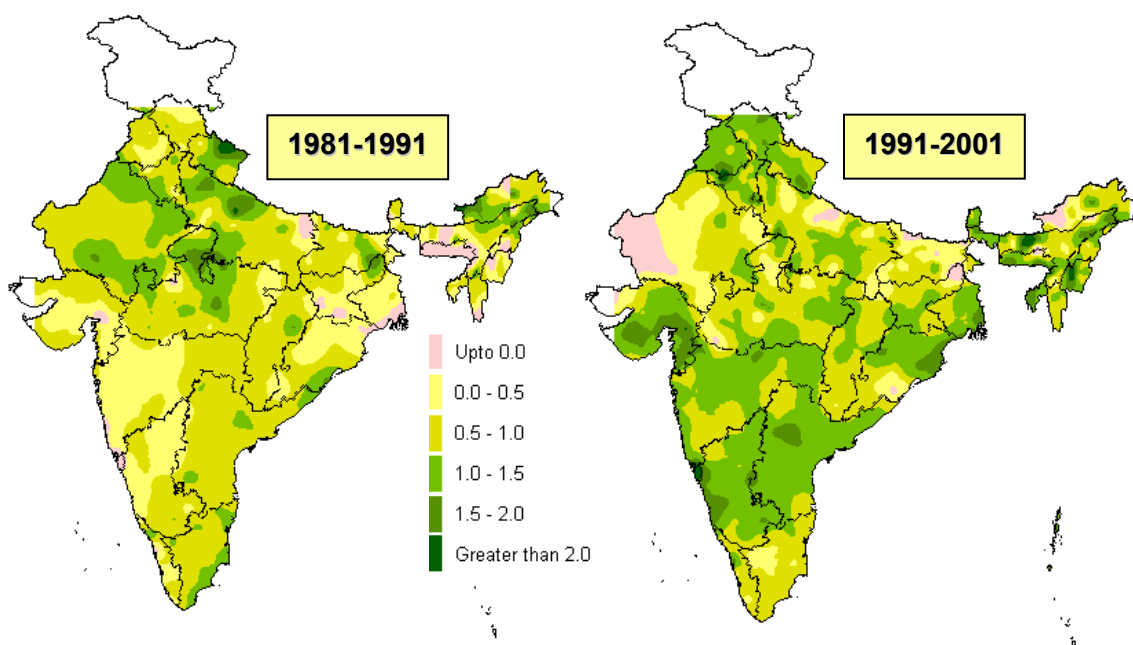
3.2 Inter-Censal Change in Fertility (1981-2001)

Besides analyzing the spatial propagation of fertility at different time points, it is indeed important to study the trends in fertility to understand the possible role of space in fertility decline. However due to numerous changes in the administrative boundaries, such an exercise is difficult if not impossible. Due to the continuous redistricting process,

⁹ Guilimoto et al 2005 also points out this phenomenon using a longitudinal fertility data.

analysis of inter-censal change in fertility is not readily possible as fertility estimates for the newly added districts are not available¹⁰. However Guilмото (2007) have elaborated a GIS based interpolation technique to visualize the inter-censal change in demographic characteristics (say, child sex ratio) which is not sensitive to changes in administrative boundaries. We borrow this concept and compute the difference between grid values of fertility by superimposing layers of different years to visualize inter-censal changes that have occurred during 1981-1991 and 1991-2001. Employing the kriging estimation technique, we first prepare grid maps of two census years and then calculate the grid difference and contour it after that. The resulting contours maps of inter-censal change in fertility are shown below. These maps indicate precisely where the fall in fertility took place during 1981 to 2001. As can be seen the decline in fertility is not at all uniform but has specific spatial pattern.

Figure 4: Inter-censal change in fertility, All India, 1981-2001



To understand the implication of these maps it may be important to re-examine the process of spatial change that have occurred during this period. From a theoretical point

¹⁰ Even if it is available, not much reliable to use. The occasional paper I of 1997, published by Registrar General of India, presented the district level fertility estimates of 1981 and 1991 using 1991 administrative map as an anchor. Surprisingly, publication from the office of the Registrar general of India do not take account of the intricacies of changing boundaries – the values of the newly formed districts between 1981 to 1991 are not calculated separately rather provided just by extrapolating from the district estimates of 1981.

of view, such a change may be due to two components: ‘a national trend affecting all regions simultaneously’ and ‘a regional trend that are found only in given areas’ (Guilmoto, 2007). While the national trend would be considered as a result of broader socio-economic change or change in structural factors, regional trend is closely associated with local, social and economic dynamics. The inter-censal change shown above indicates that structural components might be more important for fertility change during 1981 to 1991¹¹ while it is the regional trend that might have more significant role behind fertility decline during 1991 and 2001. Thus it is very hard to interpret that the contemporary decline in fertility is a ‘mechanical consequence’ of broad structural change rather seems to be more responsive to local context where spatial structure of the demographic behaviour seem to be more important to understand the process behind the rapid decline in number of child bearing. The above exercise thus suggests that the analysis of fertility change in India probably best be understood within the local context to monitor the forthcoming changes and to identify the pockets where policy interventions are indeed important.

4. Analysis of spatial pattern in a comparative framework

Even then, the role of socio-economic factors in explaining fertility decline cannot be ruled out. Palloni (1998) argued that spatial model that helps to indicate diffusion process requires ‘theorizing about the social structures, about the position that individuals occupy in them, about individual decision-making processes that accompany adoption of a behavior, and about the constraints these individuals face’. So it would be more correct to posit spatial factors along with structural factors and if the spatial effects are found to be significant after controlling for socio-economic characteristics, then it can be safely stated that space plays a very crucial role in explaining fertility change. Beside that, it is really unilluminating to confront spatial factors with structural factors when the logical context of each argument is inherently linked.

This section thus tries to analyse the role of space even after controlling for structural factors related to fertility. Using a multi-linear approach next we try to model district

¹¹ Though there are some relatively small clusters of greater decline in boarding parts of Rajasthan, Madhya Pradesh and some north western parts of Uttar Pradesh (including the newly formed state Uttaranchal).

level fertility variations of 1981 on the basis of three broad types of indicators, namely - socio-economic, anthropologic and demographic. The socio-economic factors that are supposed to be linked with fertility are female literacy, female labour force participation, male literacy, poverty and rate of urbanization. The anthropologic factors which can affect fertility behaviour are social and ethnic composition of the population i.e., percentage of Scheduled caste, percentage of Scheduled Tribe, percentage of Muslims, percentage of Christians, percentage of Buddhists and percentage of Jains. The demographic factors that can affect fertility decisions are child mortality and gender ratio of the child population 0-6 years¹². Due to the possible endogeneity between child mortality and fertility relationship, we use 'access to safe drinking water' as a proxy of child mortality which have significant effect on Child mortality outcome but does not have any direct impact on fertility¹³. Beside that access to safe drinking water can also be treated as an institutional factor which can reflect the standard of institutional setup that have a strong bearing on the status of child health.

The data for the explanatory factors are taken from various issues of 1981 population census. Only data related to poverty is taken from National Sample Survey Organization (NSSO henceforth). Considering the agro-climatic and socio-economic homogeneity of the NSS divisions, we assign the head count ratio for a region to the district included in that region. Such a procedure is already well established in demographic research (Murthi et al. 1995, et al. 2001, McNay et al. 2004). However NSSO based regional level head count ratio is available for some specific years like 1972-73, 1983-84, 1987-88 and so on. In order to calculate head count estimates for 1981, we employ the usual interpolation technique by using 1972-73 and 1983-84 poverty estimates. The result of the research strategy is given below.

¹² The theoretical under-pinning of the relationship between fertility and socio-economic characteristics are elaborated in Murthi et al.(1995).

¹³ Possible explanation of "access to safe drinking water' as a proxy of child mortality is given in Drèze et al.(2001)

**Table 3: Determinants of district level fertility variations:
All India, 1981, OLS Regression**

Variable Name	OLS
Female Literacy	-0.057 ^{***}
Female Labor Force Participation Rate	-0.025 ^{***}
Male Literacy	0.001
Urbanization	0.001
Poverty	-0.003
Access to safe drinking water	-0.004 ^{**}
Scheduled Tribes	0.004 [*]
Scheduled Castes	0.010 [*]
Gender Preference	0.063 ^{***}
Muslim	0.001
Christians	0.020 ^{***}
Sikh	-0.013 ^{***}
Buddhist	0.005
Jain	0.057
Constant	0.366
Spatial Lag Effect (ρ)	
Spatial Error Effect (λ)	
<i>Diagnostic Measures of Fit</i>	
R ²	0.71
Log Likelihood	-341.736
AIC	713.471
BIC	772.011

*** : <1%, ** : <5% & * : <10% level of significance

The result of the regression analysis indicates that the structural model can predict district level fertility variations of 1981 with sufficiently robust goodness of fit. Female literacy seems to be the major determinant along with female labour force participation, access to safe drinking water, gender preference, percentage of Christian population and percentage of Sikh population.

Next we predict the fertility rates of 2001 on the basis of the above stated model owing to the fact that contemporary fertility can be linked with historical pattern of socio-economic development of the country. This is a standard method of prediction relying on past experiences¹⁴. After predicting district level fertility rates on the basis of 1981 fertility regression results, next we calculate the difference between the predicted values

¹⁴ This method is also known as data driven method.

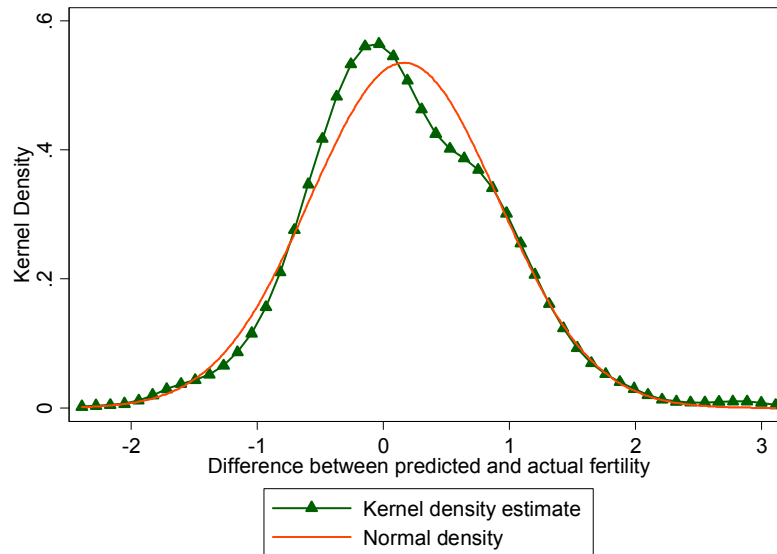
with the actual values¹⁵ as estimated by Professor Mari Bhat and presented in Bhat (2004). Out of 593 districts, in 462 cases, actual fertility is found to be lower than calculated fertility and only in 131 cases, the predicted fertility is found to be lower than actual fertility. However it should be noted that out of these 131 cases only 80 cases are statistically significant. The rest 50 cases indicate that *ceteris paribus* existing socio-economic conditions of the 1980s can predict the contemporary fertility patterns at least for these cases. On the other hand, the result of the analysis indicates that there are as much as 462 districts where actual fertility is lower than predicted fertility. However, out of these 462 cases, the result of 75 cases is statistically insignificant partly indicating that the prediction method might be appropriate for these 75 districts. But most importantly, the rest 372 districts records statistically significant difference in predicted vis-à-vis actual fertility which indicates that the existing socio-economic condition of 80s cannot be a good predictor of contemporary fertility level.

Next we examine the shape of the distribution of the difference between predicted vis-à-vis actual fertility using non parametric technique of estimation of the univariate density function¹⁶. The main purpose of such exercise is to show whether such residual or error has any definite distributional pattern. From pure statistical point of view, if the error term have a specific distributional pattern (i.e. distributed error), then it is important to analyze the nature of this distribution as such errors are far different from what is known as random error in classical regression model. In particular, we employ Kernel estimation technique which is basically a smoothed version of the histogram used to estimate the probability of the density function of a random variable. The Kernel density of the difference between predicted vis-à-vis actual is given below.

¹⁵ Here the term ‘actual’ should be interpreted with caution as the fertility estimates can be severely distorted due to the sensitivity of the infant mortality adjustment in the estimation model. However we use this coinage to clearly distinguish it from the predicted fertility level that we have done on the basis of 1981 fertility regression equation.

¹⁶ The advantage of using such technique is less rigidity of the starting hypothesis.

Figure 5: Kernel Density Graph of the residuals (i.e. difference between predicted and actual fertility): All India (Total) 2001



The above figure indicates that the residuals (i.e., the difference between predicted versus estimated fertility) is not random, rather takes a particular distributional form which is very close to normal density curve. It is now important to understand the statistical properties of these error terms, particularly in the spatial context.

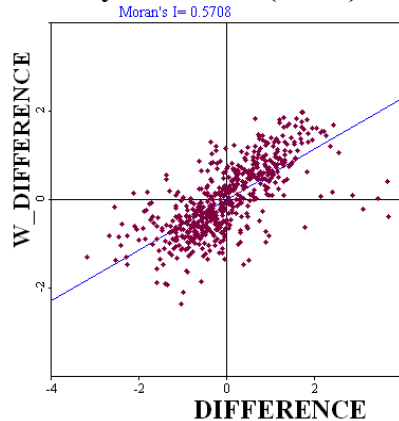
Employing global measures of spatial autocorrelation, the study indicates that the residual is highly spatially auto-correlated with Moran's Index 0.5708. To control for Modifiable Areal Unit Problem¹⁷, we have chosen inverse distance based weight matrix with k-nearest neighbours, where the number of neighbours is greater than 3¹⁸. Following Moran's scatter plot elaborates the pattern of the relationship between the 'difference in predicted and actual' and its first order spatial lag¹⁹.

¹⁷ Modifiable Areal Unit Problem (MAUP) occurs when the results of statistical analysis are highly influenced by the scale as well as the shape of aggregation.

¹⁸ We also employ different other weight matrices like rook contiguity matrix, queen contiguity matrix, k-nearest distance weight matrix with number of neighbours 2,4,5,6 and the threshold distance weight matrix. But the Moran's I is found to be highest with k-nearest distance weight matrix with number of neighbours equal to three.

¹⁹ Here the variable for analysis is the difference between predicted and actual fertility.

Figure 6: Moran's Scatter Plot of the difference between predicted and actual fertility: All India (Total) 2001



The variable plotted in the above scatter plot is the difference between predicted and estimated fertility of 2001. We can denote this difference as $D = (P - E)$, where P is the predicted fertility of 2001 on the basis of 1981 coefficients of the fertility regression model (Table 3) and E is the fertility rates for 2001 (as estimated by Bhat 2004). Like general four quadrant diagram, the above Moran's scatter plot also gives us four types of association between D and W_D , where W_D is the spatial lag of the difference between predicted and estimated fertility. In the first quadrant both D and W_D are positive. Second quadrant shows points where D is negative but W_D is positive. Third quadrant consists of points with negative values of both D and W_D and finally in fourth quadrant D is positive but W_D is negative.

The first and the third quadrants of above Moran's scatter plot (Figure 6) deserve special attention as most of the points are located in these two quadrants.

Case I: For the points in the first quadrant –

- $D > 0$, i.e. $(P-E) > 0$; Estimated fertility is lesser than predicted fertility for districts falling in this quadrant.
- $W_D > 0$; spatial lag of $(P-E)$ is also greater than zero i.e. predicted fertility rates of the neighbourhoods are greater than the estimated fertility rates of the neighbourhoods.

The concentration of points in this quadrant indicate the possibility of getting spatial pattern or spatial contiguity of positive D and positive W_D which may imply

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region/regions where estimated fertility of 2001 are lesser than what can be predicted on the basis of 1981 socio-economic, demographic and cultural set up. This may suggest that some force may be at work to cause more than predicted decline in fertility.

Case II: For the points in the third quadrant –

- $D < 0$, i.e. $(P-E) < 0$; Estimated fertility is greater than predicted fertility for districts falling in this quadrant.
- $W_D < 0$; spatial lag of $(P-E)$ is also less than zero i.e. predicted fertility rates of the neighbourhoods is lesser than the estimated fertility rates of the neighbourhoods.

Furthermore the concentration of the points in this third quadrant indicates that for a region/regions of India, actual fertility decline is perhaps slower than what can be anticipated on the basis of socio-economic and demographic correlates of reproductive behaviour. This may hint the functioning of some regional factors that may hinder the pace of fertility decline at the district level for districts falling in third quadrant of the above scatter plot diagram.

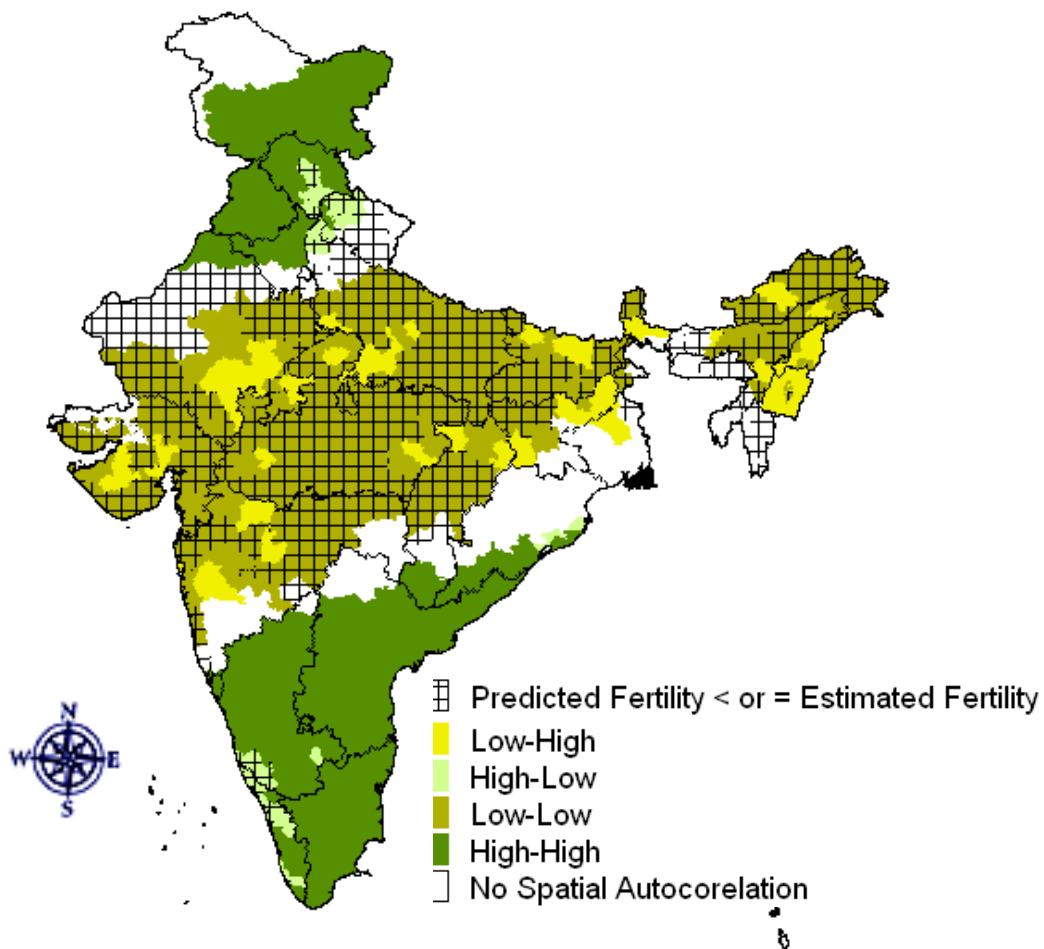
Thus regional factors may be responsible for the spatial relationship between fertility and its nearest neighbourhood. But what could be the regional factors which can hinder/help fertility decline in India? To understand the nature of the regional factors, next we map the significant local indicators of spatial association of the difference between predicted and estimated fertility. Figure 7 elaborates the spatial pattern of LISA of the difference between predicted and estimated fertility.

Four types of association can be obtained from the LISA map.

- Difference between predicted and estimated fertility is significant and positive $\{(P-E) > 0\}$ with similar pattern for the neighbourhood (positive-positive or High-High).
- Difference between predicted and estimated fertility is significant and negative $\{(P-E) < 0\}$ with similar pattern for the neighbourhood (negative-negative or Low-Low).

- Difference between predicted and estimated fertility is positive but the difference of predicted and estimated fertility rates of the neighbourhood is negative (positive-negative or High-Low).
- Difference between predicted and estimated fertility is negative but the difference of predicted and estimated fertility rates of the neighbourhood is positive (negative-positive or Low-High).

Figure 7: LISA Map of the Residuals (difference between predicted and estimated fertility): All India (Total) 2001



Two distinct patterns are emerging in respect of the difference between predicted values and estimated values. In one pattern the difference is positive, in the other pattern, the difference is negative and both cases are statistically significant. The robust clustering of 'high-high spots' in the southern and southern eastern region indicates that the difference between predicted and estimated fertility is positive, significant and spatially contiguous.

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Similar cluster of 'high-high spots' are formed in the north-western part of the country comprising of districts of Punjab, Jammu & Kashmir, parts of Haryana, Himachal Pradesh and Rajasthan.

Beside that, a robust cluster of 'low-low spots' is formed along the central western part of the country consisting of districts of the economically fast growing states like Gujarat & Maharashtra and also districts of the so called backward states like Bihar and Uttar Pradesh. Obviously, there are some spatial outliers and some districts with very less difference between predicted vis à vis estimated fertility rates. Interestingly, the districts with no spatial auto-correlation are also spatially contiguous which might be attributed to systematic propagation of different socio-economic variables.

It should be noted that the spatial outliers (25 districts marked by light green colour and 56 districts marked by yellow colour) are not always spatially random, rather form small clusters by exhibiting a very local pattern – far different from the respective regional pattern. The dual level map uses 'hash' to locate those districts where predicted values are below the estimated fertility rates. The relatively higher estimated fertility in compared to the predicted fertility in central western part of the country may be due to some local socio-political as well as cultural aberration that may hinder the pace of fertility decline resulting anisotropic diffusion of fertility in Indian population.

5. Discussion

The result of the research strategy highlights some significant aspects of spatial demography of Indian population that need to be flagged. Three distinctive divisions are discernible from the above map. The first part i.e., the north western part which is characterized by use and abuse of birth related technology. Apart from regional diversity in socio-economic indicators, the common characteristics of this region might be excessive manifestation of patriarchy which is proliferated through the use of sex selection technology and abortion of unwanted foetus. The robust clustering of fertility decline in this region clearly points out that child per woman is declining fast, but at the

cost of ‘missing girl child’ – an agenda that need to be analysed more intensively which is beyond the scope of this present study.

The second part, which is characterized by robust clustering of ‘low-low spots’, consists of number of contiguous districts of central western part of the country, engulfing the states of Bihar, Madhya Pradesh, Gujarat; a sizeable chunk of Uttar Pradesh, Rajasthan, Chattisgarh and some parts of Maharashtra and Jharkhand. Despite the wide socio-economic and political diversities in this region (starting from socio-economically forward districts of Gujarat and Maharashtra to relatively poor states like - Uttar Pradesh, Bihar and Madhya Pradesh), the common characteristics of this region might be embedded in the linguistic pattern (Indo-European), historical influence (Muslim invasion), cropping pattern (cultivation of dry cereals), land inheritance system (gender secluded), nature of socio-political institution and most importantly, kinship system which is exogamous and ‘male centered’ (a term used by Kishore 1993). These are the major ingredients of traditional ‘North-South’ divide which has significant bearing on female autonomy and unequal manifestation of patriarchy in India. The predominance of these characteristics traditionally restricts women’s autonomy resulting in excessive female subordination and thus limit female agency. Even though, fertility is declining in this part, but the pace of decline is far less than the southern and southern eastern part and surprisingly, also far slower than the north western part of the country²⁰. The pattern of fertility decline in the central western region is thus found to be closely linked with social system and female autonomy, the foundation of which rests upon specific cultural traditions. The areas marked by hash engulfs almost the entire region of the central western part of India which may be found to be indicative to understand how the existing pattern of social system and socio-political institutions can influence the relationship between fertility and its structural as well as regional correlates. In particular, it might indicate the role of religion and regionalism as the two major hindrances that can hamper the pace of fertility decline. This finding may be consistent with contemporary evolution of socio-political institutions in this region, where religion and regionalism have often

²⁰ This north western part is also a part of Indo-Aryan kinship system though different socio-economic characteristics is found to be much dissimilar than the major central western part.

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been identified as the two important dimensions of identity constructions to those in need, who find themselves ontologically insecure and existentially uncertain in the wake of globalization. Such attraction rests on the faith on these two dimensions of identity constructions to convey a picture of security, inclusion, local stability and simple answers to those questions which are inherently complex – not easier to find answers within the purview of their common knowledge²¹.

The central western part, i.e. the major chunk of ‘low-low spots’, is found to be separated from the north western parts and southern eastern part by a strip of districts with no spatial autocorrelation in residuals (between predicted vis-à-vis estimated fertility). Such spatial pattern indicates that regional diversities in fertility decline might be very distinct. Even then the region of ‘low low spots’ is found to be linked with north western parts through the pattern of the difference between predicted and estimated fertility. Such spatial propagation might indicate that within a single cultural division, two different types of spatial association can even be linked with their spatial patterns, but between two cultural divisions such spatial pattern does not have any role to play.

The third region i.e. the southern and southern eastern region, which is characterized by robust clustering of ‘high-high spots’, is traditionally known as ‘female friendly’ cultural division of India. This cultural division is characterized by spatially endogenous marriage, equal importance of affinity and spontaneity in social co-operation among males and females, inclusion of women in the property inheritance process, historical influence (Christianization), linguistic pattern (Dravidian), cropping pattern (cultivation of rice), socio-political institution (partly secular) etc. This cultural division allows greater female autonomy and encourages female’s agency and restricts detrimental

²¹ Globalization has often been criticized as the spread of Western culture and debated in academia, where studies have been concentrated on aspects of rational identity and cultures, ideas of modernity, religion and world history, the localization of the global and the transformation of state centric assumption in the social science (e.g. Kinnvall, 2006). In some versions, globalization is viewed as the path leading to greater development of all people. In other version, globalization is portrayed as the threatening force; as the new hegemony of capital market, the evils that can destroy national culture, reduce democracy, and even can make the state redundant. As a result, several questions may come out regarding the role of globalization, which are inherently complex and may not still have the appropriate answer to conclude.

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influence of patriarchy - all these seem to have a strong bearing on sharp decline in fertility in this region.

The robust clustering of 'high-high spots' and 'low-low spots' of the above LISA map indicates that fertility diffusion might be well entrenched in Indian population, though the type of diffusion is anisotropic. Such anisotropy is clearly attributed to historical, cultural context of India, and related to history of gender stratification and evolution of socio-political institutions in the Indian sub continent. While social structure can play an important role to account for regionality in the pace of fertility decline, it often responds less well to the question of social change. It is important to highlight that socio-economic change can only alter traditional structure within a very short time-period, which have a strong impact on fertility outcome (Guilmoto et al. 2000, Dev et al. 2002, etc.).

While inter-regionality in fertility decline can well be associated with social structure, the decline in fertility in each region may be an outcome of social change, and so rapid decline in fertility in a region should be associated with rapid social change within that geographical cluster. It should be noted that traditional social structure does not have such momentum which can induce social change within a very short period. India is a country that has experienced rapid social change during the last twenty years. However, the direction of the social change is not solely towards western type 'modernization', rather it follows some unexpected path like increasing girl child vulnerability or fall in rate of female labour force participation among educated women, which can be theoretically associated with increase in number of children, when the country has experienced substantial fall in fertility in its each part. Thus it is hard to assume that modern economic development can have a strong impact on reproductive change in India, rather it might be institutional evolution which is not necessarily linear (Guilmoto 2005). Such evolution and non-linearity of social institutions indicate that demographic change in India may be of sociological nature where diffusion theory might play an important role.

The diffusionist approach indicates that the diffusion of birth control plays a crucial role in the decline in fertility which spreads from person-to-person, group-to-group and region-to-region. The major evidence of diffusion is garnered from Western Europe in the Princeton European Fertility Project. However, diffusion theory is often used as synonymous with pure supply side argument of spread of birth control due to governmental efforts but it should be noted that the use of birth control technology i.e., use of contraceptives cater both demand aspect and supply aspect and thus cannot be categorized as a pure supply side approach. The geographical regularity in pure 'high-high spots' and 'low-low spots' in the map presented in this section indicates that spatial diffusion might be an important factor behind intra-regional fertility decline in India. It is hard to believe that such geographical regularity in fertility behaviour is just due to "program effect", rather it indicates spontaneous adoption of small family norms as well as effective use of contraceptive techniques, together which may have a strong impact on demographic transition within the country. Guilmoto (2005) highlights that within a region 'the boundaries of demographic change have rarely coincided with the administrative borders of the state in which family planning policies are implemented'. Close inspection of the LISA map does support this argument. In a number of states we found more than one type of robust clustering, first where estimated fertility is higher than predicted fertility and the difference between these two is statistically significant, second where difference between predicted and estimated fertility is not substantial and third, where estimated fertility is far lower than predicted fertility and the difference between these two is statistically highly significant. It would be difficult to interpret such spatial patterning within a state boundary as a reflection of variations of the functioning of health administration. On the other hand, strong demographic similarities are observed on each side, where the negative difference of (P-E) is spatially clustered with its neighbours from other states and positive difference of (P-E) is also spatially autocorrelated with districts from other neighbouring states. So the inter-regional decline in fertility can best be associated with geographical diffusion where location of each district in Indian landscape plays an important role in describing fertility decline in India.

6. Conclusion

The present paper brings out a number of salient features which are important to understand the process dynamics behind demographic transition in India. First of all, the paper tries to unmask the regional intricacies in fertility patterns and indicates robust clustering of low fertility values and its spatial propagation with time. Next, on the basis of GIS based computation technique, the study brings out the contours of fertility decline during 1981 to 1991 and 1991 to 2001. The figure representing the inter-censal change in fertility rates indicates that the contemporary decline in fertility is mostly regional where spatial diffusion might play an important role. On the basis of the socio-economic indicators which are supposed to be significantly associated with fertility, the study tries to predict district level fertility rates of 2001 on the basis of socio-economic characteristics of 1981 and found considerable difference between the predicted values and the actual values. The difference between predicted vis-à-vis actual values of fertility are found to be highly spatially autocorrelated and the nature of spatial autocorrelation is systematic – dividing the Indian landscape into three distinct segments which are thought to be closely associated with historical influence, kinship structure, crop pattern and land inheritance system. Even then the role of the socio-political institution cannot be ruled out as the pace of fertility decline is found to be lower in regions where socio-political institutions are partly non secular – affected by religiosity and/or casteism. Beside that the within region decline in fertility might be more prone to socio-spatial diffusion where individual's location in the society have a strong bearing on her number of child bearing. The significant spatial effect after controlling for structural factors indicates that fertility diffusion is well entrenched in Indian population. The existing pattern of fertility decline in India seems to be encouraging and will certainly help to reach the replacement level fertility goal in every parts within the country in near future. Furthermore, the increasing use of contraceptive in 'technological societies' of India has emerged as a major force regarding contemporary demographic transitions, give reasons to believe that fertility diffusion follows trajectories governed by the Darwinian forces of natural selection. Even then, contextual policy is important particularly for those regions where the pace of fertility decline is still slower. Such policy should be geared to uproot the traditional socio-cultural beliefs and geographical barriers which can hamper isotropic fertility

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diffusion, so important for demographic achievement in accordance with *National Population Policy 2000* which calls for **attainment of replacement level fertility by 2010.**

The results of the present analysis are of paramount interest in terms of policy evaluation and suggest that spatial effects should be considered with priority in targeting policy directions at least for those regions where fertility decline seems not to be substantial. The effectiveness of fertility diffusion in a country like India with wide socio-economic geographic diversities is a lesson and can be found useful for policy making for other high fertility countries.

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Appendix 1:

Figure 1a: Distribution of district fertility estimates for larges states 1981

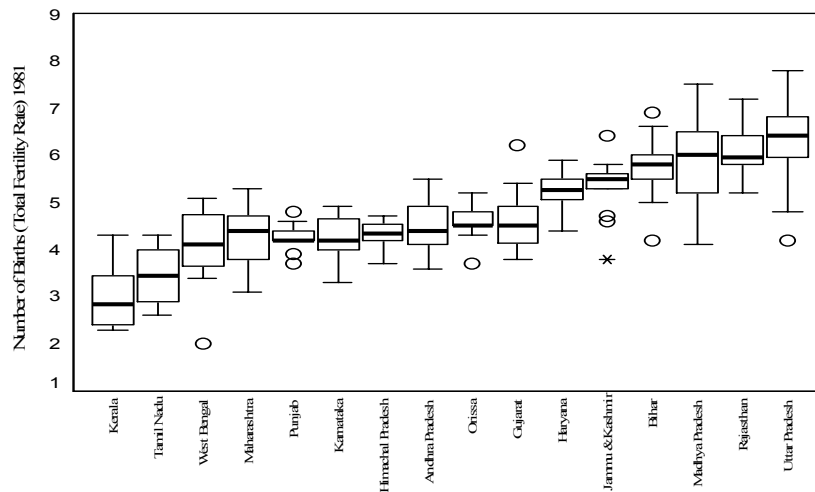


Figure 1b: Distribution of district fertility estimates for larges states 1991

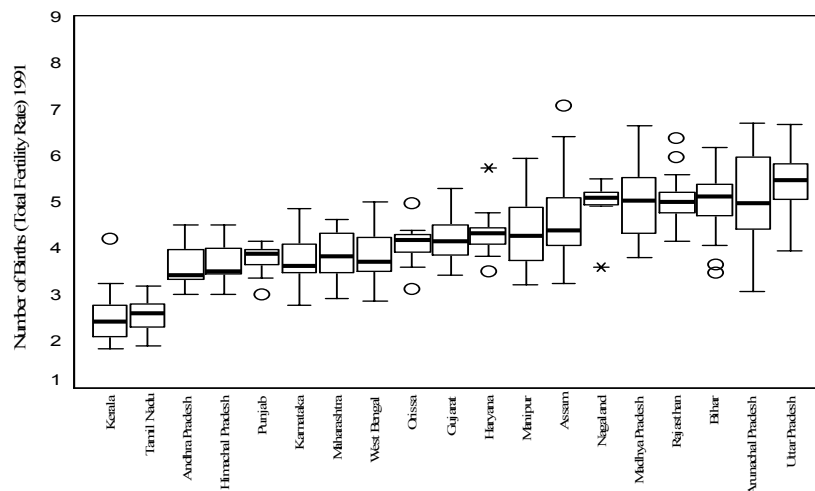


Figure 1c: Distribution of district fertility estimates for larges states 2001

